The University Of Sheffield.

P. E. Obasohan

Investigating Multiple Overlaps in the Determinants of Risk Factors of Anaemia, Malaria, and Malnutrition, and their Multimorbidity, among Children aged 6 to 59 months in Nigeria

Thesis Submitted for the Degree of Doctor of Philosophy

2022

Investigating Multiple Overlaps in the Determinants of Risk Factors of Anaemia, Malaria, and Malnutrition, and their Multimorbidity, among Children aged 6 to 59 months in Nigeria

Phillips Edomwonyi Obasohan

Thesis Submitted for the Degree of Doctor of Philosophy

School of Health and Related Research
Faculty of Medicine, Dentistry and Health
University of Sheffield

September 2022

Abstract

Background: In the last ten years multimorbidity in children under the age of five years has becoming an emerging health issue in developing countries. The absence of a proper understanding of the causes, risk factors, and prevention of these new health disorders (multimorbidity) in children is a significant cause for concern, if the sustainable development goal 3 of ensuring healthy lives and the promotion of well-being for all especially in the associated aim of ending preventable deaths of new-borns and children must be achieved by 2030. In the past, most studies conducted in Nigeria and some other least developed nations of the world focused on these multiple diseases by employing conventional analytical techniques to examine them separately as distinct disease entities. But the study of multimorbidity of anaemia, malaria, and malnutrition has not been done, especially in children.

Aim: This study aims to investigate the multiple overlaps in the impact of individual and contextual variables on the prevalence of anaemia, malaria, malnutrition, and their multimorbidity among children aged 6 to 59 months in Nigeria.

Methods: The study used two nationally representative cross-sectional surveys, the 2018 Nigeria Demographic and Health Survey and the 2018 National Human Development Report. A series of multilevel mixed effect ordered logistic regression models were used to investigate the associations between child/parent/household variables (at level 1), community-related variables (at level 2) and area-related variables (at level 3), and the multimorbidity outcome (no disease, one disease only, two or more diseases). The interaction effects between child's sex, age, and household wealth quintiles and the outcome while accounting for some covariates in the model were also investigated.

Results: 48.3% (4,917/10,184) of the sample of children aged 6-59 months cohabit with two or more of the disease outcomes. Child's sex, age, maternal education, mother's anaemia status. household wealth quintiles, the proportion of community wealth status, states with high human development index, region, and place of residence, were among the significant predictors of MAMM ($p<0.05$). There was a significant interaction effect between a child's age and wealth status when some other covariates were accounted for.

Conclusions: The prevalence of MAMM observed in the sample is large, with almost half of the children living with two or more of the diseases at the time of the survey and several potentially modifiable risk factors have been identified. If suitable actions are not urgently taken, Nigeria's ability to actualise the SDG 3 will be in grave danger. Therefore, possible actions to ameliorate this problem include developing and implementing a suitable policy that will pave the way for integrated care models to be developed.

Acknowledgements

First and foremost, I sincerely appreciate God Almighty, who has enabled me in that He counted me faithful to carry out this piece of work. I drew immeasurable strength and inspiration from Him all through the program (Isaiah 41:10, Psalm 121:1,2, Acts 22:26a). His name alone is glorified.

Secondly, my sincere thanks go to the team of supervisors: Professor Stephen J Walters (The lead), Dr Richard Jacques (Both of the School of Health and Related Research (ScHARR), University of Sheffield), and Professor Khaled Khatab (Faculty of Health and Wellbeing, Sheffield Hallam University), for their excellent counsel, stimulating talks, and unrelenting support throughout the study.

I also appreciate my academic mentors, Late Professor DJ Bartholomew (London School of Economic and Political Sciences), through his works I realised for the first time how important Statistical techniques could be to solve real life problems, and Professor Richard Riley (Keele University), whose encouraging words and teachings have inspired me on this path to success. In addition, my thanks go to Prof Jeremy Dawson and Dr Dan Green for the advice received during and after the confirmation review assessments. Also, I appreciate contributions from some members of the ScHARR community, especially Joanna Leaviss, Anthea Sutton, and Mark Clowes, for their help in systematic and scoping review management, and a big thank you to Prof Steve Julious. I appreciate my Personal Tutor, Professor Matt Stevenson for the advice I received from him during our first meeting.

In addition, I appreciate the former Rector, Dr Umar Ahmed Egbako, and the Management Staff of Niger State Polytechnic for the opportunity given to me to undergo this study. Furthermore, I thank the TETFUND (Tertiary Education Trust Fund), Nigeria, for funding the studentship award. I would also like to thank the ICF (Inner City Fund) and UNDP (United Nations Development Programme-Nigeria) for their permission to access the data sets used in this study.

I am particularly grateful to my dear wife, Dorcas Obasohan, who has always played her unquantifiable supportive roles for me even more during my studies. She was always there to remind me of the need to take some rest. Moreso, I appreciate my children, Isaac, and Wonder-Lois, who always supported me throughout the program. I recognise the positive roles played in my life by friends, colleagues, and faith-based relations, which are too numerous to list here.

Finally, I want to say a big thank you to the entire Obasohan family for this laudable achievement, and them I dedicate this thesis.

Glory to God Almighty

Publications during this study period (2019-2022)

1. **Obasohan PE**, Walters SJ, Jacques R, Khatab K. Risk Factors Associated with Multimorbidity among Children Aged Under-Five Years in Sub-Saharan African Countries: A Scoping Review. *Int. J. Environ. Res. Public Health* **2023**, *20*(2), 1377; **https://doi.org/10.3390/ijerph20021377**
2. **Obasohan PE**, Walters SJ, Jacques R, Khatab K. Individual, household, and area predictors of anaemia among children aged 6–59 months in Nigeria. *Public Health in Practice* 2022; 3: 100229 https://www.sciencedirect.com/science/article/pii/S2666535222000052.
3. **Obasohan PE,** Walters SJ, Jacques R, Khatab K. Individual and Contextual Factors Associated with Malaria among Children 6-59 Months in Nigeria: A Multilevel Mixed Effect Logistic Model Approach. *Int. J. Environ. Res. Public Health* **2021**, *18*(21), 11234; **https://doi.org/10.3390/ijerph182111234**
4. **Obasohan PE,** Walters SJ, Jacques R, Khatab K. A Scoping Review of Selected Studies on Predictor Variables Associated with the Malaria Status among Children under Five Years in Sub-Saharan Africa. *International Journal of Environmental Research and Public Health* 2021; 18, no. 4: 2119. https://doi.org/10.3390/ijerph18042119
5. **Obasohan PE**, Walters SJ, Jacques R, Khatab K. Risk Factors Associated with Malnutrition among Children Under-Five Years in Sub-Saharan African Countries: A Scoping Review. *International Journal of Environmental Research and Public Health* 2020; 17, no. 23: 8782. https://doi.org/10.3390/ijerph17238782
6. **Obasohan PE**, Walters SJ, Jacques R, Khatab K. A Scoping Review of the Risk Factors Associated with Anaemia among Children Under Five Years in Sub-Saharan African Countries. *International Journal of Environmental Research and Public Health* 2020; 17, no. 23: 8829. https://doi.org/10.3390/ijerph17238829
7. Obasohan PE. Comparing Weighted Markov Chain and Auto-Regressive Integrated Moving Average in the Prediction of Under-5 Mortality Annual Closing Rates in Nigeria. *International Journal of Statistics and Probability* 2020; Vol 9, No. 3 http://www.ccsenet.org/journal/index.php/ijsp/issue/view/0/2303
8. **Obasohan PE,** Okorie JN, Sule AL, Ndako KJ (2019) Impact of dietary patterns, individual and workplace characteristics on blood pressure status among civil servants in Bida and Wushishi communities of Niger State, Nigeria. PLoS ONE 14 (12): e0226231. https://doi.org/10.1371/journal. pone.0226231

Paper under peer review

Obasohan PE, Walters SJ, Jacques R, Khatab K. A joint model of the determinants of multimorbidity of six common childhood diseases among children aged 6-59 months in Nigeria (Under review)

Conferences/Workshops Presentations

1. Obasohan PE, Walters SJ, Jacques R, Khatab K. A Scoping review of Risk Factors Associated with Anaemia among Children of under-five years in Sub-Saharan African Countries. *European Working Group on Operations Research for Development (EWG-ORD):* A virtual workshop) held on the 7th of August 2020 as part of Operations Research of South Africa annual international conference in 2020

2. Obasohan PE, Walters SJ, Jacques R, Khatab K. A Multilevel Mixed-Effect Ordinal Logistic Regression Analysis of Multimorbidity among Children 6-59 months of Age in Nigeria. Being a rapid-fire presentation at the Royal Statistical Society (RSS) International Conference held in Manchester (September 2021) (Paper and poster presentation).

3. Obasohan PE, Walters SJ, Jacques R, Khatab K. Investigating multiple overlaps in the determinants of multimorbidity of anaemia, malaria, and malnutrition among children 6-59 months in Nigeria: The route to my thesis. Being a paper presented at the School of Health and Related Research (ScHARR) Postgraduate Conference held in June 2022

4. Obasohan PE, Walters SJ, Jacques R, Khatab K. Spatial disparities in prevalence, and socioeconomic predictors of malnutrition among children under-five years in Nigeria. Being a rapid-fire presentation at the Royal Statistical Society (RSS) International Conference held in Aberdeen (September 2022)

5. Obasohan PE. UK Public Health Science: A national conference dedicated to new research in UK public health. 24 - 25 November 2022 (Attendance only)

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AHRQ	Agency for Healthcare Research and Quality
AIC	Akaike's information criterion
AJOL	African Journal of online
ANC	Ante-Natal Care
AOR	Adjusted Odds Ratios
ARI	Acute Respiratory Infections
AUC	Area Under the Curve
BIC	Bayesian Information Criterion
BMGF	Bill and Melinda Gates Foundation
BMI	Body Mass Index
BMI	Body Mass Index
CAPI	Computer-Assisted Personal Interview
CDC	Centre for Disease Control
CI	Confidence Interval
CIAF	Composite Index of Anthropometric Failure
CINAHL	Cumulative Index to Nursing and Allied Health Literature
DRC	Democratic Republic of Congo
DSF	Decreased Significant Factors
EA	Enumeration Area
EDHS	Ethiopia Demographic and Health Survey
EUPATI	The European Patients' Academy on Therapeutic Innovation
EWG-ORD	European Working Group on Operations Research for Development
FCT	Federal Capital Territory
GII	GenderInequality Index
HAZ	Height-for-Age Z-score
HDI	Human Development Index
ICC	Intra-Class Coefficient
ICF	Inner City Funds
IJERPH	International Journal of Environmental Research and Public Health
IRD	Institute for Research Development
IRR	Incidence Rate Ratio
ISF	Increased Significant Factors
IUGR	Intrauterine Growth Restriction
KAP	knowledge, Attitude and Practice
KNHANES	Korean National Health and Nutrition Examination Survey
KR	Kids Recodes
LCA	Latent Component Analysis
LGA	Local Government Area
LLH	Log-Likelihood
LMIC	Low-Medium Income Countries
LVM	Latent Variable Model
MAMM	Multimorbidity of anaemia, malaria, and malnutrition

MAR	Missing At Random
MCAR	Missing Completely At Random
MDG	Millennium Development Goals
MDHS	Malawi Demographic and Health Survey
MESH	Medical Subject Headings
MI	Multiple Imputation
MICS	Multiple Indicator Cluster Survey
MNAR	Missing Not At Random
MNS	Micro-Nutrient Survey
MOR	Median Odds Ratios
MPI	Multidimensional Poverty Index
NBS	National Bureau of Statistics
NDHS/DHS	Nigeria Demographic and Health Survey
NHDR	National Human Development Report
NISH	National Integrated Survey of Household
NMCF	National Malaria Control Funds
NMEP	National Malaria Elimination Programme
NPC	National Population Commission
OR	Odds Ratio
PCA	Principal Component Analysis
PICOTS	Population, Intervention, Comparators, Outcomes, Timing and Study design
PR	Personal Recodes
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PSU	Primary Sampling Units
RBM	Roll Back Malaria
RD	Risk Difference
RDT	Rapid Diagnostic Test
RRR	Relative Risk Ratios
RSS	Royal Statistical Society
SDG	Sustainable Development Goals
SSA	Sub-Saharan Africa
TETFUND	Tertiary Education Trust Fund
UN	United Nations
UNDP	United Nations Development Program
UNFPA	United Nations Population Fund
UNICEF	United Nations Children Fund
USAID	United States Agency for International Development
VIF	Variance Inflation Factor
VPC	Variance Partition Coefficient
WAZ	Weight-for-Age Z-score
WHO	World Health Organisation
WHZ	Weight-for-Height Z-score
WOS	Web of Science

Chapter 1 Preamble

1.0 Introduction

Childhood mortality and morbidity rates are still very high, especially in Low- and Medium-Income Countries (LMIC). These have resulted in a severe public health burden (World Health Organization, 2022). Most childhood mortalities in developing countries are functions of unresolved preventable and treatable childhood morbidities, especially anaemia, malaria fever, and malnutrition. According to the World Health Organization and the Centres for Disease Control and Prevention, about 25% of the world's population is anaemic, with expectant mothers and children under the age of five being the most vulnerable (De Benoist *et al.,* 2008; Nikoi and Anthamatten, 2013; Obasohan *et al.,* 2020a), but since 2016, the prevalence of anaemia has increased globally by more than 40% annually (World Health Organisation, 2017). Similarly, over the last twenty years, malaria has remained a primary public health concern(Obasohan *et al.,* 2021a), with over 300 million cases reported in 2018 (Aychiluhm *et al.,* 2020). It has remained a leading cause of morbidity and mortality. Low and Medium-Income Countries (LMICs), especially Sub-Saharan Africa (SSA), contribute more than 80% of the global malaria burden (Bennett *et al.,* 2017; Ugwu and Zewotir, 2020). Though a considerable global decline has been noticed in childhood stunting, over 150 million, 50 million and 38 million children remain stunted, wasted and overweight, respectively (Global Nutrition Report, 2020). However, in 2018, there were more than 40 million overweight children under the age of five, which was contrary to expectations and in keeping with a global target on malnutrition to keep the rate of childhood obesity constant. (UNICEF / WHO / World Bank Group, 2019), indicating a gradual global rise in overweight children. It becomes more worrisome when children simultaneously co-inhabit two or more of these disease conditions. Despite its complexity, the relationship between malaria, anaemia, and malnutrition is essential for our knowledge of childhood morbidity and the formulation of successful intervention methods (Ehrhardt *et al.,* 2006). Furthermore, the lack of proper understanding of the causes, predictors, and prevention of these emerging health conditions (multimorbidity) in children is of great concern particularly in the realization of the sustainable development goal 3 of ensuring healthy lives and promotion of well-being for all especially in the associated aim of ending preventable deaths of new-borns and children by 2030.

1.1 Rationale of the study

In the past, most studies done in Nigeria and most other least developed countries of the world on multiple health conditions have addressed these emerging public health conditions in adults and children by examining them independently as single disease conditions using traditional analytical methods (Khatab and Kandala, 2011; Oladeinde *et al.*, 2012; Asafo-Agyei, Antwi and Nguah, 2013; Akosu and Afolaranmi, 2015; Alicke *et al.*, 2017; Morakinyo, Balogun and Fagbamigbe, 2018; Ali *et al.*, 2019; Parbey *et al.*, 2019; Sakwe *et al.*, 2019). However, these health conditions exist in the same ecological epidemiology system that may exhibit common causes, epidemiology, socioeconomic, demographic and environmental risk factors (Kateera *et al.*, 2015; Khatab, Adegboye and Mohammed, 2016; Teh *et al.*, 2018). The biggest challenge that these conditions pose to clinicians, researchers and health care providers are the complex ways in which the conditions interact with socioeconomic, demographic and environmental patterns (Khatab and Kandala, 2011; McGeorge, 2012; Bramley and Moody, 2016; Pathirana and Jackson, 2018).

Furthermore, the complete absence of suitable models of multimorbidity care adaptable to developing countries is an additional task for clinicians, researchers, and health care providers to unravel. The consequences of living with multimorbidity include disability, reduced quality of life, sudden death, increased health service utilization and cost of care, and preventable hospital admission (Eyowas *et al.*, 2019; Abebe *et al.*, 2020; Mofina *et al.*, 2020). To change the trajectory of providing adequate treatment for children living with multimorbidity, more research with a developing-country in focus is urgently required to understand the causes and risk factors associated with multimorbidity in children in Nigeria. This is a step in the right direction in understanding epidemiology and determinants of multimorbidity of common childhood diseases that will help government and policy makers and implementors to come up with an integrate model suitable for managing the multiple occurrences of diseases in children. The purpose of this study was to investigate the multiple overlaps in the determinants of anaemia, malaria, malnutrition and their multimorbidity among children aged 6-59 months in Nigeria.

1.2 The research questions.

This study is carried out to proffer answers to the following research questions. First, what overlapping individual and contextual risk factors are associated with anaemia, malaria,

malnutrition, and their cooccurrence among children 6-59 months of age in Nigeria using the combined data sets from two nationally representative surveys?

Developing countries with lean resources and poorly designed health systems may suffer much under these emerging health conditions in children if left unattended (Ehrhardt *et al.*, 2006), and this will strongly impact the realization of ending preventable deaths of new-borns and children by 2030

1.3 Evidence deficit

Few studies have highlighted the necessity for researchers to pay more attention to specific elements of these childhood comorbidities and multimorbidity (Ehrhardt *et al.*, 2006), using more suitable statistical methodologies that will adequately describe the coexistence of these health disorders (Khatab, Adegboye and Mohammed, 2016; Pathirana and Jackson, 2018). Attempting to investigate these health conditions independently may lead to disregarding the overall variability that could be broken down into within and between variabilities (Das, Poole and Bada, 2004). Modelling the multiple overlaps in the aetiology, epidemiology, and predictors of various coexisting health disorders will be necessary for a more acceptable method of examining the joint association between these multimorbidity (Khatab and Kandala, 2011; Khatab, Adegboye and Mohammed, 2016). Characterizations of individual illnesses in Nigeria and perhaps elsewhere are still being studied (Khatab, Adegboye and Mohammed, 2016). However, research focusing on determinants of the combination of the diseases is lacking (Pondei, Kunle-Olowu and Peterside, 2013). The biggest challenge that these conditions pose to clinicians, researchers and health care providers are the complex ways in which the conditions interact with socioeconomic, demographic and environmental patterns (Khatab and Kandala, 2011; McGeorge, 2012; Bramley and Moody, 2016; Pathirana and Jackson, 2018). Policymakers and healthcare professionals may discover that identifying illness combinations and the characteristics of people exhibiting comparable multimorbidity patterns can be highly helpful in successfully addressing multimorbidity in at-risk groups. (Park, Lee and Park, 2019). Therefore, plans and policies to reduce childhood morbidities and mortalities may fail to produce the desired effects where there is a coexistence of disease conditions. To bridge the knowledge gap, the current study seeks to apply more appropriate statistical models to explain the determinants of multimorbidity in children to help policymakers

in determining most appropriate way forward in reducing multimorbidity among children in Nigeria and increase her possibilities of realising the SDG-3.

1.4 The aim and objectives of the study

This study aims to investigate the multiple overlaps in the impact of individual and contextual variables on the prevalence of anaemia, malaria, malnutrition, and their multimorbidity among children aged 6 to 59 months in Nigeria.

The specific objectives of the thesis include:

i. To undertake a comprehensive scoping review of literature on individual and contextual risk factors associated with the prevalence of anaemia, malaria fever, malnutrition, and multimorbidity among children under-five years in Sub-Sahara Africa (SSA).
ii. To determine the prevalence of anaemia, malaria, malnutrition, and their interactions among children aged 6 to 59 months in Nigeria using data from the 2018 Nigeria Demographic and Health Survey (NDHS)
iii. To investigate the prevalence and association of individual and contextual risk factors of anaemia among children 6-59 months in Nigeria using data from the 2018 NDHS (with some incorporated contextual data from the National Human Development Report (2018 NHDR)).
iv. To investigate the prevalence and association of individual and contextual risk factors of malaria among children 6-59 months in Nigeria using data from the 2018 NDHS (with the incorporated contextual data from the National Human Development Report (2018 NHDR)).
v. To investigate the prevalence and association of individual and contextual risk factors of malnutrition among children aged 6-59 months in Nigeria using data from the 2018 NDHS (with the incorporated contextual data from the National Human Development Report (2018 NHDR)).
vi. To describe the spatial distributions of the prevalence of multimorbidity of anaemia, malaria, and malnutrition among children 6-59 months across Nigeria's state and geopolitical regions using data from the 2018 NDHS (with the incorporated contextual data from the National Human Development Report (2018 NHDR)).

vii. To investigate the individual and contextual risk factors of multimorbidity of malaria, anaemia, and malnutrition among children 6-59 months in Nigeria using data from the 2018 NDHS (with the incorporated contextual data from the National Human Development Report (2018 NHDR)).

viii. To determine the interaction effects of a child's age, sex, and household socioeconomic status on the individual and contextual risk factors of MAMM among children aged 6-59 months in Nigeria

1.5 Research design

This current study is an expo facto research design of secondary analysis of two nationally representative cross-sectional surveys of the 2018 Nigeria Demographic and Health Survey (NDHS) and 2018 National Human Development Report (NHDR). There were 10,481 children aged 6-59 months, with some of the contextual variables in NHDR incorporated into the NDHS data set. The descriptions of these surveys are in Chapter Four of this thesis.

1.6 Overview of the thesis

This thesis is made up of nine chapters. Immediately following this, Chapter One is the background information of the fundamentals in the study, which is the subject of discussion in Chapter Two, with the definition of critical concepts in the study and descriptions of issues patterning to associations in health inequalities. Chapter Three presents the reports from the scoping review on anaemia, malaria, malnutrition and multimorbidity among children in Sub-Saharan Africa (SSA). This chapter opens with the rationale statement for focusing on SSA in the reviews. Chapter Four describes the two data sets, the 2018 NDHS and the 2018 NHDR); as well as a description of the outcome variables and predictor (risk factor) variables. It also provides a statement justifying the methods used, followed by concise descriptions of the data set, the measurements and classifications of variables, and statistical analysis methods. Chapter Five reports the findings of the quantitative analysis of the survey data sets along with the baseline description of variables. While Chapter Six reports the results of the multilevel (individuals/households nested within communities nested within states) analysis of the predictors of the three different outcomes of anaemia, malaria, and malnutrition. Chapter seven contains the results of the multilevel ordered logistic analysis of MAMM. Overall, 48.3% (4917/10183) of children in the households had two or more diseases, while 16.9% (1721/10183) had all three. A total of a weighted sample of 10,481

children were captured in this study.. Chapter eight presents the results of including of some interaction terms to the choice model, and the summary and comparison of the four models/outcomes and risk factors. Finally, Chapter nine discusses the principal findings, the strengths and limitations of the study, conclusions, and recommendations.

Chapter 2 Background study

2.0 Introduction

Since 1990, there has been a significant decrease in childhood mortality worldwide. Globally, the number of children under five dying has fallen from 12.6 million in 1990 to 5.0 million in 2020. The mortality rate for children under five has also decreased globally since 1990 by 60%, from 93 fatalities per 1,000 live births in 1990 to 37 in 2020.(World Health Organization, 2022). However, in the developing countries childhood mortality and morbidity rates are still very high, resulting in a severe public health burden (UNICEF, 2022; World Health Organization, 2022), and making it extremely difficult to trust that the SDG 3 target aim of ending preventable deaths of new-borns and children could be realised by 2030. The countries' socioeconomic and quality of life are functions of childhood health status (Khatab, 2007). The most common diseases and great contributors to mortality among children under-five years in developing countries, especially in sub-Saharan Africa (SSA), include malnutrition, anaemia, malaria, diarrhoeal, fever, and acute respiratory infections (N.-B. Kandala *et al.*, 2011; UNICEF, 2022; World Health Organization, 2022). A correct understanding of the sociocultural, and environmental factors that influence the occurrence of illnesses and mortality is essential for implementing health care interventions (Khatab, 2007). Besides what is known, the socioeconomic and environmental factors determining the occurrence of these diseases individually, the study of their interactions has long been neglected, especially among children. The burden of multimorbidity could be too high for most developing countries to bear. The proper understanding of how these diseases is linked to the individual's socioeconomic, demographic, and contextual factors will help in policymaking based on informed decisions in optimizing the distribution of scarce palliatives to stop the spread of these diseases. This study focuses on three childhood diseases: anaemia, malaria, and malnutrition.

2.1 Review of fundamental concepts

The current study sought to investigate the multiple overlaps in the impact of individual and contextual variables on the prevalence of anaemia, malaria, malnutrition, and their multimorbidity among children aged 6 to 59 months in Nigeria. The topics under investigation are intricate and multifaceted; definitions of each term used in this thesis are explained below.

2.1.1 Under-five Mortality

There were concerted efforts by the global communities through the Millennium Development Goals (MDGs-4) declaration to reduce the global burden of under-five mortality (U5M) by more than 60% by 2015. From 1990 to 2012, the global U5M decreased by 50% (Atrash, 2013). Three years after, the rate had dropped to 41 deaths per 1000 live births. By 2018, global U5M was 5.3 million, which means 1 in every 28 children died before their fifth year from the initial rate of 1 out of every 11 children that died in 1990 (World Health Organization (WHO), 2017). Despite this remarkable reduction in U5M worldwide, there continued to be variations across regions of the world (Atrash, 2013; World Health Organization (WHO), 2017). For instance, there are more U5M in developing countries compared to developed countries (World Health Organisation, 2011)**,** with an 18-fold increase in U5M in SSA compared to more advanced economies. (Hill *et al.,* 2012). Over the last two decades, the U5M global reduction has had an opposite trend in SSA. Out of the global rate of U5M in 1990, SSA bore the burden of 31%; this unexpectedly grew to 49% in 2010 (Hill *et al.,* 2012), and in 2015, it accounted for 50 per cent of the global prevalence (Salako *et al.,* 1990; Suzuki, 2015). Over ten years (from 2003 to 2013), the U5M rate in Nigeria dropped by 73 deaths per 1000 live births (Obasohan, 2020) and subsequently reduced by 19 deaths per 1000 live births in 2015. Despite these achievements, Nigeria could not attain the MDG to reduce the mortality rate to at most 64 deaths per 1000 live births in 2015 (Obasohan, 2020). One out of every ten global under-five deaths is traceable to Nigeria, second behind India, accounting for over 20% U5M worldwide (Hill *et al.,* 2012). The causes of U5M are numerous and include primarily preventable and infectious diseases that were not attended to promptly. Malaria and Malnutrition (World Health Organisation, 2019) and perhaps anaemia is significantly among the major contributors to under-five morbidity and mortality, especially in SSA (Ehrhardt *et al.,* 2006).

2.1.2 Anaemia in Under-five years

Anaemia is a primary haematological and nutritional disease affecting adults and children in many countries globally, especially in Sub-Saharan Africa (Ewusie *et al.,* 2014; Ezeonwu *et al.,* 2014; Akodu *et al.*, 2016; Belachew and Tewabe, 2020). A report (Kassebaum *et al.,* 2014) cited in (Demirchyan *et al.,* 2016) noted that more than 30% of the world population was anaemic in 2010. Pregnant women and children worldwide are the worst affected by the anaemia burden. Children under-five years bear the most significant global burden of anaemia, with 47.4%, while men bear

the lowest (27.4%) (De Benoist *et al.*, 2008; World Health Organisation, , 2017). The global prevalence of anaemia with its aetiology cut across geographical, age and sex variations (Demirchyan *et al.*, 2016). In the last thirty years, the global prevalence of anaemia in under-five years has witnessed a steady decline from 51.4% in 1990 to 41.4% in 2014 but rose to 41.7% in 2016 (World Health Organisation, 2017). The United States of America and Canada have the lowest proportion of under-five anaemia at less than 10%. Mali and Yemen have the highest prevalence of more than 83% (World Health Organisation, 2017). While in Nigeria, the estimate of the prevalence of anaemia among children under-five years was 68% in 2017.

2.1.3 Malaria in Under-five years

In 2015, over 214 million malaria cases, with over 260,000 being under-five years, occurred worldwide, translating into one child dying every two minutes in 2017 (Dawaki *et al.*, 2016). With over 430,000 deaths annually, Sub-Saharan Africa contributes to over 90% of global malaria deaths. In Nigeria, malaria fever alone contributes to more than 30 per cent of under-5 mortality (World Health Organisation, 2014). Nigeria has about 51 million cases and 200,000 deaths per year, making it the highest malaria-endemic nation in the world, resulting in more than 30% of child mortality as a result of malaria cases (National Population Commission (NPC), National Malaria Control Program (NMCP) and ICF Macro, 2012; Dawaki *et al.*, 2016).

The risk of malaria infection cuts across all age segments, with women (especially the pregnant), and children (especially those under-five years), the most vulnerable (CDC-Centers for Disease Control, 2021). Malaria is a deadly disease that kills an estimated number of 30 children every hour worldwide. There were outstanding commitments by governments and global partners to end malaria-induced mortality and morbidity by 2020 (World Health Organization, 2014). The Roll Back Malaria (RBM) programme was launched in 1998 by the World Health Organization (WHO), United Nations Children Fund (UNICEF), and several funding institutions. heads of state and government from within the United Nations (UN) to reduce malaria-induced U5M by half in 2010 through prompt diagnosis, treatment, and use of insecticide-treated nets (Gup, Udo Nnorom and Amadi, 2013). These efforts are targeted primarily to improve the health-related quality of life of the child (Gup, Udo Nnorom and Amadi, 2013). Furthermore, by 2018, some commonwealth nations renewed their commitment to preventing more than 650,000 deaths arising from malaria infections by 2023 (Ready to Beat Malaria (RBM)., 2020).

Between 2001 and 2014, Nigeria implemented four National Malaria Strategic Plans (NMSPs), with the most recent, which ended in 2020 (2014-2020), aimed at reducing malaria-related deaths to zero by 2020 (National Malaria Elimination Program (NMEP), National Population Commission (NPopC), National Bureau, and ICF International, 2016). Unfortunately, this was far from being achieved. However, to scale up the intervention strategies through evidence-based data, Nigeria has conducted three nationally representative surveys, with the baseline survey conducted in 2010 and followed up in 2015. The third incorporated into the 2018 Nigeria Demographic and Health Survey (National Population Commission (NPC), National Malaria Control Program (NMCP) and International, 2012; National Malaria Elimination Program (NMEP), National Population Commission (NPopC), National Bureau, and ICF International, 2016; National Population and I. C. F. International, 2019). The *plasmodium* parasites that are most prevalent in SSA are *P. falciparum, P. vivax, P. ovale, P. malariae and P. knowlesi* (Gaston, Ramroop and Habyarimana, 2021). With over 95% transmission rates, *Plasmodium falciparum* is the most prevalent parasite causing malaria infection in Nigeria, while the *Anopheles gambiae* and *A. funestus* are the most common carriers of the parasites (National Population Commission (NPC) [Nigeria], 2012; National Malaria Elimination Program (NMEP), National Population Commission (NPopC), National Bureau, and ICF International, 2016).

2.1.4 Malnutrition in Under-five years

Malnutrition, which "refers to deficiencies, excesses, or imbalances in a person's intake of energy and nutrients" (World Health Organisation, 2020), has continued to be a public health concern world over and especially in developing countries (Endris, Asefa and Dube, 2017). Over 200 million children under-five years are either undernourished or overweight (World Health Organisation, 2020). Undernutrition in children contributes to about 45% of under-five mortality worldwide (World Health Organisation, 2020). The prevalence of malnutrition in under-five years is higher than in other age groups (Endris, Asefa and Dube, 2017). However, in the last two decades, stunting in children has witnessed a significant reduction, while overweight is increasing (Jude, Chukwunedum and Egbuna, 2019; Global Nutrition Report, 2020). In Nigeria, the 2013 Nigeria Demographic and Health Survey (NDHS) reported that 37%, 18% and 29% of the children under-five years are stunted, wasted and underweight, respectively (National Population Commission and ICF Macro, 2014). Understanding how different socioeconomic, demographic, and contextual factors determine childhood malnutrition is a great way to improve the distribution

of scarce resources for the desired interventions. Variations also exist in these malnutrition indicators as per the 'place of residence, where urban children are most likely to be more nourished than children in rural areas (National Population and I. C. F. International, 2004; Babatunde *et al.*, 2011)

2.1.5 Morbidity

The dictionary definitions of morbidity stand on the premises of two opposite ends of a pole (Fries, Bruce and Chakravarty, 2011). On one end, morbidity is defined as the 'latent trait' contributing to adverse health-related quality of life, illnesses, or weakness. At the other end of the pole is the 'diagnosis-counting metrics' of morbidity, which refers to the count of chronic diseases in an individual, an approach that is very common in many secondary data sets (Fried *et al.*, 2004; Fries, Bruce and Chakravarty, 2011). In a more simplified definition, morbidity is coined from the Latin word, 'morbidus', which means the state of being sick or unhealthy (SlidetoDoc, 2021). However, in a more specific term, morbidity is the occurrence of a single disease condition in an individual.

Concerning age-specific mortality, older people are more morbid than younger people (Public Health England, 2018). The burden of mortality increases with age, which means that as the population is ageing, higher mortality rates are experienced (Public Health England, 2018). However, childhood morbidity remains a global cause of childhood mortality and a threat to the public health system. The most common childhood morbidity and leading causes of childhood mortality in developing countries include preterm birth complications, congenital abnormalities, acute respiratory infections, malaria, diarrhoea, sepsis, anaemia, fever, and malnutrition. In Sub-Saharan Africa, efforts to reduce the impact of these childhood morbidities have caused the region and global partner's substantial amount. Despite the considerable investment, childhood morbidity remains a severe public health burden in SSA (Adedokun and Yaya, 2020).

2.1.6 Comorbidity and Multimorbidity

In contrast, comorbidity was originally referred to as the cooccurrence of two chronic disease conditions in an individual, while multimorbidity was referred to as the simultaneous occurrence of more than two disease conditions (McGeorge, 2012; Abebe *et al.*, 2020). Comorbidity and multimorbidity are emerging related constructs often used interchangeably (Valderas *et al.*, 2009). However, a significant conceptual difference in the definitions of the two concepts is that comorbidity is often associated with an index condition, while multimorbidity is with no regard to

any index disease (Mofina *et al.,* 2020). This distinction by index disease has been enshrined in MESH since 2018 (Tugwell and Knottnerus, 2019). Therefore, comorbidity is the cooccurrence of two or more disease conditions in an individual with reference to an index disease. At the same time, multimorbidity is the cooccurrence of two or more diseases in an individual without reference to an index disease. The main focus of this thesis is Multimorbidity of anaemia, malaria, and malnutrition (MAMM) in children and assumes there is no index disease.

The elderly population are the most vulnerable to multimorbidity, with over 70 per cent of those aged 65 years and above affected(McGeorge, 2012; Bramley and Moody, 2016). There are more than 33% prevalence rates of multimorbidity worldwide (Nguyen *et al.,* 2019). Children are also not left out as research begins to unveil that many children suffer from multimorbidity (Ferro *et al.,* 2019). Studies have associated multimorbidity to both demographic changes (which include an ageing population and sex differences); individual and social lifestyle (which include overweight and obesity, sedentary lifestyle, smoking and excessive alcohol use); and psychosocial factors (Eyowas *et al.,* 2019). However, the biggest challenge of these conditions to clinicians, researchers, and health care providers are the complex ways in which these conditions interact with socioeconomic, demographic and environmental patterns (Khatab and Kandala, 2011; McGeorge, 2012; Bramley and Moody, 2016; Pathirana and Jackson, 2018). In addition, the increase in the prevalence of multimorbidity in developing countries with poor health systems and over-burdened with chronic diseases are part of the significant challenges to healthcare. Furthermore, the complete absence of suitable models of multimorbidity care adaptable to developing countries is an additional task for clinicians, researchers, and health care providers to unravel.

The consequences of living with multimorbidity include disability, reduced quality of life, sudden death, increased health service utilization and cost of care, and preventable hospital admission (Eyowas *et al.,* 2019; Abebe *et al.,* 2020; Mofina *et al.,* 2020). A constructive step toward comprehending epidemiology and determinants of multimorbidity is that more research focused on developing countries is urgently needed to provide appropriate care for children living with multimorbidity. This thesis is focused on contributing to bridging these gaps.

2.1.7 The Multimorbidity of Anaemia, Malaria, and Malnutrition

There is evidence in research that anaemia, malaria, and malnutrition interrelate, resulting in adverse health outcomes and mortality, especially in children under-five years. In a recent study

conducted on SSA, Malnutrition is a vital factor causing a high proportion of malaria-related mortality (Ehrhardt *et al.*, 2006). Malaria is strongly related to anaemia in children (Sumbele *et al.*, 2015; Wanzira *et al.*, 2017). Though the relationship between malaria and malnutrition has shown some controversy, Sakwe *et al.* (Sakwe *et al.* 2019) found a significant interrelationship between malnutrition and malaria. Also, due to malaria's relationship with anaemia and malnutrition Teh *et al*. (Teh *et al.* 2018) recommended that reasonable control of anaemia and malnutrition will require adequate control of malaria infection. The anaemic child presents a more significant measure of undernutrition (Sakwe *et al.*, 2019). On the other hand, most importantly is the emergence of coexistence of these disease conditions and many others in an individual.

2.2 Issues of associations in health inequalities research

Health inequalities refer to analytical disparities of social and economic costs in the health outcomes of different groups of individuals in societies (World Health Organization, 2018). A wide range of health inequalities abounds in all countries, whether developing or developed economies, in the different social spectrum, including 'education, employment status, income level, gender and ethnicity (World Health Organization, 2018). For instance, socioeconomic disparities in health outcomes have received good attention in developed countries through constant evaluation of the system for policy formulation to tackle them (Wagstaff, 2002). Even while health inequities are important, there hasn't been much focus on them in developing nations until lately (Wagstaff, 2002), resulting in widened gaps in health inequalities between developed and developing countries. The need to foster global health equity moved the WHO in 2005 to set up a commission on social determinants of health to come up with what should be done to close the health gap. The commission believed that:

> "The poor health of the poor, the social gradient in health within countries, and the significant health inequities between countries are caused by the unequal distribution of power, income, goods, and services, globally and nationally, the consequent unfairness in the immediate, visible circumstances of people's lives – their access to health care, schools, and education, their conditions of work and leisure, their homes, communities, towns, or cities – and their chances of leading a flourishing life. This unequal distribution of health-damaging experiences is not a 'natural' phenomenon but results from a toxic combination of poor social policies and programmes, unfair economic arrangements, and bad politics". (World Health Organization, 2008).

This statement is particularly true for most developing countries, including the Nigerian health system (Abubakar *et al.*, 2022). There is a need for more studies that will contribute to a proper evaluation of the system leading to suitable policy formulations to address the health disparities. Sociocultural and economic factors, which are made up of structural factors and daily life situations, account for many health disparities between and within nations. In essence, social, demographic, and economic policies determine whether a child may reach their full potential, live a fulfilling life, or suffer from a depressed life (World Health Organization, 2008).

2.2.1 Individual child's characteristics

The health status (healthy or not) of a child in a population is a function of interrelated factors at both individual and environmental levels (Murdock, 2017). These determinants are divided into three main groups: individual characteristics, physical and social, and health services (Murdock, 2017). As for individual determinants, these are, on the one hand, biological uncontrolled inherent traits from birth that distinguish the health status of one child from another, such as age, sex, and parental affiliation. On the other hand, they could be behavioural factors that pertain to a child, which could be subject to modification via some control measures. These include health status (the child had malaria, anaemia, diarrhoea), immunization, and birth size.

2.2.2 Contextual characteristics

Contextual determinants are factors associated with the individual's physical environment that affects the health status. They include the conditions of the natural environment and those constructed by humans(Murdock, 2017). They include those factors that can be derived from the individuals in the communities or observed from the community the individual resides. In other words, they are factors that the individuals within that environment are jointly exposed to and their health outcomes. More attention is being placed on the significance of contextual factors, namely where individuals reside, for policy and the implementation of health interventions (Anjorin *et al.*, 2020). Contextual factors include the 'proportion of educated females in the community, 'community access to health facilities, 'access to clean water and 'general sanitation' (The EUPATI, 2022), and the socioeconomic status of the community.

2.2.3 Multiple overlaps

The concept of multiple overlaps in this study is associated with determining the individual and contextual factors that could simultaneously determine multiple health statuses. Most health conditions in the same ecological epidemiology system may exhibit common causes,

epidemiology, socioeconomic, demographic and environmental risk factors (Kateera *et al.*, 2015; Khatab, Adegboye and Mohammed, 2016; Teh *et al.*, 2018). The biggest challenge that these conditions pose to clinicians, researchers and health care providers are the complex ways in which the conditions interact with socioeconomic, demographic and environmental patterns (Khatab and Kandala, 2011; McGeorge, 2012; Bramley and Moody, 2016; Pathirana and Jackson, 2018). These predictors common to these diseases are what is referred to as 'multiple overlaps' and are significant to chant the course of providing cost effective and integrated care for children living with multimorbidity with the bid to speed up the realization of SDG 3 as it relates to preventable deaths of under-five years in Nigeria.

2.3 Sustainable Development Goal 2030 and the National Health Policy in Nigeria

At the Millennium Summit held in September 2000 at the United Nations (UN) headquarters in New York, member States overwhelmingly endorsed the Millennium Declaration. The eight Millennium Development Goals (MDGs) to end extreme poverty by 2015 were developed as a result of the summit (United Nations, 2022) , which initiatives were to help the world most vulnerable people (United Nations, 2008) . Three out of the eight goals were health-related targets set to: (i) reduce child mortality, (ii) improve maternal health, and (iii) combat HIV/AIDS, malaria and other diseases. Also, at the UN Sustainable Development Summit in September 2015, the post-2015 development agenda was adopted as the 2030 agenda for Sustainable Development focusing on 17 SDGs. Of utmost important to us in this study is the SDG-3 which is targeted at ensuring healthy lives and promote well-being for all at all ages. Since 2015, Nigeria is fully dedicated to leading and taking control of the implementation process to achieve the global goals through technical support of UN in Nigeria (United Nations-Nigeria, 2022) .

Nigeria has so far implemented three national health policies since 1988 when the first one was launched. The second was in 2004, while the current policy came into effect on the 22 June 2016 to achieve the universal health coverage (UHC) and other health-related sustainable development targets (Nigeria Finder, 2022). The essence of these current policy was to create access to basic health care after the achievement attained in the health sector over the last twenty-five years which include combating the menace of HIV/AIDS, Tuberculosis, Malaria, Poliovirus, Guinea worm infection, the spread of Ebola, as well as issues relating to maternal and child health (MCH) (Nigeria Finder, 2022). Two major points of interest in this health policy are (i) the reduction in

maternal and infant mortality, the uptake of vaccines, and the better management and avoidance of public health emergencies, and (ii) Providing all Nigerians with financial risk protection, especially the country's most vulnerable and poor people. The first point relates strongly with the SDG 3, and particularly in the associated goals which seek to lower the rate of maternal deaths worldwide and eliminate unnecessary infant and child deaths (United Nations, 2022). The second is at the heart of the whole SDG goals which recognise that by ending poverty can improve whatever strategies are adopted to increase health status, access to education, eliminate inequality, and stimulate wealth of the nation.

As for the SDG-3, in Nigeria, the UN and global partners have committed over 290 million US Dollars to ensure maximum dividend for the target vulnerable people (United Nations-Nigeria, 2022). However, Nigeria needs more than $USD350 billion to fully achieve all the SDGs, an amount far more than 800% of the country's 2022 national budget (Ajala, 2022). As with the health sector, For the past 20 years, Nigeria has not been able to meet the 15% of her national budget for health sector. The 2022 budget for health was less than 5% of the nation's budget. This can hardly be enough to meet up with the realisations of the current national health policies. The country's low commitment to the socio-economic development that is the bane of the SDGs achievement means Nigeria is very unlikely to meet the SDGs by 2030. For instance, by 2019 index report, the country was ranked 159th out of 162 countries in achieving SDGs so far (Ajala, 2022). This is even more worrisome now that the public health sector is being saddled with an emerging multimorbidity of childhood diseases. In the light of the above, the principal contribution of the results from this study will help the policymakers to come up with informed decisions that will maximize the use of scarce resources by addressing multiple and cooccurrence of childhood diseases rather than independent approach.

2.4 Ethical approval

The School of Health and Related Research (ScHARR) Ethics Committee of the University of Sheffield had granted permission for this research investigation to be conducted ethically (Reference Number: 031534). Two nationally representative samples were used in this study's secondary analysis. The 2018 National Human Development Report and the 2018 Nigeria

Demographic and Health Survey were used with permission from the Inner-City Fund (ICF)-International and the United Nations Development Program (UNDP)

2.5 Chapter Summary

By first outlining the significant concepts under consideration, this chapter has provided the background to the current study. The thesis's concept of multimorbidity in health essentially views childhood diseases like anaemia, malaria, and malnutrition as "coexistence in the same ecological-epidemiology system" that share common individual and contextual predictors as opposed to the "independent existence of diseases". The term "health inequalities" has also become widespread within and between nations, especially in developing countries. The differences in the concept of multimorbidity and comorbidity have been described in the chapter. The thesis defined comorbidity as the cooccurrence of two or more disease conditions in an individual with reference to an index disease. At the same time, multimorbidity is the cooccurrence of two or more diseases in an individual without reference to an index disease. This thesis focuses on MAMM in children and assumes there is no index disease.

Until recently, the lack of nationally representative surveys to capture data for anaemia, malaria, and malnutrition in Nigeria, has created the existence of dearth of knowledge gaps which has resulted in relatively few studies that have investigated the determinants of cooccurrence of childhood diseases in public health in Nigeria. Therefore, a series of four scoping reviews of the SSA literature was conducted to identify the evidence regarding how individual and contextual factors influence anaemia, malaria, malnutrition, and multimorbidity of childhood diseases in SSA. The findings of these four reviews are presented in the following chapter. We extended the search to cover SSA because other African countries are more similar to Nigeria in the context of childhood diseases.

Chapter 3 Scoping Reviews of Literature

3.0 Introduction

This Chapter discusses the scoping reviews of existing evidence on anaemia, malaria, malnutrition, MAMM and other childhood diseases among children aged under-five years in sub-Saharan Africa. It begins with the rationale for conducting scoping reviews, the review objectives, scoping review on multimorbidity of childhood diseases among children aged under-five years in Sub-Saharan Africa (SSA), and the results from evidence from individual scoping reviews associated with the three outcome variables (anaemia, malaria, and malnutrition).

3.1 Rationale

Globally, especially in advanced countries and perhaps in the adult population, the study of multimorbidity as a health challenge has received much attention because co-occurring diseases in children in high-income countries have not become so much a public health problem. However, the same is not valid for low- and medium-income countries (LMIC), where the health system is overwhelmed with many challenges, including children's health. Furthermore, the non-availability of nationally representative data has resulted in a lack of research on multimorbidity among children in LMIC. For instance, until the 2018 NDHS, there has not been any nationally representative survey that has captured data simultaneously for anaemia, malaria, and malnutrition in children aged under-five years.

The focus of the current study is the multimorbidity of three of the most common childhood diseases (anaemia, malaria, and malnutrition) among children aged 6-59 months in Nigeria. However, given that there are relatively few studies on multimorbidity among children aged under-five years using nationally representative surveys has warranted expanding the scoping review to cover not just the multimorbidity of childhood diseases but also individual outcome variables of anaemia, malaria, and malnutrition (as they were available in the literature), in sub-Saharan Africa. However, these health conditions (anaemia, malaria, and malnutrition) exist together in the same ecological epidemiology system and, as such, may exhibit common causes, epidemiology, socioeconomic, demographic, and environmental risk factors (Kateera *et al.*, 2015; Khatab, Adegboye and Mohammed, 2016; Teh *et al.*, 2018). Therefore, the identification and description of these predictors as well as studies using appropriate statistical analyses will be a vital tool to enhance the direction of this thesis.

3.1.1 Review Objectives

The objectives of this scoping review were explicitly to locate and examine the existing studies conducted on nationally representative health survey data to identify individual socioeconomic, demographic, and contextual risk factors for developing (i) multimorbidity of childhood diseases, (ii) anaemia, (iii) malaria, (iv) malnutrition among children aged under five years in Sub-Saharan Africa (SSA).

3.1.2 Summary of the chapter

The focus of this study is multimorbidity among children using three of the most common childhood diseases (anaemia, malaria, and malnutrition) as proxy indicators of disease co-occurrence. The chapter begins with the scoping reviews of evidence from studies relating to the risk factors associated with multimorbidity among children under-five years in sub-Saharan African countries. The Section is followed by reports extracted from three other scoping reviews conducted on anaemia, malaria, and malnutrition. Firstly, the paper titled: *A Scoping Review of the Risk Factors Associated with Anaemia among Children Under Five Years in Sub-Saharan African Countries* was conducted on selected papers published between 1 January 1990 and 26 June 2020. The outcome of this review was published in the *International Journal of Environmental Research and Public Health*. 2020 (Obasohan *et al.*, 2020a). Secondly, the scoping review titled*: A Scoping Review of Selected Studies on Predictor Variables Associated with the Malaria Status among Children under Five Years in Sub-Saharan Africa* was conducted for existing publications between 1 January 1990 and 31 December 2020. The review's outcome was published in the *International Journal of Environmental Research and Public Health*. 2020 on 22 February 2021 (Obasohan *et al.*, 2021a). Thirdly, the scoping review titled: *Risk Factors Associated with Malnutrition among Children Under-Five Years in Sub-Saharan African Countries: A Scoping Review*, was carried out on included papers published between 1 January 1990 and 31 July 2020. The review's outcome was also published in the *International Journal of Environmental Research and Public Health*. 2020 on 26 November 2020(Obasohan *et al.*, 2020b). The full texts of these papers are attached in Appendix C.1, C.2, and C.3, respectively. Then, the last part of this chapter collates all the identified risk factors for multimorbidity, anaemia, malaria, and malnutrition in the target population, followed by the risk factors that are common to all four reviews (multimorbidity, anaemia, malaria, malnutrition), including the direction of the associations between the risk factors and the outcomes.

3.2 Scoping review of factors associated with multimorbidity among children aged under-five years in sub-Saharan African countries

3.2.1 Introduction

Children's health is affected by childhood multimorbidity, a rising public health issue in developing nations. However, multimorbidity affects more than 70% of those aged 65 and older, making the elderly group the most at risk (Bramley & Moody, 2016; McGeorge, 2012). The frequency of multimorbidity is greater than 33% worldwide (Nguyen *et al.*, 2019). However, children are not excluded, however, as research shows that a sizable proportion of children experience multimorbidity (Ferro *et al.*, 2019). Numerous studies have linked multimorbidity to psychosocial factors, individual and social lifestyle choices (such as overweight and obesity, sedentary behaviour, smoking, and excessive alcohol consumption), and demographic changes (such as the ageing population and gender inequalities) (Eyowas *et al.*, 2019). The intricate way these disorders interact with socioeconomic, demographic, and environmental patterns presents the biggest challenge to doctors, researchers, and healthcare professionals (Bramley & Moody, 2016; Khatab & Kandala, 2011; McGeorge, 2012; Pathirana & Jackson, 2018). The most significant issues facing the healthcare system also include the rise of multimorbidity in developing nations with subpar healthcare systems, a burden of chronic diseases, and the realization of SDG 3 by 2030. The scoping review of these studies is significantly more important than their importance for making evidence-based healthcare decisions about the prevention of multimorbidity in Nigeria and the SSA. Apparently, because of the diverse nature in which multimorbidity research is being conducted, it becomes challenging to conduct research synthesis to compare studies across variabilities in methodology, geographical locations, and disease components (Fortin *et al.*, 2005; Roomaney *et al.*, 2021). However, the purpose of this scoping review was to identify and compare the existing literature that investigates the individual socioeconomic, demographic, and contextual risk factors associated with multimorbidity among children under-five years of age in Sub-Saharan Africa (SSA), with the view to identify study gaps in the outcome of interest, analytical approach, and geographical locations. The review regarding the factors that influence the prevalence of multimorbidity in children under five in SSA has not been done. Consequently, this research tries to close this gap. Therefore, the aim of this scoping review is finding and describe papers that studied the relationship between socioeconomic,

demographic, and contextual characteristics and the prevalence of multimorbidity among children aged under five years in Sub-Saharan Africa countries and have used classical regression analysis methods.

3.2.2 Methodology

The methodology described in this section was the same used in other scoping reviews that have already been published.

3.2.2.1 Design

This scoping review was tailored along with the enhanced framework of Arkey and O'Malley (Arksey and O'Malley, 2005), the recommendations of Lecac et al (Levac, Colquhoun and O'Brien, 2010), and guidelines of the Agency for Healthcare Research and Quality (AHRQ) (FDA Media, 2020). The five key steps include: (1) research question identification, (2) identification of the relevant study sources, (3) evidence and eligibility criteria selection, (4) data charting, and (5) results collating, summarising and reporting (Maphosa *et al.*, 2020). However, the pattern of reporting the results in this scoping review followed the UNICEF extension for Scoping Reviews (PRISMA-ScR) guidelines (Larissa Shamseer, 2015; Tricco *et al.*, 2018).

3.2.2.2 Protocol and registration declaration

There was no review protocol and registration done for this scoping review

3.2.2.3 Identification of the research questions

We based the research question on the research purpose that was stated using the Population, Intervention, Comparators, Outcomes, Timing and Study design (PICOTS) framework of AHRQ ((FDA Media, 2020). The primary research question for this scoping review is: "what are the risk factors associated with multimorbidity among children under five years in sub-Saharan Africa countries". Furthermore, the thesis answering the following questions:

- What types of frequentist statistical analyses were employed in the existing evidence to determine the risk factors associated with multimorbidity among children under five?
- What are the various childhood disease combinations that formed the multimorbidity structures examined in the eligible studies?
- What are the possible gaps in knowledge identified from the selected literature?

3.2.2.4 Eligibility criteria

Studies included in the review followed the PICOTS criteria enumerated and defined as follows:

Inclusion criteria

Population (P): The studies included male and female children under five years of age who resided in any Sub-Saharan Africa (SSA) country. The review also includes studies involving adults (or/and above-five years children) and under-5 years children, provided data for under-five was reported differently from others.

Intervention (I): Studies that focused on predictors or risk factors or determinants of multimorbidity among under-5 or preschool children in SSA that covered both individual and contextual exposures using classical regression methods only.

Comparator (C): The presence of two or more diseases versus no diseases was the focus of the comparators in the studies. We restricted the search to papers that have used regression for the purpose of manageable focus considering the time limit that is available for this project, and for the ease of comparing the findings across papers. In addition, we omitted studies that have used Bayesian approach because it would require specifying priori-probabilities and these may not be appropriate comparing with studies using classical frequentist approach which do not require priori-probability distributions.

Outcomes (O): Studies that involved two or more childhood diseases that were evaluated jointly rather than independently such that the outcomes reflect the interactions of the diseases.

Timing (T): The publication period for the article is between 1 January 1990 and 19 March 2022 to capture recent publications on the topic from when the UNICEF conceptual framework of causes of malnutrition was in effect, the MDG and SDGs

Settings/Design (S): Observational studies such as cross-sectional and longitudinal studies focused on risk factors as exposures.

Exclusion criteria

1. Studies involved older children, but no separate data involving under-five years was made.
2. Studies do not meet the definition of 'multimorbidity' as the "cooccurrence of two or diseases among children under five years without reference to an index disease".

3. Studies not written in the English language

Steps involved in the inclusion and exclusion processes

The following were the priority steps adopted in including or excluding studies extracted for full reading:

1. If the study is multimorbidity, then
2. Is the unit of analysis children aged under-five years? then
3. Is the country of analysis from SSA? then
4. Does the study utilise a nationally representative survey in data collection?
5. Does the study utilise classical regression methods in the analysis?

If the answers to all these steps are 'yes', the paper is included, otherwise, it is excluded

3.2.2.5 Identify the relevant sources of evidence

Information sources

The candidate (PEO) of the School of Health and Related Research (ScHARR), the University of Sheffield, United Kingdom conducted the literature search from MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), PubMed, Scopus, and web of science. It included only papers written in English, and the publication date was between January 1990 and March 2022. The search was first carried out on 19 September 2021 and updated on 19 March 2022.

3.2.2.6 Selection of sources for evidence and eligibility criteria

Search strategy

In this scoping review, the search terms were first entered into MEDLINE (Ovid) as shown in Table 3.1 with mapping by subject headings marked. Next, the search terms were derived from the PICOTS categories. These terms were then repeated for other databases consulted.

Table 3 1: Draft Search strategy and terms for MEDLINE (Ovid)

S/N	Terms and keywords	Results
1	'Sub-Saharan Africa' OR SSA OR 'low-and middle-income countries	37452
2	Socioeconomic OR demographic OR contextual OR environmental OR community OR determinants OR risk factor OR predictor OR Association	3298141
3	comorbidity OR comorbidity OR multimorbidity OR multimorbidity OR multiple chronic conditions OR multi-diseases	451419
4	Logistic regression OR multilevel regression OR multinomial logistic OR random-effects OR hierarchical OR fixed effects OR mixed-effects	55708
5	1 AND 2 AND 3 AND 4	12
6	Limit 6 to human and English language and infant<to one year> OR preschool child <1 to 6 years>	
	Limit to last 30 years (1990 to 2020)	12

Selection Process

The reviewer, PEO, screened all the selected literature for titles and abstracts using the inclusion and extraction criteria as a benchmark. This process was done twice from two citation managers platforms (Endnote and Zotero). The full-text first full-text report was conducted for all the selected articles. Papers excluded were noted with reasons. This process was vetted by three overseeing a team of supervisors.

3.2.2.7 Data Charting Management

The data extracted from the included articles were first deposited into a Microsoft Excel sheet designed by the reviewer for this review. The relevant information extracted includes authors/year of publication, the paper title, study objectives, outcome of interest, the sample size (and age of participants), method of data analysis used, the procedure adopted (study design), and perceived difference in the approach, and study location.

3.2.3 Results

The results section reports the profile of the quantitative analysis of risk factors associated with multimorbidity among children aged under-5 years in SSA following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklists (Larissa Shamseer, 2015; Tricco *et al.,* 2018).

3.2.3.1 Selection of Sources of Evidence

A total of 261 articles were identified from all the electronic databases consulted (MEDLINE(Ovid)=12, CINAHL=43, PUBMED= 124, Scopus = 27, Web of Science (WOS) = 50, other sources (from references) = 5)., out of which 22 duplicates were removed (see Figure 1). Further, 173 were removed after the abstracts and titles were read for eligibility. Out of the 66 articles selected for full-text reading, an additional 60 were removed for various reasons (including (i) participants are above under five years (6), (ii) not multimorbidity (MM) paper as per the definition of MM (26), (iii) Bayesian approach (4), non-national coverage (6), (iv) Systematic reviews (3), (v) No full text found (15)). Therefore, data from a sample of 6 articles were finally extracted and reported in this study.

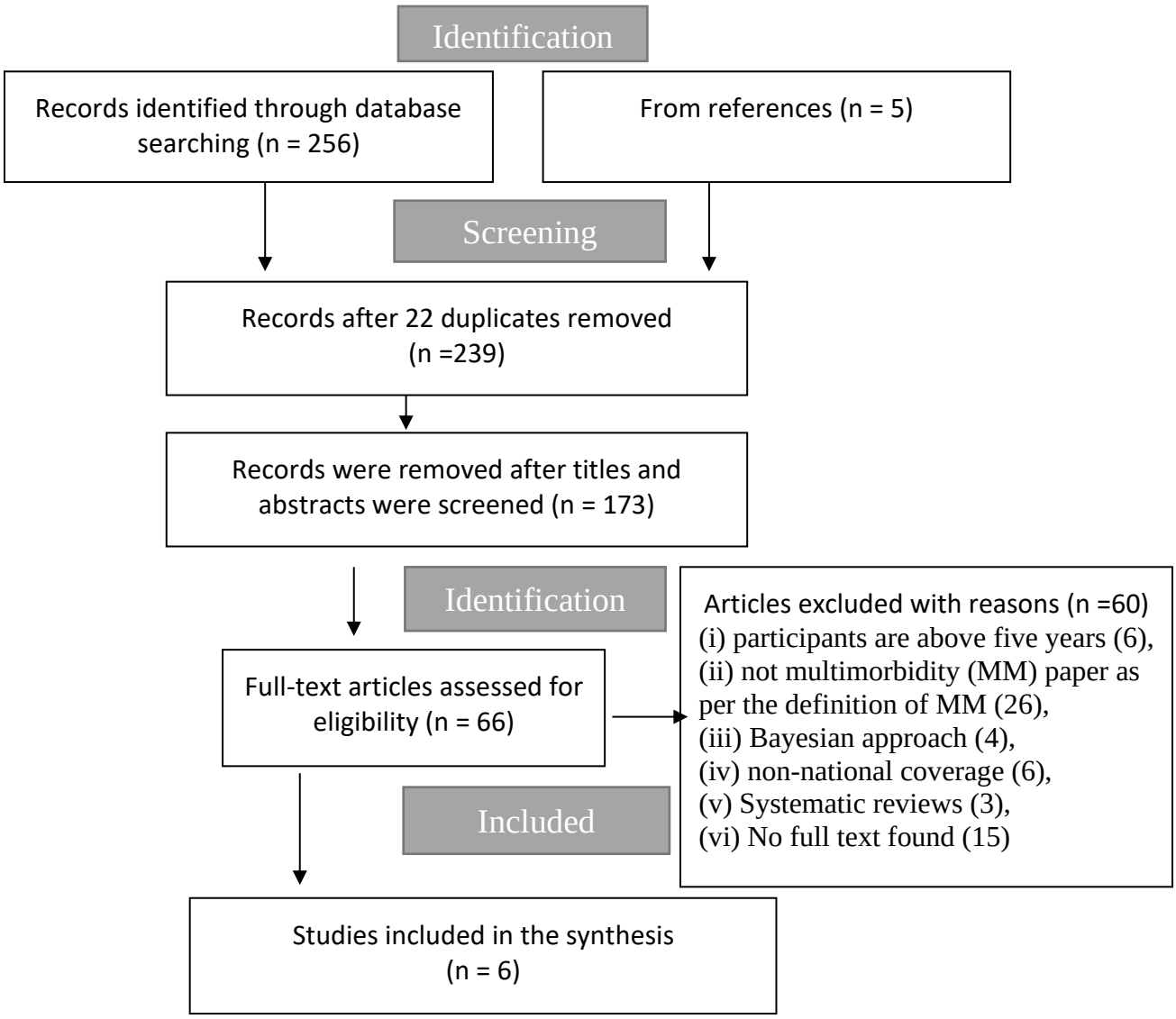


Figure 3 1 PRISMA Flow chart for multimorbidity studies

3.2.3.2 Characteristics of sources of evidence

To answer the scoping review questions raised previously, some relevant information extracted from the selected papers is contained in Tables 3.2 and 3.3. This section describes the characteristics of the sources of evidence

Table 3 2 Distribution of the study characteristics

Authors & Dates	**Title**	**Objectives**	**Outcome variables (Prevalence)**	**Sample size (participant's age)**	**Methods of analysis**	**Country/Survey**
Adedokun 2020(Adedokun, 2020)	Correlates of childhood morbidity in Nigeria: Evidence from ordinal analysis of cross-sectional data	Correlates of childhood morbidity in Nigeria: Evidence from ordinal analysis of cross-sectional data	Pneumonia, diarrhoea, and malaria (9.0%)	27,571 (Under-5)	Generalised ordinal logistic regression mode	Nigeria, Nigeria Demographic and Health Survey (NDHS 2013)
Atsu *et al* 2017(Atsu, Guure and Laar, 2017)	Determinants of overweight with concurrent stunting among Ghanaian children	This paper presents the burden, the individual-level, and contextual determinants of overweight with concurrent stunting among Ghanaian children.	overweight with concurrent stunting (1.2%)	7550 (0-5 years)	A multivariable Poison regression model	Ghana Multiple Indicator Cluster Survey (MICS 2011)
Duah *et a*l 2020(Duah *et al.,* 2020)	Comorbid patterns of anaemia and diarrhoea among children aged under five years in Ghana: a multivariate complex sample logistic regression analysis and spatial mapping visualisation	To investigate the prevalence and independent predictors of comorbid patterns of anaemia and diarrhoea in children aged <5 years in Ghana.	Anaemia and Diarrhoea (9.28%)	2343 (under-5 years)	multivariate logistic regression	Ghana Ghana Demographic and Health Survey (GDHS 2014).
Mulatya & Mutuku 2014(Mulatya and Mutuku, 2020)	Assessing Comorbidity of Diarrheal and Acute Respiratory Infections in Children Under 5 Years: Evidence from Kenya's Demographic Health Survey 2014. J. Prim. Care Community Health	This study seeks to assess the prevalence of comorbidity of pneumonia and diarrheal in children under-5 years, and to identify risk factors associated with comorbidity of pneumonia and diarrheal in children	Diarrheal and acute respiratory infection (ARI) (2.2%)	18 702 (under-5 years)	Multivariate logistic regression	Kenya Kenya Demographic Health Survey (KDHS 2014)
Geda *et al* 2021(Geda *et al.,* 2021)	Multiple anthropometric and nutritional deficiencies in young children in Ethiopia: a multilevel analysis based on a nationally representative data	To examine the risk factors of cooccurrence of undernutrition and anaemia among children of age 6–59 months in Ethiopia based on nationally representative data	Concurrent stunting & anaemia (24.8%)	9218 (6-59 months)	Mixed effect logistic regression	Ethiopia. Ethiopian Demographic and Health Survey (EDHS 2016)
Tran *et al* 2019 (Tran *et al.,* 2019)	Comorbid anaemia and stunting among children of preschool age in low- and middle-income countries: a syndemic	To determine the prevalence of comorbidity of anaemia and stunting, among children aged 6–59 months in low- and middle-income countries	concurrent stunting and anaemia (21.5%)	193 065 (6-59 months)	Multinomial logistic models	Multi-countries Demographic and Health Surveys (DHS 2005–2015)

Study characteristics

In Table 3.2, all the papers were related to secondary analysis of nationally representative surveys. Five of the papers had singular national setting, while, one study was multi-countries study (Tran *et al.*, 2019). The sample size for the studies included range from 2343 to 193065 children of under five years of age. There were six distinct disease conditions (Pneumonia, diarrhoea, malaria, overweight, stunting, and anaemia), analysed in the included studies. One of the studies (Adedokun, 2020) had three concurrent diseases, while the rest five studies had two current diseases as their multimorbidity outcome of interest. The prevalence of the multimorbidity in these studies range from 1.4% to 24.8%. Two of the studies applied multivariate logistic regression analysis (Duah *et al.*, 2020; Mulatya and Mutuku, 2020), one study each used, generalised ordinal logistic regression analysis (Adedokun, 2020), multivariate poison regression model (Atsu, Guure and Laar, 2017), Mixed effect logistic regression (Geda *et al.,* 2021), and multinomial logistic regression model (Tran *et al.*, 2019). Five of the studies included in the review used Demographic and Health Survey (DHS) data set of their respective country of focus, while one used data from multiple indicator cluster survey (Atsu, Guure and Laar, 2017). The survey years range from 2011 to 2016. But the only multi-country study collected data from difference countries for surveys over a 10 year period, from 2005 to 2015(Tran *et al.*, 2019).

Table 3.3 presents the results of the statistically significance of child-, parental- household-, and community-related predictors, which were classified into harmful, protective and no significance effects.

Table 3 3: Distribution of the extracted risk factors of multimorbidity

Child-related variables	
Child's age	**Protective effects** < 1year (ref), 3 years and above, aOR = 0.43 (0.34–0.55) (Adedokun, 2020). 0-11 months (ref) 12-23 months, aPR=0.991 (0.982–0.999) (Atsu, Guure and Laar, 2017). 0.5-1 year (ref), 1-2 years, aRRR=0.59 (0.55-0.64), 2-3 years, aRRR=0.87 (0.80-0.94) (Tran *et al.*, 2019) ‡. **Harmful effects** 24-59 months (ref), 6 - 23 months, OR=2.17 (1.42 to 3.33) (Duah *et al.*, 2020). <6 months (ref), 6 - 11 months, aOR = 3.48 (2.02-5.99), 24-35 months, aOR=2.84 (1.71-4.70) (Mulatya and Mutuku, 2020). 0-23 months (ref), 24-35 months, aOR=6.55 (5.26-8.15), 36-59 months, aOR=4.29 (3.43-5.36) (Geda *et al.*, 2021).

	0.5-1 year (ref), 3-4 years, aRRR = 1.27 (1.18-1.37), 4-5 years, aRRR = 1.86 (1.72-2.01) (Tran *et al.,* 2019).
Child's sex	**Protective effects** Male (ref), Female sex, aOR=0.84 (0.74-0.93) (Geda *et al.,* 2021) Female (ref), Male sex, aRRR= 0.78 (0.75-0.81) (Tran *et al.*, 2019) **Harmful effects** Female (ref), Male sex, OR=1.50 (1.04 to 2.16) (Duah *et al*., 2020)
Child's birth size	**Protective effects** Large (ref), Average size at birth, aOR = 0.68 (0.57–0.82) (Adedokun, 2020)
Diarrheal status	**Harmful effects** No (ref), Had diarrhoea, aPR=1.019 (1.006–1.032) (Atsu, Guure and Laar, 2017)
Fever status	**Harmful effects** No (ref), Had fever, OR=4.37 (2.94 to 6.50) (Duah *et al.,* 2020)
Vaccination status	**Protective effects** No (ref), Ever been vaccinated, aPR=0.997 (0.960–0.995) (Atsu, Guure and Laar, 2017)
Breastfeeding status	**Protective effects** No (ref), Ever been breastfed, aPR=0.995 (0.984–1.006) (Atsu, Guure and Laar, 2017)
Parental-related variables	
Maternal education status	**Protective effects** No education (ref), Secondary education and above, aOR=0.64 (0.48-0.86) (Geda *et al.,* 2021) Secondary or higher (ref), Primary education, aRRR=0.43 (0.41-0.46), No formal education, aRRR=0.20 (0.19-0.21) (Tran *et al*., 2019) **Harmful effects** No education (ref), Incomplete primary education, aOR = 1.66 (1.11-2.50) (Mulatya and Mutuku, 2020).. Primary education, aOR=1.29 (1.13-1.46), secondary/higher, aOR=1.42 (1.23-1.65) [14]
Paternal education status	**Protective effects** No formal education (ref), Secondary or higher education, OR=0.57 (0.33 to 0.97) (Duah *et al.,* 2020) No education (ref), Secondary or higher education, aOR=0.81 (0.65-1.00) (Geda *et al.,* 2021)
Caregiver's age	**Protective effects** 15-19 years (ref), 30-34 years, aOR=0.49 (0.28-0.85),40-44 years, aOR = 0.47 (0.23-0.95) (Mulatya and Mutuku, 2020)
Maternal exposure to media	**Protective effects** Never exposed (ref), Exposed to media, aOR = 0.82 (0.67–0.99) (Adedokun, 2020)
Household-related variables	
Wealth status	**Protective effects** Poorest (ref), Richer wealth households, aOR = 0.83 (0.70–0.99) (Adedokun, 2020).

	Poorest (ref), Richer household, OR=0.38 (0.16 to 0.89) (Duah *et al.,* 2020) Poor (ref), Middle wealth quintile, aOR = 0.58 (0.39-0.85), Highest wealth quintile aOR=0.43 (0.24-0.77) (Mulatya and Mutuku, 2020) Poorer/poorest (ref), Middle wealth quintile, aOR=0.73 (0.61-0.87) Richer/richest, aOR=0.64 (0.54-0.75) (Geda *et al*., 2021) Richest (ref), 4th wealth quintile, (Richer) aRRR=0.71 (0.65-0.77) Middle wealth quintile, aRRR=0.62 (0.57-0.68) 2nd quintile (poorer), aRRR=0.55 (0.50-0.60) Poorest wealth quintile, aRRR=0.49 (0.45-0.53) (Tran *et al.,* 2019) **Harmful effects** Poorest (ref), 4th wealth quintile, aPR=1.011 (1.001–1.021) (Atsu, Guure and Laar, 2017)
Number of under-5 years	**Harmful effects** 0-1 (ref), Had two children aged <5 years, OR=1.80 (1.14 to 2.84) (Duah *et al.,* 2020)
Household size	**Protective effects** 1-5 (ref), Had ≥6 members, OR=0.46 (0.28 to 0.75) (Duah *et al.,* 2020)
Ethnicity of household head	**Harmful effects** Akan (ref), Head is of the Ewe tribes, aPR=1.023 (1.000–1.046) (Atsu, Guure and Laar, 2017)
The religion of household head	Orthodox (ref), Religion (others, beside Orthodox) aOR=1.37 (1.17-1.61 (Geda *et al.,* 2021)
Sanitation	Median (ref), Sanitation score aOR=1.12 (1.01-1.24) (Geda *et al*., 2021)
Community-related variables	
Maternal education status	**Protective effects** Mean (ref), maternal education at cluster level, aOR=0.94 (0.90-0.98) (Geda *et al.,* 2021)
State-related variables	
Region of residence	**Harmful effects** North-Central (ref), North-East, aOR = 5.34 (3.86–7.39), South-East, aOR = 3.17 (2.15–4.66) (Adedokun, 2020)
Place of residence	**Protective effects** Urban (ref), Rural, aRRR=0.72 (0.67-0.77) (Tran *et al.,* 2019)

aOR=adjusted odd ratios, aRRR=adjusted relative risk ratios, aPR=adjusted poison ratio, Tran et al (Tran *et al.,* 2019) reported the aRRR for being healthy relative to concurrent stunting and anaemia as baseline

3.2.3.3 Child-related characteristics

Child's age

Of the six studies included in the review, four papers (67%) (Tran *et al.,* 2019; Duah *et al.,* 2020; Mulatya and Mutuku, 2020; Geda *et al.,* 2021), found significant harmful effects of child's age in developing a multimorbidity among children aged under-five years. Duah et al (Duah *et al.,* 2020) found a more than two-folds harmful effects of comorbid anaemia and diarrhoea for children aged 6-23 months compared to children aged above 24 months, while Mulatya & Mutuku, and Geda *et al* found a higher odds of contracting comorbid, diarrhoea and pneumonia (ARI), and concurrent stunting and anaemia, respectively for older children compared to children aged under 1 year (Mulatya and Mutuku, 2020; Geda *et al.,* 2021). On the other hand, Adedokun (Adedokun, 2020) found more than twice the protective effects for older children aged three years and above contracting multimorbidity of pneumonia, diarrhoea and malaria versus combined none of the diseases, one of the diseases, and two of the diseases when compared with children aged less than one year. Similarly, Atsu *et al* (Atsu, Guure and Laar, 2017) found a borderline significant protective effect for children aged 12-23 months compared to children aged less than 12 months, and Tran *et al* (Tran *et al.,* 2019) found a near twice protective (risk) effects for healthy versus comorbid of stunting and anaemia children aged 1- 2 years compared to children aged 0.5-1year. However, Atsu *et al* (Atsu, Guure and Laar, 2017) found no significant effects for children aged 24-35, 36-47, 48-59 months of being overweight and concurrently stunted, just as Adedokun (Adedokun, 2020) reported no significant effects for children aged 1-2 years compared to children aged less than 1 year.

Child's sex

Another critical child-related characteristic reported in most of the studies under review is the sex of the child (See Table 3). Duah *et al* (Duah *et al.,* 2020) found that it is more harmful to male children to contract comorbid anaemia and diarrhoea compared to female children. Similarly, Geda *et al* (Geda *et al.,* 2021) reported a protective effect for female children compared with male children. Similarly, Tran *et al* (Tran *et al.,* 2019) found that male children are 22% less likely to be healthy relative to contracting concurrent stunting and anaemia compared to female children. Two studies (33%) reported no significant effects of a child's sex on concurrent overweight and

stunting (Atsu, Guure and Laar, 2017) and diarrheal with an acute respiratory infection (ARI) (Mulatya and Mutuku, 2020).

Other child-related predictors extracted from the papers under review include child's size at birth, childbirth order and history of having fever within the two weeks before the survey. Adedokun (Adedokun, 2020) found a protective effect of multimorbidity of pneumonia, diarrhoea, and malaria fever for children whose mothers perceived they have 'average size' at birth relative to children whose mothers perceived they were 'large size' at birth, but found no significant effect for children born to mothers who perceived were born 'small' relative to children born 'large' size. Also, the paper found no significant effect on children's birth order. There were more than four-folds harmful effects for children who had fever two weeks before the survey to contract comorbid diarrhoea and anaemia when compared with children who had no fever.

3.2.3.4 Parental- and household-related characteristics

Among the parental and household variables extracted from the studies selected for review, parental educational status had mixed conclusions. For instance, Mulatya & Mutuku (Mulatya and Mutuku, 2020)reported higher odds of contracting comorbid diarrheal and acute respiratory infection (ARI) among children of caregivers who had incomplete primary education relative to those without formal education, on the contrary, two other studies (Duah *et al.,* 2020; Geda *et al.,* 2021) found protective effects of fathers having secondary education and above relative to no education (Duah *et al.,* 2020; Geda *et al.,* 2021), and mothers had secondary education and above (Geda *et al.,* 2021). Geda et al (Geda *et al.,* 2021) found no significant effects on mothers and fathers who had no primary education. Contrary to expectation, Adedokun (Adedokun, 2020) found that increased maternal education status serves as harmful effect for children who are cohabiting with 'two or more childhood diseases compared with children of mothers with no formal education. Atsu et al found no significant effects on maternal education status(Atsu, Guure and Laar, 2017). Furthermore, household wealth status was reported in almost all the papers included in the study. Tran et al, found that the higher the household wealth quintiles, the more protective the children are being healthy relative to contracting concurrent stunting and anaemia (Tran *et al.,* 2019). So, the RRR of 0.49 for poorest wealth quintile vs richest wealth quintile implies that households in the poorest wealth quintile have 0.49 times the risk of being healthy compared to households in the richest wealth quintile (i.e., they are less likely to be

healthy than richer households - and consequently more likely to have comorbidities than richer households) [19]. Other protective effects include maternal exposure to mass media (Adedokun, 2020) and the child living in a household with a size greater than 5 members (Duah *et al.,* 2020). However, Atsu et al (Atsu, Guure and Laar, 2017) reported harmful effects for children from fourth wealth quintile households relative to poorest households. In addition, Adedokun's study reported no significant effects of poorer, richer, and richest households on children contracting multimorbidity of diarrhoea, pneumonia, and fever versus combined of 'none of the diseases', 'one of the diseases', and 'two of the diseases'. When compared with children from the poorest household wealth quintile.

3.2.3.5 Community- and area-related characteristics

Being from North-East and South-East of Nigeria was associated with higher odds of multimorbidity among children under 5 years (Adedokun, 2020). Rural children were more protective to being healthy relative to concurrent stunting and anaemia compared with those who dwell in urban areas (Tran *et al.,* 2019). One study that used multilevel analysis (Geda *et al.,* 2021) found protective effects for children from a community with mean maternal education at the cluster level(Geda *et al.,* 2021).

3.2.3.6 No significant effects-related characteristics

The review also identified those variables that were not significant predictors of multimorbidity among children under under-five years. For instance, Adedokun (Adedokun, 2020) reported that children of mothers of all ages and education levels the poorer and more prosperous. Richest household wealth quintiles, North-West, or South-South region of residence, child's age is 1-2 years, born tiny, birth order at all levels, delivered in a health facility, lives in a household with access to an improved source of drinking water and cooking method were no significant risk factors of multimorbidity of diarrhoea, fever, and pneumonia among children under five years of age in Nigeria. Similarly, Child's age is 24-35, 36-47, 48-59 months; sex; religion of household head, maternal education status; household wealth quintile is second, middle and richest, area of residence, child's mosquito net utilisation, a child diagnosed with malaria using the rapid test, child had cough were not significant predictors of overweight with concurrent stunting among Ghanian children under-five years of age (Duah *et al.,* 2020). In addition, a number of children aged <5 years in a household; or the child is from a household with wealth quintile is poorer, middle, most

prosperous; access to an improved source of drinking water, improved primary floor material, locality of residence is rural, region of residence were not found to significantly predict multimorbidity in children (Atsu, Guure and Laar, 2017). Also, Geda et al (Geda *et al.*, 2021) did not find that child's nutritional status, sex, residence, exclusive breastfeeding between 0 and 6 months, and combined morbidity from diarrheal and ARI, caregivers had Primary education completed, and secondary and above were significant risk factors of multimorbidity of comorbid anaemia and stunting. Mother's age attained primary education level, father also had attained primary education level, the child never breastfed, and the level diet diversity score were no significant predictors of concurrent anaemia and stunting.

3.2.4 Discussion

The scoping review was conducted by searching for evidence of studies to establish the prevalence of multimorbidity of childhood diseases among children under five in Sub-Saharan Africa. The search was done first on 19 September 2021 and updated 19 March 2022, covering publications between 1 January 1990 and 19 March 2022. It included studies that had national coverage and used nationally representative surveys. The selected papers were such that they applied classical regression analysis to determine the risk factors associated with multimorbidity of childhood diseases. This restriction of statistical techniques used was necessary because this study was a precursor of a larger study which focuses on frequentist classical regression method, and to inform parallel comparisons of findings among studies. Out of the 261 studies found, only 6 met the inclusion criteria and were reviewed. The disease structure considered in the studies spans the most common childhood diseases in Low- and Middle- Income- Countries (LMICs). These include anaemia, diarrhoea, malaria, pneumonia, and nutritional deficiency indicators (stunting, underweight, wasting, overweight).

Adedokun (2020) (Adedokun, 2020) conducted the determinants of overlap among three outcome variables which resulted in classifying multimorbidity as a count of four ordinal groups of 'no disease', 'one disease only', 'two diseases', and 'three or more diseases. The study used the 2013 Nigeria Demographic and Health Survey (2013 NDHS) data set, applying a generalised ordinal logistic regression model. Also, in Atsu et al's (Atsu, Guure and Laar, 2017) study, the outcome variables of interest, stunting, overweight and their concurrency (having overweight and stunted simultaneously) variables were classified into being overweight and concurrently stunted or not.

The predictors were classified into three groups (hierarchical levels): distal, proximal intermediate. Finally, the prevalence ratios of the outcomes were computed. Though three models were formulated, they were not subjected to model fit to ascertain the model of best fit.

In the same way, Dual *et al* (Duah *et al.*, 2020) in their study, presented a multivariate analysis of determinants of comorbid anaemia and diarrhoea status. However, Mulatya & Mutuku (Mulatya and Mutuku, 2020) reported the overlap in the determinants of comorbid diarrhoeal and ARI determinants. The children without multimorbidity and those with only one of the diseases were combined with no comorbidity. Furthermore, Geda et al (Geda *et al.*, 2021)had two separate analyses. (1) a count of the number of composite indexes of anthropometric failure (CIAF) of nutrition indicator a child has, (2) Having concurrent stunting and anaemia or not. The predictors of concurrent stunting and anaemia were reported in the review. Similarly, Tran et al (Tran *et al.*, 2019) examined the comorbidity of anaemia and stunting and were compared it with those of healthy children. Data from 43 Low- and Middle- Income- Countries (LMICs) were pooled together to analyse three models: anaemia compared with comorbidity, stunting compared with comorbidity, and comorbidity compared with healthy children. The model of comorbidity and healthy children was reported with comorbidity as baseline.

Accordingly, this study found relatively high prevalence of under-five multimorbidity in some SSA countries. This prevalence ranges from 1.2% in Ghana from a study titled 'Determinants of overweight with concurrent stunting among Ghanaian children', by Atsu *et al*. 2019, to 9.28% also in Ghana, according to a study titled: 'Comorbid patterns of anaemia and diarrhoea among children aged under five years in Ghana: a multivariate complex sample logistic regression analysis and spatial mapping visualisation' by Duah *et al*. 2020, and 9.0% in Nigeria for children cohabiting with pneumonia, diarrhoea, and malaria (Adedokun 2020). Though it is difficult to draw a blanket comparison for these studies, the prevalence of cooccurrence of childhood diseases is fast becoming a public health burden in LMIC. Child's age and household wealth quintiles are the two most important predictors of multimorbidity in under-five children in SSA. Irrespective of the disease combination, they stood out as predictors in all the studies. As for the child's age, there were no clear patterns in the direction of the significance, which may be partly because of the diversities in the study diseases and study settings. Similarly, for household wealth status, findings showed that the higher the wealth status, the less likely the children will cohabit with multiple diseases in SSA. However,

Tran *et al.* 2019 found the similar conclusion from a pooled data set in 43 LMICs, that the poorer the household the more likely the children will cohabit with stunting and anaemia versus healthy children when compared with those from richest household. The possible reason for this is that wealthier households may have more resources to acquire those things that will impact good healthy living compared with those from poorer households. The study also found that female children are less likely to cohabit with multiple diseases compared with their male counterparts. There are assertions that constitution of breast milk is a function of which gender is breastfeeding. Tran *et al* states that girls breast feed long than boys (Tran *et al* 2019).

Parental education status was also an important predictor of multimorbidity. The more educated the parents are the less likely the children will cohabit with two or more diseases. Compared to children who live in urban areas, children who live in rural regions are more likely to experience comorbidity (Tran *et al*, 2019). In SSA countries, residing in a rural location always has disadvantages in terms of living standards, economic standing, and accessibility to healthcare. In order to avoid this co-morbidity, kids who live in rural regions require greater assistance.

However, four studies that used the Bayesian approach were excluded from the reviewed papers for ease of comparing the findings, but three found valuable results that have revealed further study gaps worthy of mentioning. This includes examining the spatial variations across the study settings and in most cases, considered the nonlinearity of some covariates. The three most essential childhood diseases of interest in these studies were non-malaria fever, acute respiratory infection, and diarrheal.

First, Kazembe and Namangale (2007) evaluated the risk factors for children under-five years cohabiting with fever, diarrhoea, and pneumonia, and measured the geographical impacts specific to a given location. Using 2000 edition of the Malawi Demographic and Health Survey (MDHS), the study applied a hierarchical multinomial regression model from the Bayesian perspective. The data was grouped into two different geographic levels (subdistricts and districts). The child's age, place of residence, undernutrition, use of bed nets, and Vitamin A were among the risk variables of child comorbidity. The central and southern-eastern regions were found to have higher residual risk levels. The prevalence of comorbidity (as referred to in the paper) of 2 or more diseases among children aged under five in Malawi was 42%. The distinction between these terms comorbidity and multimorbidity became evident when this was enshrined in MESH beyond 2018 (Tugwell and Knottnerus, 2019).

Second, Takele et al (2020) examined the spatial variations of comorbidity of diarrhoea, fever, and cough among young children aged under-five years in Ethiopia using the Ethiopia Demographic and Health Survey (EDHS 2016). The primary focus of this study was to account for the nonlinear of some metrical covariates and spatial variations while adjusting for other covariate risk factors. The paper reported the prevalence of comorbidity of two or more diseases among male children, 12.3%, and female children, 12.5%. The paper also reported that comorbidity was a significant concern for infants between 10 and 15 months in Ethiopia. In addition, the research showed that male children, those not breastfed, live in homes without toilets, use spring water, are born first, have a working mother, are anaemic, and have a mother without formal education, are at a higher risk of developing several ailments. The paper applied the Bayesian multinomial logit approach in the analysis.

Thirdly, Khatab and Kandala (2011)' s paper covered the exact research location as with this current study (Nigeria). The focus of the study was to use flexible geoadditive probit models to examine the effects of various bio-demographic and socioeconomic factors on joint childhood illnesses in Nigeria. Flexible in the sense that the investigation incorporated the 'latent variable modelling' into geoadditive Bayesian semiparametric models approached used in Kandala (2007). The multiple diseases of interest were diarrhoea, cough, and fever, used as indicators for the unobservable 'health status' among children aged under-five years in Nigeria using the 2003 Nigeria Demographic and Health Survey (NDHS). The outcomes point to some significant underlying regional trends of the three diseases, with a distinct south-eastern divide in childhood morbidities. The study recommended, among others, that for effective and affordable control and planning of the three illnesses, the search for overlapping common risk factors and their geographical implications may help us better understand the aetiology of diseases.

3.2.4.1 Some identified study gaps

Only in recent times, perhaps in the 2018 Nigeria Demographic and Health Survey (2018 NDHS), there was an expanded collection of more childhood diseases, including anaemia, acute respiratory infection (ARI), malaria, malnutrition, diarrhoea, fever, and sickle cell anaemia. Other than sickle cell anaemia, which is an inherited condition (CDC, 2016), information on anaemia, malaria, and malnutrition was objectively gathered using accepted practises. For, diarrhoea, ARI, and fever, mothers were asked whether their kids had any of the illnesses in the two weeks prior to the survey.

The accuracy of the information for these variables is determined by the ability of the mother to recall the accurate diagnosis of the illness correctly. In a society like most SSA, where maternal literacy is low, it may not be possible to get accurate results. To the best of our knowledge, the current research demonstrates that no prior study has integrated such paediatric disorders with data objectively gathered from the survey as a multimorbidity framework. Studies to investigate the determinants of the cooccurrence of these three childhood diseases are urgently needed to repose confidence in the outcome of the analyses. In addition, almost all the included data sets were from nationally representative surveys with clear evidence of hierarchy. However, most of the existing studies did not take into consideration the multilevel structure and apply the appropriate statistical methods. Furthermore, most of the studies reviewed considered concurrency of two childhood diseases, therefore classified the outcome of interest as a dichotomous variable, and used multivariate logistic or poison regression method, where children with concurrent of the two diseases were compared with children without the two diseases (none of the disease, and any one of the diseases).

3.2.4.2 Conclusions

Multimorbidity, until recently, has been associated with the adult population, but this has changed, especially in the LMIC, where more and more children are found to suffer from these emergent disease structures. The relatively few studies in this area of research showed the need for more studies to be done that will help policymakers to make sound policies to combat the growing trend of multimorbidity in LMIC and thereby improve the public health sectors. Particularly, the areas of intense need are that policymakers bear in mind that children from lower-income families appear to need more extensive and intense interventions in nations with considerable inequality, especially if resources are typically scarce. The findings in this study have also shown considerable clustering of childhood diseases around nutrition-related diseases in SSA. This requires more studies to be carried out that will inform integrated care-framework to be developed by clinicians, healthcare workers and providers to reduce the burden of multimorbidity in SSA.

3.3 Part 2: A scoping review of the risk factors associated with anaemia among children under five years in Sub-Saharan African countries

3.3.1 Introduction

This scoping review, "A Scoping Review of the Risk Factors Associated with Anaemia among Children Under Five Years in Sub-Saharan African Countries", was conducted on existing literature between 1 January 1990 and 26 June 2020. The review outcome was published in one of the journals on 27 November 2020, the *International Journal of Environmental Research and Public Health*. 2020 (Obasohan *et al.*, 2020a). (Full text is attached in Appendix C.5). However, this section reports the extracted results from the review.

3.3.2 Results

The results section reports the profile of the quantitative analysis of risk factors associated with anaemia in under-five children in SSA. Results extracted are those reported from the studies that investigated risk factors (both protective and harmful effects) which were evident by Odds Ratios (OR), Relative Risk Ratios (RRR) or Risk Difference (RD) and Regression Estimates (RE).

3.3.3 The study profile counts

A total of 217 studies (publications) were extracted from the electronic databases (PubMed=140, Scopus=13, Medline=1) and another 63 studies from Google Scholar (using adjusted search terms to accommodate the length required for search terms in google scholar). Other sources searched include MeasureDHS journal publications while using overall conditions such as 'Anaemia' filtered for African countries and publication years between 1990 and 2020. The search yielded 43 studies. Twenty-six (26) other reviews were added from checking the references of the included studies and AJOL=1. After removing 20 duplicate studies, the first scoping glance at the titles and abstracts eliminated further 215 studies (publications). Fifty-two (52) studies were subjected to full-text examination, which resulted in retaining 20 publications for this review after excluding 32 other studies (see figure 3.1). The reasons for the exclusion of most of the studies were:

(i) Using other analytical methods rather than classical regression analysis,

(ii) Studies did not report separate results for children 0-59 months,

(iii) Studies which considered anaemia outcomes based on maternal or child's specifics,

(iv) Studies not from SSA countries

(v) Papers without the full text available.

The 20 publications that met the inclusion criteria were further subjected to full-text scrutiny to answer the scoping review question. However, in this scoping review, the unit of analysis was the country for which unique analysis for the data set was done. It means that a study of two nations analysed separately from the nationally representative surveys from each country was counted as two studies. On the other hand, studies in several countries with pooled data as a single analysis were counted as one study. Overall, a total of 24 country studies were included in this review.

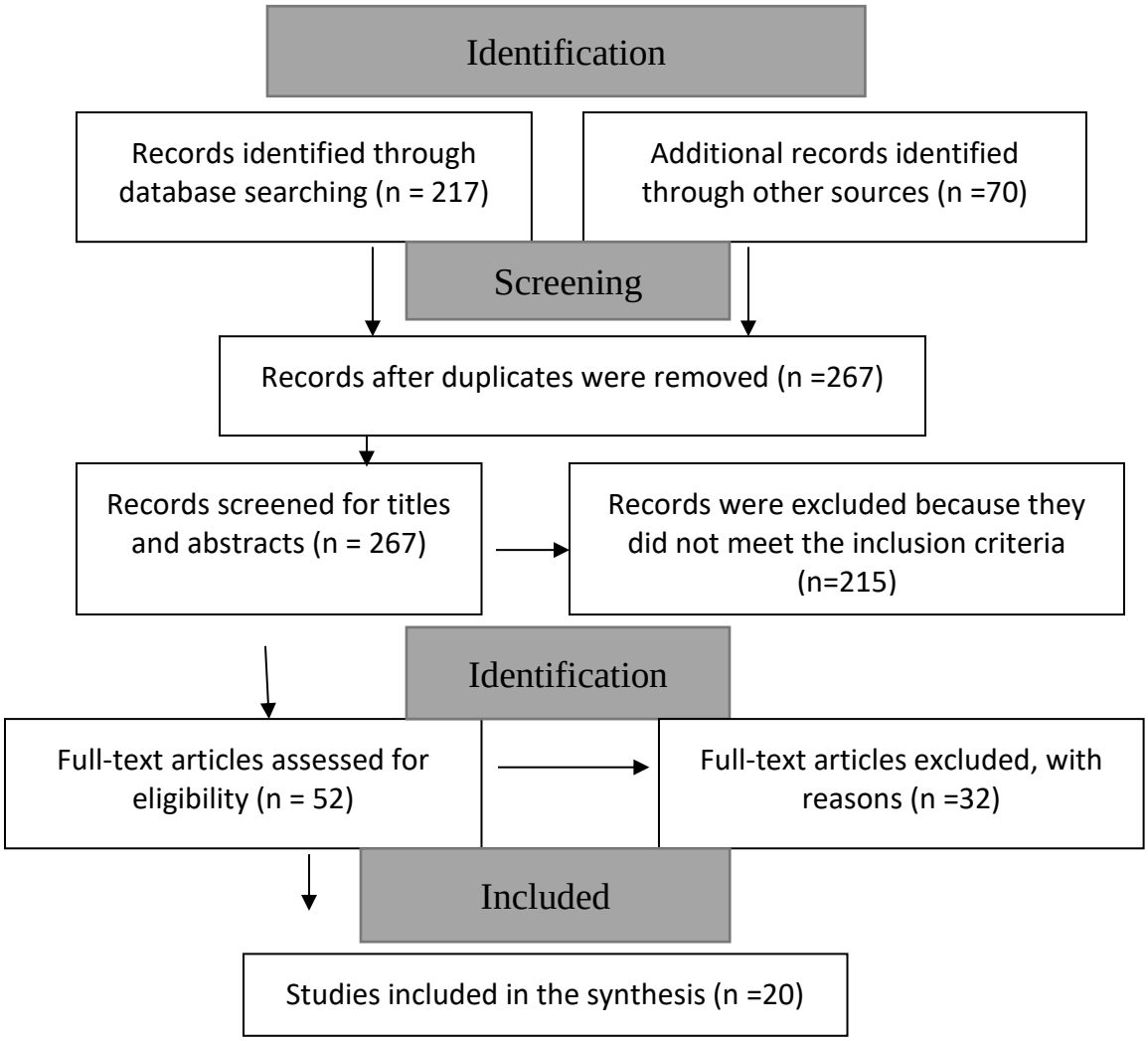


Figure 3 2 : Flowchart of Inclusion of Studies for Anaemia Review.

3.3.5 Classifications of the risk factors

This section reports the distributions of the studies by variable groups: Child-related, parental/caregiver-related, household-related, and community-related.

3.3.5.1. Child-Related Variables

Table 3.4 describes the distributions of child-related variables in the included studies. Out of the twenty-four (24), unique country-based studies, only one study (Jones *et al.,* 2018) did not consider the child's age as part of the investigated child-related variables. This implies that 96% of the studies considered the age of the child (0-59 months), as a risk factor either as classified into different degrees of age groups or used as an interval variable. These studies found that the age of the child is a significant predictor of the development of anaemia among children under under-five in SSA. The chances of having anaemia are much higher for children at a lower age, (below 24 months) than an older age (Dwumoh *et al.,* 2014; Nambiema *et al.,* 2019; Ngnie-Teta *et al.,* 2007; Ntenda, Nkoka, *et al.,* 2018, 2018). For instance, Nambiema et al. (Nambiema, Robert and Yaya, 2019) found a protective effect of a child's age with Odds Ratio (OR) (OR=0.22, 95% CI = 0.17 – 0.29); Ngnie-Teta *et al.,* (Benin Republic study) (Ngnie-Teta *et al.,* 2007) found an increased risk of developing anaemia for children aged 6-11 months with (OR=4.05, 95% CI =2.40 – 7.09) and 12-35 months with (OR=2.81 95% CI = 1.99 – 4.52) when compared with children aged above 35 months. Also from a Mali study, Ngnie-Teta *et al.,* (Ngnie-Teta *et al.,* 2007) found that a child aged 6-11 months (OR=1.73, 95% CI = 1.32 - 2.92) or 12-35 months (OR=2.90, 95% CI = 2.24 – 3.92) is more likely to be anaemic when compared with a child more than 35 months

Table 3 4: Distribution of child-related variables in anaemia from the 24 country-specific results

Risk factor: Child-related Variables	Number of studies which investigated the risk factor (%)	References
Age of the child	23/24 (96%)	(Asresie *et al.*, 2020; Austin *et al.*, 2012; Douglas Andabati Candia, 2017; Dwumoh *et al.*, 2014; Hershey *et al.*, 2017; Immurana & Urmi, 2017; Kawo *et al.*, 2018; Machisa *et al.*, 2013; Menon *et al.*, 2015; Mohammed *et al.*, 2019; Moschovis *et al.*, 2018; Muchie, 2016; Nambiema *et al.*, 2019; Ngnie-Teta *et al.*, 2007; Nikoi & Anthamatten, 2013; Ntenda, Chuang, *et al.*, 2018; Ntenda *et al.*, 2019; Ntenda, Nkoka, *et al.*, 2018; Ojoniyi *et al.*, 2019; Semedo *et al.*, 2014)
Sex of the child	17/24 (71%)	(Austin *et al.*, 2012; Douglas Andabati Candia, 2017; Dwumoh *et al.*, 2014; Hershey *et al.*, 2017; Immurana & Urmi, 2017; Jones *et al.*, 2018; Kawo *et al.*, 2018; Machisa *et al.*, 2013; Mohammed *et al.*, 2019; Moschovis *et al.*, 2018; Nambiema *et al.*, 2019; Ngnie-Teta *et al.*, 2007; Nikoi & Anthamatten, 2013; Ntenda *et al.*, 2019; Ntenda, Nkoka, *et al.*, 2018, 2018; Ojoniyi *et al.*, 2019; Semedo *et al.*, 2014)
Has Health Insurance	4/24 (17%)	(Nikoi and Anthamatten, 2013; Dwumoh, Essuman and Afagbedzi, 2014; Immurana and Urmi, 2017; Ojoniyi *et al.*, 2019)

Perceived Birth Size	3/24 (12%)	(Muchie, 2016; Kawo, Asfaw and Yohannes, 2018; Mohammed, Habtewold and Esmaillzadeh, 2019)
Ever Had Vaccination Status	1/24 (4%)	(Austin *et al.*, 2012; Semedo *et al*., 2014)
Product of multiple births	2/24 (8%)	(Moschovis *et al*., 2018; Ojoniyi *et al.*, 2019)
Preceding Birth Interval	1/24 (4%)	(Moschovis *et al*., 2018)
Birth Order	6/24 (25%)	(Immurana & Urmi, 2017; Moschovis *et al*., 2018; Muchie, 2016; Ngnie-Teta *et al*., 2007; Ntenda *et al*., 2019)
Iron supplement	4/24 (17%)	(Jones *et al.*, 2018; Kawo *et al.*, 2018; Machisa *et al*., 2013)
Duration of breastfeeding	4/24 (17%)	(Jones *et al.*, 2018; Machisa *et al.*, 2013; Mohammed *et al*., 2019; Semedo *et al*., 2014)
Breastfeeding	2/24 (8%)	(Austin *et al.*, 2012; Mohammed *et al.*, 2019; Moschovis *et al*., 2018)
Had diarrhoea in last 2 weeks	12/24 (50%)	(Asresie *et al.*, 2020; Austin *et al*., 2012; Jones *et al.*, 2018; Machisa *et al*., 2013; Moschovis *et al.*, 2018; Ngnie-Teta *et al.*, 2007; Ntenda *et al*., 2019; Ntenda, Nkoka, *et al*., 2018; Semedo *et al*., 2014)
Had fever in last 2 weeks	11/24 46%)	(Asresie *et al.*, 2020; Austin *et al*., 2012; Jones *et al.*, 2018; Machisa *et al*., 2013; Moschovis *et al.*, 2018; Nikoi & Anthamatten, 2013; Ntenda *et al.*, 2019; Ntenda, Nkoka, *et al.*, 2018)
Vitamin A Consumption	4/24 (16.6%)	(Austin *et al.*, 2012; Jones *et al.*, 2018; Machisa *et al.*, 2013; Mohammed *et al.*, 2019; Ntenda, Chuang, *et al.*, 2018; Ntenda *et al.*, 2019)
Min Dietary Diversity (MDD)	1/24 (4%)	(Austin, Fawzi and Hill, 2012; Mohammed, Habtewold and Esmaillzadeh, 2019)
Min Meal Frequency (MMF)	1/24 (4%)	(Mohammed, Habtewold and Esmaillzadeh, 2019)
Treatment for intestinal worms in the last 6 months	3/24 (12%)	(Jones *et al.*, 2018; Moschovis *et al*., 2018; Ntenda, Nkoka, *et al*., 2018)
Nutrition status	1/24 (4%)	(Nambiema, Robert and Yaya, 2019)
Stunting	9/24 (37%)	(Austin *et al.*, 2012; Kawo *et al*., 2018; Moschovis *et al.*, 2018; Ngnie-Teta *et al.*, 2007; Ntenda, Chuang, *et al.*, 2018; Ntenda *et al.*, 2019; Ntenda, Nkoka, *et al.*, 2018)
Wasting	3/24 (12%)	(Kawo, Asfaw and Yohannes, 2018; Ntenda, Chuang, *et al.*, 2018)
underweight	5/24 (20%)	(Ntenda, Nkoka, *et al.*, 2018)
Overweight	1/24 (4%)	(Ojoniyi *et al.*, 2019)
Malaria status (Blood Smear)	3/24 (12%)	(Hershey *et al.*, 2017; Nambiema, Robert and Yaya, 2019; Ntenda *et al.*, 2019)
Malaria status (Rapid Test)	1/24 (4%)	(Menon and Yoon, 2015)

Furthermore, the sex of the child as a risk factor predicting the chance of developing anaemia among children of under-five years in SSA was reported in 17 studies, (representing 71%). Almost all these 17 studies reported significant variations in anaemia status by sex. In almost all the studies

that reported sex as a risk factor, found that a male child was more prone to having anaemia than a female child (Douglas Andabati Candia, 2017; Dwumoh *et al.*, 2014; Mohammed *et al.*, 2019; Moschovis *et al.*, 2018; Ntenda *et al.*, 2019; Ojoniyi *et al.*, 2019).

Comorbidities of anaemia with having diarrheal and fever, (in the last two weeks before the survey) were reported in 12, (50%) and 11 (46%) studies respectively. Moschovis *et al* (Moschovis *et al.*, 2018) reported a slightly harmful effect of anaemia for a child who had non-bloody diarrheal (OR=1.11, 95% CI = 1.04 – 1.18), bloody diarrheal (OR=1.21, 95% CI = 1.07 – 1.36), when compared with a child without diarrheal in the last two week before the survey(Moschovis *et al.*, 2018). But, Jones *et al* (Jones *et al.*, 2018) found no significant effect (OR=1.1, 95% CI=0.77 – 1.6). Also, significantly higher odds of developing anaemia among children of under-five years in SSA was reported for children that had a fever in the last two weeks before the survey than those that had not, (OR=1.42, 95% CI = 1.36 – 1.49) (Moschovis *et al.*, 2018), (OR=1.46, 95% CI=1.04 – 2.32) in Mali (Ngnie-Teta *et al.*, 2007)**.** Besides, the strong relationship between anaemia and nutrition indicators, stunting as a risk factor was examined in 9, (36%) of the included studies. In comparison 'wasting' was examined in 3, (12%) of the included studies. Moreover, nutrition status (a composite of all the nutrition indicators) was only reported in one, (4%) of the 24 studies(Nambiema, Robert and Yaya, 2019). The odds of under-five anaemia was 1.82 times for a malnourished child than a well-nourished child (Nambiema, Robert and Yaya, 2019).

Treatment for intestinal worms in the last 6 months was reported as a significant factor in Moschovis *et al* **(**OR=1.06, 95% CI = 1.02 – 1.11) (Moschovis *et al.*, 2018), but not significant in Jones *et al* (OR=0.98, 95% CI = 0.76 – 1.3) (Jones *et al.*, 2018). Birth order as a risk factor for anaemia in children under-five years of age was reported in six (6) countries studies. Two studies reported significant harmful effects, but contrary to one another. Mischovis *et al.*, (Moschovis *et al.*, 2018) found that having lower birth order is significantly harmful in developing under-five years anaemia compared with having more than three birth order, while, Ngnie-Teta *et al*, **(**Benin Republic study) (Ngnie-Teta *et al.*, 2007),concluded that being born as the sixth birth order or later is significantly two folds more harmful than a single birth order (OR=2.05, 95% CI = 1.02 – 3.97)

3.3.5.2. Distributions of Parental/Caregivers-Related Variables

The included studies frequently reported mother's age, work status, educational status, and anaemia status. Table 3.5 indicates that the mother's educational status was reported in 21 (84%) of the studies, followed by mother's age (13 studies) and mother's anaemia status (12 studies).

Therefore, among the parental/caregiver-related variables, 84% of the studies placed the mother's educational status as one of the most frequently considered risk factors of anaemia in under-five children in SSA. The results from most of these 21 studies showed that as the level of educational status of the mother increases, the chances that the child will develop anaemia reduce. For instance, Nambiema et al (Nambiema, Robert and Yaya, 2019) found that a child whose mother has a secondary level of education and above has a lower adjusted odds of developing anaemia than a child whose mother has no education (aOR=0.67, 95% CI = 0.52 – 0.86).

Table 3 5Distribution of study characteristics by Parental/caregiver-related variables in Anaemia

Parental/Caregiver-related variables	Number of studies which investigated the risk factor	References
Mother's age in years (grouped)	13/24 (54%)	(Asresie *et al.*, 2020; Dwumoh *et al.*, 2014; Immurana & Urmi, 2017; Mohammed *et al.*, 2019; Moschovis *et al.*, 2018; Muchie, 2016; Ngnie-Teta *et al.*, 2007; Ntenda, Chuang, *et al.*, 2018; Ntenda *et al.*, 2019; Ntenda, Nkoka, *et al.*, 2018; Ojoniyi *et al.*, 2019)
Mother's age at child's birth	1/24 (4%)	(Machisa *et al.*, 2013)
Mother working Status	6/24 (25%)	(Asresie *et al.*, 2020; Immurana & Urmi, 2017; Kawo *et al.*, 2018; Muchie, 2016; Nambiema *et al.*, 2019; Ojoniyi *et al.*, 2019)
Mother's educational status	20/24 (83%)	(Asresie *et al.*, 2020; Austin *et al.*, 2012; Douglas Andabati Candia, 2017; Dwumoh *et al.*, 2014; Immurana & Urmi, 2017; Jones *et al.*, 2018; Kawo *et al.*, 2018; Machisa *et al.*, 2013; Menon *et al.*, 2015; Mohammed *et al.*, 2019; Moschovis *et al.*, 2018; Muchie, 2016; Nambiema *et al.*, 2019; Ngnie-Teta *et al.*, 2007; Nikoi & Anthamatten, 2013; Ntenda, Chuang, *et al.*, 2018; Ntenda *et al.*, 2019; Ntenda, Nkoka, *et al.*, 2018; Ojoniyi *et al.*, 2019)
Father's educational status	4/24 (17%)	(Immurana & Urmi, 2017; Muchie, 2016; Ngnie-Teta *et al.*, 2007)
Father is alive at the date of the survey	1/24 (4%)	(Nambiema, Robert and Yaya, 2019)
Mother's Marital status	3/24 (12%)	(Immurana and Urmi, 2017; Kawo, Asfaw and Yohannes, 2018; Ojoniyi *et al.*, 2019)
Mother's body mass index (kg/m2)	4/24 (17%)	(Machisa *et al.*, 2013; Mohammed *et al.*, 2019; Moschovis *et al.*, 2018; Nikoi & Anthamatten, 2013)
Mother's anaemia status	12/24 (50%)	(Asresie *et al.*, 2020; Machisa *et al.*, 2013; Mohammed *et al.*, 2019; Moschovis *et al.*, 2018; Muchie, 2016; Nambiema *et al.*, 2019; Nikoi & Anthamatten, 2013; Ntenda, Chuang, *et al.*, 2018; Ntenda *et al.*, 2019; Ntenda, Nkoka, *et al.*, 2018)
ANC attendance	1/24 (4%)	(Mohammed, Habtewold and Esmaillzadeh, 2019)
Religion status	2/24 (8%)	(Muchie, 2016; Immurana and Urmi, 2017)
Mother's iron supplementation during pregnancy	¼ (4%)	(Machisa *et al.*, 2013)

There was also a clear-cut pattern of how the variations in the mother's age affect the chances a child will develop anaemia. For instance, Moschovis *et al*(Moschovis *et al.*, 2018), Asresie *et al*

(Asresie *et al.,* 2020) and Ojoniyi *et al* (Ojoniyi *et al.,* 2019) reported a drop in the odds of having anaemia among children of under-five years as the mothers' age increase.

The mother's anaemia status was reported in 12 (50%) of the studies included in this scoping review. Moschovis *et al* (Moschovis *et al.*, 2018) found that a child whose mother was anaemic had an 85% greater odds of having anaemia than another child whose mother was not anaemic (OR=1.85, 95% CI=1.76-1.95). Iron supplementation during pregnancy was reported in only one study (Machisa *et al.*, 2013) and was not a significant risk factor, (RRR=1.00, 95% CI = 0.7-1.6).

3.3.5.3. Distributions of Household-Related Variables

Another critical component of the risk factors associated with anaemia among children of under-five years in SSA was the household-related variable. Table 3.6 shows the details of the distribution of various household-related risk factors. Wealth status, a proxy of household socioeconomic status, was one among many factors that drew more attention in this category of risk factors. Twenty-one (21), studies (representing 87%), considered for this scoping review were examined for wealth status. Most of the studies that reported significant effects of household wealth status on under-five anaemia in SSA countries established that the higher the wealth quintiles, the lower the risk of developing anaemia among under-five year anaemia (Douglas Andabati Candia, 2017; Hershey *et al.*, 2017; Moschovis *et al.*, 2018; Ojoniyi *et al.*, 2019). The Hershey et al. (Hershey *et al.*, 2017), Mohammed et al. (Mohammed, Habtewold and Esmaillzadeh, 2019), and Moschovis *et al* (Moschovis *et al.,* 2018) studies found, respectively, that being in the richest category [(OR=0.55, 95% CI=0.44-0.70), (OR=0.48, 95% CI=0.33-0.63), (OR=0.417, 95% CI=0.287-0.547)] had significant protective effect for under-five years anaemia. On the contrary, Ntenda *et al***.** (Ntenda, Chuang, *et al.*, 2018) found in their Malawi study (OR=0.81 95% CI=0.60-1.08), Mozambique study (OR=0.48, 95% CI=0.38-1.24), and Namibia study (OR=0.76, 95% CI=0.53-1.11) that being in higher quintiles of wealth status is protective but not a significant factor.

Closely following the effect of wealth status in this category of household-related risk factors was the place of residence (that is, whether the household under study is in a rural or urban area). With 18 (75%) studies, the place of residence was the second most examined household-related variable as a risk factor associated with anaemia among children of under-five years in SSA countries. However, among the studies that reported a significant association of place of residence, there were no clear-cut conclusions relating to the comparison of rural and urban dwellers. For instance,

Menon and Yoon (OR=0.768, 95% CI=0.592-0.996) (Menon and Yoon, 2015), Mohammed *et al* (Mohammed, Habtewold and Esmaillzadeh, 2019) and Moschovis *et al* (Moschovis *et al.*, 2018) reported protective effect for rural than for urban, while Ngnie-Teta *et al* (Ngnie-Teta *et al.*, 2007) in Mali study, (OR=2.04, 95% CI=1.38-3.44), Nambiema *et al.*, (OR=0.66, 95% CI=0.53-0.82) (Nambiema, Robert and Yaya, 2019) and Dwumoh *et al,* (uOR=0.53, 95% CI=0.46-0.65) (Dwumoh, Essuman and Afagbedzi, 2014), found that it was more harmful to a child in the rural area in developing anaemia than in the urban area of SSA.

Table 3 6 Distribution of study characteristics by household-related variables

Household-related variables	Number of studies which investigated the risk factor	References
Wealth status	21/24 (87%)	(Asresie *et al.*, 2020; Austin *et al.*, 2012; Douglas Andabati Candia, 2017; Dwumoh *et al.*, 2014; Hershey *et al.*, 2017; Jones *et al.*, 2018; Kawo *et al.*, 2018; Machisa *et al.*, 2013; Menon and Yoon, 2015; Mohammed *et al.*, 2019; Moschovis *et al.*, 2018; Nambiema *et al.*, 2019; Ngnie-Teta *et al.*, 2007; Nikoi & Anthamatten, 2013; Ntenda, Chuang, *et al.*, 2018; Ntenda, Nkoka, *et al.*, 2018; Ojoniyi *et al.*, 2019)
Place of residence	18/24 (75%)	(Douglas Andabati Candia, 2017; Dwumoh *et al.*, 2014; Jones *et al.*, 2018; Kawo *et al.*, 2018; Menon and Yoon, 2015; Mohammed *et al.*, 2019; Moschovis *et al.*, 2018; Nambiema *et al.*, 2019; Ngnie-Teta *et al.*, 2007; Ntenda, Chuang, *et al.*, 2018; Ntenda *et al.*, 2019; Ntenda, Nkoka, *et al.*, 2018)
Household had bed net	2/24 (8%)	(Menon and Yoon, 2015; Jones *et al.*, 2018)
Age of Household-Head	1/24 (4%)	(Immurana and Urmi, 2017)
Recent anti-malaria indoor residual spraying of household	1/24 (4%)	(Jones *et al.*, 2018)
Household size	4/24 (17%)	(Asresie *et al.*, 2020; Machisa *et al.*, 2013; Moschovis *et al.*, 2018; Ngnie-Teta *et al.*, 2007)
Number of children U5 in household	3/24 (12%)	(Asresie *et al.*, 2020; Kawo *et al.*, 2018; Muchie, 2016; Ojoniyi *et al.*, 2019)
Water source outside the premises	1/24 (4%)	(Moschovis *et al.*, 2018)
Improved Source of drinking water	8/24 (33%)	(Austin *et al.*, 2012; Douglas Andabati Candia, 2017; Jones *et al.*, 2018; Kawo *et al.*, 2018; Mohammed *et al.*, 2019; Moschovis *et al.*, 2018; Muchie, 2016)
Improved Type of toilet facilities	2/24 (8%)	(Jones *et al.*, 2018; Moschovis *et al.*, 2018)
Unsafe stool disposal	1/24 (4%)	(Moschovis *et al.*, 2018)
Improved Floor material type	1/24 (4%)	(Moschovis *et al.*, 2018)
Sex of Household Head	2/24 (8%)	(Jones *et al.*, 2018)
Shared Toilet Facilities with Other household members	1/24 (4%)	(Moschovis *et al.*, 2018)
Use Biomass for cooking	3/24 (12%)	(Moschovis *et al.*, 2018; Ntenda, Nkoka, *et al.*, 2018)
Under-5 slept under mosquito net last night	4/24 (17%)	(Hershey *et al.*, 2017; Machisa *et al.*, 2013; Ngnie-Teta *et al.*, 2007)
Household ownership of livestock	1/24 (4%)	(Jones *et al.*, 2018)

However, Ntenda *et al* (Ntenda *et al.,* 2019) discovered it was more harmful in rural than in an urban areas, but it was not a significant factor (OR=1.27, 95% CI=0.53-3.01).

Other risk factors that were of utmost importance in many of the studies included in this scoping review include:

(i) Household size in four, (17%) studies,

(ii) The number of children that were under-five years living in the same household (17%),

(iii) Having an improved source of drinking water reported in eight (33%) studies and

(iv). The child slept under a mosquito net the previous night before the surveys (17%).

Two studies reported findings on the use of Biomass for cooking in three country-related studies. Contrary to the expectation from other studies not included in this review (Mishra and Retherford, 2007; Page, Patel and Hibberd, 2015) that exposure to biofuel for cooking and heating may result in harmful effects of developing anaemia in children than those exposed to cleaner cooking and heating fuel. The studies (Moschovis *et al.*, 2018; Ntenda, Nkoka, *et al.,* 2018) included in this scoping review found the opposite conclusion. Moschovis *et al* (OR=0.99, 95% CI=0.90-1.10) (Moschovis *et al.,* 2018), Ntenda *et al* (Ntenda, Chuang, *et al.,* 2018) in Mozambique study (OR=0.93, 95% CI=0.50-1.73), and in Namibia study (OR=0.92, 95% CI=0.58-1.45) reported protective association to use biofuel for cooking but it was not significant.

3.3.5.4. Distribution of study characteristics by Community-related variables

Community-based risk factors (Table 3.7) were not very popular in all the studies added to this review. The few that are of general importance are the community poverty and wealth statuses, (these were computed as the mean per cent of the community wealthiest households), and community female educational status (computed as the mean per cent of women in the community that has primary education and above). There were four studies in this category. Other variables included the distance to the nearest health facility and level of access to safe drinking water for the community.

Some of the studies generally included their country's region or place of residence as community risk factors. However, since the regions were not unique for all studies, they were dropped from the list of risk factors at the community levels.

Table 3 7 Distribution of study characteristics by community-related variables

Community variables	Number of studies which investigated the risk factor	References
Community wealth	4/24 (17%)	(Jones *et al.*, 2018; Ntenda, Nkoka, *et al.*, 2018)
Community Female Education	4/24 (17%)	(Ntenda, Chuang, *et al.*, 2018; Ntenda, Nkoka, *et al.*, 2018)
Community Distance to Health Facility	3/24 (12%)	(Ntenda, Nkoka, *et al.*, 2018)
Community safe water access	3/24 (12%)	(Ntenda, Nkoka, *et al.*, 2018)

3.4 Part 3 Scoping review of risk factors associated with malaria among children under-five years in Sub-Sahara Africa

3.4.1 Introduction

This part of the scoping review titled: "A Scoping Review of Selected Studies on Predictor Variables Associated with the Malaria Status among Children under Five Years in Sub-Saharan Africa", was conducted for existing publications between January 1990 and December 2020. The outcome was also published in one of the journals on 22 February 2021, *the International Journal of Environmental Research and Public Health*. 2020 on 22 February 2021 (Obasohan *et al.*, 2021a), (The full text is attached in Appendix C.4).

3.4.2 The Results

3.4.2.1. Description of Study Records

This review aimed to synthesise evidence from published articles describing the determinants (socioeconomic, demographic, and contextual) of the malaria status of children under five years in SSA between January 1990 and December 2020. The flowchart diagram in Figure 1 shows the selected studies for review. A total of 1157 records were identified from all the databases consulted. Ninety-three (93) were retained for full-text examination, and only thirteen (13) unique publications (with 18 country-specific studies) met the inclusion criteria and were examined for this review.

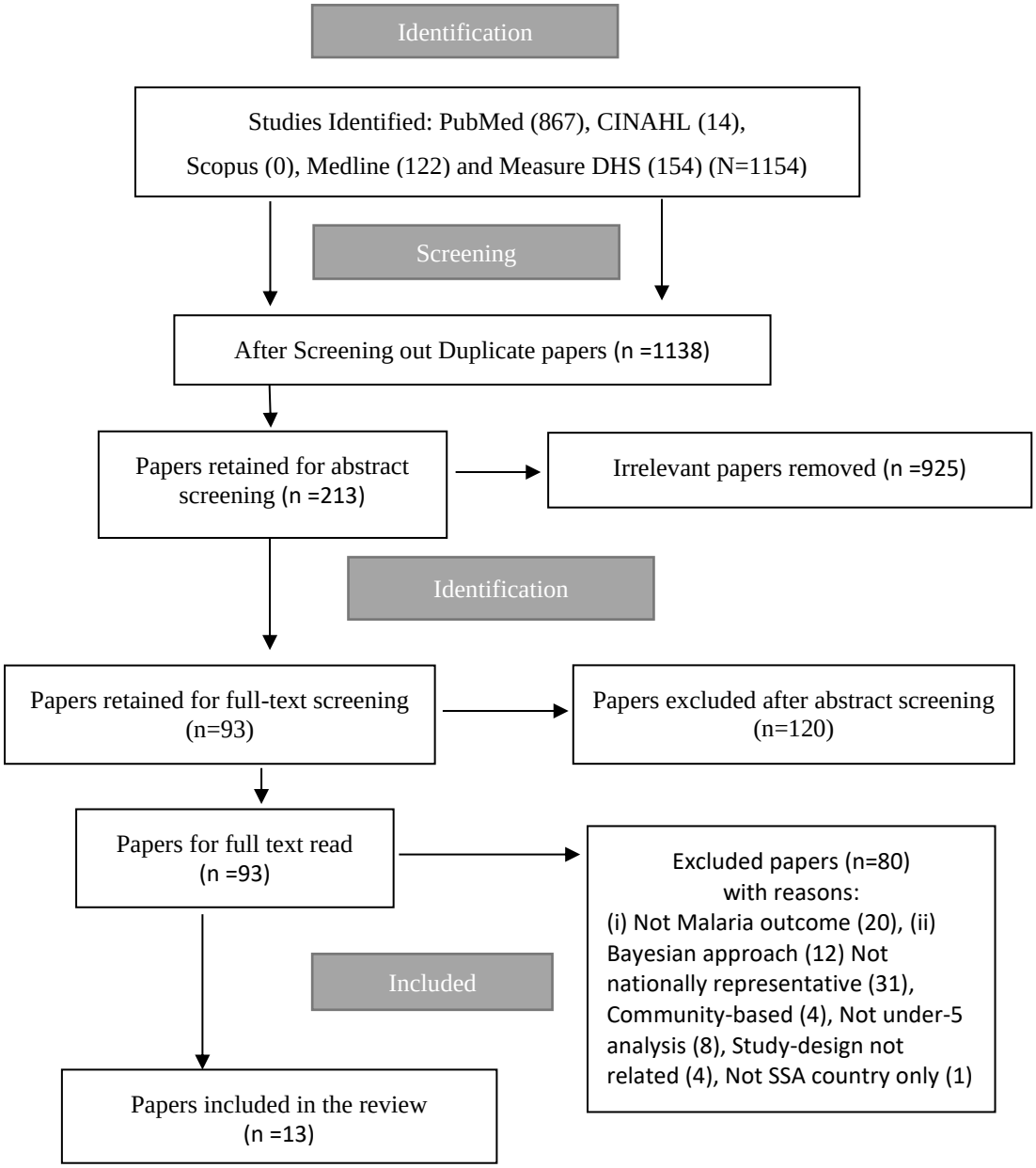


Figure 3 3 Flowchart of Inclusion of Studies for Malaria Review

3.4.2.2. Data Synthesis Method

The results were appraised using the narration of the descriptive statistics and odds of the likelihood of the risk factors and the outcome variable (malaria status).

3.4.2.3 Predictors associated with Malaria Status

The socioeconomic, demographic, and contextual determinants of malaria status among children under five years in SSA were grouped into child-related variables, mothers or caregiver-related

variables, household-related variables, and environmental or Area-related variables and interaction terms. These variables include age of the child, weight, anaemia status, birth order status; maternal age and education status, parent's knowledge, attitude, and practices of some basic facts about malaria fever; the type of material used to construct the building, distance from a health facility and cluster altitude as factors identified that are associated with malaria status among children under five years in SSA. A factor was considered statistically significant concerning each paper considered the *p*-value cut-off (0.01, 0.05, or 0.001). In addition, in a situation where the factor was classified into different categories or dummies, the factor was labelled as statistically significant if at least one of the categories or dummies compared to the reference category was statistically significant.

3.4.2.4 Child-Related Variables

Table 3.8 shows the evidence found on child-related variables. This study revealed the child's age's role in the tendency for the child to be infected with malaria parasites. Eleven (11) of the country-specific studies investigated a child's age being under five years as a predictor of their potential malaria status. Nine studies found that the child's age in at least one of the age groups was significantly associated with the prevalence of malaria among under five years in SSA. In most of the studies, it was found that as the child's age increases, the odds of contracting malaria fever also increase. However, Semakula et al. (Semakula *et al.,* 2015) in their multi-country study found no statistical significance in Tanzania (OR: 1.26, CI: 0.94–1.70, $p = 0.128$) and Burundi (OR: 0.79 CI: 0.60–1.05, $p = 0.108$), but found significant effect in Malawi (OR: 1.85 CI: 1.33–2.56, $p < 0.001$] and Liberia (OR: 2.10 CI: 1.59–2.80, $p < 0.001$]. Three studies investigated the sex of a child as a predictor of the prevalence of malaria among under five years old children in SSA. Surprisingly, these three studies ((OR: 0.96 CI: 0.91–1.02, $p = 0.18$) (Berendsen *et al.*, 2016), (OR: 0.927, $p = 0.2627$) (Ugwu and Zewotir, 2018), and (OR: 1.04 CI: 0.82–1.32, $p = 0.764$)) (Wanzira *et al.,* 2017) found no statistically significant effect. Also, three studies that explored the effect of birth order found statistically significant effects (OR: 1.03 CI: 1.01–1.06, $p = 0.011$) (Berendsen *et al.,* 2019) when the child was second-order compared to the 1st child born: (OR: 1.43 CI: 1.04–1.96, $p = 0.03$) (Chitunhu and Musenge, 2015) and [marginal effect: 0.045, $p < 0.01$) (Njau *et al.,* 2014).

Table 3 8 Association between child-related variables and malaria status

S/N	Variables	Significance Levels	Number of Studies	Association Effect (95% CI)
1	Age of the child	S:	9	Increased significant factors (ISF) OR: 1.05 (1.04–1.06)(Berendsen *et al.*, 2019) OR: 1.03 (1.02, 1.04) (Chitunhu and Musenge, 2015) 7–23: OR: 2.29 (1.21–4.34), 24–59: OR: 5.67 (3.01–10.70) (Morakinyo, Balogun and Fagbamigbe, 2018) OR: 1.85 (1.33–2.56) (Semakula *et al.*, 2015) OR: 2.10 (1.59–2.80) (Semakula *et al.*, 2015) 6–11: OR: 2.22 (1.88, 2.62); 12–23: OR: 3.70 (3.12, 4.37) 24–35: OR: 5.00 (4.25, 5.87) (Siri, 2014) 13–24: OR: 1.7039 (1.34–2.16); 25–36: OR: 2.624 (2.06–3.33); 37–48: OR: 3.591 (2.82–4.55); 49–59: OR: 4.97 (3.888–6.38) (Ugwu and Zewotir, 2018) 7–12: OR: 1.62 (1.04–2.52); 13–24: OR: 2.20 (1.47–3.29); 25–36: OR: 3.47 (2.32–5.20); 37–48: OR: 3.69 (2.47–5.50); 49–59: OR: 4.01 (2.57–6.45)(Wanzira *et al.*, 2017) 24–35: OR: 1.5 (1.0–2.5) ≥48: OR: 2.2 (1.4–3.5) (Zgambo, Mbakaya and Kalembo, 2017) decreased significant factors (DSF) 36 month+ OR: 0.80 (0.72, 0.88) (Siri, 2014)
		NS:	2	
2	Vaccination status	S:	1	DSF: OR: 0.88 (0.82 to 0.94) (Berendsen *et al.*, 2019)
		NS:	-	
3	Preceding birth interval	S:	1	ISF: OR: 1.00 (1.00 to 1.00) (Berendsen *et al.*, 2019)
		NS:	-	
4	Birth order	S:	3	ISF: OR: 1.03 (1.01–1.06) (Berendsen *et al.*, 2019) Second: OR: 1.43 (1.04, 1.96) (Chitunhu and Musenge, 2015) β: 0.045 (Njau *et al.*, 2014)
		NS:	-	
5	Breastfeeding status	S:	1	DSF: currently: 0.85 (0.73–0.99) (Berendsen *et al.*, 2019)
		NS:	-	
6	Fever in the last 2 weeks	S:	1	ISF: OR: 1.967 (1.71–2.26) (Ugwu and Zewotir, 2018)
		NS:	-	
7	Anemic	S:	2	ISF: OR: 2.982 (2.54–3.49) (Ugwu and Zewotir, 2018) DSF: OR: 0.95 (0.94, 0.96) (Chitunhu and Musenge, 2015)
		NS:	-	
8	Place of delivery	S:	1	DSF: public: 0.85 (0.78 to 0.92); private: 0.78 (0.70 to 0.87) (Berendsen *et al.*, 2019)
		NS:	-	
9	The child slept under a mosquito bed net	S:	4	ISF: OR: 1.21 (1.08–1.36) (Morakinyo, Balogun and Fagbamigbe, 2018) OR: 1.47 (1.16–1.89) (Semakula *et al.*, 2015) DSF: OR: 0.77 (0.60, 0.99) (Chitunhu and Musenge, 2015) OR:0.65 (0.56–0.77)(Semakula *et al.*, 2015)
		NS:	5	

OR: odds ratio, ME: marginal effect, β: coefficient estimate, S: significant, NS: not significant, ISF: increased significant factors, DSF: decreased significant factors.

Contrary to expectation, whether or not a child slept under a long-lasting insecticide-treated net was reported in five out of nine studies (OR: 0.93 CI: 0.84–1.02, $p = 0.13$) (Berendsen *et al.*, 2019); ((in Malawi study), OR: 0.88 CI: 0.73–1.07, $p = 0.202$) (Semakula *et al.*, 2015); ((in Liberia study), OR: 0.99 CI: 0.85–1.17, $p = 0.945$) (Semakula *et al.*, 2015); OR: 0.93 CI: 0.81–1.07] (Siri, 2014); (OR: 1.5 CI: 0.9–2.4 $p = 0.146$) (Zgambo, Mbakaya and Kalembo, 2017), not to be a significant predictor of malaria infection among children under five years in SSA.

3.4.2.5 Maternal-Related Variables

Table 3.9 describes the factors predicting the likelihood that a child would contract malaria fever at the maternal-related-variable level. Out of three studies that analysed maternal age as a predictor of contracting malaria fever among children under-fives in SSA, two studies (Anumudu *et al.*, 2007; Amoran *et al.*, 2014) (Njau *et al.*, 2014; Siri, 2014) found no statistically significant effect. While, Berendsen et al. 2019 (Berendsen *et al.*, 2019) found a statistically significant effect (OR: 0.99 CI: 0.98–0.99, $p = 0.00047$) of maternal age (Berendsen *et al.*, 2019). However, Zgambo et al. 2017 (Zgambo, Mbakaya and Kalembo, 2017) did not find any statistically significant effect of maternal education on the likelihood of malaria infection among children under five years in SSA.

Table 3 9 Association between maternal-related variables and malaria status

S/N	Variables	Significance Levels	Number of country studies	Association Effect (95% CI)
1	Maternal age	S:	1	DSF: OR: 0.99 (0.98 to 0.99) (Berendsen *et al.*, 2019)
		NS:	2 (Njau *et al.*, 2014; Siri, 2014)	
2	Maternal education status	S:	6	ISF: no Education: OR: 2.0454 (1.36–3.07); primary: OR: 1.5311 (1.03–2.28); secondary+: OR: 1.547 (1.07–2.23) (Ugwu and Zewotir, 2018) DSF: primary: OR: 0.91 (0.86 to 0.96); secondary+: OR: 0.73 (0.67 to 0.78) (Berendsen *et al.*, 2019). primary: OR: 0.53 (0.37, 0.76) (Chitunhu and Musenge, 2015) PS: β: −0.032; above primary: β: −0.047 [31] OR: 0.993 (0.990–0.996) (Siri, 2014) Primary: OR: 0.75 (0.59–0.96); secondary: OR: 0.61 (0.43–0.86); Tet: OR: 0.11 (0.02–0.53) (Wanzira *et al.*, 2017)
		NS:	1 (Zgambo, Mbakaya and Kalembo, 2017)	
3	Maternal body mass index	S:	1	DSF: OR: 0.97 (0.96–0.98) (Berendsen *et al.*, 2019)
		NS:	-	
4	Maternal ante-natal care	S:	1	DSF: β: −0.029(Njau *et al.*, 2014)
		NS:	-	
5	Number of births in 5 years	S:	1	ISF: OR: 1.08 (1.03–1.13) (Berendsen *et al.*, 2019)
		NS:	-	
6	Maternal knowledge of malaria fever	S:	2	ISF β: 0.013 [31] DSF: yes: OR: 0.78 (0.62–0.99) (Njau *et al.*, 2014; Yang *et al.*, 2020)
		NS:	-	
7	Number of children ever born	S:	1	ISF β: 0.003 (Njau *et al.*, 2014)
		NS:	-	
8	Mother has access to phone	S:	**1**	**DSF:** β: −0.030 (Njau *et al.*, 2014)
		NS:	-	

OR: odds ratio, ME: marginal effect, β: coefficient estimate, S: significant, NS: not significant, ISF: increased significant factors, DSF: decreased significant factors.

In addition, maternal knowledge of malaria fever was found to be a statistically significant predictor of under-five malaria cases in SSA. Children whose mothers showed knowing malaria fever were less likely to be infested with malaria *parasitemia* (β: −0.013, $p < 0.01$) (Njau *et al.*, 2014) and (OR: 0.78 CI: 0.62–0.99, $p = 0.037$) (Wanzira *et al.*, 2017).

3.4.2.6. Household-Related Variables

Table 3.10 describes the distribution of significant effects of household-related variables on the likelihood of developing malaria infections among children under five years in SSA. The most widely assessed household-related predictors are household socioeconomic status (designated as household wealth), place of residence (urban or rural), Household size, improved water source and improved toilet facilities. All eleven country-specific studies that investigated household wealth as a predictor found at least one of the categories statistically significant predictor of malaria status. The higher the household wealth quintile, the less likely it is that the child in the household would contract malaria fever. The thirteen country-specific studies that found a statistically significant effect of the place of residence all reported that it was more harmful to a child under five years in rural SSA than in urban areas in contracting malaria fever. Though Wanzira et al. 2017 (Wanzira *et al.*, 2017) and Zgambo et al. *2017* (Zgambo, Mbakaya and Kalembo, 2017) found no statistically significant effect of place of residence, they reported a more protective effect for urban children than rural children (OR: 1.74 CI: 0.92–3.29, $p = 0.089$) (Wanzira *et al.*, 2017), (OR: 2.3 CI: 0.9–6.0, $p = 0.075$) (Zgambo, Mbakaya and Kalembo, 2017).

Table 3 10 Association between household-related variables and malaria status

S/N	Variables	Significance Levels	Number of country studies	Association Effect (95% CI)
1	Household wealth status	S:	11	ISF: international wealth index square: 1.00 (1.00 to 1.00) (Berendsen *et al.*, 2019) poor: 5.51 (3.83–7.93) poorer: 5.15 (3.72–7.13) middle: 3.51 (2.64–4.65) richer: 1.89 (1.46–2.45) (Morakinyo, Balogun and Fagbamigbe, 2018) poorest: OR: 3.5498 (1.508–8.35); poorer: OR: 5.6013 (2.69–11.63); middle: OR: 2.4569 (1.46–4.12); richer: OR: 1.8258 (1.24–2.67) (Ugwu and Zewotir, 2018); poorest: OR: 4.7 (1.3–16.2) (Zgambo, Mbakaya and Kalembo, 2017) DSF: OR: 0.95 (0.93–0.98) (Chitunhu and Musenge, 2015) ME: −0.034 (−0.1543– 0.0773) (Njau *et al.*, 2013); ME: −0.070 (−0.0943–0.0267) (Njau *et al.*, 2013); ME: −0.116 (−0.1876–−0.0583) (Njau *et al.*, 2013) poor: β: −0.019 (0.017); less poor: β: −0.033 (0.018); middle: β: −0.065 (0.018); rich: β: −0.123 (0.019) (Njau *et al.*, 2014) OR: 0.990 (0.987–0.992) (Siri, 2014) poorer: 0.70 (0.50–0.99); middle: 0.75 (0.50–1.12) 0.157; richer: OR: 0.40 (0.27–0.61); richest: OR: 0.17 (0.08–0.36) (Wanzira *et al.*, 2017)
		NS:	-	
2	Place of residence	S:	**13**	ISF: rural: OR: 1.91 (1.63–2.25) (Berendsen *et al.*, 2019) rural: OR: 1.83 (1.18–2.83) (Chitunhu and Musenge, 2015), rural: OR: 1.59 (1.33–1.89) (Morakinyo, Balogun and Fagbamigbe, 2018), ME: 0.002 (0.0781–0.1228) ME: 0.055, CI: (0.0005–0.1097) (Njau *et al.*, 2013) rural: β: 0.024 (Njau *et al.*, 2014) rural: OR: 4.57 (1.86–11.25) (Ugwu and Zewotir, 2018) DSF: urban: OR: 0.94 (0.61–1.42)(Semakula *et al.*, 2015) OR: 0.26 (0.13–0.49) (Semakula *et al.*, 2015) urban: OR: 0.39 (0.25–0.60)(Semakula *et al.*, 2015)

				urban: OR: 0.72 (0.570.92) (Semakula *et al.*, 2015) urban: OR: 0.59 (0.50–0.71) (Siri, 2014)
		NS:	2 (Wanzira *et al.*, 2017; Zgambo, Mbakaya and Kalembo, 2017)	
3	Household had bed net	S:	**4**	DSF: ME: −0.055 (−0.1187–0.008) (Njau *et al.*, 2013); ME: −0.034 (−0.1233–0.0387) (Njau *et al.*, 2013) ME: −0.098 (−0.0419–0.1494) (Njau *et al.*, 2013) β: −0.076 (Njau *et al.*, 2014)
		NS:	1 (Zgambo, Mbakaya and Kalembo, 2017)	
4	Age of household head	S:	4	ISF: ME: 0.006 (−0.0004–0.0016) (Njau *et al.*, 2013); ME: 0.001 (−0.0005–0.0029) (Njau *et al.*, 2013), OR: 1.019 (1.007–1.031) (Ugwu and Zewotir, 2018) DSF: ME: −0.009 (0.0012–0.0032)(Njau *et al.*, 2013)
		NS:	-	
5	Insecticide residual spray	S:	2	DSF: OR: 0.37 (1.08–1.36) (Morakinyo, Balogun and Fagbamigbe, 2018) OR: 0.23 (0.08–0.61) (Wanzira *et al.*, 2017)
		NS:	2 (Zgambo, Mbakaya and Kalembo, 2017; Ugwu and Zewotir, 2018)	
6	Household size	S:	**7**	ISF: OR: 1.03 (1.01–1.04) (Berendsen *et al.*, 2019) ME: 0.015 (0.0021–0.0285) (Njau *et al.*, 2013) ME: 0.004 (−0.0059–0.0050) (Njau *et al.*, 2013) ME: 0.005 (−0.0163–0.0055) (Njau *et al.*, 2013) β: 0.009 (Njau *et al.*, 2014) OR: 1.46 (1.24–1.73) (Siri, 2014), OR: 1.108 (1.03–1.17) (Ugwu and Zewotir, 2018)
		NS:	-	
7	Number of under-5 in household	S:	3	ISF: ME: 0.049 (0.0331–0.6565) (Njau *et al.*, 2013) DSF: ME: −0.025 (−0.1787–−0.0181) (Njau *et al.*, 2013) ME: −0.044 (−0.0742–−0.0156) (Njau *et al.*, 2013)
		NS:	**1** (Njau *et al.*, 2014)	
8	Source of water outside	S:	**1**	DSF: OR: 0.97 (0.96, 0.99) (Chitunhu and Musenge, 2015)
		NS:	**1** (Ugwu and Zewotir, 2018)	
9	Improved water source	S:	**5**	ISF: borehole: OR: 1.50 (1.10–1.88); unprotected well: OR: 1.56 (1.29–1.88); protected well: OR: 2.19 (1.53–3.10); river/lakes: OR: 2.45 (1.81–3.31) (Semakula *et al.*, 2015) borehole: OR: 1.75 (0.61–0.93); protected well: OR: 1.44 (0.25–0.78) (Semakula *et al.*, 2015) borehole: OR: 1.19 (0.36–3.60); protected well: OR: 1.36 (1.041.78); unprotected spring: OR: 1.65 (1.012.71) 0.047; river/lakes: OR: 1.55 (1.12–2.16) (Semakula *et al.*, 2015) unprotected: OR: 1.17 (1.07, 1.27) (Yang *et al.*, 2020) DSF: piped (yard): OR: 0.13 (0.03–0.32); public pipe: OR: 0.70 (0.51–0.95); private taps: OR: 0.62 (0.39–0.95) protected spring: OR: 0.78 (1.06–2.83) (Semakula *et al.*, 2015). piped (yard): OR: 0.05 (0.00–0.58); public pipes: OR: 0.52 (1.25–1.84); private tap: OR: 0.23 (0.04–0.75) (Semakula *et al.*, 2015); piped (yard): OR: 0.23 (0.12–0.43); public: OR: 0.33 (0.23–0.47) (Semakula *et al.*, 2015) public: OR: 0.27 (0.13–0.51) (Semakula *et al.*, 2015) piped: 0.52 (0.45–0.59) (Yang *et al.*, 2020)
		NS:	**2** (Ugwu and Zewotir, 2018; Berendsen *et al.*, 2019)	
10	Improved toilet facility	S:	**7**	ISF: open toilet: OR: 1.35 (1.11–1.63) no toilet: OR: 3.57 (2.35–5.42); pit: OR: 1.30 (1.07–1.58) (Semakula *et al.*, 2015) no toilet: OR: 1.66 (1.20–2.30) (Semakula *et al.*, 2015) no toilet: OR: 1.24 (0.821.28 (Semakula *et al.*, 2015) no toilet: 1.635 (1.209–2.21) (Ugwu and Zewotir, 2018) no toilet: OR: 1.35 (1.24, 1.47) (Yang *et al.*, 2020) DSF: medium-quality: OR: 0.85 (0.78 to 0.92) (Berendsen *et al.*, 2019); flush toilet: 0.40 (0.18–0.78)

				(Semakula *et al.*, 2015) flush toilet: OR: 0.04 (0.02–8.01) (Semakula *et al.*, 2015) flush toilet: 0.53 (0.390.73)(Semakula *et al.*, 2015); flush toilet: OR: 0.51 (0.43, 0.61) (Yang *et al.*, 2020)
		NS:	-	
11	Sex of household head	S:	**1**	DSF: male: ME: −0.029 (−0.0637–0.0049) (Njau *et al.*, 2013)
		NS:	**4**	
12	Use biomass for cooking	S:	**2**	ISF: firewood: OR: 1.80 (1.23–2.68) (Semakula *et al.*, 2015) firewood: OR: 1.44 (0.98–2.16) (Semakula *et al.*, 2015) DSF: charcoal: OR: 0.58(0.38–0.85)(Semakula *et al.*, 2015)
		NS:	-	
13	Under 5 years, child slept under bed net	S:	**2**	ISF: yes: OR: 1.33 (1.04–1.71) (Wanzira *et al.*, 2017) DSF: OR: 0.83 (0.78–0.88) (Tusting *et al.*, 2020)
		NS:	**1** (Ugwu and Zewotir, 2018)	
14	Household ownership of livestock	S:	**4**	ISF: goat: OR: 1.32 (1.09–1.60) (Semakula *et al.*, 2015) goat: 1.26 (1.07–1.48) OR: 1.17 (0.98–1.38) (Semakula *et al.*, 2015) DSF: cattle: OR: 0.55 (0.45–0.67) pigs: OR: 0.18 (0.09–0.33) (Semakula *et al.*, 2015) cattle: OR: 0.51 (0.40–0.65) (Semakula *et al.*, 2015) cattle: OR: 0.54 (0.35–0.83) cattle: OR: 0.74 (0.55 1.00) (Semakula *et al.*, 2015)
		NS:	-	
15	Improve building materials	S:	**2**	ISF: nothing improved: OR: 1.05 (1.02–1.12) (Morakinyo, Balogun and Fagbamigbe, 2018); OR: 0.88 (0.83–0.93) (Tusting *et al.*, 2020)
		NS:	**1** (Tusting *et al.*, 2020)	
16	Household head education status	S:	**2**	ISF: ME: 0.027 (−0.0023–0.0567) (Njau *et al.*, 2013) DSF: primary school+: β: −0.009 (0.004) (Njau *et al.*, 2014)
		NS:	**1** (Njau *et al.*, 2013)	
18	Household connected electricity	S:	**1**	ISF: no: OR: 1.14 (0.88–1.48) (Ugwu and Zewotir, 2018)
		NS:	-	
19	Roofing material	S:	**1**	DSF: palm leaf: OR: 0.7171 (Ugwu and Zewotir, 2018)
		NS:	-	

OR: odds ratio, ME: marginal effect, β: coefficient estimate, S: significant, NS: not significant, ISF: increased significant factors, DSF: decreased significant factors.

It is worthy of note that access to mass media, number of rooms in the household and type of wall material were found not to be statistically significant predictors of malaria fever among children under-five in SSA (Njau *et al.*, 2013; Ugwu and Zewotir, 2018). The variations in household ownership of livestock were a statistically significant predictor of malaria status in children under five years in SSA. Semakula et al. 2015 (Semakula *et al.*, 2015) reported consistent findings in their four country-specific studies that a child from a household that owns cattle has a lower odd of contracting malaria *parasitemia* than a child from a household without livestock (Tanzania (OR: 0.55 CI: 0.45–0.67, $p < 0.001$); Burundi (OR: 0.51 CI: 0.40–0.65, $p < 0.001$); Malawi (OR: 0.54 CI: 0.35–0.83, $p < 0.001$); Liberia (OR: 0.74 CI: 0.55–1.00, $p < 0.05$)).

3.4.2.7 Environmental/Area-related Variables

In consideration of environmental-related predictors, three variables (regional variations, malaria endemicity, and community-free bed net distribution) were attractive for investigation among the included studies. Table 3.11 reports that Njau et al. 2013 (Njau *et al.*, 2013) found that the predicted marginal effects (ME) of malaria-endemic areas for malaria fever in Angola, Tanzania and Uganda were significantly ME: 0.01 ($p < 0.10$), ME: 0.095 ($p < 0.05$) and ME: 0.288 ($p < 0.01$) points, respectively. Additionally, the same authors (Njau *et al.*, 2013) reported an insignificant increase in the predicted marginal effects of 25.1% points for free bed net in the community among malaria-positive children in Angola, but a significant reduction of 1.5% ($p < 0.1$) and 8.2% ($p < 0.05$) in Tanzania and Uganda, respectively.

Table 3 11 Association between environmental-related variables and malaria status

S/N	Variables	Significance Levels	Number of country Studies	Association Effect (95% CI)
1	Community wealth status	S:	1	ISF: cluster level: OR: 0.984 (0.979, 0.988) (Siri, 2014)
		NS:	-	
2	Community distance to health facilities	S:	2	ISF: ME: 0.084 (0.0560–0.1128) (Njau *et al.*, 2013) ME: 0.102 (0.0525–0.1521) (Njau *et al.*, 2013)
		NS:	-	
3	Cluster altitude	S:	1	ISF: OR 1.0003 (0.991–1.1003) (Ugwu and Zewotir, 2018)
		NS:	1 (Chitunhu and Musenge, 2015)	
4	Community insecticide net use	S:	1	ISF: OR: 0.43 (0.27, 0.70)(Levitz *et al.*, 2018)
		NS:	-	
5	Regional variations	S:	3	
		NS:	1 (Zgambo, Mbakaya and Kalembo, 2017)	
6	Malaria endemicity	S:	4	ISF: ME: 0.010 (−0.0778–0.0572) (Njau *et al.*, 2013) ME: 0.095 (0.0357–0.1561) (Njau *et al.*, 2013) ME: 0.288 (−0.5526–−0.0247) (Njau *et al.*, 2013) high: β: 0.093 (Njau *et al.*, 2014)
		NS:	-	
7	Free bed net in community	S:	3	ISF: ME: 0.251 (0.0226–0.4801) (Njau *et al.*, 2013) DSF: ME: −0.015 (−0.0134–0.0405) (Njau *et al.*, 2013) ME: −0.082 (0.1479–0.0494) (Njau *et al.*, 2013)
		NS:	-	
	Country-specific	S:	1	ISF: Liberia: OR: 1.09 (0.95–1.24); Uganda: OR: 40.15 (29.74–54.20); Malawi: OR: 16.68 (12.38, 22.48); Senegal: OR: 1.01 (0.77, 1.32); Nigeria: OR: 31.91 (23.86, 42.67) (Siri, 2014) DSF: Rwanda: OR: 0.15 (0.10, 0.21); Tanzania: OR: 0.82 (0.63, 1.07); Madagascar: OR:0.73 (0.57, 0.94) (Siri, 2014)
		NS:	-	

OR: odds ratio, ME: marginal effect, β: coefficient estimate, S: significant, NS: not significant, ISF: increased significant factors, DSF: decreased significant factors.

Also, significant regional variations were reported across the six geopolitical zones of Nigeria. Morakinyo et al. 2018 (Morakinyo, Balogun and Fagbamigbe, 2018), which found reduced odds of malaria infections among children 6–59 months in North Central (OR: 0.61 CI: 0.47–0.79, $p <$

0.01); North East (OR: 0.35 CI: 0.27–0.46, $p < 0.01$); North West (OR: 0.49 CI: 0.37–0.64, $p < 0.01$); South East (OR: 0.59 CI: 0.44–0.79, $p < 0.01$); South-South (OR: 0.42 CI: 0.31–0.55, $p < 0.01$), when compared with children from South West. Contrary to Morakinyo et al. 2018 (Morakinyo, Balogun and Fagbamigbe, 2018) report on Nigeria study, Ugwu et al. 2018 (Ugwu and Zewotir, 2018) found insignificant effects on regional variations in South East, South-South, South West, and North Central when compared with North West, but found significant odd of malaria-positive cases among 6–59 months in North East (OR: 0.3059, $p = 0.015$) when compared with north West.

3.4.2.8. Interactions-related Variables

Interaction-related predictors were reported by two papers in four country-specific studies (Table 3.12). Njau et al. 2013 (Njau *et al.*, 2013) reported a significant decrease of 4.6% ($p < 0.05$) points in the predicted marginal effects among malaria-positive children in Angola concerning interaction terms of free bed net and wealth status but found an insignificant reduction of 0.9% and 6.4% in Tanzania and Uganda, respectively.

Table 3 12 Association between interaction-related variables and malaria status

S/N	Variables	Significance Levels	Number of country Studies	Association Effect (95% CI)
1	Free bed net/wealth status	S:	1	DSF: ME: −0.046 (−0.0668–0.1772) (Njau *et al.*, 2013)
		NS:	2	
2	Wealth/place of residence	S:	1	DSF: poorest/rural: OR: 0.3567 (0.13–0.96); poorer/rural: OR: 0.2770 (0.11–0.66); middle/rural OR: 0.4477 (0.22–0.91); richer/rural: OR: 0.4174 (0.22–0.78) (Ugwu and Zewotir, 2018)
		NS:	-	
3	Number in household/age of household head	S:	1	DSF: OR: 0.9984 (0.997–0.999) (Ugwu and Zewotir, 2018)
		NS:	-	

OR: odds ratio, ME: marginal effect, β: coefficient estimate, S: significant, NS: not significant, ISF: increased significant factors, DSF: decreased significant factors.

Ugwu et al.(Ugwu and Zewotir, 2018) found significant interaction effects of wealth index (poorest, poorer, middle, richer and richest) and place of residence (rural or urban). In consideration of the report, the middle and richer household group in the rural area (OR: 0.448 CI: 0.2197–0.9124, $p = 0.027$ and OR: 0.417 CI: 0.2213–0.7871, $p = 0.007$) displayed a higher odd of malaria-positive than the poorest and poorer household group in the rural area (OR: 0.3567 CI: 0.1319–0.0429, $p = 0.0429$ and OR: 0.2770 CI: 0.1149–0.6677, $p = 0.004$) using richest and urban as a reference category. There were no significant interaction effects of region and place of residence on the odds of contracting malaria parasitaemia among children 6–59 months in Nigeria.

3.5 Part 4: Scoping review of risk factors associated with malnutrition among children aged under-five years in Sub-Sahara Africa

3.5.1 Introduction

This scoping review titled: "Risk Factors Associated with Malnutrition among Children Under-Five Years in Sub-Saharan African Countries: A Scoping Review" was conducted on the existing literature published between 1 January 1990 and 31 July 2020. The review's outcome was also published in one of the journals on 26 November 2020, the *International Journal of Environmental Research and Public Health*. 2020 on 26 November 2020 (Obasohan *et al.*, 2020b). (The full text is attached in Appendix C.3). However, in this section, the results of the evidence of risk factors associated with malnutrition were extracted here.

3.5.2 Results

The results section reports the profile of the quantitative analysis of risk factors associated with malnutrition in under-five children in SSA following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklists (Larissa Shamseer, 2015; Tricco *et al.*, 2018).

3.5.2.1 Selection of Sources of Evidence

A total of 224 unique papers were identified from the various electronic databases (EMBASE=12, PUBMED = 18, WOS = 74, Scopus = 103, Cochran Library =0, CINAHL =12). Additionally, 5 other studies were retrieved from other sources (the reviewer's files).

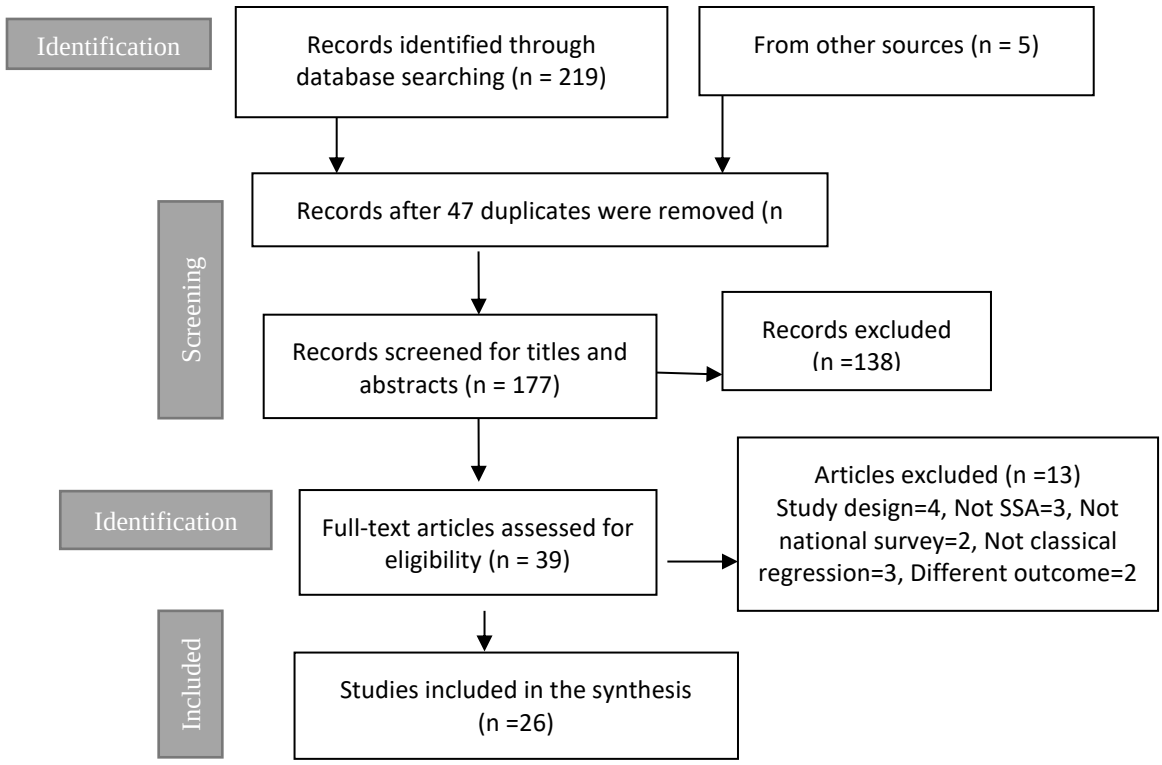


Figure 3 4 Flowchart of Inclusion of Studies for Malnutrition Review.

Twenty-five studies were duplicated in the search at different times (twice, thrice, 4 or 5 times). The duplication led to the removal of 47 titles. Out of a total of 177 studies screened for titles and abstracts, 138 studies were removed for not meeting the inclusion criteria. A total of 26 studies were finally selected for this study after excluding 13 papers. The reasons for excluding these papers are listed in the chart below.

Characteristics of Significant Risk Factors

Table 3.13 contains the predictor variables considered for each study selected for this scoping review. It also listed the significant risk factors concerning stunting, wasting, underweight and overweight children less than five years old. The choice of predictor variables to examine in the most review was guided by the UNICEF framework of causes of undernutrition in children (UNICEF, 2013). These were classified as child-related, parental/household-related and community or area-related factors. On the child-related risk factors, sex and age (in months categories) were the most frequent significant predictors of stunting (13 studies), wasting (4 studies), underweight (4 studies), overweight (no study), and stunting (12 studies), wasting (6 studies), underweight (4 studies), overweight (1 study), respectively. In the parental category, maternal education was the most active predictor in 14, 3, 5 and 1 studies for stunting, wasting,

underweight and overweight, respectively. Out of the 28 studies on stunting, 16 reported a significant association between household wealth status for stunting. Place of residence from the community-related category was significant in stunting (5 studies), wasting (3 studies) and underweight (1 study). There was significant comorbidity of a child having diarrhoea in the last two weeks before the survey, with stunting (4 studies) and underweight (2 studies) captured in this review.

Table 3 13 Predictors of malnutrition among children aged under five years in sub-Sahara Africa

Author and Data	Outcome variables	Prevalence	Predictors investigated	Significant predictors and effect sizes
Adekambi et al (2013)(Adekanmbi, Kayode and Uthman, 2013)	Stunting	25.6%	Child's age, sex, birth weight, type of birth; Mother's age, education, breastfeeding, immunisation, BMI work status, birth interval, household under-5 size, ethnicity, mother health seeking, type of family, wealth status; Community place of residence, region, poverty rate, illiteracy rate proper sanitation and safe water	Child's age: 12-23 months 2.36 (2.04–2.74); 24-35 months 2.12 (1.82–2.48); 36-47 months 2.09 (1.79–2.44) 48-59 months 2.06 (1.76–2.41), Sex (Male): 1.04 (1.10–1.26)., Birthweight is low <2500g: 1.21 (1.10–1.33); Type of birth is multiple birth 1.89 (1.52–2.32), Birth interval <24 months: 1.19 (1.09–1.30), Mother's age is 35-49 years: 0.91 (0.82–0.99), Mother's education is: Secondary, 0.84 (0.64–0.97), Higher 0.75 (0.35–0.86), Maternal health seeking behaviour is highest: 0.83 (0.66-0.92); Breastfeeding; 6-12 months: 2.14 (1.84–2.49), 13-24 months: 2.52 (2.12–3.00), 25+ months: 3.52 (2.73–4.55); BMI, <18.5: 1.26 (1.14–1.39), >25 :0.79 (0.72–0.87); wealth status. Rich:1.21 (1.04–1.41), Middle: 1.51 (1.27–1.79), Poor: 1.58 (1.31–1.91), Poorest: 1.64 (1.33–2.01); Community region Northwest: 1.26 (1.14–1.29), Northeast: 1.35 (1.27–1.43), Southeast: 0.49 (0.39–0.56), South-south: 0.76 (0.78–0.89), South-west: 0.97 (0.72–1.00), illiteracy rate.: 1.49 (1.19–1.88)
Acharya et al (2020) (Acharya *et al.*, 2020)	Stunting and overweight	2.7%	Forest cover loss, child's age, sex, mother's education level, age, anaemia status, overweight status, household wealth, size, improved water, sanitation, own agriculture, own livestock, place of residence, the distance of cluster to the nearest road (Km)	Forest cover lost: 4.801 [0.816, 28.25] mother's education is Secondary school: 0.802 [0.679, 0.947], mother's age in years: 0.991 [0.983, 0.998] wealth status is low: 1.163[1.006, 1.343], highest 0.842[0.690, 1.026] improved sanitation is No: 1.258[1.113, 1.421]; Forest cover (2000) % 0.995 [0.991, 1.000] child's age in months: 1.032[1.012, 1.053]
Agadjanian et al (2003)(Agadjanian and Prata, 2003)	wasting and stunting	Nil	place of residence, degree of war, region of residence, language spoken at home, Age, full immunisation for age,	Age,12–23 months: 2.13 (1.51, 30.2); 24–35 months: 1.92 (1.35, 2.73); 36–59 months: 2.95(2.12, 4.09); immunization status (yes): 0.62(0.46, 0.84); Region of war impact is Heavier: 1.27 (1.03, 1.53); Household own a radio: 0.80 (0.66, 0.98); Water is treated: 0.66 (0.52, 0.83)
Aheto (2020)(J. M. K. Aheto, 2020)	severe stunting	5.30%	Type of birth, sex, age, diarrhoea, fever, place of delivery, size at birth, number of children, health insurance, currently breastfeeding, wealth status, maternal education	Birth type is multiple: − 0.334 (− 0.457, 0.150); Child's age in months: −0.023(− 0.027, − 0.020); diarrheal (Yes) − 0.249(− 0.418, − 0.044); place delivered is home −0.199(− 0.358, − 0.046); birth size is small: − 0.397(− 0.530, − 0.233); maternal age: 0.035(0.024, 0.045); maternal education: −0.358 (−0.556, − 0.223); Nos of children<5 years in household: −0.338(− 0.459, − 0.193); maternal had health insurance 0.294(0.164, 0.422); wealth status (poor): −0.250(− 0.390, − 0.124)
Akombi et al (2019)(Akombi *et al.*, 2019)	Undernutrition (Stunting, wasting and underweight)		Child's age, mother's age, sex of the child, mother's education, father's education, wealth index, place of residence, and region.	Child's age in months, 1.02 [1.02, 1.02]; Female: 0.79 [0.75, 0.84]; Maternal age is 25-34 years: 0.87 [0.81, 0.93], 35 years+: 0.83 [0.77, 0.90]; Maternal education is Secondary+: 0.72 [0.65, 0.79]; Father's education is secondary+: 0.86 [0.79, 0.94]; Richer: 0.74 [0.67, 0.82] Richest: 0.53 [0.47, 0.59]; Rural :1.16 [1.06, 1.26]; Region Northeast: 1.43 [1.27, 1.60], Northwest: 2.61 [2.33, 2.92], South east: 0.52 [0.44, 0.61], South west: 0.65 [0.56, 0.75], South South: 0.86 [0.75, 0.98]
Akombi et al (2017(Akombi, Agho, Hall, Merom, *et al.*, 2017)			Geopolitical zone and type of residence, wealth index, marital status, maternal literacy, paternal education, paternal occupation, maternal education and maternal work status, source of drinking water, reading of the newspaper, watching television, listening to the radio, delivery factors, pre/post-delivery factors and child factors, mother's age, mother's age at birth and mother's body mass index, place of delivery, mode of delivery and type of delivery assistance, antenatal clinic visits,	North East:1.53 (1.26,1.87), North West: 2.74 (2.29,3.27), South East: 0.49 (0.39,0.62), South West: 0.65 (0.52,0.80); Poorer: 0.87 (0.76,0.98) Middle: 0.77 (0.66,0.89) Richer: 0.62 (0.52,0.73) Richest: 0.45 (0.37,0.55); Maternal is working >12 months: 1.54 (1.23,1.93); Read newspaper (No): 1.18 (1.02,1.38); Watch television is No: 1.38 (1.23,1.55); Maternal BMI is 25+: 0.79 (0.66,0.95); Type of birth assistance is traditional birth attendant: 1.19 (1.05,1.36), No-one: 1.24 (1.07,1.44); Duration of breastfeeding is > 12 months: 3.28 (2.95,3.65); Child's sex is female: 0.81 (0.75,0.87); Birth size is large: 0.69 (0.61,0.78); child had diarrheal is yes: 1.31 (1.16,1.49)

			the timing of postnatal care check-up, currently breastfeeding, and duration of breastfeeding, Child's sex, birth order, child's age in months, perceived birth size, preceding birth interval, the child had diarrhoea and had fever 2 weeks preceding the survey.	
Akombi et al (2017)(Akombi, Agho, Hall, Wali, *et al.*, 2017)	Wasting and underweight	18% and 29%	Place of residence, region, wealth index, Mother's work status, education, father's education, occupation, marital status, mother's literacy, source of drinking water, media factors newspaper, radio, television, Mother's age, age at birth, type, mode & place of delivery, ANC, the timing of postnatal check, breastfeeding, Child's birth order, birth interval, sex, birth size, age, had diarrhoea, had a fever	Rural: 0.72 (0.59, 0.89); North east:1.51 (1.19, 1.91) North West: 2.42 (1.93, 3.03) South South: 0.67 (0.52, 0.85); Mother had secondary+ education: 0.79 (0.67, 0.94); Father had secondary+ education: 0.77 (0.67, 0.88); Maternal watch television: 0.78 (0.68, 0.88)> Maternal BMI is 18.5-24.9: 0.76 (0.64, 0.90), 25+: 0.68 (0.56, 0.83); Birth assistance is Traditional Birth Attendant: 1.39 (1.11, 1.73) Relative: 1.44 (1.14, 1.80); Place of delivery is health facility (caesarean): 0.61 (0.39, 0.94); Birth size is average: 0.85 (0.74, 0.97), Large: 0.66 (0.57, 0.76); Female: 0.83 (0.77, 0.89); Had fever is yes: 1.18 (1.06, 1.32); Child's age in months: 0.98 (0.98, 0.98)
Amaral et al (2017)(Amaral, Herrin and Gulere, 2017)	Stunting and wasting	22.2% and 3.1%	Staple Budget Share, spending, place of residence, mother present, sex, household head educated.	Budget share: 1.007 (1.002, 1.011); Spending: 0.995 (0.991, 0.998); Place of residence is Urban: 0.492 (0.354, 0.685); Mother is present (yes): 0.723 (0.526, 0.992); Child's sex is male: 1.498 (1.237, 1.815)
Amare et al (2019)(Amare, Ahmed and Mehari, 2019)	Stunting and wasting	Nil	Child's age, sex. Birth order, birth weight. Mother's marital status, age at child's birth, educational status, BMI, working status, maternal stature; place of residence, region, wealth status, improve drinking water, toilet type, cooking fuel type	Child's age is 12-17 months: 3.50 (2.59–4.74), 18-23 months 7.81 (5.73–10.65), 24-59 months 6.59 (5.00–8.68); Child's sex is female: 0.82 (0.74–0.90); birth weight is smaller than average: 0.82 (0.67–0.99), average: 0.68 (0.59–0.78), larger than average: 0.54 (0.47–0.63); above primary education: 0.66 (0.52–0.84); Maternal BMI is Normal: 0.84 (0.74–0.94), Overweight: 0.57 (0.45–0.71); Maternal stature is short: 2.03 (1.44–2.86); Wealth quintile is middle:0.77 (0.65–0.91), richer:0.69 (0.58–0.82), richest: 0.62 (0.49–0.79), non-improve toilet: 1.28 (1.07–1.53); traditional cooking fuel: 1.66 (1.18–2.32)
Doctor & Nkhana-Salimu (2017)(Hv and S, 2017)	stunting and underweight	32.60%	Place and region of residence, wealth index, source of drinking water, toilet facilities, mother's education status, age, number of under-5, child's sex, age, birth-order, size at birth, had diarrhoea, had fever, had cough	Region is central: 1.26 [1.14, 1.39]; Wealth status is poorer: 0.87 [0.78, 0.96], Middle:0.83 [0.75, 0.92], Richer:0.70 [0.63, 0.78] Richest:0.48 [0.42, 0.54]; Mother has secondary+ education: 0.68 [0.59, 0.74]; Child is female: 0.78 -[0.73, 0.83]; Child's age is 7-12 months 1.72[1.51, 1.96], 13-23 months 4.59[4.08, 5.17], 24-35 months 5.91[5.22, 6.68], 36-59 months 5.02[4.47, 5.63]; Birth size is average: 0.70 0.64, 0.76] large: 0.55 [0.50, 0.61], Child had diarrheal (Yes): 1.09 [1.00, 1.18
Gebru et al (2019) (Gebru *et al.*, 2019)	stunting	38.39%	Child's age, sex, mother's BMI, age, education, occupation, marital status, perceived child's birth size, child had diarrhoea and/or fever in the last weeks, father's education, occupation, wealth index, place of delivery, number of under-5 children in the household, antenatal care visits, mother's age at 1st birth, birth type, birth interval and mass-media exposure.	Child's age is 12-23 months: 5.04(3.95–6.41), 24-59 months: 10 (7.71–12.98); Child is female: 0.85 (0.75–0.94); Type of birth is single: 0.50 (0.30–0.85); Medium: 1.20 (1.02–1.40) Small: 1.68(1.40–2.00); Women education level is secondary+ 0.73(0.57–0.95); Maternal BMI is normal: 1.34(1.03–1.75), Underweight: 1.56(1.17–2.08); Wealth status is rich: 0.66(0.54–0.79); Religion status is Muslim: 1.45(1.12–1.88), Others(Catholic, traditional): 1.66 (1.0–2.57); Rural: 1.29(1.06–1.58)
Kuche et al (2020)(Kuche *et al.*, 2020)	length-for-age (Stunting)	Nil	Child's dietary diversity, age, sex, Household wealth, maternal education, women decision making power, paternal domestic chores, food insecurity, min women dietary diversity, animal source food types, fruit & vegetable types, land owned	Dietary diversity: 2: 0.42[0.10, 0.75]; 3: 0.35[0.02, 0.68], 4: 0.42[0.08, 0.77] −0.25[−0.34, −0.16]; Child's age in months -0.25[-0.34, -0.16], Child is female: 0.19[0.06, 0.32]; Household wealth is middle: 0.11[−0.06, 0.29], richest: 0.30[0.10, 0.49], Maternal education in years 0.02[0.004, 0.04]; Fruit and vegetable types: 0.05[0.005, 0.10], Land owned in hectares: 0.08[0.02, 0.15]
Machisa et al (2013)(Machisa,	stunting	27.60%	Child's age, sex, anaemia, birth order, preceding birth interval. Birthweight, recent episode of an acute	Cooking fuel: 1.6 (1.0–2.5), Child is female: 0.6 (0.4–0.9), Child's age is 12-23 months: 2.9 (1.7–5.1), 24-36 months: 3.2 (1.8–5.7); Child's birthweight is

Wichmann and Nyasulu, 2013)			respiratory infection, diarrhoea and fever; mother's age, BMI, highest education, Iron supplement, anaemia status; household use of biomass fuel, place of residence, region, number of people in household, wealth index	>2500g: 0.5 (0.3–0.9), Birth interval is >24 months: 0.7 (0.5–0.9); High: 0.7 (0.4–0.9)
Magadi (2011)(Magadi, 2011)	Undernutrition (Stunting, wasting underweight)	Nil	Household HIV status. Paternal orphan, child's age sex, multiple birth, birth order, Birth interval, breastfed, birth size, place of residence, mother's age, education, single parenting, wealth status, Community HIV prevalence, country HIV prevalence, GDP per capital	Mother is HIV+: 1.28[1.16, 1.42], other adults is 0.97[0.95, 0.99]; Paternal orphan: 0.86[0.75, 0.98]; Child's age is 1 years: 3.65[3.36, 3.96], 2 years: 3.26[3.00, 3.54], 3 years: 3.39[3.12, 3.68], 4 years: 3.21[2.95, 3.49], Child is female: 0.81[0.78, 0.84]; Child is twin (yes): 2.13[1.89, 2.39]; Child's birth order is second: 0.82[0.76, 0.89], third: 0.91[0.84, 0.98], Fourth: 0.92[0.86, 0.99] 25-36 years: 0.86[0.81, 0.91], 0.65[0.59, 0.72], >36 years: 0.74[0.70, 0.79],; Up to 6 months: 0.47[0.39, 0.56]; > 6months: 0.74, Child's birth size is average: 0.74[0.70, 0.78], > average: 0.62[0.59, 0.66]; Place of residence is rural: 1.32(1.23, 1.42); Maternal age is 20-24 years: 0.86[0.81, 0.91], 25-29 years: 0.78[0.70, 0.87]; 30-34 years: 0.73[0.65, 0.83], 35 years+: 0.69[0.60, 0.78]; Primary: 0.85[0.77, 0.94], Secondary+: 0.67[0.62, 0.73], Single parent is (yes) 1.14, Wealth status is poorer: 0.93[0.87, 0.98], Middle: 0.88[0.83, 0.94], Richer: 0.78[0.73, 0.84], Richest: 0.53[0.48, 0.58],
Miller et al (2007)(Miller CM *et al.*, 2007)	underweight	Nil	Child being orphan, child's age, Sex, number of dependent children, Age of caregiver, household head education, (some secondary, primary, some primary). Water source (piped- water) Electricity, Household-head working; wealth index, Top 20%, Middle 40% Bottom 40%	Child is orphan (yes): Child's age 1.59[1.51–1.67]; 2.67[1.85–3.85], 2.54[1.76–3.66]; Child's sex is female 0.91, Household head education level with some secondary education: 2.22 [1.35–3.66], Primary: 2.00[1.24–3.22], Some primary: 2.71[1.63–4.50]; Piped water: 0.51[0.49–0.54]; Had electricity in household (Yes): 0.56[0.53–0.58]; Household head is working (Yes): 0.69[0.66–0.72] Wealth status is middle 40%: 1.55[1.48–1.63], Bottom 40%: 1.66[1.58–1.74]
Nankinga et al (2019)(Nankinga, Kwagala and Walakira, 2019)	nutritional status (stunting, wasting, underweight)	Nil	Residence, region, wealth status, toilet type, source of drinking water, sex of household head, marital status, maternal occupation, mother's employer, decision making power, distance a problem to health services, child's sex, age, birthweight,	Maternal age is 35-49 years: 0.69[0.56–0.86]; Maternal education is primary: 0.78[0.62–0.97], Secondary+: 0.64[0.47–0.88], Agriculture: 2.00[1.26–3.19], Manual work: 2.00[1.27–3.14] Child's birthweight is >2.5kg: 0.59[0.45–0.78]; Not weighed at birth 0.64[0.48-0.86], Child is dewormed (Yes): 1.18 [1.00–1.39]
Nshimyiryo et al (2019)(Nshimyiryo *et al.*, 2019)	Stunting	38%	Child's sex, age group, parity, birthweight, had diarrhoea in last two weeks; Mother's height, educational level, took parasite controlling drugs during pregnancy, number of days of daily intake of iron tablets, breastfeeding within the first hour after birth and household's wealth index, size, access to improved water, improved toilet facility, and household place of residence, region altitude	Child's sex is male: 1.51 (1.25–1.82); Child's age is 6-23 months: 4.91 (3.16–7.62), 24-59 months: 6.34 (4.07–9.89); Child's birth weight is >2500g: 2.12 (1.39–3.23) Mother's height is >145cm: 3.27 (1.89–5.64); Mother's highest education is Primary: 1.71 (1.25–2.34), No education: 2.00 (1.37–2.92); Mother took parasite drug during pregnancy (No): 1.29 (1.09–1.53); Middle: 1.45 (1.12–1.86), Low(poor): 1.82 (1.45–2.29)
Ssentongo et al (2019)(Ssentongo *et al.*, 2019)	stunting, wasting and underweight	27%, 4% and 7%	Child age, sex, birth order, Vitamin A supplementation, deworming, had diarrhoea, anaemia level, wealth status, mother educated, father educated, mother working, father working, Iodised salt owns the land for agriculture, owns livestock, place of residence, region	Took vitamin A (Yes): 1.55 95% CI: 1.2– 1.9
Takele et at (2019)(Takele, Zewotir and Ndanguza, 2019)	stunting	Nil	Child's sex, age, birth interval, Mother's BMI, household wealth index, source of drinking water, type of toilet facility, breastfed, mother's education level and region	Child is female: 0.84 (−0.271, − 0.079); Child's age is 12-23 months: 5.556 (1.413, 2.001), 24-59 months: 7.479 (1.746, 2.228); Maternal BMI is <18.5: 0.812 (−1.064, − 0.200); Wealth status is middle: 0.791 (−0.399, − 0.084) Rich: 0.648 (−0.571, − 0.256); Use of internet is Yes: 0.433 (−1.289, − 0.332); Type of toilet is Latrine: 1.405 (0.006, 0.638), No facility: 1.523

				(0.064, 0.726); Breastfed (No): 1.225 (0.093, 0.312); Primary: 0.869 (−0.251, − 0.006) Secondary+: 0.638 (− 0.636, − 0.186)
Tusting et al (2020) (Tusting *et al.*, 2020)	stunting, wasting and underweight	30%, 8% and 22%	improved drinking water, improved sanitation, house built with finished materials Improved house, the household head had secondary education+; children mean age, child sex	Improved materials: 0.88(0.83, 0.92), Improved housing: 0.83(0.77,0.88)
Ukwuani & Suchindran (2003)(Ukwuani and Suchindran, 2003)	Stunting and wasting	42.6% and 8.9%	Women's economic activity, maternal education, paternal education, occupation, wealth index, type of marriage, religion, duration of breastfeeding, sex of the child, birth order, prenatal care, place of delivery, birth size, food supplement, immunisation, had to fever, had to cough, had diarrhoea, source of drinking water, types of toilets, place of residence, region	Maternal education is primary: 1.33, Secondary+: 1.37; Wealth status is medium: 0.79, High: 0.64; Christian: 0.70; Duration of breastfeeding (Median): 1.04 Maternal age at birth: 0.98; Child's sex is (male): 1.14; Birth order is 4-6: 1.36, 7+: 1.53; Birth size is Very large: 0.78; Child had immunization (Yes): 0.79; Child had diarrheal (yes): 1.48; South south: 0.80; Child's age: 1.01; Child had fever (Yes): 1.23; Types of toilet is flush: 1.4
Yaya et al (2019)(Yaya *et al.*, 2019)	stunting, wasting, underweight and overweight	Nil	Inter-pregnancy interval (<24 months, 24-36 months, 37-59 months and ≥ 60 months)	Inter-pregnancy interval is <24 months:1.26 (1.21–1.31), 37-59 months: 0.88 (0.85–0.91), >60 months: 0.74 (0.71–0.77)

3.5.3 Conclusion

In this scoping review, several significant risk factors predicted that a child under five years of age in an SSA country would develop malnutrition were identified. The evaluation also found that stunting as an index was preferred above other anthropometric measures of malnutrition due to study bias. When overweight and/or micronutrient deficiencies were disregarded as indicators of malnutrition, the analysis also uncovered several shortcomings in the recent research examined. According to the authors, the omission may have something to do with the difficulties associated with the methodology used to determine the true level of malnutrition when these indicators are considered. Several of the nationally representative surveys utilised in the research reviewed were gathered about the overweight and/or micronutrient status of children under five years old. Iron, iodine, and vitamin A consumption levels are used to determine the degree of micronutrient deficiencies in children under five in developing nations. Iodine and vitamin A were assessed subjectively by looking at the kind of foods the child consumed the day before the survey, in contrast to iron, which was quantified through a biomarker evaluation of blood samples to ascertain the anaemia status [47]. This method cannot objectively evaluate a child's micronutrient status. As a result, it can be challenging for researchers to consider them when figuring out the nutritional status of kids under five in impoverished nations. Finally, with only five years left until the deadline for achieving the WHO's nine targets for reducing childhood malnutrition, a conclusion was drawn from this scoping review that a comprehensive research strategy is required to adequately address all the anthropometric indicators of malnutrition in a population. Many planners and policymakers will access crucial documents from such results to help them make educated decisions.

3.6 Comparing the predictors for the four outcomes (anaemia, malaria, malnutrition, and multimorbidity)

This section compares the significance and direction of predictors for all four outcome variables considered in this study. Though the table was a bit complex to generate due to the papers considered not using the same classifications for the variables. However, the situation was managed so that standard classification and reference categories were chosen. A situation where other studies had chosen the reverse as the reference; it reported the directions in the opposite. In

so doing, the results in the following Tables are to a higher degree of accuracy has placed the studies in their correct perspectives.

3.6.1 Child-related variables

Table 3.14 presents the comparisons among child-related characteristics. The sex of the child was not a significant predictor of children contracting malaria fever among children below five years of age in Sub-Saharan Africa. All the papers on malnutrition reported that the sex effect was more protective for females than males. Also, the child's age was a significant factor across the four outcome variables. Most studies reported that the child's age was a harmful effect as the child's age increased. In the malaria studies, only one study (Siri, 2014) reported that age was protective. Similarly, five out of the seven studies that found the child's age as a significant predictor reported a protective effect for age (Atsu, Guure and Laar, 2017; Tran *et al.*, 2019; Adedokun, 2020; Duah *et al.*, 2020; Mulatya and Mutuku, 2020). Furthermore, children having fever two weeks before the survey was a common predictor for all the outcome variables, and all reported a 'harmful effect' except one study in the anaemia group who reported a protective effect for fever (Nikoi and Anthamatten, 2013). Two studies found contradicting results of the significant effect of anaemia status on children contracting malaria fever (Chitunhu and Musenge, 2015; Ugwu and Zewotir, 2018).

Table 3 14 The directions (Harmful or Protective) effects common to all outcome variables among child-related variables

S/N	Variables	Significance Levels	Anaemia	Malaria	Malnutrition	Multimorbidity
1	Sex of the child (Male as reference)	**Harmful effects** Increased Significant Factors (ISF)	(Nikoi and Anthamatten, 2013; Immurana and Urmi, 2017)			(Tran *et al.*, 2019)
		Protective effects Decreased Significant Factors (DSF)	(Douglas Andabati Candia, 2017; Moschovis *et al.*, 2018; Mohammed, Larijani and Esmaillzadeh, 2019; Ntenda *et al.*, 2019; Ojoniyi *et al.*, 2019; Duah *et al.*, 2020)		(Adekanmbi *et al.*, 2013; Akombi, Agho, Hall, Merom, *et al.*, 2017; Akombi *et al.*, 2019; Amaral *et al.*, 2017; Amare *et al.*, 2019; Gebru *et al.*, 2019; Hv & S, 2017; Kuche *et al.*, 2020; Machisa *et al.*, 2013; Magadi, 2011; Miller CM *et al.*, 2007; Nankinga *et al.*, 2019; Nshimyiryo *et al.*, 2019; Takele *et al.*, 2019; Ukwuani & Suchindran, 2003)	(Geda *et al.*, 2021) (Duah *et al.*, 2020)
2	Age of the child (Younger age as reference)	(ISF)	(Ngnie-Teta, Receveur and Kuate-Defo, 2007; Austin, Fawzi and Hill, 2012; Semedo *et al.*, 2014; Muchie, 2016; Moschovis *et al.*, 2018; Ntenda, Nkoka, *et al.*, 2018; Mohammed, Larijani and Esmaillzadeh, 2019; Asresie, Fekadu and Dagnew, 2020)	(Berendsen *et al.*, 2019), (Chitunhu and Musenge, 2015), (Morakinyo, Balogun and Fagbamigbe, 2018), (Semakula *et al.*, 2015), (Semakula *et al.*, 2015), (Siri, 2014), (Ugwu and Zewotir, 2018), (Wanzira *et al.*, 2017), (Zgambo, Mbakaya and Kalembo, 2017)	(Adekanmbi *et al.*, 2013; Agadjanian & Prata, 2003; Akombi *et al.*, 2019; Amare *et al.*, 2019; Gebru *et al.*, 2019; Hv & S, 2017; Machisa *et al.*, 2013; Magadi, 2011; Miller CM *et al.*, 2007; Nshimyiryo *et al.*, 2019; Takele *et al.*, 2019; Ukwuani & Suchindran, 2003)	(Geda *et al.*, 2021) (Tran *et al.*, 2019)
		(DSF)	(Douglas Andabati Candia, 2017; Duah *et al.*, 2020; Hershey *et al.*, 2017; Immurana & Urmi, 2017; Kawo *et al.*, 2018; Menon *et al.*, 2015; Mohammed *et al.*, 2019; Moschovis *et al.*, 2018; Nambiema *et al.*, 2019; Nikoi & Anthamatten, 2013; Ntenda, Chuang, *et al.*, 2018; Ntenda *et al.*, 2019; Ojoniyi *et al.*, 2019)	(Siri, 2014)	(Akombi, Agho, Merom, Hall, *et al.*, 2017; Nankinga, Kwagala and Walakira, 2019; Acharya *et al.*, 2020; Justice Moses K. Aheto, 2020; Kuche *et al.*, 2020)	(Adedokun, 2020), (Atsu, Guure and Laar, 2017), (Tran *et al.*, 2019), (Duah *et al.*, 2020) (Mulatya and Mutuku, 2020)
3	Has health insurance (No as reference)	ISF	(Nikoi & Anthamatten, 2013; Ojoniyi *et al.*, 2019)			
		DSF	(Duah *et al.*, 2020; Immurana & Urmi, 2017)			
4	Birth size	ISF			(Ukwuani and Suchindran, 2003; Nshimyiryo *et al.*, 2019)	

	(Small as reference)	DSF	(Kawo *et al.*, 2018; Machisa *et al.*, 2013; Mohammed *et al.*, 2019)		(Magadi, 2011; Akombi, Agho, Hall, Merom, *et al.*, 2017; Gebru *et al.*, 2019; Nankinga, Kwagala and Walakira, 2019; Justice Moses K. Aheto, 2020)	(Adedokun, 2020)
5	Vaccination status	ISF:				
		DSF:		(Berendsen *et al*., 2019)	(Agadjanian and Prata, 2003; Ukwuani and Suchindran, 2003) 3, 25	(Atsu, Guure and Laar, 2017)
6	Product of multiple birth (No vs Yes)	ISF	(Ojoniyi *et al.*, 2019)		(Magadi, 2011; Adekanmbi, Kayode and Uthman, 2013)	
		DSF				
7	Preceding birth interval (None as reference)	ISF:		(Berendsen *et al*., 2019)	(Adekanmbi, Kayode and Uthman, 2013)	
		DSF:			(Magadi, 2011; Machisa, Wichmann and Nyasulu, 2013; Yaya *et al.*, 2019)	
8	Birth order (Lower order as reference)	ISF:	(Immurana & Urmi, 2017; Moschovis *et al.*, 2018; Ngnie-Teta *et al.*, 2007)	(Berendsen *et al*., 2019) (Chitunhu and Musenge, 2015), (Njau *et al.*, 2014)	(Ukwuani and Suchindran, 2003)	
		DSF:			(Magadi, 2011)	
9	Breastfeeding status	ISF:			Duration: (Ukwuani and Suchindran, 2003; Magadi, 2011; Adekanmbi, Kayode and Uthman, 2013; Akombi, Agho, Hall, Merom, *et al.*, 2017)	
		DSF:		(Berendsen *et al*., 2019)		(Atsu, Guure and Laar, 2017)
10	Had diarrhoeal 2 weeks before survey	ISF	(Machisa *et al.*, 2013; Ngnie-Teta *et al.*, 2007; Semedo *et al.*, 2014)		(Ukwuani and Suchindran, 2003; Akombi, Agho, Hall, Merom, *et al.*, 2017; Hv and S, 2017)	(Atsu, Guure and Laar, 2017)
		DSF	(Moschovis *et al*., 2018)		(Akombi, Agho, Merom, Hall, *et al.*, 2017; Justice Moses K. Aheto, 2020)	
11	Fever in the last 2 weeks	ISF:	(Asresie *et al.*, 2020; Jones *et al.*, 2018; Moschovis *et al.*, 2018; Ntenda, Chuang, *et al.*, 2018; Ntenda *et al.*, 2019)	(Ugwu and Zewotir, 2018)	(Ukwuani and Suchindran, 2003; Akombi, Agho, Merom, Hall, *et al.*, 2017; Hv and S, 2017)	(Duah *et al.*, 2020)
		DSF:	(Nikoi & Anthamatten, 2013)			
12	Child had acute respiratory diseases	ISF				
		DSF				
13	Child took vitamin A syrup	ISF			(Ssentongo *et al.*, 2019)	
		DSF	(Mohammed *et al.*, 2019; Ntenda *et al.*, 2019)			
14	Minimum dietary Diversity	ISF			(Kuche *et al.*, 2020)	
		DSF	(Austin *et al.*, 2012)			
15	Minimum meal frequency	ISF				
		DSF	(Mohammed *et al.*, 2019)			

16	Deworming in last 6 months before survey	ISF	(Ntenda *et al.*, 2019)		(Nankinga, Kwagala and Walakira, 2019)	
		DSF	(Moschovis *et al.*, 2018)			
17	Anaemia status	ISF:		(Ugwu and Zewotir, 2018)		
		DSF:		(Chitunhu and Musenge, 2015)		
18	Malaria status	ISF	(Hershey *et al.*, 2017; Menon *et al.*, 2015; Nambiema *et al.*, 2019; Ntenda *et al.*, 2019)			
		DSF				
19	Stunting (No versus Yes)	ISF	(Moschovis *et al.*, 2018; Muchie, 2016; Ngnie-Teta *et al.*, 2007; Ntenda, Chuang, *et al.*, 2018)			
		DSF				
20	Wasting (No versus Yes)	ISF	(Muchie, 2016)			
		DSF				
21	Underweight	ISF	(Asresie *et al.*, 2020)			
		DSF	(Ntenda, Chuang, *et al.*, 2018)			
22	Overweight	ISF	(Ojoniyi *et al.*, 2019)			
		DSF				
23	Place of delivery	ISF:			(Akombi, Agho, Hall, Merom, *et al.*, 2017; Akombi, Agho, Merom, Hall, *et al.*, 2017)	
		DSF:		(Berendsen *et al.*, 2019)	(Aheto, 2020)	
24	Child slept under a mosquito bed net	ISF:		(Morakinyo, Balogun and Fagbamigbe, 2018), (Semakula *et al.*, 2015)		
		DSF:		(Chitunhu and Musenge, 2015) (Semakula *et al.*, 2015)		

3.6.2 Parental-related variables

Among the parental-related characteristics in Table 3.15, maternal age and education level statuses were reported as significant predictors for all four outcomes. Some studies from all four outcomes reported decreased significant effects for children of older mothers with Berendsen et al (Berendsen *et al.*, 2019) in malaria and Mulatya et al (Mulatya and Mutuku, 2020) in multimorbidity. Additionally, some studies in anaemia (Asresie *et al.*, 2020; Douglas Andabati Candia, 2017; Duah *et al.*, 2020; Moschovis *et al.*, 2018; Ngnie-Teta *et al.*, 2007; Semedo *et al.*, 2014), and malnutrition (Adekanmbi *et al.*, 2013; Aheto, 2020) reported increased significant effects. Paternal education level had protective effects for anaemia, malnutrition and multimorbidity but was not part of the variables selected as a predictor in malaria fever studies.

Table 3 15 The directions (Harmful or Protective) effects common to all outcome variables among parental-related variables

			Anaemia	Malaria	Malnutrition	Multimorbidity
S/N	**Variables**	**Significance Levels**				
1	Maternal age	Increased Significant Factors (ISF)	(Asresie *et al.*, 2020; Douglas Andabati Candia, 2017; Duah *et al.*, 2020; Moschovis *et al.*, 2018; Ngnie-Teta *et al.*, 2007; Semedo *et al.*, 2014)		(Adekanmbi, Kayode and Uthman, 2013; Justice Moses K. Aheto, 2020)	
		Decreased Significant Factors (DSF)	(Immurana & Urmi, 2017; Ntenda, Chuang, *et al.*, 2018)	(Berendsen *et al.*, 2019)	(Magadi, 2011; Akombi *et al.*, 2019; Nankinga, Kwagala and Walakira, 2019)	(Mulatya and Mutuku, 2020)
2	Maternal education status	(ISF)	(Moschovis *et al.*, 2018; Muchie, 2016; Semedo *et al.*, 2014)	(Ugwu and Zewotir, 2018)	(Ukwuani and Suchindran, 2003; Gebru *et al.*, 2019; Nshimyiryo *et al.*, 2019; Kuche *et al.*, 2020)	(Mulatya and Mutuku, 2020)
		(DSF)	(Asresie *et al.*, 2020; Austin *et al.*, 2012; Douglas Andabati Candia, 2017; Duah *et al.*, 2020; Immurana & Urmi, 2017; Jones *et al.*, 2018; Kawo *et al.*, 2018; Mohammed *et al.*, 2019; Moschovis *et al.*, 2018; Ngnie-Teta *et al.*, 2007; Semedo *et al.*, 2014)	(Berendsen *et al.*, 2019), (Siri, 2014), (Wanzira *et al.*, 2017)	(Agadjanian and Prata, 2003; Magadi, 2011; Adekanmbi, Kayode and Uthman, 2013; Akombi, Agho, Merom, Hall, *et al.*, 2017; Hv and S, 2017; Akombi *et al.*, 2019; Amare, Ahmed and Mehari, 2019; Gebru *et al.*, 2019; Nankinga, Kwagala and Walakira, 2019; Takele, Zewotir and Ndanguza, 2019; Acharya *et al.*, 2020)	(Geda *et al.*, 2021) (Tran *et al.*, 2019)
3	Paternal education status	(ISF)				
		(DSF)	(Immurana & Urmi, 2017)		(Akombi, Agho, Merom, Hall, *et al.*, 2017; Akombi *et al.*, 2019)	(Duah *et al.*, 2020) (Geda *et al.*, 2021)
4	Maternal work status	(ISF)	(Immurana & Urmi, 2017; Muchie, 2016; Ojoniyi *et al.*, 2019)		(Akombi, Agho, Merom, Hall, *et al.*, 2017)	
		(DSF)	(Kawo *et al.*, 2018; Nambiema *et al.*, 2019)		(Miller CM *et al.*, 2007)	
5	Father's alive	(ISF)				
		(DSF)				
6	Maternal body mass index	ISF	(Moschovis *et al.*, 2018; Nikoi & Anthamatten, 2013)			
		DSF		(Berendsen *et al.*, 2019)		
7	Maternal anaemia status	ISF	(Asresie *et al.*, 2020; Machisa *et al.*, 2013; Moschovis *et al.*, 2018; Muchie, 2016; Nambiema *et al.*, 2019; Nikoi & Anthamatten, 2013; Ntenda, Nkoka, *et al.*, 2018)			
		DSF	(Mohammed *et al.*, 2019; Ntenda, Chuang, *et al.*, 2018)			
8	Maternal religious status	ISF				
		DSF	(Immurana & Urmi, 2017; Muchie, 2016)			
9		ISF				

	Maternal ante-natal care	DSF		(Njau *et al.*, 2014)		
10	Number of births in 5 years	ISF:		(Berendsen *et al.*, 2019)		
		DSF:				
11	Maternal knowledge of malaria fever	ISF		(Njau *et al.*, 2014)		
		DSF		(Yang *et al.*, 2020)		
12	Number of children ever born	ISF:		(Njau *et al.*, 2014)		
		DSF:				
13	Mother has access to phone/media	ISF:				
		DSF:		(Njau *et al.*, 2014)		(Adedokun, 2020)

3.6.3 Household-related variables

In the household-related variables, Table 3.16 shows that only household wealth status was a common predictor of all four outcomes. More studies reported decreased significant effects than increased significant effects. One study (Nikoi & Anthamatten, 2013) from among the anaemia studies reported the harmful effect of increased household wealth quintile, followed by two studies from malnutrition and multimorbidity studies. In multimorbidity, Mulatya et al and Tran et al (Tran *et al.*, 2019; Mulatya and Mutuku, 2020) found protective effects of household wealth status. Additionally, three outcomes (anaemia, malaria, and multimorbidity) found the 'number of under-five years children in a household as a significant predictor. It is also worthy of note that malaria fever studies considered and found more significant predictor variables than the three other outcomes.

Table 3 16 The directions (Harmful or Protective) effects common to all outcome variables among household-related variables:

			Anaemia	Malaria	Malnutrition	Multimorbidity
1	Household wealth status	ISF:	(Nikoi & Anthamatten, 2013)	(Berendsen *et al.*, 2019) (Morakinyo, Balogun and Fagbamigbe, 2018), (Ugwu and Zewotir, 2018), (Zgambo, Mbakaya and Kalembo, 2017)	(Akombi, Agho, Hall, Merom, *et al.*, 2017; Akombi *et al.*, 2019)	(Adedokun, 2020) (Atsu, Guure and Laar, 2017)
		DSF:	(Austin *et al.*, 2012; Douglas Andabati Candia, 2017; Duah *et al.*, 2020; Hershey *et al.*, 2017; Immurana & Urmi, 2017; Kawo *et al.*, 2018; Mohammed *et al.*, 2019; Moschovis *et al.*, 2018; Muchie, 2016; Nambiema *et al.*, 2019; Ngnie-Teta *et al.*, 2007; Ntenda, Chuang, *et al.*, 2018; Ntenda, Nkoka, *et al.*, 2018; Ojoniyi *et al.*, 2019; Semedo *et al.*, 2014)	(Chitunhu and Musenge, 2015), (Njau *et al.*, 2013), (Njau *et al.*, 2013),) (Njau *et al.*, 2013), (Njau *et al.*, 2014), (Siri, 2014), Wanzira *et al.*, 2017)	(Ukwuani and Suchindran, 2003; Miller CM *et al.*, 2007; Adekanmbi, Kayode and Uthman, 2013; Machisa, Wichmann and Nyasulu, 2013; Hv and S, 2017; Amare, Ahmed and Mehari, 2019; Gebru *et al.*, 2019; Nshimyiryo *et al.*, 2019; Takele, Zewotir and Ndanguza, 2019; Acharya *et al.*, 2020; Justice Moses K. Aheto, 2020; Kuche *et al.*, 2020)	(Mulatya and Mutuku, 2020) (Tran *et al.*, 2019)
2	Household had bed net	ISF:				
		DSF:		(Njau *et al.*, 2013), (Njau *et al.*, 2013), (Njau *et al.*, 2013), (Njau *et al.*, 2014)		
3	Age of household head	ISF		(Njau *et al.*, 2013), (Njau *et al.*, 2013), (Ugwu and Zewotir, 2018)		
		DSF		(Njau *et al.*, 2013)		
4	Insecticide residual spray	ISF				
		DSF		(Morakinyo, Balogun and Fagbamigbe, 2018), (Wanzira *et al.*, 2017)		
5	Household size	ISF	(Machisa *et al.*, 2013; Moschovis *et al.*, 2018; Ngnie-Teta *et al.*, 2007)	(Berendsen *et al.*, 2019), (Njau *et al.*, 2013), (Njau *et al.*, 2013), (Njau *et al.*, 2013), (Njau *et al.*, 2014), (Siri, 2014), (Ugwu and Zewotir, 2018)		
		DSF	(Moschovis *et al.*, 2018)			(Duah *et al.*, 2020)
6	Number of under-5 in household	ISF	(Kawo *et al.*, 2018; Ojoniyi *et al.*, 2019)	(Njau *et al.*, 2013)		(Duah *et al.*, 2020)
		DSF	(Muchie, 2016)	(Njau *et al.*, 2013), (Njau *et al.*, 2013)		
7	Source of water outside	ISF	(Moschovis *et al.*, 2018)			
		DSF		(Chitunhu and Musenge, 2015)		
8	Improved water source	ISF:		(Semakula *et al.*, 2015), (Semakula *et al.*, 2015) (Semakula *et al.*, 2015) (Yang *et al.*, 2020)		

		DSF:	(Kawo *et al.*, 2018; Muchie, 2016)	(Semakula *et al.*, 2015), (Semakula *et al.*, 2015), (Semakula *et al.*, 2015) (Semakula *et al.*, 2015) (Yang *et al.*, 2020)	(Miller CM *et al.*, 2007)	
9	Improved toilet facility	ISF		(Semakula *et al.*, 2015), (Semakula *et al.*, 2015), (Semakula *et al.*, 2015), (Ugwu and Zewotir, 2018), (Yang *et al.*, 2020)	(Ukwuani and Suchindran, 2003; Amare, Ahmed and Mehari, 2019; Takele, Zewotir and Ndanguza, 2019)	
		DSF	(Jones *et al.*, 2018)	(Berendsen *et al.*, 2019), (Semakula *et al.*, 2015), (Semakula *et al.*, 2015), (Semakula *et al.*, 2015), (Yang *et al.*, 2020)		
10	Sex of household head	ISF	(Jones *et al.*, 2018)			
		DSF		(Njau *et al.*, 2013)		
11	Use biomass for cooking	ISF		(Semakula *et al.*, 2015), (Semakula *et al.*, 2015)		
		DSF		(Semakula *et al.*, 2015)		
12	Under 5 years child slept under bed net	ISF	(Ngnie-Teta *et al.*, 2007)	(Wanzira *et al.*, 2017)		
		DSF		(Tusting *et al.*, 2020)		
13	Household ownership of livestock	ISF	(Jones *et al.*, 2018)	(Semakula *et al.*, 2015), (Semakula *et al.*, 2015)		
		DSF		(Semakula *et al.*, 2015), (Semakula *et al.*, 2015), (Semakula *et al.*, 2015)		
14	Improve building materials	ISF:		(Morakinyo, Balogun and Fagbamigbe, 2018), (Tusting *et al.*, 2020)		
		DSF:			(Tusting *et al.*, 2020)	
15	Household head education status	ISF:		(Njau *et al.*, 2013), (Njau *et al.*, 2014)	(Miller CM *et al.*, 2007)	
		DSF:			(Amaral, Herrin and Gulere, 2017)	
16	Household connected electricity	ISF:		(Ugwu and Zewotir, 2018)		
		DSF:				
17	Roofing material	ISF				
		DSF		(Ugwu and Zewotir, 2018)		

3.6.4 Community-related variables

Apart from place and region of residence, most community or contextual-related variables were not observable variables in the studies. However, the only place of residence (urban and rural) was unique for all studies that considered the variables. Nevertheless, the regions of residence varied depending on the country of study. Table 3.17 shows that place of residence was protective for children who live in a rural area for some studies across the four outcome variables. At the same time, it was reported harmful in some studies only in anaemia, malaria, and malnutrition. Community wealth, distance to the health facility, cluster altitude, community insecticide net use, and community free bed net were found to significantly affect malaria fever significantly.

Table 3 17 The directions (Harmful or Protective) effects common to all outcome variables among community-related variables

			Anaemia	**Malaria**	**Malnutrition**	**Multimorbidity**
1	Community wealth status	ISF		(Siri, 2014)		
		DSF				
2	Community distance to health facilities	ISF		(Njau *et al.*, 2013), (Njau *et al.*, 2013)		
		DSF				
3	Cluster altitude	ISF		(Ugwu and Zewotir, 2018)		
		DSF				
4	Community insecticide net use	ISF		(Levitz *et al.*, 2018)		
		DSF				
5	Regional variations	ISF:				(Adedokun, 2020)
		DSF:				
6	Malaria endemicity	ISF		(Njau *et al.*, 2013), (Njau *et al.*, 2013), (Njau *et al.*, 2013), (Njau *et al.*, 2014)		
		DSF				
7	Free bed net in community	ISF		(Njau *et al.*, 2013)		
		DSF		(Njau *et al.*, 2013), (Njau *et al.*, 2013)		
8	Multi Dimension Poverty Index	ISF	(Jones *et al.*, 2018; Machisa *et al.*, 2013)			
		DSF				
9	Place of residence	ISF	(Menon *et al.*, 2015; Moschovis *et al.*, 2018)	(Berendsen *et al.*, 2019), (Chitunhu and Musenge, 2015), (Morakinyo, Balogun and Fagbamigbe, 2018), (Njau *et al.*, 2013), (Njau *et al.*, 2014), (Ugwu and Zewotir, 2018)	(Magadi, 2011; Akombi *et al.*, 2019; Gebru *et al.*, 2019)	
		DSF	(Duah *et al.*, 2020; Nambiema *et al.*, 2019; Ngnie-Teta *et al.*, 2007)	(Semakula *et al.*, 2015), (Semakula *et al.*, 2015), (Siri, 2014)	(Akombi, Agho, Merom, Hall, *et al.*, 2017; Amaral, Herrin and Gulere, 2017)	(Tran *et al.*, 2019)

3.7 Strengths and Weaknesses

The strengths of this review are that to the best of the researcher's knowledge this is the first scoping review on risk factors associated with anaemia, malaria, malnutrition, and multimorbidity of childhood diseases among children aged under-five years in SSA countries that have used statistical regression modelling techniques on nationally representative survey samples. However, there are some limitations but not restricted to the following: (i) some potential studies may have been excluded due to the search strategies adopted. (ii) since SSA countries include non-English speaking, some potential papers that were not written in English may have been lost to search (iii) the studies included had analytical techniques restricted to classical statistics regression methods. Therefore, potential papers that used Bayesian statistical techniques in their analyses were excluded, (iv) there was no assessment of the potential risk of publication bias conducted

3.8 The chapter summary

According to evidence from this recent scoping literature review, variations in the individual and contextual factors continue to influence anaemia, malaria, malnutrition and multimorbidity of childhood diseases in SSA. It is still not well understood if these predictors overlap in the determinants of multimorbidity among children. However, tentative results generated from the scoping data presented in this synthesis strongly support the interdependencies of anaemia, malaria, and malnutrition status in a child's health. It is advised that more research be done to confirm these preliminary findings and bridge existing knowledge gaps. This is what this thesis is out to contribute. Furthermore, the next chapter will describe the two data sets used in this thesis. Also, it describes the methodology and statistical analysis plans that will be adopted to achieve our objectives in the thesis

Chapter 4 Methods and Materials

4.0 Introduction

This study did not collect data on its own but utilised two nationally representative cross-sectional data sets from the 2018 Nigeria Demographic and Health Survey (NDHS 2018), and the 2018 National Human Development Report (NHDR 2018)(United Nations Development Programme (UNDP), 2018).

This chapter aims to give a general summary of the research methodology used in this quantitative study. First, the chapter recalls the aims and objectives of the study. Then, it describes the study setting, the two data sets, the outcome variables, the predictor variables, and the statistical methods used in this study.

4.1 The aims and study setting

4.1.1 The research aims and objectives

As stated in Chapter 1, this study aims to investigate the multiple overlaps in the impact of individual and contextual variables on the prevalence of the multimorbidity of anaemia, malaria, and malnutrition among children aged 6 to 59 months in Nigeria.

The specific objectives of the thesis include:

i. To undertake a comprehensive scoping review of literature on individual and contextual risk factors associated with the prevalence of anaemia, malaria fever, malnutrition, and multimorbidity among children under under-five years in Sub-Sahara Africa (SSA).

ii. To determine the prevalence of anaemia, malaria, malnutrition, and their interactions among children aged 6 to 59 months in Nigeria using data from the 2018 Nigeria Demographic and Health Survey (NDHS)

iii. To investigate the prevalence and association of individual and contextual risk factors of anaemia among children 6-59 months in Nigeria using data from the 2018 NDHS (with some incorporated contextual data from the National Human Development Report (2018 NHDR)).

iv. To investigate the prevalence and association of individual and contextual risk factors of malaria among children 6-59 months in Nigeria using data from the 2018 NDHS (with the incorporated contextual data from the National Human Development Report (2018 NHDR)).

v. To investigate the prevalence and association of individual and contextual risk factors of malnutrition among children under-five years in Nigeria using data from the 2018 NDHS (with the incorporated contextual data from the National Human Development Report (2018 NHDR)).

vi. To describe the spatial distributions of the prevalence of multimorbidity of malaria, anaemia, and malnutrition among children 6-59 months across Nigeria's state and geopolitical regions using data from the 2018 NDHS (with the incorporated contextual data from the National Human Development Report (2018 NHDR)).

vii. To investigate the individual and contextual risk factors of multimorbidity of malaria, anaemia, and malnutrition among children 6-59 months in Nigeria using data from the 2018 NDHS (with the incorporated contextual data from the National Human Development Report (2018 NHDR)).

viii. To determine the interaction effects of a child's age, sex, and household socioeconomic status on the individual and contextual risk factors of MAMM among children aged 6-59 months in Nigeria

4.1.1 Study Setting

Nigeria is a country located in West Africa, sharing boundaries with Cameroon, Niger, Benin Republic and the Atlantic Ocean with a total area of 923,768 Square Kilometres (National Population Commission (NPC), National Malaria Control Program (NMCP) and ICF Macro, 2012; National Malaria Elimination Program (NMEP), National Population Commission (NPopC), National Bureau and ICF International, 2016). The Nigerian population grew from over 140 million people in 2006 population census (Kayode, Adekanmbi and Uthman, 2012; Macrotrends, 2020), to more than 180 million people in 2016. The population is expected to rise to over 260 million by 2030 with an estimated annual national growth rate of 2.38%, making her the most populous black nation in the world (Macrotrends, 2020). Nigeria's population density was estimated at about 215 people per square kilometre in 2018 from approximately 194 people per square kilometre in 2015 (Tradingeconomics, 2020). The country has a variety of rich ethnic groups of over 250 (Kayode, Adekanmbi and Uthman, 2012), speaking different dialects and customs. The three major ethnic groups with a population of 68% are the Fulani/Hausa, Yoruba and Igbo, while the Bini, Ijaw, Kanuri, Ibibio, Ebira, Nupe Tiv and other minority ethnic groups accounted for 32% (Mustapha, 2005; Kayode, Adekanmbi and Uthman, 2012).

4.2 Describing the data sets

This study uses two independent data sets, with one data set incorporated into another. The original data set was the 2018 Nigeria Demographic and Health Survey (otherwise known as 2018 NDHS), and the second data set was the 2018 National Human Development Report (known as NHDR 2018). The two datasets are described in this section. However, for statistical analyses, three components of NHDR 2018: the Human Development Index (HDI), the Multi-dimensional Poverty Index (MPI), and the Gender Inequality Index (GII), were incorporated into the 2018 NDHS as contextual variables at the state level. The merging approach could not directly compare individual, household, and community data because the NHDR survey did not visit the same residences as the NDHS. However, the state definitions and identification numbers used in both surveys were the same. As a result, it was easy to combine NHDR's variables (MPI, HDI, and GII) at the state level and then merge to NDHS individuals, households and communities based on state identifiers (Smith and Shively, 2019).

4.2.1 2018 Nigeria Demographic and Health Survey (2018 NDHS)

4.2.1.1 The Etymology of 2018 NDHS

Demographic and Health Survey (DHS) is an organisation which started in 1984 to collect comparable population-based data on fertility, contraception, maternal and child health, and nutrition in developing countries (Fabic, Choi and Bird, 2012). In the 1970s and 1980s, organisations now is DHS operated as World Fertility Survey and Contraceptive Prevalence Surveys (Fabic, Choi and Bird, 2012), respectively. Since its inception in over 90 countries, DHS has overseen over 300 demographic and health surveys (Wikipedia Contributors, 2019). The first DHS for Nigeria (NDHS) was carried out in 1990 (1990 NDHS) and published in 1992. The 1990 NDHS was conducted by the Federal Office of Statistics of Nigeria with technical assistance from Institute for Research Development-IRD/Macro International and was solely funded by United States Agency for International Development (USAID) (Federal Office of Statistics[Nigeria] and IRD/Macro International, 1992). The 2018 NDHS was the sixth in the series but the fifth to be collected by National Population Commission. Unlike the earlier version of the survey (1990-2013-Nigeria Demographic and Health Surveys), conducted by the National Population Commission (NPC), the 2018 Nigeria Demographic and Health Survey (2018 NDHS) was unique because the National Population Commission (NPC) and National Malaria Elimination Programme (NMEP) of the Federal Ministry of Health, Nigeria (National Population Commission (NPC) and ICF International, 2014; National Population Commission (NPC)[Nigeria] and ICF, 2019) jointly conducted it. Also, the 2018 NDHS, was

funded by the United States Agency for International Development (USAID) with the support of other international donors such as Global Fund, the United Nations Population Fund (UNFPA), Bill and Melinda Gates Foundation (BMGF), and World Health Organisation (WHO)(National Population Commission (NPC)[Nigeria] and ICF, 2019). However, the technical assistance for the 2018 NDHS like in every other past surveys was provided by Inner City Fund-ICF International via the MEASURE DHS program, a USAID-funded project (National Population Commission (NPC)[Nigeria] and ICF, 2019)

4.2.1.2 The Purpose of 2018 NDHS

Demographic and Health Surveys (DHS) are conducted to provide a broad nationally-representative household data to monitor and evaluate the impact of some population, health and nutrition indicators such as "fertility, reproductive health, maternal and child health, immunisation and survival, HIV/AIDS, maternal and child mortality, malaria, and women and children nutrition statuses" in the various countries of interest (Wikipedia Contributors, 2019; The DHS Program, 2020). The National Population Commission is the agency in Nigeria with the statutory responsibility of collecting, collating, and analysing demographic data for Nigeria (National Population Commission (NPC) and ICF International, 2014). The 2018 NDHS was designed to generate reliable estimates for key indicators at the national level that will assist policymakers and programme managers and have a basis for an informed decision on issues that will improve the health of the people in the country. It was also to provide relevant indicators for the Sustainable Development Goals (SDGs) for Nigeria (National Population Commission (NPC)[Nigeria] and ICF, 2019)

4.2.1.3 The Population Settings

Nigeria has 37 administrative divisions (36 states and the Federal Capital Territory (FCT). These 37 political and administrative areas are sub-divided into 774 Local Government Areas (LGAs), and each of the LGAs was divided into wards, with each LGA having between 10 and 15 political 'wards (OpenStreetMap Wiki contributors, 2020). Estimates for key indicators in this survey were presented both in national, geopolitical zones, the states, the Federal Capital Territory (FCT), and rural and urban areas (National Population Commission (NPC)[Nigeria] and ICF, 2019). Nevertheless, the last National Population and Housing Census (NPHC) conducted in 2006 formed the bases upon which the previous three NDHSs (2008, 2013 and 2018) built their sampling designs. For possible administrative convenience in the 2006 population census, the 2006 NPHC divided LGA into smaller localities (not political Wards)

to smaller manageable areas known as census enumeration areas (EAs). So, the 2018 NDHS sampling frame was based on these NPHC EAs demarcations. NDHS used the EAs as the Primary Sampling Units (PSU) (National Population Commission (NPC)[Nigeria] and ICF, 2019)

4.2.1.4 How was 2018 NDHS Data collected?

In 2018 NDHS, the 36 states and FCT were separated into urban and rural areas (the visualisation of the sampling procedure is shown in figure 4.1). Any locality with more than 20,000 people was considered an urban area (National Population Commission (NPC)[Nigeria] and ICF, 2019), resulting in the identification of 74 strata (Each state and FCT having urban and rural). In NDHS, samples were selected separately from the strata using a two-stage stratified cluster design.

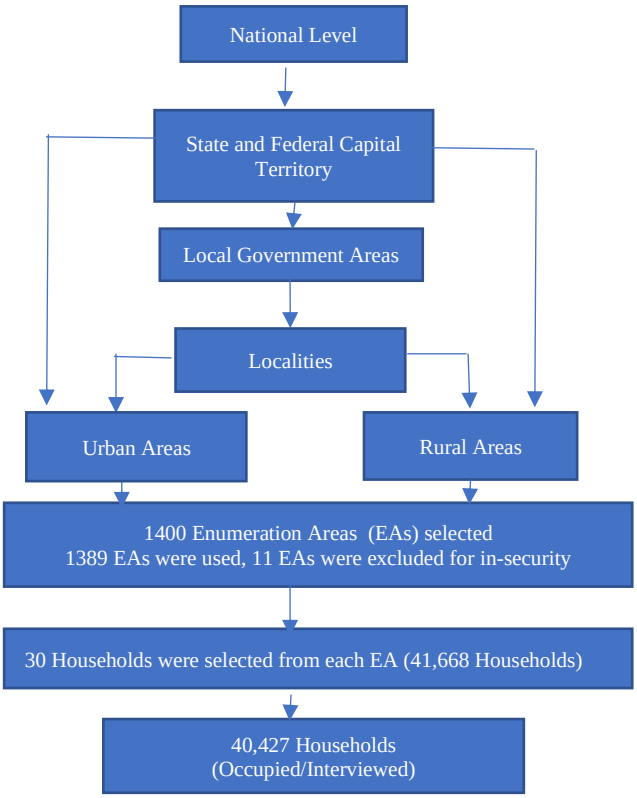


Figure 4 1 Flowchart Describing the Sampling Procedure

At the first stage, representative 1,400 enumeration areas (EAs) were selected as the sampling units with probability proportional to the EA size, doing this survey with the largest sample size compared to other five previous surveys (National Population Commission (NPC)[Nigeria] and ICF, 2019). The second stage involved a complete listing of households in each of the selected 1,400 EAs. A fixed number of 30 households were randomly selected from each EA using equal probability sampling. 11 EAs were excluded from being captured because of

insecurity. As a result, a total of 41,668 households were earmarked for sampling, but only 40,427 households representing a response rate of 99.4% were finally captured in the survey (National Population Commission (NPC)[Nigeria] and ICF, 2019).

The target groups were women aged 15-49 years from all the randomly picked households and men aged 15-59 years in one-third of all randomly selected households across Nigeria (National Population Commission (NPC)[Nigeria] and ICF, 2019). Man's questionnaire was not originally part of the DHS (National Population Commission (NPC)[Nigeria] and ICF, 2019; The DHS Program, 2020). One eligible woman in each of the chosen man's subsamples of the household was randomly picked to answer additional questions concerning domestic violence (National Population Commission (NPC)[Nigeria] and ICF, 2019). The 2018 NDHS marked the first time in Nigeria DHS that a computer-assisted personal interview (CAPI) that allowed faster data transmission was used. Besides, children 6-59 months in 14,000 households (representing one-third of the selected households) had their blood samples taken for malaria (via Rapid Diagnostic Test-RDT), anaemia, and genotype testing. Two-thirds of the children tested for malaria using RDT, were further tested for malaria using the macroscopic test. In all, four questionnaires (The Household Questionnaire, the Woman's Questionnaire, Man's Questionnaire, and the Biomarker Questionnaire) which were extracted from the standard Demographic and Health Survey (DHS-7) questionnaires and reflected health indicators important to Nigeria were used for the 2018 NDHS:

4.2.1.5 When was 2018 NDHS Data collected?

2018 Nigeria Demographic and Health Survey began with a pre-test training that lasted for 3-weeks from 30 April to 20 May 2018. This training was designed to prepare the trainers for the primary training and ensure they can use the questionnaires and procedures in the major Nigerian languages. Forty-five participants were included in the training, which focused on critical parts of the survey, interview techniques, and methods for completing the questionnaire. The training was carried out by ICF staff (National Population Commission (NPC)[Nigeria] and ICF, 2019).

Before the primary training, Biomarker training on biomarker data collection and recording for 37 nurses and 37 laboratory scientists was held from 25 June to 6 July 2018. The initial preparation for 2018 NDHS was carried out for 358 participants from the state level across the country. The training lasted for five weeks, from 16 July 2018 to 13 August 2018 (National Population Commission (NPC)[Nigeria] and ICF, 2019).

The 2018 NDHS data collection fieldwork started on 14 August 2018 and ended on 29 December 2018. Thirty-seven teams of nine data collectors each (made up of one supervisor, field editor, nurse, and lab scientist; two male and three female interviewers) were assigned across the different clusters in the zones. The fieldwork was regularly monitored by the NDHS team, the state coordinators from NPC and NMEP, and ICF staff (National Population Commission (NPC)[Nigeria] and ICF, 2019)

4.2.1.6 What Kind of data was collected?

Generally, information was collected on fertility levels, fertility preferences, awareness and use of family planning methods, marriage, child feeding practices, nutritional status of women and children, adult and childhood mortality, knowledge and attitudes regarding HIV/AIDS, fistula and female genital mutilation (National Population Commission (NPC)[Nigeria] and ICF, 2019). Specifically, the nutritional status of both women and children in the selected households was assessed (National Population Commission (NPC)[Nigeria] and ICF, 2019). Furthermore, malaria slides were assessed at the household and laboratory levels using rapid diagnostic tests and microscopy on thick blood smears for children aged 6-59 months, respectively. In addition, haemoglobin measurement for anaemia was taken from the eligible women and children from the household containing sub-samples for men.

Also, the 2018 NDHS marked Nigeria's first-time sickle cell anaemia testing. The experience acquired from this testing will form the basis upon which other DHS surveys for the disease will be captured globally. Also, in response to various stakeholders' requests, additional data were included in 2018 NDHS. These include: social and behavioural change communication (SBCC) on malaria, minimum dietary diversity among women, female genital mutilation, fistula and disability (National Population Commission (NPC)[Nigeria] and ICF, 2019)

The household questionnaire collected demographic information on the age, sex, marital status, education, and relationship to the head of the household from all members and visitors to the selected household. Other information contained in the household questionnaire includes characteristics of the household's dwelling, such as type of toilet facilities; the source of drinking water; materials used for flooring, roofing and external walls; ownership of mosquito nets and ownership of various durable goods (National Population Commission (NPC)[Nigeria] and ICF, 2019). From this household questionnaire, data relating to age, sex and marital status were used to identify women eligible for the woman's questionnaire (must be aged 15 – 49 years). The questions asked in the woman's questionnaire centred on the following:

Background characteristics (including educational attainment, media exposure and age), History of birth and child survival, family planning methods: Knowledge, use, and source), minimum dietary diversity, marriage and sexual activity, fertility preferences (including the desire for more children and the ideal number of children)(National Population Commission (NPC)[Nigeria] and ICF, 2019). Also collected were information on antenatal, delivery, and postnatal care, vaccinations and childhood illnesses, breastfeeding and infant feeding practices; women's work status and husbands' background characteristics, knowledge, attitude and practice (KAP) regarding HIV/AIDS and other sexually transmitted diseases (STDs), Knowledge, attitudes, and practice concerning other health concerns (e.g., smoking), Fistula, Female genital cutting, Adult and maternal mortality, and Domestic violence (National Population Commission (NPC)[Nigeria] and ICF, 2019) (The DHS Program, 2020)

The man's questionnaire was used to collect data from all eligible men aged 15-59 in one-third of the entire selected household (i.e., from 14,000 households). The man's questionnaire was patterned the same way as the woman's but excluded questions on maternal and child health. On the other hand, the biomarker questionnaire was used to record the outcomes of anthropometry measurements and other biomarkers for women and children. Another questionnaire used for this survey was the fieldworker questionnaire which was used to collect necessary background information on those who collect data from the field(National Population Commission (NPC)[Nigeria] and ICF, 2019)

4.2.2 2018 National Human Development Report (NHDR 2018)

United Nations Development Program-Human Development Report (UNDP-HDRs) started in 1990 to provide total indicators on human development beyond the usual income and wellbeing (United Nations Development Programme (UNDP), 2018). The 2018-NHDR for Nigeria focuses on the human devastation in the North-East of Nigeria with the view of coming up with multidimensional UN-Humanitarian Development and Peace Nexus using the sub-national region as a case study.

The data source for the report was from combination of some national representative surveys: (i) National Bureau of Statistics (NBS), (ii) Multiple Indicator and Cluster Survey (MICS), and (iii) National Bureau of Statistics/United Nation Development Program Survey conducted in 2017- known as Human Development Index-HDI 2017 Survey. Nigeria has 36 states and the Federal Capital Territory (FCT). Each state and FCT was divided into urban and rural settings. The enumeration areas used in this survey were as demarcated by the National Integrated Survey of Household (NISH). A total of 66,600 households (HHs) were chosen for the study,

with 15 HHs coming from each of the 120 EAs in each of the 36 states and the FCT. HDI-2017 covers data on demographic status; all forms of human mortality, work history, access to potable water, sanitation, housing materials, information on primary industries, information from Ministry, Department and Agencies (MDAs), educational level from HHs, and anthropometric indices. Four significant indicators of human development were constructed from these data sources. These include Human Development Index (HDI), the Multidimensional Poverty Index (MPI); the Inequality-adjusted Human Development Index (I-HDI), and Gender Inequality Index (GII). In this study, data were extracted for HDI, MPI, and GII as part of our contextual risk factors at the state level. It is well known that national socioeconomic development captured by Human Development Index (HDI) (Alijanzadeh, Asefzadeh and Zare, 2016; Shao *et al.*, 2019), and the Multidimensional Poverty Index (MPI), are strong determinants of public health outcomes. Nevertheless, the ways these socioeconomic indicators may be associated with childhood multimorbidity, especially in LMICs, are still lacking in the literature. These formed parts of the areas this thesis will address.

4.2.2.1 Human Development Index (HDI)

Human Development Index is all about people being able to live their full potential (United Nations Development Programme (UNDP), 2018). It summarises human progress in 3 dimensions: (i) Longevity (health and wellbeing), (ii) Exposure (educational attainment, and (iii) standard of living (income). In 2018-UNDP/NBS compilation for HDI was done at Nigeria's state and FCT levels. The HDI was computed by taking the geometric mean of the 3-dimension indices of HDI (United Nations Development Programme (UNDP), 2018). Further description of the variable and its compilation are reported in 2018 NHDR (United Nations Development Programme (UNDP), 2018). In this study, HDI was considered an indicator of state socioeconomic status. Not only is HDI a valuable indicator of socioeconomic progress, but it is also an excellent predictor of infant and maternal mortality rates for certain nations (Lee *et al.*, 1997), hence an expected useful predictor of child's health outcomes at state levels.

4.2.2.2 Multidimensional Poverty Index (MPI)

The Multidimensional Poverty Index (MPI) was developed by Oxford Poverty & Human Development Initiative (OPHI) in collaboration with UNDP's Human Development Report (UNDP-HDR) as a measure of acute poverty (Oshio & Kan, 2014; Santos & Alkire, 2011; United Nations Development Programme (UNDP), 2018). MPI was computed from the 2017 HDI Survey. It measures the percentage of the dimensions in which the people are

multidimensionally poor (United Nations Development Programme (UNDP), 2018). MPI has 4-dimensions with 11 indicators. (i) Health (2 indicators); (ii) Education (2 indicators); (iii) Standard of living (6 indicators); and (iv). Labour force participation (1 indicator). MPI was compiled at the state level. It is essential to understand that an absolute monetary definition of poverty does not accurately portray the complexity of hardship. According to the Lancet article (Oldfield, 2019), the Global Multidimensional Poverty Index classifies 689 million children—nearly two in five—as multidimensionally poor, meaning that they experience deprivation in at least a third of these indicators at the household level. Though the assessment is based on ten weighted indicators that span living standards, education, and health, children are more frequently and severely affected by multidimensional poverty than adults in 103 countries with data from 2006 to 2016, with 87 per cent of these children living in sub-Saharan Africa and South Asia (Oldfield, 2019).

4.2.2.3 Gender Inequality Index (GII)

The percentage of potential human development lost because of gender disparity is known as the Gender Inequality Index (GII). It discusses gender-based discrimination or accomplishment gaps in particular areas and how much such gaps hinder human progress. It ranges from 0 (where men and women perform equally) to 1 (when one gender performs as poorly as possible) across all measured dimensions. The indicators listed below represent the aspects of reproductive health, empowerment, and the labour market that make up GII in this study (United Nations Development Programme (UNDP), 2018). GII has three dimensions reproductive health index, empowerment index, and labour market index. GII was also compiled at the state level.

4.2.2.4 Description of data merging

Fig 4.2 shows that 40,427 households were surveyed in NDHS, having 34,192 under-five (U-5) children. Anthropometric and biomarkers data were obtained from U-5 children from one-third of households with U-5 children. Anthropometric data was used to measure the nutrition indicators, which were obtained from 11,731 U-5 children and information stored in the 'De jure household population' (PR) file. Similarly, biomarkers used to measure anaemia and malaria (RDT) Status were obtained from 10,480 children aged 6-59 months. Information for anaemia was stored in the kid recode file (KR), while malaria was stored in the same file as nutrition status (PR file). When PR was finally merged to the KR file, the number of children

aged 6-59 months with the three outcomes was 10,451 (the number included in this study). However, 10,184 children aged 6-59 months had complete information on the three outcomes.

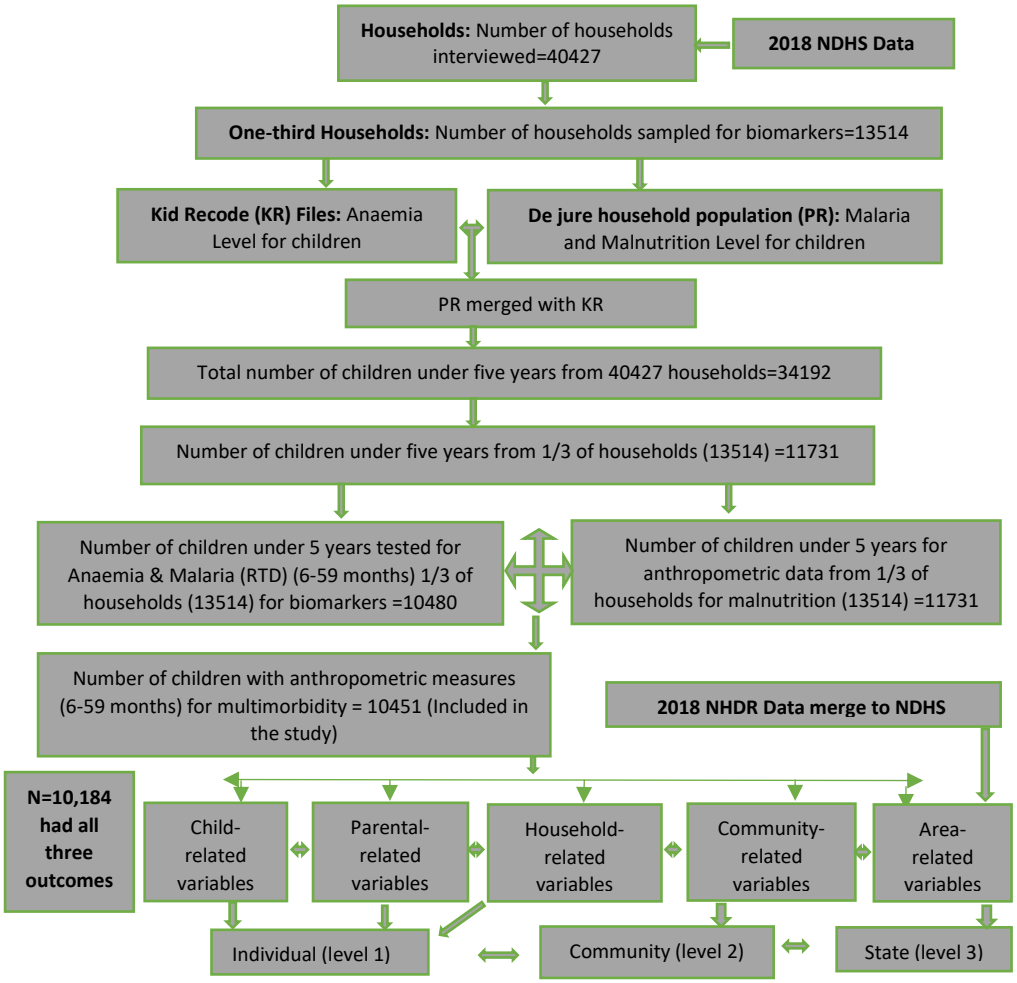


Figure 4 2 Flowchart describing the number of children and categories of variables

4.3 Variable Descriptions

This section describes the variables used (both the dependent and the independent variables) at the various levels (Individual, Household, and community).

4.3.1 The Dependent Variables

Three response (dependent) variables are considered in this study as indicators for childhood multimorbidity: anaemia, malaria, and malnutrition statuses. These variables were captured at the individual level. The rationale for choosing the three outcome variables was explained, along with a brief explanation of how each was categorised and used in this study. The significant overlaps among the three outcomes were also described and categorised.

4.3.1.1 Anaemia Status

The anaemia status for children 6-59 months was determined by reading the haemoglobin (Hb) levels from a finger-prick/stick blood sample using HemoCure Hb 201+ device. There was an adjustment in EAs whose altitude is more than 1,000 metres for the haemoglobin levels. The anaemia status was classified such that a haemoglobin (Hb) level less than 11.0 grams per decilitre was considered 'anaemic', between 10.0 and 10.9 grams per decilitre was considered as 'mildly anaemic', between 7.0 and 9.9 grams per decilitre was considered as 'moderately anaemic', less than 7.0 grams per decilitre was considered 'severely anaemic', and 11.0 grams per decilitre or greater was considered 'not anaemic'. However, for this study, these anaemia statuses (whether mildly, moderately, or severely anaemic) were collapsed into one group, such that haemoglobin level less than 11.0 grams per decilitre was regarded as 'anaemic' and classified as '1', otherwise, for 11.0 grams or more than was 'not anaemic' and classified as '0'.

4.3.1.2 Malaria Status

In 2018 NDHS diagnostic tests for malaria parasites were carried out for children aged 6 – 59 months in approximately one-third of the selected households (where a men's questionnaire was administered). Malaria is a fever, but not all fever is malaria. The policy in Nigeria does not allow presumptuous treatment of all fever as malaria until it has been appropriately diagnosed (National Population Commission (NPC)[Nigeria] and ICF, 2019). Two testing methods were adopted in 2018 NDHS to assess the presence or absence of malaria:

(i) Malaria Rapid Diagnostic Tests (mRDTs) were conducted on blood samples from pricking the finger or heal of children from the household. Men's questionnaire was administered using SD Bioline Ag Pf (HRP-II). The RDTs detect the Histidine-rich protein-II (HRT-II) human whole blood (antigen). The results were either positive or negative for *plasmodium falciparum (Pf).*

(ii) Laboratory microscopy investigation on thick blood smears was done for a three-quarter of the households where mRDTs was done. Malaria results were also classified as either positive or negative.

Most researchers preferred using thick microscopy blood smear results to classify the presence or absence of Pf. However, Azikiwe *et al* (2012)(Azikiwe *et al.*, 2012) found that *mRDTs* and microscopy laboratory investigation for malaria *Pf* yield similar results, with *mRDTs* being more precise than blood smears (Azikiwe *et al.*, 2012; Adinan, Damian and Msuya, 2015). Also, in a recent scoping review (Obasohan *et al.*, 2021a), *mRDT* was more frequently used in

studies than microscopic smears. Additionally, in 2018 NDHS, *mRDTs* accounted for more samples than microscopic blood smear laboratory tests. Moreover, the test of independence between the *mRDT* and microscopic blood smear results showed that they are dependent. Therefore, in this study, the malaria status of children 6 – 59 months of age in Nigeria using *mRDT* was classified as '1' if the result was positive and '0' when the result was negative.

4.3.1.3Malnutrition status

In NDHS, the malnutrition status (MNS) of children under-five years was determined through the measurement of anthropometric indices expressed as (i) Stunting: measured as height-for-age Z-score (HAZ) of less than minus two standard deviations from the median of the reference population. It is an indicator of growth retardation. (ii) Wasting: a measure of weight-for-height Z-score (WHZ) of less than minus two standard deviations from the median of the reference population. (iii) Underweight: a measure of weight-for-age Z-score (WAZ) of less than minus two standard deviations from the median of the reference population (N. B. Kandala *et al.*, 2011; National Population and I. C. F. International, 2019); these are measures of undernutrition. (iv) Overweight is also a measure of weight-for-height Z-score (WHZ) of more than plus (+) two standard deviations above the median of the reference population (National Population and I. C. F. International, 2019), considered as a measure of 'overnutrition'.The measure of malnutrition was considered in this study as the outcome of either undernutrition or overnutrition indicators. A recumbent length for children less than two years old was taken lying down, while children two years and above had their height standing up using Shorr Board measuring instrument. On the other hand, the weights of the children were measured with the SECA scale (model 878U) (National Population Commission (NPC)[Nigeria] and ICF, 2019). In this study, a measure of the overall description of malnutrition status among children aged 6-59 months in Nigeria was taken. The composite index for malnutrition was computed using the four indicators (stunting, wasting, underweight, and overweight). Children with no trace of anthropometric failure were classified as '0', labelled as 'well nourished', and those that have at least one of the four indicators were classified as '1', labelled as 'poorly nourished' (Nandy and Jaime Miranda, 2008; Bamiwuye, Wet and Adedini, 2013; Nandy, Daoud and Gordon, 2016).

4.3.1.4 Biomarker measurements in NDHS

Results of anthropometry measures and other biomarkers for women and children were recorded using the Biomarker Questionnaire. Only in the subsample where men's survey (one-third of the entire households surveyed) was administered were these measurements obtained.

Height and weight measurements for women aged 15 to 49 years and children aged 0 to 59 months, haemoglobin testing for women aged 15 to 49 years and children aged 6 to 59 months and testing for malaria and sickle cell disease in children aged 6 to 59 months were all included as biomarkers in this survey.

4.3.2 Rationale for choice of the three disease outcomes

There were seven different childhood diseases captured in the 2018 NDHS. These include acute respiratory infection (ARI), Pneumonia as the most severe outcome, non-malaria fever, diarrhoeal, anaemia, malaria, malnutrition, and sickle cell disease. Information about these illnesses in the survey was either obtained subjectively or objectively. The statuses of the first three: ARI, non-malaria fever, and diarrhoeal, were obtained subjectively by asking the mother or caregiver if the child had had any symptoms relating to the disease in the last two weeks before the survey. Given Nigeria's low maternal literacy level, the power of recall and the ability to correctly diagnose the actual disease presentation may be deficient (Masangwi *et al.*, 2015). As such, the data collected may not be accurate (Kandala, 2013). Whereas the statuses of the rest four (anaemia, malaria, malnutrition, and sickle cell disease) were objectively obtained using appropriate WHO-recommended procedures (National Population Commission (NPC)[Nigeria] and ICF, 2019). The use of objective measures of the cooccurrence of diseases has essential advantages, which include a better understanding of the disease burden and its patterns (Abebe *et al.*, 2020). However, sickle cell disease, though a noncommunicable disease, was dropped because it is a genetic acquired illness (National Health Service (NHS), 2017), which may not align with the same disease etiological processes as with anaemia, malaria, and malnutrition. In this study, these diseases have been used as proxies for multimorbidity (health status) in children aged 6-59 months in Nigeria (Kandala *et al.*, 2007; Khatab and Kandala, 2011). Additionally, the 2018 NDHS was the first time these three diseases, anaemia, malaria, and malnutrition, have been captured simultaneously in any nationally representative health survey. Therefore, a research gap existed.

4.3.3 Multimorbidity Status

To classify multimorbidity across anaemia, malaria, and malnutrition of children 6-59 months in Nigeria, the 'Composite Index of Multi-morbidity' (CIMM), a technique adapted from the Composite Index of Anthropometric Failure (CIAF), was used (Nandy and Jaime Miranda, 2008; Nandy, Daoud and Gordon, 2016). In general, the classification often results in 2^n mutually exclusive parameters. The multimorbidity (with three outcomes) was classified into

eight independent groups, such that it can have multi-categorical responses represented in three intersecting sets of anaemia, malaria, and malnutrition (Figure 4.3):

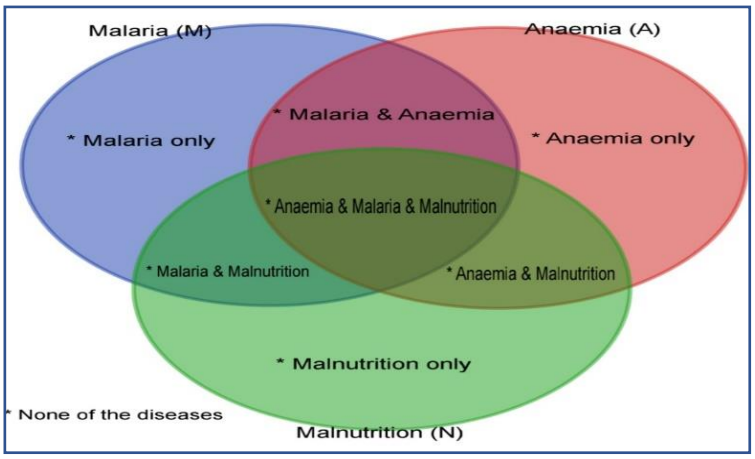


Figure 4 3 Diagram representing the intersection of the three outcome diseases

From the intersecting diseases (Figure 4.3), it recognises four distinct groups/categories: Those that had 'no disease' at all and are classified as '0'; those that had 'one disease only' and are classified as '1'; those that had two diseases only, and classified as '2', and those that had 'all three diseases, and classified as '3'. However, to align with the multimorbidity of cooccurrence of two or more diseases in an individual without reference to an index disease, categories 2 and 3 were grouped into one (having two or more diseases). Therefore, the ordered set of multimorbidity conditions is S = {0, 1, 2}.

4.3.4 Independent variables (Predictor variables)

The four independent scoping reviews conducted for anaemia, malaria, malnutrition, and multimorbidity identified several significant potential predictor variables. Apart from the DHS data set, some studies reviewed used other nationally representative surveys. The observable variables were added together, mainly at the individual, parental, and household levels. Those found in 2018 NDHS were identified, defined, and classified by levels, and to be comparable to previous research, most of the factors were reclassified (Kandala *et al.*, 2007; Kandala, 2013). Table 4.1 shows the variables that were identified, found in DHS, and included for analysis. In this study, there are no principal predictors of interest. The inclusion of these variables was subject to the following priority conditions: (i) Is the variable captured in NDHS 2018? (ii) Is the variable associated with multimorbidity? (iii) Is the variable associated with all three disease outcomes? (iv) Is the variable associated with at least two disease outcomes? Some exceptional cases arose where some variables that served as risk factors for any outcome were considered at the researcher's discretion.

Table 4 1 showing the variables identified and included for analysis

1.	Variables	NDHS	Anaemia	Malaria	Malnutrition	Multimorbidity	Number	Included	Remarks
2.	Sex of the child	YES	YES	NO	YES	YES	3	YES	
3.	Age of the child	YES	YES	YES	YES	YES	4	YES	
4.	Birth size	YES	YES	NO	YES	YES	3	YES	
5.	Vaccination status	YES	NO	YES	YES	YES	3	YES	
6.	Product of multiple birth	NO	YES	NO	YES	NO	2	NO	
7.	Preceding birth interval	YES	NO	YES	YES	NO	2	YES	
8.	Birth order	YES	YES	YES	YES	NO	3	YES	
9.	Breastfeeding status	YES	NO	YES	YES	YES	3	YES	
10.	Had diarrhoeal 2 weeks before the survey	YES	YES	NO	YES	YES	3	YES	
11.	Fever in the last 2 weeks	YES	YES	YES	YES	YES	4	YES	
12.	Child had acute respiratory diseases (Cough)	YES	NO	NO	NO	NO	0	YES	
13.	Child took vitamin A syrup	YES	YES	NO	YES	NO	2	YES	
14.	Minimum dietary diversity	YES	YES	NO	YES	NO	2	NO	Aged 6-23 months
15.	Minimum meal frequency	YES	YES	NO	NO	NO	1	NO	Aged 6-23 months
16.	Deworming in last 6 months before the survey	YES	YES	NO	YES	NO	2	YES	
17.	Anaemia status	YES	NO	YES	NO	NO	1	YES	One of the outcomes
18.	Malaria status	YES	YES	NO	NO	NO	1	YES	One of the outcomes
19.	Stunting	YES	YES	NO	NO	NO	1	YES	Used in an outcome
20.	Wasting	YES	YES	NO	NO	NO	1	YES	Used in an outcome
21.	Underweight	YES	YES	NO	NO	NO	1	YES	Used in an outcome
22.	Overweight	YES	YES	NO	NO	NO	1	YES	Used in an outcome
23.	Place of delivery	YES	NO	YES	YES	NO	2	YES	
24.	Child slept under a mosquito bed net	YES	NO	YES	NO	NO	1	NO	
25.	Maternal age	YES	YES	YES	YES	YES	4	YES	
26.	Maternal education status	YES	YES	YES	YES	YES	4	YES	
27.	Paternal education status	YES	YES	NO	YES	YES	3	YES	
28.	Maternal work status	YES	YES	NO	YES	NO	2	YES	
29.	Maternal body mass index	YES	YES	YES	NO	NO	2	YES	
30.	Maternal anaemia status	YES	YES	NO	NO	NO	1	YES	Perceived important
31.	Maternal religious status	YES	YES	NO	NO	NO	1	YES	Perceived important
32.	Has health insurance cover	YES	YES	NO	NO	NO	1	NO	
33.	Maternal ante-natal care	YES	NO	YES	NO	NO	1	NO	
34.	Number of births in 5 years	YES	NO	YES	NO	NO	1	NO	
35.	Maternal knowledge of malaria fever	YES	NO	YES	NO	NO	1	NO	
36.	Number of children ever born	YES	NO	YES	NO	NO	1	NO	
37.	Mother has access to phone/media/television	YES	NO	YES	NO	YES	2	YES	
38.	Mother health seeking behaviour	YES	NO	NO	YES	NO	1	NO	
39.	Maternal stature	NO	NO	NO	YES	NO	1	NO	

40.	Maternal HIV status	NO	NO	NO	YES	NO	1	NO	
41.	Paternal orphan	YES	NO	NO	YES	NO	1	NO	
42.	Household wealth status	YES	YES	YES	YES	YES	4	YES	
43.	Household had bed net	YES	NO	YES	NO	NO	1	YES	Perceived important
44.	Age of household head	YES	NO	YES	NO	NO	1	YES	Perceived important
45.	Insecticide residual spray	YES	NO	YES	NO	NO	1	NO	
46.	Household size	YES	YES	YES	NO	YES	3	YES	
47.	Number of under-5 in household	YES	YES	YES	NO	YES	3	YES	
48.	Source of water outside	YES	YES	YES	NO	NO	2	NO	Also improved water source
49.	Improved water source	YES	YES	YES	YES	NO	3	YES	
50.	Improved toilet facility	YES	YES	YES	YES	NO	3	YES	
51.	Sex of household head	YES	YES	YES	NO	NO	2	YES	
52.	Use biomass for cooking	YES	NO	YES	NO	NO	1	YES	Perceived important
53.	Under 5 years, child slept under bed net	YES	YES	YES	NO	NO	2	YES	
54.	Household ownership of livestock	NO	YES	YES	NO	NO	2	NO	
55.	Improve building materials	YES	NO	YES	YES	NO	2	YES	
56.	Household head education status	YES	NO	YES	YES	NO	2	YES	
57.	Household connected electricity	YES	NO	YES	NO	NO	1	YES	Perceived important
58.	Roofing material	YES	NO	YES	NO	NO	1	YES	Perceived important
59.	Household ownership of radio	YES	NO	NO	YES	NO	1	NO	
60.	Watch television	YES	NO	NO	YES	NO	1	NO	
61.	Household staple budget share	NO	NO	NO	YES	NO	1	NO	
62.	Household spending status	NO	NO	NO	YES	NO	1	NO	
63.	Fruits and vegetables	NO	NO	NO	YES	NO	1	NO	
64.	Household land ownerships	NO	NO	NO	YES	NO	1	NO	
65.	Household HIV status	NO	NO	NO	YES	NO	1	NO	
66.	Household use of internet	YES	NO	NO	YES	NO	1	NO	

Potential individual socioeconomic, demographic, and contextual determinants, as well as their classification as proximal and other factors for children, are described in the following section, and grouped as child-, parental-, household-, community-, and area-related variables.

4.3.5 Variable definitions and classifications

The predictor variables considered for this study were found through previous scoping reviews (Obasohan *et al.*, 2020a, 2020b, 2021a), categorised following earlier research and as presented in the NDHS 2018 final report (Wanzira *et al.*, 2017). Children under the age of five (Kids' Recode) and household members (People's Recode) were two files in the 2018 NDHS that were combined using a common identifier to produce variables suitable for this research

(Demographic and Health Survey, 2021). A population's health status, whether good or bad, depends on several linked elements at both the individual and environmental levels (Murdock, 2017). These elements are referred to as determinants and are categorised into three primary groups: personal traits, environmental and social factors, and health services (Murdock, 2017). Regarding individual determinants, these are, on the one hand, biologically uncontrollable factors present at birth that set one child's health condition apart from another, such as age, sex, and parentage.

On the other hand, they might be child-specific behavioural traits that can be changed using restrictions like diet, vaccinations, food supplements, and others In addition, the physical and social environment of the home is related to other factors that affect children's health outcomes (Murdock, 2017). In this study, the factors that affect a childhood's risk of contracting multimorbidity of anaemia, malaria, and malnutrition (MAMM) were broken down into factors related to the child, the parents, the home cluster, and the area.

4.3.5.1 Child-related characteristics

The child's age was divided into quintiles of one-year intervals, with the reference group (6-11 months) denoting the time before the child started to walk. Twelve to twenty-three months is another significant milestone (for instance, immunisation completion), followed by 24-36 months for some children, and 36 months and above denotes the start of preschool. In addition, the mother's perception of the child's birth size was classified into three categories: large, average, and small. Their birth order determines the child's rank among the other children of the same mother; the impact of this on the child's health result is not fully understood (Black, 2017). Although breastfeeding is beneficial for a child in the first few years of life (Northern Ireland, 2015), this was categorised as: (i) ever breastfed, not currently breastfeeding (ii) never breastfed (iii) still breastfeeding; whether the child had taken iron, vitamin A, and deworming treatment in the previous six months. These provide the child with some of the nutrients needed, strengthening the child's natural immunity against diseases.

Additionally, two weeks before the survey, a child's Diarrhoea, fever, or acute respiratory infection (ARI) was considered. The conventional way of malnutrition is measured is by stunting, wasting, and undernutrition which together measures the level of undernutrition, and overweight/obesity as a measure of overnutrition. The anthropometric measure for each of these indicators are used to identify the ‘presence of’ or ‘not’ of poor nourishment in children. From the data available to us (NDHS) we can only identify malnutrition as having either of

undernutrition or/and overnutrition indicators. So, using the composite index of anthropometric failure (CIAF), nutritional status was determined by constructing a composite index from the four nutrition indicators (stunting, wasting, underweight, and overweight) (Nandy and Jaime Miranda, 2008; Myrskylä and Fenelon, 2012; Bamiwuye, Wet and Adedini, 2013). Children were categorised as "well-nourished" if there was no sign of anthropometric failure, and as "poorly nourished" if at least one of the four signs was present. Anaemia status was derived from the record of whether the child was mildly, moderately, or severely anaemic. It was collapsed into one group, such that a child with a haemoglobin level less than 11.0 g per decilitre was regarded as being "anaemic" and classified as "one"; otherwise, for 11.0 g or more was "not anaemic" and classified as "zero" (Obasohan *et al.*, 2021b).

4.3.5.2 Parental-related characteristics

According to similar studies, the age of the mother at her most recent birthday was categorised as younger (under 25 years old), middle-aged, and older (over 34 years old) moms (Myrskylä and Fenelon, 2012; Duncan *et al.*, 2018; Adedokun and Uthman, 2020). The mother's age at the time of her first child's birth was also crucial for the analysis. Younger moms have less expertise in caring for infants, and the health of their offspring is very likely to suffer. The age at first birth was divided into three categories: (i) 10–19 years, (ii) 20–29 years, and (iii) 30 years and older (Jennings-Edquist, 2020). Age groups of women are frequently supported at 10-year intervals. Maternal and child health heavily depends on the mother's employment status, the father's employment status, and the mother's educational status. The knowledge, attitude, and practice (KAP) of some common paediatric disorders can be improved by maternal literacy. Also, it is essential to investigate the impact of fathers' educational attainment on their children's health. This effect will probably moderate maternal features' impact on the child's health. Mother slept under a mosquito net; mother's body mass status (kg/m2); marital status (never in a union, in a union, widow/divorced/separated); mother's education status (i) no education; (ii) primary; (iii) secondary, and (iv) tertiary; mother's marital status (never in a union, in a union, widow/divorced/separated); and maternal anaemia statuses (whether mild, moderate, or severe) were grouped so that mild, moderate, or severe were considered to be "anaemic" and categorised as: "one", otherwise, it was "not anaemic" and classified as "zero". Several antenatal care visit mothers attended during the child's pregnancy were also provided. The WHO suggested a minimum of four visits at the time of the survey (Obasohan, Karo and Obasohan, 2018; National Population and I. C. F. International, 2019). The composite index score from the mother's level of engagement in decisions about her health, significant

purchases, and family trips were used to calculate maternal autonomy (Bamiwuye, Wet and Adedini, 2013). Three and four are "less" autonomous, while five and six are "more" autonomous. The scale extended from three to six. There are four categories for maternal ethnicity, and religion status was included because it affects both mother and child health outcomes and helps define people's worldviews (Obasohan, 2014).

4.3.5.3 Household-related characteristics

When utilising the principal component analysis (PCA), to create a composite score from a few durable products, one can determine the wealth level of a household. Originally from the data set, wealth status was divided into quintiles. Data from the full country sample was used to create a single asset index, which is then used in all its tabulations that are shown in DHS reports. But, based on either rural data or urban data, separately constructed household wealth indices were not created for the two demographic groupings (The DHS Program, 2016) . This is one major identified limitation of using the wealth status as it is presently constructed in NDHS data set and will not reflect the socio-economic status in Nigeria for the rural/urban dichotomy. However, in this study, five categories of wealth status were derived: poorest, poorer, middle, richer, and richest groups. The number of bedrooms in the home, even though in the survey, the number of sleeping spaces in a home was given as scale values, where less than 10% indicated having five or more sleeping spaces. Since a typical Nigerian building has one, two, three, or four bedrooms, this variable was divided into five groups in this analysis. Other variables include households have mosquito bed nets; the household number measures the number of people who live in a household. It was initially a scale variable; however, for this analysis, it was classified into four categories by the average typical family sizes of four to five members Additionally, improved drinking water sources, toilet facilities, floor materials, roofing materials, and wall materials (these materials can be raw, rudimentary, or finished. Unimproved materials are raw and rudimentary, and the finished materials are improved (Lia and Taylor, 2016). The number of children under five years old in the household was also treated as a category, as in previous studies (Kawo, Asfaw and Yohannes, 2018; Oguoma *et al.*, 2021); household head sex; household head age (years) in groups. Particularly on the issue of health, the age of the household head is significant in several developing nations because it affects how maturely final decisions are made: (i) less than 34 years, (ii) 35-44 years, (iii) 45-55 years, (iv) 56 years or more. The number of under-five years children who slept under a bed net the night before the survey: (i) none, (ii) all children, (iii) some children, (iv) no children (National Population and I. C. F. International, 2019). Whether the home had electricity was

also categorised as ‘No’ or ‘Yes’. The presence or absence of electricity in the household can impact food storage, and cooling at specific seasons can also affect children's health. The kind of cooking fuel used at home was also considered.

4.3.5.4 Community-related characteristics

At the community level, the proportion of cluster households without bed nets and the proportion of communities whose distance to the nearest medical facility is not a significant issue; the proportion of low maternal education level and low cluster wealth were considered in this study. There was no direct collection of data for these variables at cluster level, so they were derived by aggregating their individual household characteristics. Based on the median (50th percentile) score for each variable as is the case in previous studies for ease of comparison, the categories of 'low' and 'high' were determined (Dhewantara, Ipa and Widawati, 2019).

4.3.5.5 Area-related characteristics

The six geopolitical zones in Nigeria that the child dwells in make up the region of residence. Seasonal differences among the zones can have different effects on health outcomes, especially for children under five; place of residence is the area in which the child's household is located and is divided into urban and rural areas; state human development index (SHDI). The average of important measures of area human development is determined by each state's human development index. Children from these communities will be more resistant to diseases the higher the HDI. These state HDI classifications used in this study were taken from NHDR 2018 (United Nations Development Programme (UNDP), 2018); State socioeconomic situation is assessed using the state multidimensional poverty index (SMPI), which is used as a stand-in for the multidimensional poverty index of the communities

Table 4 2 Classifications of the variables used in the analysis

Variables	**Classifications**	**Variables**	**Classifications**
Child-related variables		**Household-related variables**	
Age of the child	(i) 6-11 months (ii) 12-23 months (iii) 24-35 months (iv) 36-47 months (v) 48-59 months	Wealth status	(i) Poorest (ii) Poor (iii) Middle (iv) Rich (v) Richest
Sex of the child	(i) Male, (ii) Female	Household had bed net	(i) No (ii) Yes
Mother’s perceived Birth Size of the child	(i) large (ii) average (iii) small	Household size	(i) 2-3 (ii) 4-6 (iii) 7-9 (iv) 10+
Child Ever Had Vaccination Status	(i) No, (ii) Yes	Under-five years child slept under net	(i) No, (ii) Yes

Preceding Birth Interval	(i) None (ii) 8-24 months (iii) 25-35 months (iv) 36-59 months (v) 60+ months	Number of children U5 in household	(i) 0-3 (ii) 4-6 (iii) 7 and above
Birth Order	(i) 1st order (ii) 2nd or 3rd order (iii) 4th-6th order (iv) 7th+ order	Improved Source of drinking water	(i) No (ii) Yes
Iron supplement	(i) No, (ii) Yes	Improved Type of toilet facilities	(i) No (ii) Yes
Duration of Breastfeeding	(i) ever breastfed, not currently breastfed (ii) never breastfed (iii) still breastfeeding	Unsafe stool disposal	(i) No (ii) Yes
Had Diarrhoea in last 2 weeks	(i) No, (ii) Yes	Improved Floor material type	(i) No (ii) Yes
Had fever in last 2 weeks	(i) No, (ii) Yes	Sex of Household Head	(i) Male (ii) Female
Child had acute respiratory infection in 2 weeks before survey	(i) No, (ii) Yes	Household head educated	(i) No education, (ii) Primary, (iii) Secondary (iv) Tertiary
Vitamin A Consumption	(i) No, (ii) Yes	Shared Toilet Facilities with Others household members	(i) No (ii) Yes
Treatment for intestinal worms in the last 6 months	(i) No, (ii) Yes	Use Biomass for cooking	(i) No (ii) Yes
Nutritional Status	(i) Well-nourished (ii) Poorly nourished	Under-5 slept under a mosquito net last night	(i) No (ii) Yes
Stunting	(i) No, (ii) Yes	**Community-related variables**	
Wasting	(i) No, (ii) Yes	The proportion of Community wealth level	(i) Low (ii) High
underweight	(i) No, (ii) Yes	The proportion of community distance to a health facility is no big problem	(i) Low (ii) High
Overweight	(i) No, (ii) Yes	The proportion of community maternal education level	(i) Low (ii) High
Malaria status (RTD)	(i) No, (ii) Yes	The proportion of community households with no bed net	(i) Low (ii) High
Anaemia status	(i) No, (ii) Yes	**Area-related variables**	
Place of delivery	(i) Home (ii) Public Health facility (iii) Private health facility (iv) Elsewhere	State Multidimensional Poverty Index (SMPI)	(i) Low (ii) High
Parental-related variables		State Human Development Index (SHDI)	(i) Low (ii) High
Mother's age group	(i) <18 years, (ii) 19-24 years, (iii) 25-34 years (iv) 35 years+	Community Female Education	(i) Low (ii) High
Mother's age at first birth	(i) <18 years, (ii) 19-24 years, (iii) 25-34 years (iv) 35 years+	Region of residence	(i) North Central (ii) North-East (iii)North-West (iv) South-East (v) South-South (vi) South-West
Mother working Status	(i) Not working (ii) Working	Place of residence	(i) Rural (ii) Urban
Mother's educational status	(i) No education, (ii) Primary, (iii) Secondary (iv) Tertiary		
Father's educational status	(i) No education, (ii) Primary, (iii) Secondary (iv) Tertiary		
Father's Occupation	(i) Not working (ii) Working		

Mother's marital status	(i) Married (ii) Not married (iii) Divorce/Separated/Widowed		
Mother's body mass index (kg/m2)	(i) <18.5 (ii) 18.5-25.0 (iii) >25.0		
Mother's anaemia status	(i) Normal (ii) Anaemic		
ANC attendance/Health seeking	(i) 0 (ii) 1-3 (iii) >4		
Religion status	(i) Catholic (ii) Other Christians (iii) Muslim (iv) Others (traditional)		
Mother's iron supplementation during pregnancy	(i) No (ii) Yes		
A mother living with a Partner	(i) Living with a partner (ii) living somewhere else		

. The MPI of a community indicates how vulnerable its residents are to disease. In the NHDR 2018 (United Nations Development Programme (UNDP), 2018), this categorisation of MPI per state is also included. Finally, gender inequality index was also considered and derived from NHDR 2018.

4.4 Analyses Techniques

To effectively answer the research questions and establish the objectives listed in sections 1.2 and 1.4, this section describes the various statistical techniques used. The first part describes the data set-up (the incorporation of the two data sets into one another), followed by the applied statistical methods.

4.4.1 Data merging

The original data set is a nationally representative sample from the 2018 Nigeria Demographic and Health Survey (2018 NDHS). The NDHS is a complex, multi-factor, and multidimensional data set. Although there is a single unit data recode, for distribution purposes, it is placed in different recode files by the unit of analysis (Demographic and Health Survey, 2022). The units of analysis in this study are children 6-59 months of age living in a household. All information required to answer the research questions is stored in:

(i) Kid Recode (KR) file. This has information about the children born within the last five years before the survey date. The KR holds the data for one of the outcome diseases, anaemia status among children 6-59 months of age.

(ii) People's Recode (PR) file. This also has information on every household member who slept in the house the previous night. In addition, the PR file holds the data for the two other outcome diseases: malaria fever and malnutrition statuses among children 6-59 months of age, and under-five years of age, respectively.

The PR file was merged to the KR file through a unique identifier to produce one single file-PR-KR merge (a detailed description is displayed in figure 4.2), a subset of the 2018 NDHS. The second data, the 2018 National Human Development Report (2018 NHDR), is a nationally representative sample conducted by the United Nations Development Program (UNDP-Nigeria). The three contextual variables of interest (Human Development Index (HDI), Multi-dimensional Poverty Index (MDPI), and Gender Inequality Index (GII) were captured at the state, and Federal Capital Territory (FCT) levels and so were extracted. The state and FCT identifiers incorporated these three variables into the merged file.

4.4.1.1 Rationale for the sub-sample of children 6-59 months

The 2018 NDHS was designed to capture information from different age brackets, especially for children born within five years of the survey. The initial survey was conducted with women of reproductive age (15-49 years) and men (15-59 years). This thesis used three disease conditions with data collected for different age groups. First, anaemia and malaria statuses were collected for children 6-59 months in one-third of all the selected households (the households where the men's questionnaire was administered). On the other hand, anthropometric measurements used to determine the nutrition status were taken from children aged under-five years from one-third of all the selected households in the survey. Since the outcome of interest in this thesis is the multimorbidity of these three disease conditions, and it involved computing the intersections of the three diseases, invariably, children 0-5 months of age in the nutrition status were automatically excluded because they do not have data for anaemia and malaria. Therefore, the age range for the units of analysis is 6-59 months.

4.4.2 Statistical analysis methods

The statistical analyses used in this study to adequately address the different dimensions of the research questions and objectives were carried out in four stages. First, all the responses and predictor variables were coded into categorical variables (Table 4.1).

4.4.2.1 Research Questions

The following was the main research question addressed in this thesis:

What are the multiple overlaps in the impact of individual and contextual variables on the MAMM among children 6-59 months in Nigeria?

However, in more specific terms, the study addressed the following sub-questions in four stages:

1. What are the descriptions of individual and contextual characteristics of children under-five years in Nigeria at baseline (response rates), as captured in 2018 NDHS?

2. What is the independent prevalence of the three outcomes of anaemia, malaria, and malnutrition concerning the individual and contextual characteristics among children 6-59 months of age in Nigeria?
3. What are the differences between groups in the individual and contextual characteristics concerning the three outcomes of anaemia, malaria, and malnutrition among children 6-59 months in Nigeria?
4. Are there variations in the proportion of children in each outcome of anaemia, malaria, and malnutrition across the communities and states levels
5. What are the significant independent effects of individual and contextual factors on the outcomes of anaemia, malaria, and malnutrition among children 6-59 months of age in Nigeria?
6. What are the differences between groups in the individual and contextual characteristics concerning the number of occurrences of MAMM among children 6-59 months in Nigeria?
7. Are there variations in the MAMM across the levels of clusters?
8. What are the multiple overlaps in the associations of individual and contextual factors with the MAMM among children 6-59 months in Nigeria?
9. What are the interaction effects of a child's sex, age, and household socioeconomic status on the impact of individual and contextual risk factors of MAMM among children 6-59 months of age in Nigeria?

4.4.2.2 Data Analysis Procedure

At the first level of analysis, the thesis addressed research questions one, two, and three. Firstly, frequency counts and percentages were computed at the baseline to determine the response rates for all the variables considered in this study. Secondly, frequency counts and percentages were also calculated to describe the characteristics of both the response (dependent) and predictor (independent) variables, performed a series of independent bivariate analyses of the associations between the child-, parental-, household-, and community-related predictors with each of the three categorical response variables using Chi-square test. At the second level of analysis, questions four and five were addressed. Given the hierarchical structure of the 2018 NDHS data set and the correlation structure of the data that frequently occurs in such a multistage survey sampling (Dey and Raheem, 2016), this study found some clustering in the data. Children, parents, and households were taken as individual characteristics at level-1, nested in communities/clusters at level-2, and nested in 36 states of Nigeria and the Federal

Capital Territory (FCT) at level-3. Therefore, 3-level mixed effect logistic regression models were fitted to test the effects of all the selected predictors with each disease outcome variable (anaemia, malaria, and malnutrition) to avoid possible under-estimation of parameters associated with the single-level model (Dey and Raheem, 2016). In the third level of analysis, it proffers solutions to questions six, seven, and eight, where it conducted a series of bivariate analyses of the association between the child-, parental-, household-, and community-related variables and the interactions between the three outcome diseases (such that it take into consideration multi-categorical responses of the number of diseases a child has (See section 4.3.3), following a natural order of 0, 1, 2 or more.

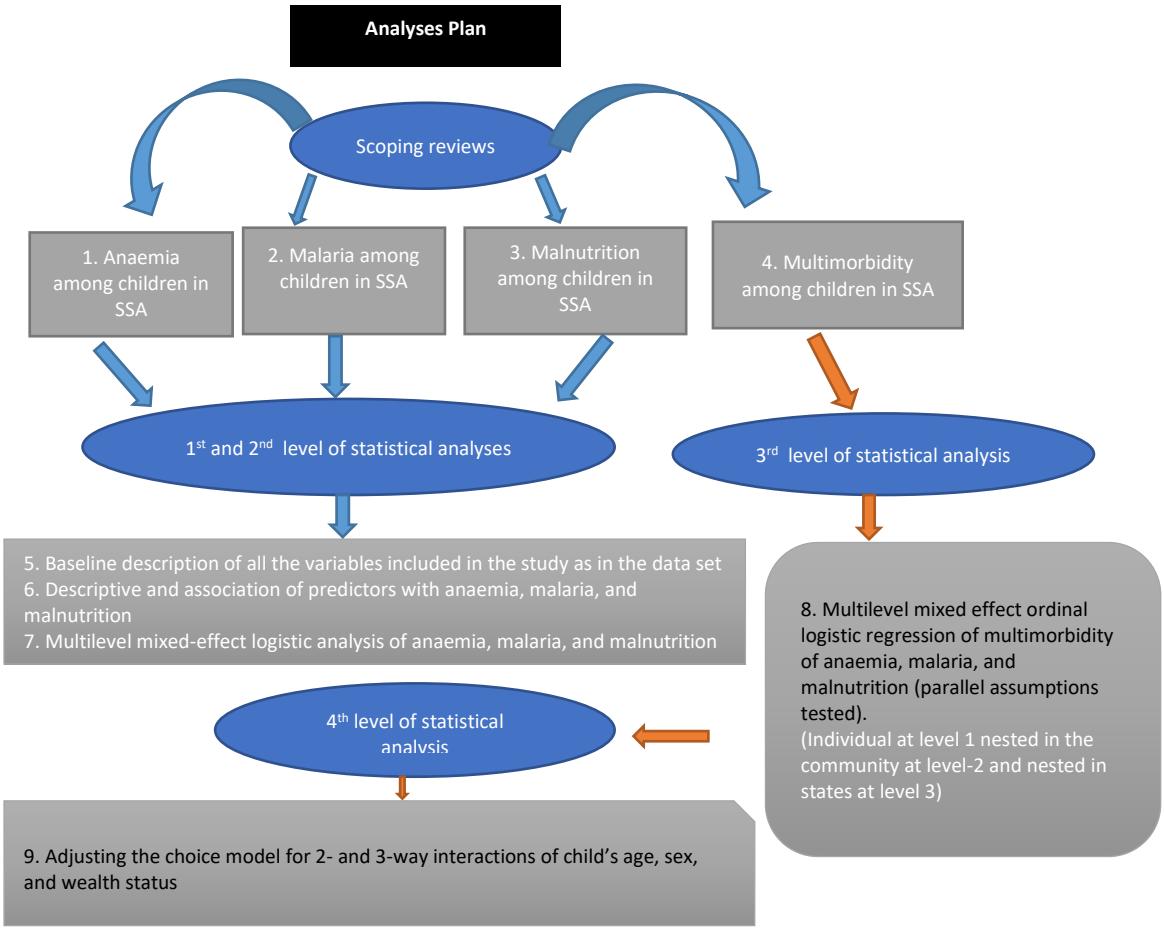


Figure 4 4 Flow chart describing the step-by-step analysis procedures

Furthermore, three-level mixed-effects ordered logistic regression models were fitted to determine the multiple overlaps in the variables that simultaneously predict the number of occurrences of MAMM among children 6-59 months of age in Nigeria. Finally, at the fourth level, the interaction effects of a child's sex, age, and household socioeconomic status on the impact of individual and contextual risk factors of MAMM among children 6-59 months of age

in Nigeria were computed. All the analyses were performed using Stata MP4 version 17 (StataCorp, College Station, USA), at 5% alpha level of statistical significance.

4.4.3 Rationale for the methods

The main aim of this study is to investigate the individual, contextual and area risk factors associated with occurrences of MAMM among children 6-59 months of age in Nigeria using three-level mixed-effects ordered logistic regression models.

4.4.3.1 Modelling the outcome variables independently

In the past, different statistical methods have been proposed for analysing problems of multimorbidity from a complex data set. One such method is modelling each disease independently as a function of several predictors, then multiplying the estimated risks, which is a potentially naive method of multi-outcome risk predictions. This strategy does not take advantage of the potential links between the outcomes and is only effective if the outcomes are conditionally independent given the covariates (Martin *et al.,* 2021). Previous studies (Kazembe *et al.,* 2007; El-Sayed *et al.,* 2010; Osterbauer *et al.,* 2012; Alicke *et al.,* 2017; Ali *et al.,* 2019), applied the single-level logistic regression method for independent analyses of each outcome of interest in their studies. Adopting this approach in this current study may solve the problem of identifying which of these three outcomes (anaemia, malaria, and malnutrition) are predicted by specific explanatory variables of interest. However, the single-level logistic method may ignore other issues of interest. (i) Intra-cluster correlation may be present in an individual having more than one of the outcomes, especially with clusters in a complex data set such as the one used in this study. (ii) By carrying out several tests on the same variables from the same data set in independent analyses on each outcome will produce an increased type I error that may result in wrong estimation of the effect size, thereby leading to a biased conclusion. (iii) The primary construct of interest in this study is multimorbidity; therefore independent analyses of each outcome will ignore this underlying conditions (Das, Poole and Bada, 2004). (iv) Another issue is that, as the model becomes more complex, some explanatory factors in one equation become dependent variables in another, both of which are a part of the same model, which, when ignored, may lead to endogeneity biases (Kandala, 2013).

4.4.3.2 Multivariate multilevel logistic modelling

To avoid the problem of ignoring clustering in a complex data set (limitation (i) above), Masangwi et al; Mothale & Ncayiyana; and Halliday et al, have applied multilevel logistic regression to the analysis of cooccurrence of childhood diseases, but would not correctly account for limitations (ii), (iii), and (iv). Furthermore, some studies, Das et al (Das, Poole and

Bada, 2004), and Gaston et al (Gaston, Ramroop and Habyarimana, 2021) have used a multivariate joint analysis within the generalised linear mixed model. The focus of these two studies is to jointly model the outcome of interest in longitudinal perspectives while also determining the outcome-specific effects. This method highlights the ability to consider the residual correlation parameters. Martins et al recognised that the degree of dependencies between the outcomes that the approach can handle has been proven in prior studies to be impacted by the residual correlation parameter, being bound by the marginal probabilities and hence unable to take values in the complete [-1, 1] range (Martin *et al.*, 2021).

4.4.3.3 Multinomial logistic regression

Alaba and Chola used multinomial logistic regression to analyse the cooccurrence of chronic health conditions in an adult population (Alaba and Chola, 2013). Participants in the South African National Income Dynamic Survey (SA-NIDS) were questioned about whether they were currently suffering from one or more chronic health conditions, such as cancer, high blood pressure, diabetes or high blood sugar, stroke, asthma, or tuberculosis (TB), as determined by a doctor. For the study, these medical conditions were combined to create a summative multimorbidity index ranging from 0 to 4. The following three conditions were then generated as a categorical variable: 0) no chronic disease, 1) the presence of one chronic disease, and 2) multimorbidity (i.e., presence of 2 or more chronic diseases) (Alaba and Chola, 2013). Though the study used Stata's stratified multistage design feature, this will not account for the random effects at various clusters; therefore, limitation (i) could not be resolved. However, in another study, Dey and Raheem applied a multilevel multinomial logistic regression model (MMLRM) using SAS 9.4's PROC GLIMMIX for multinomial distribution to predict the haemoglobin level among children aged 6-59 months in India. The outcome variable included four ordinal categories: the degree of anaemia (severe, moderate, mild, and non-anaemic). In addition, the state of residency was considered the level-2 variable in this multivariate logistic regression model with a two-level random intercept (Dey and Raheem, 2016). The study considered the 'ordinal categories' as nominal in the analysis. However, in a similar investigation, Kandala 2013 considered the different levels of anaemia as ordinal and used multilevel ordinal logistic regression models (Kandala, 2013). Often, multinomial was recommended as an alternative to analysing ordinal categories, especially when parallel assumptions have been violated (McNulty, 2021).

4.4.3.4 Multivariate Poisson regression modelling

While studying the overweight with concurrent stunting, Atsu et al used a multivariable Poisson regression model, but the conditions were investigated independently (Atsu, Guure and Laar, 2017). Poisson regression (PR) could have been applied to model multimorbidity if the results had been viewed as count variables instead of ordinal ones. When the dependent variable in PR is a count, for instance, of events like the arrival of a phone call at a call centre, it is possible. Although it is understood that covariates like the time of day impact the probability of occurrences per unit of time, the events must be independent because the arrival of one call will neither increase nor decrease the likelihood of another. But in this study

1) It is unclear whether the three diseases or outcomes are independent.

2) Because NDHS is cross-sectional data rather than longitudinal data and is just calculating the number of outcomes (multimorbidity) present at a specific time rather than the number of outcomes in a person over time (the data of the survey).

3) The designs are not quantifying the incidence of the multimorbidity but the prevalence when results from a Poisson model are reported as an incidence rate ratio (IRR).

4) The Poisson model assumes no theoretical upper bound on the range of possible values for the (counts) variable. However, in our scenario, there are all three multimorbidity; therefore, the maximum is 3. As a result, it was determined that using PR to model the multiple outcomes and multimorbidity as count outcomes was inappropriate for the reasons mentioned above (McCullagh and Nelder, 1989; StataCorp., 2021; Walters, Campbell and Machin, 2021). However, Atsu et al (Atsu, Guure and Laar, 2017) applied a Multivariable Poisson regression model while accounting for clustering variations but treated each disease separately.

4.4.3.5Multivariate Bayesian modelling

Though this current study is highly tinted towards the frequentist's approach, other studies have examined the determinants of multimorbidity in children with SSA using different Bayesian methods. For instance, in Khatab and Kandala, the latent individual unobserved variable "health state" or "frailty" of children was modelled using the geo-additive latent variable model (LVM), which used the three observable illness variables (Diarrhoea, cough, and fever) as indicators. Using this modelling technique, they could study how common risk factors affect kids' specific vulnerabilities while automatically considering the correlation between diseases and indicators of health status (Khatab and Kandala, 2011). Using the 2003 Demographic and Health Surveys (DHS) data for Nigeria, the LVM was expanded to examine the impact of risk variables and the spatial effects on the unobservable variable "health status" of a child under

the age of five. Furthermore, Kandala and others have used Bayesian geo-additive model based on Markov-chain–Monte-Carlo techniques to examine the predictors of different childhood diseases across some SSA countries (Kandala, Magadi and Madise, 2006; Kandala *et al.*, 2008, 2009). The approach was justified because strictly linear predictors could not be assumed due to the existence of non-linear effects for some covariates and the data's geographic characters. Also, Khatab et al (Khatab, Adegboye and Mohammed, 2016) used the Bayesian approach to determine area-specific predictors of co-morbidity of diarrhoeal, cough, and fever. This technique recognised and accounted for the three limitations of the single-level logistic model stated above.

4.4.3.6 Structural equation model

Some previous studies have applied latent component analysis (LCA) to establish the pattern of multimorbidity. For instance, Park et al used LCA in Korean adult population over some chronic diseases because they believed these diseases cluster. The study opined that multimorbidity is a complicated condition. It is far more practicable to use statistics to divide a population into a few subgroups with similar chronic disease combinations rather than analysing every possible disease combination. The LCA patterns for multimorbidity can be extracted using 'generalised structural equation model' (gsem) platforms in Stata. In Park et al study, following the best model choice, each respondent was allocated to the class for which their computed membership probability was the highest (An ideal fit is indicated when the average posterior probability is higher than 70%). Then multinomial logistic regression was performed to determine the risk factors. However, the study did not consider the multistage design in Korean National Health and Nutrition Examination Survey (KNHANES), therefore ignoring the data's hierarchy. Nevertheless, in this current study applying LCA could only result in two non-distinct latent classes (both contained the three outcomes but at different intensities), which could result in categorising the latent construct into 'low' or 'high' MAMM. This outcome will not fit well into the focus of this current study design and the definition of multimorbidity, which is the cooccurrence of two or more diseases.

4.4.3.7 Ordinal logistic regression model

Ordinal (ordered) logistic regression model is another technique applied in some previous studies to model the determinants of multimorbidity. For instance, Adedokun (Adedokun, 2020) proposed using a generalised ordered logistic regression model to determine the correlates of childhood morbidity of Pneumonia, diarrhoeal, and fever in Nigeria. The paper considered overlaps among the three outcome variables, classifying the diseases into four ordinal groups

of 'no disease', 'one disease', 'two diseases', and 'three or more diseases. This approach is like the one used in this present study but differs in some ways.

(i) The analysis unit was children under-five years in Nigeria, whereas this current study used a sample of children aged 6-59 months in Nigeria.

(ii) The outcome variables described in Adedokun (2020) were Diarrhoea, fever, and ARI, whereas, for this current study, they are anaemia, malaria, and malnutrition.

(iii) The data set was 2013 NDHS, but this current study uses 2018 NDHS. For the first time, data for anaemia, malaria fever, and malnutrition indicators were captured simultaneously in any nationally representative secondary survey.

(iv) The measurement of the three outcome variables, Pneumonia, fever, and Diarrhoea, used in the previous study was subjectively obtained by asking the mothers of the children to state if the children had suffered any of the conditions in the last two weeks before the survey. However, the three outcomes in the current study were obtained via laboratory tests and standard measurements as recommended by WHO.

(v) Also, in 2013 NDHS being a multistage cluster survey, the hierarchical nature of the data set was not considered, such that variations across the levels of clusters were ignored. However, this study applied a three-level mixed effect ordered logistic regression model and recognised the need to break down the overall variability into within and between cluster variabilities.

Similarly, Kandala (2013) used 'the standard modelling techniques', multilevel ordinal logistic regression to model the association between socioeconomic and demographic variables and anaemia among children aged under-five years and women in three SSA countries. The anaemia status was classified as 'not anaemic', 'mild', and 'moderate/severe. In addition, the complex sampling design mentioned above was considered using multilevel models.

It is worthy of note that the advantages of using this model (multilevel mixed-effect ordinal logistic regression) in this study over traditionally treating each outcome independently using binary logistics. This is because (i) it recognises the possibilities of carrying out multiple comparisons and avoids any possible increase in Type I error (random error correlations), which results from ignoring the simultaneous relationships among the diseases resulting in biased conclusions (Gabr, 2016). Furthermore, this approach recognised the complexities in the data set by applying a hierarchical concept. The ordinal concept is that the interactions of these diseases were taken as ordered counts, rather than nominal, such that the children who

had 'no disease at all, 'had one disease only', and 'had two or more diseases' were classified respectively as. 0, 1, or 2. This classification falls under multimorbidity, defined as the coexistence of two or more diseases in an individual without reference to an index disease (Abebe *et al.*, 2020). The composite scores for the three diseases (malnutrition, malaria, and anaemia) are calculated to reflect the child's total number of diseases. In addition, being a baseline aged-specific study, it has adopted this simplified approach of creating a composite score that defined the order of occurrence of the combination of these diseases. We recognised that this simplified approach would stimulate the needed interest for further study, leading to more understanding of the determinants of multimorbidity among children in LMIC.

4.4.4 Model Specifications

This section describes the various model used to address the research questions beginning with the multilevel mixed effect logistic regression model to the multilevel mixed effect ordered logistic regression. It then concluded with a brief description of multilevel moderation analysis.

4.4.4.1 Multilevel mixed effect logistic regression

The multilevel logistic model is nothing more but an extension of the single-level logistic regression by including the source of variations between and within clusters while considering the hierarchical nature of the data set. Carle (Carle, 2009) outlined three benefits of MLM to analysts, including identifying which covariates predict individual-level differences, predicting cluster-level differences, and determining within and between cluster-level variations. In this section, a description of binary logistic regression was given first before extending it to MLM.

Logistic Regression Model (LRM)

Our interest in this study is getting a model that correctly predicts the probability of occurrence of disease conditions from covariates of interest. The body of statistics that handles prediction better is regression analysis. Linear regression applies when the outcome variable (dependent variable) is continuous (interval or scale). However, when the outcome variable is dichotomous (categorical or binary), logistic regression could handle the analysis better than linear regression.

In binary outcomes where 'no disease' is coded as '0' and 'having disease' is coded as '1', it is observed that the predicted values can take values from 0 and 1. Nevertheless, linear regression for this Type of outcome can spool out of the range of 0 and 1. It is unbounded between $-\infty$ and $+\infty$, which is inappropriate in these circumstances (Sommet and Morselli, 2017). The interpretations of the results when linear regression (LR) is used differ from when binary

logistic regression (BLR) is applied. For instance, in the case of a child having the disease, LR will produce the predicted mean at any independent variable value; this is not the interest here. However, to predict the probability that a child will come up with the disease, given that the independent variable is at a value of interest. Binary logistic regression can do this better. So,

$$P(Y_i = 1) = \frac{exp^{(\beta_0 + \beta_1 X_i)}}{1 + exp^{(\beta_0 + \beta_1 X_i)}} \quad (1)$$

Where: Y_i = the conditional probability that the outcome variable result into 1 (having the disease condition of interest)

X_i = the predictor variable for a child *i*.

Given the exponentiation in the equation, the function results in an S- shape ranging from between 0 and 1 along the y-axis.

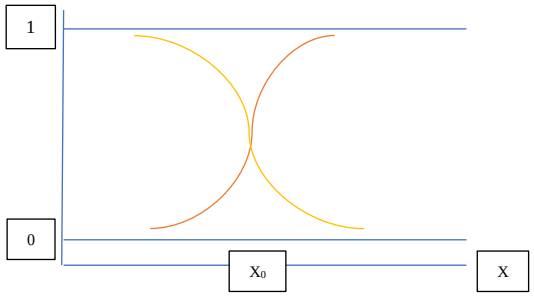


Figure 4 5 Logistic function

β_j is the j^{th} coefficient of the j^{th} independent variables, and β_0 is the intercept.

The S-shape depends on whether $\beta_j<0$ *or* $\beta_j>0$ (See fig 4.5).

The study prefers to find the conditional probability that the outcome is present (π) over the probability that the outcome is not present (1- π) in order to make meaningful interpretations rather than simply making predictions about the conditional probability that the outcome is present (represented as π). A link function that can convert the conditional probability of an S-shaped distribution into a linear combination as a function of the predictors is therefore necessary; the logit transformation is advantageous for making the function normal. (Gabr, 2016; Kawo, Asfaw and Yohannes, 2018).

Now, consider the odds of having the outcome disease.

$$Odds = \frac{P(Y_i=1)}{1 - P(Y_i=1)} \; or \; \frac{\pi}{1-\pi} \quad (2)$$

This ratio is the probability of being in the state of interest over the probability of not being in the state, known as odds. Then the logit transformation results into

$$\pi_i = logit(Odds) = log\left[\frac{P(Y_i=1)}{1 - P(Y_i=1)}\right] \quad (3)$$

By substituting $P(Y_i = 1)$ in equation (1) into equation (3), it turns into a linear combination of predictors (equation 4)

$$\pi_i = logit(Odds) = \beta_0 + \sum_i^n \beta_i X_i + \mu \quad (4)$$

β_i are the coefficients of their corresponding covariates X_i and could be interpreted as the effect of the predictor variable X_i on the *log-odds* of having the disease. In other words, it could mean the amount an increase (or decrease) of one unit in the predictor variable will produce as an expected increase (or decrease) in the *log-odds* of having the disease after adjusting for other covariates (in the case of multivariate analysis). The exponentiation of β_i gives the odds ratio, which refers to the amount one can multiply the probability of the outcome of interest occurring rather than not occurring (Sommet and Morselli, 2017).

Alternatively, it can convert the *log-odds* of the outcome of interest to the predicted probability of the outcome of interest for ease of interpretation (Williams, 2012; Dey and Raheem, 2016), using:

$$Predicted\ probability\ (PP)\ \rho_i = \frac{e^{\beta_0 + \sum_i^n \beta_i X_i + \mu}}{1 + e^{\beta_0 + \sum_i^n \beta_i X_i + \mu}} \quad (5)$$

Multilevel Logistic Model (MLM)

At the second level of analysis, multilevel mixed-effect logistic models were fitted for each of the outcome diseases (anaemia, malaria, and malnutrition), as a function of individual and contextual covariates. The model specification for a three-level mixed-effects logistic regression such that children, parents, and households were grouped as individual characteristics at level-1, nested in communities/clusters at level-2, and nested in states and federal capital territory (FCT) at level-3 were described. The 'mixed effects' imply that it contains more than one source of variabilities. In addition, it contains both 'fixed effect' and 'random effect' components, such that the random effects are specified for states and communities nested in states (Stata.com, 2021).

The dependent variable of interest is dichotomous and follows the Bernoulli (π_{ijk}) distribution with a logit link function:

$$\eta_{ijk} = \beta^*_{0,0} + \sum_{i=1}^n \beta^*_{a,i} W_{a,ijk} + \sum_{j=1}^m \beta^*_{b,j} X_{b,jk} + \sum_{k=1}^p \beta^*_{c,k} Z_k + \varepsilon_{0,jk} + \varepsilon_{0,k} + \varepsilon_{0,ijk} \quad (6)$$

Where η_{ijk} is the predicted log odds of individual child *i* (level 1) in community (com) *j* (level-2), and in state (sta) *k* (level-3). $\beta^*_{0,0}$ represent the overall intercept (the grand mean of level-3), $\beta^*_{a,i}$, $\beta^*_{b,j}$, and $\beta^*_{c,k}$ are, respectively, the *n*th, the *m*th, and the *p*th coefficients associated with *W* (level-1), *X* (level-2), and *Z* (level-3) predictors, respectively. And $\varepsilon_{0,jk}$ represent the

random effect of *j*th community in *k*th state, while $\varepsilon_{0,k}$ denotes the state level random effect, with the assumption that $\varepsilon_{0,jk} \sim N(0, \sigma^2_{com})$ and $\varepsilon_{0,k} \sim N(0, \sigma^2_{sta})$ are mutually independently distributed (Gabr, 2016; Rozi *et al.*, 2016; StataCorp., 2021), and $\varepsilon_{0,ijk} \sim N(0, \frac{\pi^2}{3})$, and independent of the random intercepts(StataCorp., 2021). Equation (6) has a logistic transformation.

$$\eta_{ijk} = ln\left(\frac{\pi_{ijk}}{1-\pi_{ijk}}\right) \quad (7)$$

and it denotes the probability that an *i*th child in *j*th community and in *k*th state will suffer from the outcome of interest.

4.4.4.2 Multilevel mixed effects ordered logistic regression model

The focus of this thesis is to investigate the multiple overlaps in the individual, contextual and area factors associated with the occurrences of MAMM among children 6-59 months of age in Nigeria using three-level mixed-effects ordered logistic regression models.

The outcome variable is the occurrence of MAMM classified into 'no disease', one disease only', two or more diseases' as functions of other covariates grouped into child-, parental-, household-, community-, and state-related factors. This section described the model specification for three-level mixed-effects ordered logistic regression.

Schematic description of a three-level data structure

This study considered that a level-3 structure was better than a level-2 structure. Therefore, the model was structured along a three-level structure such that children/parental/household units at level-1, because children from the same parent and household tend to be more similar than children from other households because they share the same characteristics, are nested within communities/clusters at level-2, and nested within states at level-3.

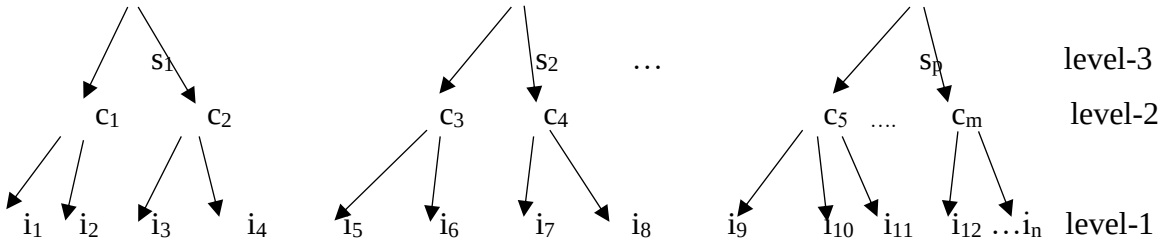


Figure 4 6 A schematic diagram representing a three-level data structure

Multilevel mixed-effects ordinal logistic model specification

The specification of the three-level mixed-effects ordinal (or ordered) logistic model in this thesis followed the one described in Raman & Hedeker (Raman and Hedeker, 2005). There are *i=1,2,..,n* individual-level units nested within *j=1, 2,…,m* community-level units that are

further nested within *k=1, 2, …, p* state-level units. There are three ordered categories (c=0, 1, 2), representing the number of co-occurrences of the diseases in the individual child. Therefore, the response variable of interest is ordinal and follows the logistic (Y_{ijk}) distribution with a logit link function:

$$Y_{ijk} = \beta^*_{0,0} + \sum_{i=1}^{n} \beta^*_{a,i} W_{a,ijk} + \sum_{j=1}^{m} \beta^*_{b,j} X_{b,jk} + \sum_{k=1}^{p} \beta^*_{c,k} Y_{c,k} + \upsilon_{0,jk} + \upsilon_{0,k} + \varepsilon_{0,ijk} \quad (8)$$

Where $\beta^*_{0,0}$ represents the overall intercept (the grand mean of level-3), $\beta^*_{a,i}$, $\beta^*_{b,j}$, and $\beta^*_{c,k}$ are, respectively, the *n*th, the *m*th, and the *p*th coefficients associated with *W* (level-1), *X* (level-2), and Y (level-3) covariate vectors, respectively. And $\upsilon_{0,jk}$ represents the random effect of *j*th community in *k*th state, while $\upsilon_{0,k}$ denotes the state level random effect, with assumption that $\upsilon_{0,jk} \sim N(0, \sigma^2_{com})$ and $\upsilon_{0,k} \sim N(0, \sigma^2_{sta})$ are identical and independently distributed (Gabr, 2016; Rozi *et al.*, 2016), and $\varepsilon_{0,ijk} \sim N(0, \frac{\pi^2}{3})$, assumed to follow standard logistic distribution (Raman and Hedeker, 2005).

The underlying latent variables are the three outcomes: anaemia, malaria, and malnutrition, and each are classified as binary ('0' marked the absence of the disease, and '1' marked the presence of the disease), which is related to the unobserved ordinal primary response variable Y (classified as '0', 'no disease'; '1', 'one disease only'; '2', 'two or more diseases') resulting into two thresholds μ, such that $1 \leq \mu \leq c\text{-}1$, with c representing the categories of co-occurrences of the condition of the child. The sample size is not equal across the three levels. So, consider that an individual child i in community j in state k is picked, the probability that Y_{ijk} is in ordered response category c, after accounting for the random effects at community level $\upsilon_{0,jk}$, and state-level $\upsilon_{0,k}$, while assuming a logit function, is given by:

$$P\left(Y_{ijk} = c \middle| \upsilon_{0,jk}, \upsilon_{0,k}\right) = \omega\left[\left(\mu_c - \varphi_{ijk}\right)\right] - \omega\left[\left(\mu_{c-1} - \varphi_{ijk}\right)\right] \quad (9)$$

where $\varphi_{ijk} = \sum_{i=1}^{n} \beta^*_{a,i} W_{a,ijk} + \sum_{j=1}^{m} \beta^*_{b,j} X_{b,jk} + \sum_{k=1}^{p} \beta^*_{c,k} Y_{c,k} + \upsilon_{0,jk} + \upsilon_{0,k}$, an extract from (8), and $\omega(.)$ is the cumulative distribution function (cdf), represented as $\omega(\varphi) = \frac{1}{[1+\exp(-\varphi)]}$. (Raman and Hedeker, 2005).

As proposed in Raman & Hedeker (Raman and Hedeker, 2005), the set $\beta^*_{0,0} = 0$, such that it estimates *C-1* cut-offs. Then, the cumulative probabilities for the ordinal categories $1 \leq c \leq C$ are given as:

$$Pr_{ijk/c} = P\left(Y_{ijk} \leq C \middle| \upsilon_{0,jk}, \upsilon_{0,k}\right) = \omega(\mu_c - \varphi_{ijk}) \quad (10)$$

However, (10) can be written differently as finding the probability of observing the outcome *c* in this format.

$Pr_{ijk/c} = P(Y_{ijk} = C|c,\ \upsilon_{0,jk}, \upsilon_{0,k}) = \omega(\mu_c - \varphi_{ijk}) - \omega(\mu_{c-1} - \varphi_{ijk})$, where μ_0 = -∞ and $\mu_C = +\infty$ (StataCorp., 2021).

The mixed effect ordered logistic regression in (10) is now written in terms of cumulative logits for proportional odds assumption to include random effects at community level $\upsilon_{0,jk}$, and state-level $\upsilon_{0,k}$ as:

$$log\frac{Pr_{ijk/c}}{1-Pr_{ijk/c}} = \mu_c - \left(\sum_{i=1}^{n}\beta_{a,i}^{*}W_{a,ijk} + \sum_{j=1}^{m}\beta_{b,j}^{*}X_{b,jk} + \sum_{k=1}^{p}\beta_{c,k}^{*}Y_{c,k} + \upsilon_{0,jk} + \upsilon_{0,k}\right) \quad (11)$$

Finally, the study obtained the likelihood equations by the standardisation of the random effects at the state level with $\theta_k\sigma_{sta}^2$, and community level with $\theta_{jk}\sigma_{com}^2$, to be on the same scale as the regression estimates, then

$$\varphi_{ijk} = \sum_{i=1}^{n}\beta_{a,i}^{*}W_{a,ijk} + \sum_{j=1}^{m}\beta_{b,j}^{*}X_{b,jk} + \sum_{k=1}^{p}\beta_{c,k}^{*}Y_{c,k} + \theta_{jk}\sigma_{com}^2 + \theta_k\sigma_{sta}^2 \quad (12)$$

4.4.5 Test of assumptions

This section outlined the basic assumptions of the ordered logistic regression and presented a step-by-step approach to the assumptions that were confirmed in the thesis.

4.4.5.1 Assumptions of Ordered Logistic Regression

Four important assumptions ordered logistic regression needs to fulfil before one can trust the results (Laerd Statistics, 2018; Lee, 2019)

1. The ordinal nature of the response variable. The response variable should be categorical that follow a natural order in it, E.g., 0, 1, 2, 3, etc. In this study, the outcome variable of interest, the order of occurrences of MAMM takes the values 0, 1, or 2, representing 'none of the three diseases', 'one of the diseases only', and 'two or more diseases' conditions.
2. At least one or more of the predictor variables are either continuous, ordinal (which may not be taken as ordinal when performing ordinal analysis), categorical or dichotomous variables. However, in this thesis, all the predictor variables are categorical.
3. There must be no multicollinearity among the independent variables. That is, there should not be any two or more predictor variables that are highly correlated with one to another.
4. The proportional odds assumption should not be violated. This assumption means that the coefficients for each pair of outcomes at each cumulative cut-off are the same, resulting in one model.

From equation (12), the covariates *W*, *X*, and *Y* could fall into three categories. The model, which includes covariates that did not violate the proportional assumption, is considered a proportional odds model. Also, the model which contains both covariates that violate and do not violate the proportional assumption is called a partial proportional odds model. The model contains all covariates that violate the proportional assumption is known as the non-proportional odds model (Raman and Hedeker, 2005).

4.4.5.2 Multicollinearity of binary and ordinal logistic

Multicollinearity is a statistical phenomenon characterised by highly correlated predictor variables in a logistic regression model (Midi, Sarkar and Rana, 2010). The presence of multicollinearity can lead to unreliable and unstable estimates and erroneous variances, affecting confidence intervals and hypothesis tests(Midi, Sarkar and Rana, 2010). The problem is that when the independent variables get more highly correlated, determining which predictor variable is causing the effect on the outcome becomes increasingly tricky (Williams, 2015). Identifying these variables is commonly done through the computations of the correlation coefficient matrix for the independent variables, but not a sufficient mode (Midi, Sarkar and Rana, 2010). An additional way is to calculate the tolerance and variance inflation factors (VIF), which estimates how much a coefficient's variance is "inflated" due to linear correlation with other predictors (Allison, 2012). The rule of thumb is that VIF is usually greater than or equal to one. Allison (Allison, 2012) thinks that if VIF is greater than 2.50 it can constitute a problem (Williams, 2015). Others have suggested that VIF between 5 and 10 may be problematic (Williams, 2015; Fissuh, 2017). A way of dealing with multicollinearity is that the objectionable variable is "dropped." However, if the variable has a legitimate place in the model, this might lead to a specification error, which is much worse than multicollinearity (Williams, 2015). For logit transformation cases, as in our study, 'collin' command (written by Philip Ender at UCLA) in STATA was used.

4.4.5.3 Resolving the violation of proportional odds assumption

In ordinal logistic analysis, proportional odds assumptions are often violated (expecting the coefficients of the covariate to be the same for each value of c (categories)). Ignoring the violation may 'lead to incorrect, incomplete, or misleading results' (Williams, 2006). Nevertheless, in some situations, the issue of violation of assumption may not cause serious problems, especially when the sample size is large. This study involved fitting three-level mixed-effects ordinal logistic regression models. To test the violation of proportional assumption in Stata is challenging, and is not straightforward, especially using *brant* and

omodel tests after mixed effect ordered logistic regression (The Stata Forums, 2021). However, this approach is a straightforward generalisation of the single-level model to account for the data set's hierarchical structure (Kandala, 2013). In that case, the thesis adopted a naïve way to check whether the assumption is violated or not. In this study, there is no restriction on theoretical frame regarding the inclusion of any specific independent variable of interest; therefore, all variables that scaled through the multicollinearity test were equally essential and examined for proportionality assumption in the following steps as recommended in (The Stata Forums, 2021):

1. On the full model (considering all the independent variables), brant test was used after ordinal logistic regression to identify which variables were proportional in their coefficients or not. Then the individual predicted probabilities and the mean $(\bar{x}_1)$were computed.
2. Brant test was also performed on the partial model (after removing those variables that violated the proportionality assumption in step 1) and found no more violation of the proportionality assumption. Then, individual predicted probabilities and the mean $(\bar{x}_2)$were computed.
3. The test of difference in the two predicted means $(\bar{x}_1 - \bar{x}_2)$ was computed and found no significant difference at 5% level (both at two- or at one-tailed test).

Given the above, the assumption of non-violation of proportionality was upheld while using the mixed effects ordered logistic regression analysis method to investigate the multiple overlaps in the association between the individual, contextual, and MAMM among children 6-59 months of age in Nigeria.

4.6 Model Building

4.6.1 Outcome variable classifications

Section 4.3.3 Venn diagram was used to express the three outcome variables into the eight possible interactions. The eight interacting sets were coded in the following dichotomous outcomes in Table 4.3, and for each of the diseases, anaemia, malaria, and malnutrition, the score of '0' was allotted to 'no presence of the disease, and a score of '1' was allotted to 'presence of the disease'.

Table 4 3 Coding system used for the outcome classifications

S/N	Variables	Outcomes	Scores
1	No disease	No anaemia No Malaria No malnutrition	0 0 0
2	Anaemia only	Anaemic No malaria No malnutrition	1 0 0
3	Malaria only	No anaemia Malaria positive No malnutrition	0 1 0
4	Malnutrition only	No anaemia No malaria Poorly nourished	0 0 1
5	Anaemia and malaria	Anaemic Malaria positive No malnutrition	1 1 0
6	Anaemia and malnutrition	Anaemic No malaria Poorly nourished	1 0 1
7	Malaria and malnutrition	No anaemia Malaria positive Poorly nourished	0 1 1
8	Anaemia, malaria, and malnutrition	Anaemia Malaria positive Poorly nourished	1 1 1

S/N=Serial numbering

Table 4.4 shows the combination of the outcome classifications from Table 4.3 to form the order of occurrence of the multimorbidity outcomes.

Table 4 4 Distribution of classifications of multimorbidity

S/N	Outcomes	combination	classifications
1	None of the three diseases	1	0

2	Had only one of the three diseases	2, 3, & 4	1
3	Had two or more diseases	5, 6, 7 & 8	2

S/N=Serial numbering

4.6.2 Predictor variables classifications

The predictor variables considered in this thesis were classified into child-, parental-, household-, community-, and state-related variables. The following tables describe the coding methods used for the analysis. All the categorical predictor variables were used as factor variables in analysis (In Stata these are treated like dummy variables)

(i) Child-related variables

Table 4 5 Coding system for child-related variables

Variables	**Classifications**	**Coding**
Age of the child	(i) 6-11 months	0
	(ii) 12-23 months	1
	(iii) 24-35 months	2
	(iv) 36-47 months	3
	(v) 48-59 months	4
Sex of the child	(i) Male	0
	(ii) Female	1
Mother's perceived Birth Size of the child	(i) large	0
	(ii) Average	1
	(iii) small	2
Preceding Birth Interval	(i) None	0
	(ii) 8-24 months	1
	(iii) 25-35 months	2
	(iv) 36-59 months	3
	(v) 60+ months	4
Birth Order	(i) 1st order	0
	(ii) 2nd or 3rd order	1
	(iii) 4th-6th order	2
	(iv) 7th+ order	3

Iron supplement	(i)	No	0
	(ii)	Yes	1
Duration of breastfeeding	(i)	Ever breastfed, not currently breastfed	0
	(ii)	Never breastfed	1
	(iii)	Still breastfeeding	2
Had diarrhoea in last 2 weeks before the survey	(i)	No	0
	(ii)	Yes	1
Had fever in last 2 weeks before the survey	(i)	No	0
	(ii)	Yes	1
Child had acute respiratory infection in last 2 weeks before the survey	(i)	No	0
	(ii)	Yes	1
Vitamin A consumption	(i)	No	0
	(ii)	Yes	1
Treatment for intestinal worms in the last 6 months	(i)	No	0
	(ii)	Yes	1
Place of delivery	(i)	Home	0
	(ii)	Public Health facility	1
	(iii)	Private health facility	2
	(iv)	Elsewhere	3

(ii) Parental-related variables

Table 4 6 Coding system for parental-related variables

Mother's age in 10-year group	(i)	15-24 years	0
	(ii)	25-34 years	1
	(iii)	35years^{+}	2
Mother's age at first birth	(i)	10-24 years	0
	(ii)	25-36 years	1
	(iii)	37-49 years	2
Mother working status	(i)	Not working	0
	(ii)	Working	1

Mother's educational status	(i)	No education	0
	(ii)	Primary	1
	(iii)	Secondary	2
	(iv)	Tertiary	3
Father's educational status	(i)	No education	0
	(ii)	Primary	1
	(iii)	Secondary	2
	(iv)	Tertiary	3
Father's occupation	(i)	Not working	0
	(ii)	Working	1
Mother's body mass index (kg/m2)	(i)	<18.5	0
	(ii)	18.5-25.0	1
	(iii)	>25.0	2
Mother's anaemia status	(i)	Normal	0
	(ii)	Anaemic	1
ANC attendance/Health seeking	(i)	0	0
	(ii)	1-3	1
	(iii)	≥4	2
Religion status	(i)	Catholic	0
	(ii)	Protestant	1
	(iii)	Muslim	2
	(iv)	Others (traditional)	3
Mother's iron supplementation during pregnancy	(i)	No	0
	(ii)	Yes	1

(iii) Household-related variables

Table 4 7 Coding system for household-related variables

Wealth status	(i)	Poorest	0
	(ii)	Poor	1
	(iii)	Middle	2
	(iv)	Rich	3
	(v)	Richest	4
Household had bed net	(i)	No	0

	(ii)	Yes	1
Household size	(i)	2-3	0
	(ii)	4-6	1
	(iii)	7-9	2
	(iv)	10+	3
Under-five years child slept under net	(i)	No child	0
	(ii)	All children	1
	(iii)	Some children	2
	(iv)	No net in household	3
Number of children U5 in household	(i)	0-3	0
	(ii)	4-6	1
	(iii)	7 and above	2
Improved source of drinking water	(i)	No	0
	(ii)	Yes	1
Improved Type of toilet facilities	(i)	No	0
	(ii)	Yes	1
Improved Floor material type	(i)	No	0
	(ii)	Yes	1
Sex of household head	(i)	Male	0
	(ii)	Female	1
Household head educated	(i)	No education	0
	(ii)	Primary	1
	(iii)	Secondary	2
	(iv)	Tertiary	3
Shared toilet facilities with others household members	(i)	No	0
	(ii)	Yes	1
Use biomass for cooking	(i)	No	0
	(ii)	Yes	1
Under-5 slept under a mosquito net last night	(i)	No	0
	(ii)	Yes	1

(iv) Community-related variables

Table 4 8 Coding system for household-related variables

Proportion of community wealth level	(i) (ii)	No Yes	0 1
Proportion cluster distance to health facility is no big problem	(i) (ii)	No Yes	0 1
Proportion of community maternal education level	(i) (ii)	No Yes	0 1
Proportion of community household with no bed net	(i) (ii)	No Yes	0 1

(v) Area-related variables

Table 4 9 Coding system for area-related variables

State Multidimensional Poverty Index (SMPI)	(i) (ii) (iii) (iv) (v)	Lowest Mild Average Above average Highest	0 1 2 3 4
State human development index (SHDI)	(i) (ii) (iii) (iv) (v)	Lowest Low Average High Highest	0 1 2 3 4
Gender inequality index (GII)	(i) (ii) (iii) (iv) (i)	Lowest Low Average High Highest	0 1 2 3 4
Region of residence	(i) (ii) (iii) (iv) (v)	North-Central North-East North-West South-East South-South	0 1 2 3 4

	(vi)	South-West	5
Place of residence	(i)	Rural	0
	(ii)	Urban	1

4.6.3 Postestimation techniques

After mixed effect ordinal logistic analysis, post estimation techniques of special interest include estimating intraclass correlations (ICC), nested groups' compositions, and displaying standard deviations and correlations. The most important in this group is the ICC which is described in more detail as follows:

4.6.3.1 Intraclass correlation (ICC)

The intraclass correlation coefficient (ICC) represents the proportion of the total variation in the model that can be accounted for by variations across the different levels of clusters. For example, in our model (three-level model), two intraclass correlation coefficients were identified: the one about children/individuals nested in community-level and community-level groups nested in the state-level group (Prestevez, 2016; Rozi *et al.*, 2016). Therefore:

$$ICC_{com} = Corr\left(\eta^*_{ijk}, \eta^*_{i'jk}\right) = \frac{\sigma^2_{com} + \sigma^2_{sta}}{\sigma^2_{com} + \sigma^2_{sta} + \frac{\pi^2}{3}} \quad (13)$$

ICC_{com} is the correlation between two children/individuals (unit of analysis) within the same community and state (MLwiN User Forum., 2009; Leckie *et al.*, 2020; StataCorp., 2021).

But equation (13), in terms of the variance partition coefficient (VPC) differs as it does not have a corresponding interpretation, therefore

$$VPC_{com} = \frac{\sigma^2_{com}}{\sigma^2_{com} + \sigma^2_{sta} + \frac{\pi^2}{3}} \quad (14)$$

refers to the proportion of the total variance in the same state, but different communities (Leckie *et al.*, 2020)

$$ICC_{sta} = Corr(\eta^*_{ijk},\ \eta^*_{i'j'k}) = \frac{\sigma^2_{sta}}{\sigma^2_{com} + \sigma^2_{sta} + \frac{\pi^2}{3}} \quad (15)$$

ICC_{sta} represents the correlation between two children/individuals within the same state but who live-in different communities/clusters. VPC refers to the proportion of the total variance attributable between state levels (Leckie *et al.*, 2020).

From (13), (14), and (15), σ^2_{com} is across community variance, σ^2_{sta} is the across the state variance, and $\frac{\pi^2}{3} \simeq 3.29$ is the between children/individuals' variance with scale factor 1, and

for standard logistic distribution (Gabr, 2016). However, there is no definition for individual-level intraclass correlation (StataCorp., 2021).

Unlike the correlation coefficient between two variables whose values fall between -1 and +1, the values of intraclass correlations are between 0 and 1. The 95% confidence interval for the ICCs can be obtained through logit transformation of the point estimate of the ICCs (StataCorp., 2021) using

$$\text{Logit}\left(\overline{icc}^{(g)}\right) \pm z\alpha_{/2} \frac{\overline{SE}\left(\overline{icc}^{(g)}\right)}{\overline{icc}^{(g)}\left(1-\overline{icc}^{(g)}\right)} \quad (16)$$

where $\overline{icc}^{(g)}$ the point estimate of the intraclass correlation of level g

$\overline{SE}\left(\overline{icc}^{(g)}\right)$ is the standard error of the point estimate

$z\alpha_{/2}$ is the 97.5th quantile of the standard normal distribution with α = 5%, and

Logit is given as in (3) and (7) above.

Let x_u and x_l be the upper and lower values, respectively, of the interval (16), then the 95%CI for $ICC^{(g)}$ is given by $\left(\frac{1}{1+e^{-x_l}}, \frac{1}{1+e^{-x_u}}\right)$.

The values of ICCs help to establish the need for multilevel analysis as against the single-level analysis. The rule of thumb (but not a standard rule all the time) could be that hierarchical modelling may not be necessary when the ICC is less than 5% at the null model (Heck, Thomas and Tabata, 2014).

4.6.3.2 Median odds ratios

Some contentions regarding whether using intraclass correlation and its associated measures on the logistic scale to explain the geographical heterogeneity in epidemiological studies is appropriate. Studies have argued that in multilevel linear regression, individual and geographical heterogeneities are on the same scale, making between-level partitioning easy. Nevertheless, this is not the case in multilevel dichotomous regression, where the individual level is on the probabilistic scale, and the geographic level is on the logistic scale, making comparison difficult (Merlo *et al.*, 2006). Lian (Lian, 2015) noted that the spatial variation in the multilevel model denoted by the area-level variance does not have meaningful units and is challenging to interpret in epidemiology. Alternative measures are the median odds ratio (MOR) and interquartile odds ratio (IqOR). In addition to computing the ICCs, the MORs were computed and interpreted.

The MOR is the median of the odds ratio between the area or community at highest risk and the area or community at lowest risk of MAMM. In other words, MOR gave the mean

difference of the risk of multimorbidity of two children with the same level-1 characteristics and picked randomly from two states or communities. In a more practical interpretation, MOR tells us how much of an increased risk of MAMM is for a child moving from one state or community to another state or community, respectively, with a higher risk of the outcomes. The formula for computing MOR is given as:

$$MOR_{sta} = \exp\left(\sqrt{2\ x\ \sigma^2_{sta}}\ x\ 0.6745\right)$$

Where 0.6745 is the $Z_{0.75}$ of a standard normal distribution with mean 0 and standard deviation1, and σ^2_{sta} is the state level variance. Alternatively:

$$MOR_{sta} = \exp\left(\sqrt{0.9099\ x\ \sigma^2_{sta}}\right)$$

The value of MOR will always be greater or equal to 1. MOR=1 signifies no difference in the probability of a child having two or more combinations of anaemia, malaria, and malnutrition between states, while greater than 1 indicates differences in the state level.

Also, other standard post-estimation techniques to help understand the model are described as follows.

4.6.3.3 Assessing the Model fit statistic

The model fit was determined using the combination of the following three measures:

(i) Evaluating the log-likelihood

The log-likelihood was computed to measure the goodness of fit of the model. The higher the log-likelihood, the better the model fit (ZACH, 2021). The values of log-likelihood range from -∞ to +∞. The default integration method in STATA is the *'mvaghermite'* that computes for mean and variance adaptive Gauss-Hermite quadrature, which has been used for random-effect models. The log-likelihood compared with a chi-square given as twice the difference between the log-likelihood of the 'new' (unrestricted) model and that of the 'baseline' (restricted) model, with a degree of freedom equals the difference between the number of parameters in the new model and the baseline model.

$$\chi^2 = 2[ll(new) - ll(baseline)],$$

$$where, df = parameters(new) - parameters(baseline)$$

Under this condition, the null hypothesis is that the two models are not different in their fitting, against the alternative hypothesis that the new model fits significantly better than the baseline model at the p-value<0.05.

(ii) Evaluating the Akaike's information criterion (AIC) and Bayesian information criterion (BIC)

This study evaluated ten models with varied numbers of predictors. AIC was used to measure how well each model fits the data. The AIC is a function of the number of predictors in the model and the log-likelihood. As much as possible, AIC penalises the models for using more parameters to avoid over-fitting and chooses the model that explains more variations in the dependent variable (Bevans, 2021). The model with the lowest value of AIC was considered the best fit, and if the difference between the AICs of the models being compared was more than 2, it was considered a better fit. The AIC has a derivation from the frequentist probability. Additionally, the Bayesian information criterion (BIC) complements the AICs for model fit selection. Given a set of models for the data, the smaller the BIC, the better fit the model. Just as in AIC, the BIC penalises for increased parameters. BIC was derived from Bayesian probability (Brownlee, 2019). When the decision criteria for AIC and BIC did not agree, the AIC was used as a preference for our choice of a better fit.

(iii) Significance of predictor estimates

The predictor estimates were given in terms of proportional odds ratios and were obtained by stating the '***or'*** options in the mixed effect ordered logistic regression command. In this study, the response variables are in 3-classes (k=0, 1, & 2), and should be seen from a cumulative perspective such that comparing children of certain predictor's category having the highest class (k=2) versus those in the combined classes of (k=0 or 1) of the response variable, have the proportional odds times larger (in the case odds ratios is greater than one), or times smaller (in the case odds ratios is less than one), or no difference (in the case odds ratio is equal to one), when compared with the children in the predictor's reference category, while other predictors in the model are held constant. However, for a continuous predictor variable, the interpretation would be that for every unit change in the predictor variable, the odds of children in the class (k=2) versus combined classes of (k=0 or 1) are the proportional odds times larger (in the case odds ratios is greater than one), or times smaller (in the case odds ratios is less than one), or no difference (in the case odds ratio is equal to one). For every proportional odds ratio, the 95% confidence interval was reported indicating the lower and upper limits within which there is 95% chance for the true population parameter lies. All statistical significance was determined at $p<0.05$ level.

4.6.4 Multilevel models Building

In this study, the multilevel mixed effect ordinal logistic models were fitted systematically at the first step using the five major components (child-, parental- household-, cluster-, and state-related) of predictors considered in this project (Table 4.10). This fitting was done to

reduce the risk of over-fitting (Hartnell, 2011), and to control the complexity in adding components of the related predictors.

Table 4 10: Overview of the model component structures at different predictors level

Model	Component structures	Predictors
0	Variance component only	No predictor
1	Child-related only	Sex, age, birth size, birth order, prebirth interval, Child took iron syrup, child breastfeeding status, child took deworming syrup, the child had fever in the last two weeks before the survey
2	Parental-related only	Maternal educational status, maternal residing with partner, maternal religious status, maternal anaemia status, maternal body weight status, paternal work status
3	Household-related only	Household wealth status, household head age, children under-5 who slept under bed net last night before the survey, household size,
4	Community-related only	Community wealth status, community maternal education status, low community distance from the health facility, low community with bed net
5	State-related only	Multidimensional poverty index, human development index, Gender inequality index, region of residence, place of residence

The second stage of the model fitting was to subsequently add each component of related predictors to the child-related component (model 1). By adding model 2 to model 1, model 3 to model 1, combined model 1 to model 2 to model 3, then add model 4, and lastly, add model 5 (Table 4.11).

Table 4 11 Overview of the model component structures combining predictors at different level

Model	Component structures	Predictors
6	Model 1 + Model 2 (Child-related + Parental-related)	Sex, age, birth size, prebirth interval, child took iron syrup, child breast feeding status, child took deworming syrup, child had fever in the last two weeks before the survey, child's place of delivery, maternal educational status, maternal residing with partner, maternal antenatal care visit, maternal religious status, maternal anaemia status, maternal body weight status, paternal work status
7	Model 1 + Model 3 (Child-related + Household-related) The essence of this stage was done to investigate the changes that may occur to model 1 relative to model 3	Sex, age, birth size, birth order, prebirth interval, child took iron syrup, child breast feeding status, child took deworming syrup, child had fever in the last two weeks before the survey, household wealth status, children under-5 who slept under bed net last night before the survey, sex of household head, household size
8	Model 1 + Model 2 + Model 3 (Child-related + Parental-related + Household-related) (Individual level characteristics)	Sex, age, birth size, birth order, prebirth interval, child took iron syrup, child breast feeding status, child took deworming syrup, child had fever in the last two weeks before the survey, maternal educational status, maternal residing with partner, maternal religious status, maternal anaemia status, maternal body weight status, paternal work status, household wealth status, children under-5 who slept under bed net last night before the survey, sex of household head, household size
9	Model 1 + Model 2 + Model 3 + Model 4	Sex, age, birth size, birth order, prebirth interval, child took iron syrup, child breast feeding status, child took deworming syrup, child

	(Child-related + Parental-related + Household-related + Community-related) (Individual & community level characteristics)	had fever in the last two weeks before the survey, maternal educational status, maternal residing with partner, maternal religious status, maternal anaemia status, maternal body weight status, paternal work status, household wealth status, children under-5 who slept under bed net last night before the survey, sex of household head, household size, community wealth status, community maternal education status, low community distance from health facility, low community with bed net
10 (Full Model)	Model 1 + Model 2 + Model 3 + Model 4 + Model 5 (Child-related + Parental-related + Household-related + Community-related + Area-related) (Individual, community, & state level characteristics)	Sex, age, birth size, birth order, prebirth interval, child took iron syrup, child breast feeding status, child took deworming syrup, child had fever in the last two weeks before the survey, maternal educational status, maternal residing with partner, maternal religious status, maternal anaemia status, maternal body weight status, paternal work status, household wealth status, children under-5 who slept under bed net last night before the survey, sex of household head, household size, community wealth status, community maternal education status, low community distance from health facility, low community with bed net, multidimensional poverty index, human development index, region of residence, place of residence

Furthermore, some interaction terms were considered in this analysis in addition to the chosen model of interest (model 10). by adjusting model 10 for all the possible interaction terms between Child's age, sex, and household wealth quintiles on the MAMM among children aged 6-59 months in Nigeria. A two-way interaction effect tests the moderation effect of one predictor variable over the relationship between the other predictor and the outcome of interest (multimorbidity) (Dawson, 2014). For instance, a two-way interaction effect of a child's sex and wealth quintiles on multimorbidity outcome is the conditional association between wealth quintiles and multimorbidity relative to the child's sex. Similarly, a three-way interaction effects of a child's age, sex, and household wealth explain the effect of the child's sex (second variable) on the influence household wealth quintile and multimorbidity is moderated by the child's age (first variable). In other words, the variations in the child's sex in the effects of wealth index on multimorbidity differ by the child's age. Therefore, Table 4.12 shows the five models generated to illustrate these analyses.

Table 4 12 Overview of the model component structures with interaction terms.

Model	**Component structures**	**Predictors**
11	Model 10 + interactions of sex and household wealth	Sex, age, birth size, birth order, prebirth interval, the child took iron syrup, child breastfeeding status, child took deworming syrup, the child had fever in the last two weeks before the survey, maternal educational status, maternal residing with partner, maternal religious status, maternal anaemia status, maternal body weight status, paternal work status, household wealth status, children under-5 who slept under bed net last night before the survey, sex of household head, household size,

		community wealth status, community maternal education status, low community distance from health facility, low community with bed net, multidimensional poverty index, human development index, region of residence, child's sex*household wealth
12	Model 10 + interactions between sex and age	Sex, age, birth size, birth order, prebirth interval, child took iron syrup, child breastfeeding status, child took deworming syrup, child had fever in the last two weeks before the survey, maternal educational status, maternal residing with partner, maternal religious status, maternal anaemia status, maternal body weight status, paternal work status, household wealth status, children under-5 who slept under bed net last night before the survey, sex of household head, household size, community wealth status, community maternal education status, low community distance from the health facility, low community with bed net, multidimensional poverty index, human development index, region of residence, child's sex*child's age
13	Model 10 + interactions between age and household wealth	Sex, age, birth size, birth order, prebirth interval, child took iron syrup, child breastfeeding status, child took deworming syrup, child had fever in the last two weeks before the survey, maternal educational status, maternal residing with partner, maternal religious status, maternal anaemia status, maternal body weight status, paternal work status, household wealth status, children under-5 who slept under bed net last night before the survey, sex of household head, household size, community wealth status, community maternal education status, low community distance from the health facility, low community with bed net, multidimensional poverty index, human development index, region of residence, child's age*household wealth
14	Model 10 + interactions of sex and household wealth + interactions between sex and age + interactions between age and household wealth	Sex, age, birth size, birth order, prebirth interval, child took iron syrup, child breastfeeding status, child took deworming syrup, child had fever in the last two weeks before the survey, maternal educational status, maternal residing with partner, maternal religious status, maternal anaemia status, maternal body weight status, paternal work status, household wealth status, children under-5 who slept under bed net last night before the survey, sex of household head, household size, community wealth status, community maternal education status, low community distance from the health facility, low community with a bed net, multidimensional poverty index, human development index, region of residence, child's age*household wealth, child's age*child's sex, child's sex*household wealth
15	Model 14 + interactions between sex, age, and household wealth	Sex, age, birth size, birth order, prebirth interval, child took iron syrup, child breastfeeding status, child took deworming syrup, child had fever in the last two weeks before the survey, maternal educational status, maternal residing with partner, maternal religious status, maternal anaemia status, maternal body weight status, paternal work status, household wealth status, children under-5 who slept under bed net last night before the survey, sex of household head, household size, community wealth status, community maternal education status, low community distance from the health facility, low community with a bed net, multidimensional poverty index, human development index, region of residence, child's age*child's sex*household wealth

4.7 The chapter summary

An outline of the research methodology and data used in the current study is provided in this Chapter. The study's main aim was to investigate the multiple overlaps in the impact of individual and contextual variables on the prevalence of the multimorbidity of anaemia, malaria, and malnutrition among children aged 6 to 59 months in Nigeria. The study's specific objectives were first to investigate the individual and contextual risk factors associated with multimorbidity of anaemia, malaria, and malnutrition (MAMM) among children aged 6-59 months in Nigeria. The second is to determine the interaction effects of a child's age, sex, and household socioeconomic status on the individual and contextual risk factors of MAMM among children aged 6-59 months living in Nigeria. Given these, nine research questions were formulated to direct the study.

This study uses two separate data sets, with one of the data sets combined with the other. The first set of data came from the 2018 Nigeria Demographic and Health Survey (also known as the 2018 NDHS), while the second set came from the 2018 National Human Development Report (known as NHDR 2018). The study applied four levels of statistical analysis. At the first level of analysis, the thesis addressed research questions one, two, and three. At the second level of analysis, questions four and five were addressed. Given the hierarchical nature of the 2018 NDHS data set, it identified some clustering in the data such that children, parents, and household were taken as individual characteristics at level-1, nested in communities/clusters at level-2, which in turn are nested in 36 states of Nigeria and Federal Capital Territory (FCT) at level-3. The third level of analysis proffers solutions to questions six, seven, and eight, where it conducted a series of bivariate analyses of the association between the child-, parental-, household-, and community-related variables and the interactions between the three outcome diseases. Finally, at the fourth level, the interaction effects of a child's sex, age, and household socioeconomic status on the impact of individual and contextual risk factors of MAMM among children 6-59 months of age in Nigeria were computed

The following four chapters were designed to address each level of quantitative analysis. Chapter 5 addresses the first level of analysis (answers research questions 1-4), Chapter 6 addresses the second level of analyses (question 5), while Chapter 7 devotes to the 3rd level of analysis and addresses questions 6, 7, and 8. Chapter 8 answers question 9 at the 4th level of analysis

Chapter 5 Quantitative analysis 1

5.0 Introduction

This Chapter started with the presentation of the sample description of variables considered in the analyses. The sample was based on 10,451 children aged 6-59 months whose data were collected for the outcome variables (anaemia, malaria, and malnutrition) in the 2018 edition of the Nigeria Demographic and Health Survey (NDHS).

5.1 Findings

This section presents the answers to research questions 1 – 4 raised in this study.

5.1.1 Baseline description of independent variables

Research question 1:

What are the descriptions of individual and contextual characteristics of children aged 6-59 months in Nigeria at baseline (response rates), as captured in 2018 NDHS?

The baseline sample characteristics comprised the description of all the variables considered in this study. If sample weights are correctly determined and used in tabulation, either an oversampling or an under-sampling of any stratum does not affect representation. The dataset in this study included sample weights, which were used for all tabulation and the preliminary model exploration (Kandala, 2013). "*Svyset"* command in Stata was used to adjust for under- and over-reporting in the survey using a weighting factor of (v005/1000000), where v005 is the sample weight (Kawo, Asfaw and Yohannes, 2018; Adedokun, 2020). Therefore, a weighted sample of 10,481 children was extracted for this study. The descriptions of individual and contextual characteristics are presented in the following categories: child-, parental-, household-, community-, and state-related variables. The percentages of each category of the variables were based on the total number available for each variable.

5.1.1.1 Child-related characteristics

Table 5.1 shows that 51% (5363/10481) of the children were male. Children's age categories differ by 12 months interval, except in the first category (6-11 months). About 24% (2488/10481) of the children in the age group, 12-23 months, and 12% (1276/10481) in the 6 -11 months category. More than a third of the children were perceived as average birthweight. Only about 26% (2751/10478), 16% (1711/10479), and 13% (1380/10478) reported having fever, cough, and diarrheal, respectively, in the last two weeks before the survey. More than 50% of the children were born at home compared to 45% born in health facilities (public and private).

Table 5 1 Distribution of child-related characteristics

Variables	N	%
Sex of child		
Male	5363	51.2
Female	5118	48.8
Total	10481	100
Child's age in group		
6-11 months	1276	12.2
12-23 months	2488	23.7
24-35 months	2219	21.2
36-47 months	2276	21.7
48-59 months	2221	21.2
Total	10481	100
Child's birth Size		
Small	950	9.2
Average	8141	78.7
Large	1255	12.1
Total	10346	100
Preceding birth interval		
None	2012	19.2
8-24 months	2263	21.6
25-35 months	2970	28.4
36-59 months	2404	23
60+ months	811	7.8
Total	10461	100
Took Vitamin A supplements		
No	5443	52.2
Yes	4992	47.8
Total	10435	100
duration of breastfeeding		
ever breastfed, not currently breastfeeding	7648	73.1
never breastfed	171	1.6
still breastfeeding	2644	25.3
Total	10481	100
Took Iron | supplements		
No	8443	80.8
Yes	2002	19.2
Total	10445	100
Had Fever in last 2 weeks before the survey		
No	7727	73.8
Yes	2751	26.3
Total	10478	100
Had cough in last 2 weeks before the survey		
No	8768	83.7
Yes	1711	16.3
Total	10479	100
Diarrheal in last 2 weeks before the survey		
No	9098	86.8
Yes	1380	13.2
Total	10478	100
Treatment for intestinal worms in the last 6 months		
No		
Yes		
Place of child's delivery		
Home	5494	52.4
Public facility	3058	29.2
Private facility	1712	16.3
Elsewhere	217	2.1
Total	10481	100

5.1.1.2 Parental-related characteristics

In Table 5.2, over 50% (5427/10481) of the children in the sample whose mothers/caregivers were aged 25 - 34 years old. About a quarter of the sample were children whose mothers/caregivers worked. Children whose mothers/caregivers had their first baby were more than 84% (8822/10481) in the sample. Mothers/caregivers of 39% (4087/10481) of the children

have no formal education compared with just 10% (1017/10481) with higher education. Fewer than 10% (897/10014) of the children whose mothers/caregivers do not reside with their partner. Mothers of about 64% (4182/6555) of the children attended antenatal care more than three times during their conception. Mothers/caregivers of over 58% (5946/10198) of the children were anaemic. Only about 3% (311/10481) have fathers that do not work, and 30% (2984/9882) are with no formal education.

Table 5 2 Distribution of parental-related characteristics

Variables	N	%
Maternal age group in 10 years		
15-24 years	2132	20.4
25-34 years	5427	51.8
35 years+	2922	27.9
Total	10481	100
Respondent is currently working		
No	3084	29.4
Yes	7397	70.6
Total	10481	100
Maternal age at first birth		
10-24 years	8822	84.2
25-36 years	1628	15.5
37-49 years	30	0.3
Total	10481	100
Highest educational level		
No education	4087	39
Primary	1688	16.1
Secondary	3688	35.2
Higher	1017	9.7
Total	10481	100
Currently residing with husband/partner		
Living with her partner	9117	91
Staying elsewhere	897	9
Total	10014	100
Maternal autonomy level		
Low autonomy	5223	49.8
High autonomy	5258	50.2
Total	10481	100
Total	10481	100
Ante-Natal Care visits during pregnancy of the child		
None	1383	21.1
1-3 visits	991	15.1
4 and above visits	4182	63.8
Total	6555	100
Maternal religious status		
Catholic	1050	10
Other Christians	3533	33.7
Islam	5832	55.6
Traditional & others	66	0.6
Total	10481	100
Mother took iron tab during pregnancy		
No	1840	27.7
Yes	4812	72.3
Total	6652	100
Mother's anaemia status		
Not Anaemic	4252	41.7
Anaemic	5946	58.3
Total	10198	100
Maternal body mass index		
Normal	5401	60.8
underweight	899	10.1
Overweight	1704	19.2
Obese	882	9.9
Total	8887	100
Paternal Work Status		
No	311	3
Yes	10170	97
Total	10481	100
Partner education status		
No education	2984	30.2
Primary education	1444	14.6
Secondary education	3833	38.8
Tertiary education	1620	16.4
Total	9882	100

5.1.1.3 Household-related characteristics

From Table 5.3, the number of children 6-59 months in each household wealth quintile varies. There were more children in the richer household, 21.1% (2212/10481), followed by the middle wealth household, 21% (2197/10481).

Table 5 3 Distribution of household-related characteristics

Variables	N	%
Household wealth index		
Poorest	1954	18.6
Poorer	2027	19.3
Middle	2197	21
Richer	2212	21.1
Richest	2091	20
Total	10481	100
Household head age group		
less 34 years	2936	28
35-44 years	4046	38.6
45-55 years	2158	20.6
56 years+	1340	12.8
Total	10481	100
Children under 5 slept under a mosquito bed net last night		
No child	1351	13
All children	4841	46.5
Some children	1017	9.8
No net in household	3198	30.7
Total	10406	100
Under-5 in household		
0-3	9340	89.1
4-6th	1077	10.3
7th+	65	0.6
Total	10481	100
Household had electricity		
No	4414	42.6
Yes	5948	57.4
Total	10362	100
Source of drinking water		
Unimproved source	3196	30.5
Improved source	7285	69.5
Total	10481	100
Type of toilet facility		
Unimproved toilet facilities	4737	45.2
Improved toilet facilities	5744	54.8
Total	10481	100
Type of cooking fuel		
Electricity & Gas	1252	12
Biofuel	9225	88.1
Total	10477	100
Floor Materials		
Unimproved floor materials	2971	28.4
Improved floor materials	7510	71.7
Total	10481	100
Wall Materials		
Unimproved wall materials	3367	32.1
Improved wall materials	7114	67.9
Total	10481	100
Sex of household head		
Male	9357	89.3
Female	1124	10.7
Total	10481	100
Shared Toilet Facilities		
No	4915	61.8
Yes	3044	38.3
Total	7959	100
Household had mosquito bed net for sleeping		
No	3225	30.8
Yes	7256	69.2
Total	10481	100
Number of people in the household		
2-3	1014	9.7
4-6	5001	47.7
7-9	2512	24
10+	1954	18.6
Total	10481	100
Youngest child's stool disposed Properly (Unsafe)		
No	3710	56.3
Yes	2884	43.7
Total	6594	100

About 38% (4046/10481) of the children are from a household whose head is middle aged, 35-44 years. 34% (3578/10481) of the children reside in a two-bedroom household compared with 8.4% (884/10481) who live in a household with more than four bedrooms. A little above 57% (5948/10362) reside in a household connected to electricity. 30% (3196/10481) of the children aged 6-59 months were living in a household not connected to an improved source of drinking water.

Furthermore, about 89% (9357/10481) of the children reside in a male-headed household. The households of about 31% (3225/10481) of the children do not have mosquito bed nets for sleeping. There were more children in a household with 4-6 members, 47.7% (5001/10481), followed by a household with 7-9 members, 24% (2512/10481).

5.1.1.4 Community-related characteristics

Table 5.4 aggregated the distribution of cluster wealth levels from the household wealth quintiles. In the sample, there were 54% (5698/10481) of the children aged 6-59 months residing in a community classified as high wealth level (median and above), compared with 46% (4783/10481) of the children living in low community wealth level (less than median). About 54% (5629/10481) of the children were associated with a high (median and above) proportion of community mothers/caregivers whose distance to a health facility to get medical help for themselves is no big problem.

Similarly, the proportion of maternal community education level was constructed by aggregating the maternal education level and computing the mean education level for every respondent. This was classified as either low (below median) or high (median and above). An approximately equal number of children (50.8% and 49.2%) were associated with low and high community maternal education levels, respectively. In addition, children from the high proportion of community households with no bed net were more, 51.3% (5374/10481), compared to those children from the low proportion of community households with no bed net, 48.7% (5107/10481).

Table 5 4 Distribution of community-related characteristics

Variables	N	%	95% CI
Proportion of community wealth level			
Low	4783	45.6	
High	5698	54.4	
Total	10481	100	
Proportion community distance to health facility is no big problem			
Low	4852	46.3	
High	5629	53.7	
Total	10481	100	
Proportion of community maternal education level			
Low	5156	49.2	
High	5325	50.8	
Total	10481	100	
Proportion of community households with no bed net			
Low	5107	48.7	
High	5374	51.3	
Total	10481	100	

5.1.1.5 Area-related characteristics

Table 5.5 presents the sample of children's distributions by state-related variables. Three variables, the multidimensional poverty index (MPI), the human development index (HDI), and Gender Inequality Index (GII) were extracted from the 2018 National Human Development Report and incorporated into the 2018 NDHS. In MPI, 30.2% (3168/10481) of children aged 6-59 months were associated with above-average deprivation in states, followed by 22.5% (2359/10481) associated with averagely deprived in MPI states. Similarly, 26.3% (2759/10481) of the children are from the states with high human development index, followed by children from the states with low HDI, 23.5% (2464/10481). Also, about 40% (4145/10481) of the children are from tates classified to have high GII followed by states with lowest GII (27%).

Table 5 5 Distribution of state-related characteristics

Variables	N	%
Multidimensional poverty index by state		
Highly deprived	899	8.6
Above averagely deprived	3168	30.2
Averagely deprived	2359	22.5
Mildly deprived	1994	19
Lowest deprived	2062	19.7
Total	10481	100
Human development index (HDI) by state		
Lowest HDI	2232	21.3
Low HDI	2464	23.5
Average HDI	2271	21.7
High HDI	2759	26.3
Highest HDI	754	7.2
Total	10481	100
Gender inequality index by State (GII)		
Lowest GII	2810	26.8
Low GII	1206	11.5
Average GII	986	9.4
High GII	4145	39.6
Highest GII	1333	12.7
Total	10481	100
Region of residence		
North-central	1451	13.8
North-east	1635	15.6
North-west	3050	29.1
South-east	1368	13.1
South-south	1118	10.7
South-west	1859	17.7
Total	10481	100
Type of place of residence		
Urban	4624	44.1
Rural	5857	55.9
Total	10481	100

Furthermore, among the six geopolitical zones in Nigeria, children from South-south were the least represented, 10.7% (1118/10481), while children from North-west geopolitical zone had the highest, 29.1% (3050/10481). More children aged, 6-59 months were captured in the survey from the rural area, 55.9% (5857/10481), compared with their counterparts from the urban area, 44.1% (4624/10481).

5.2 Spatial distribution of the proportions of the three outcomes

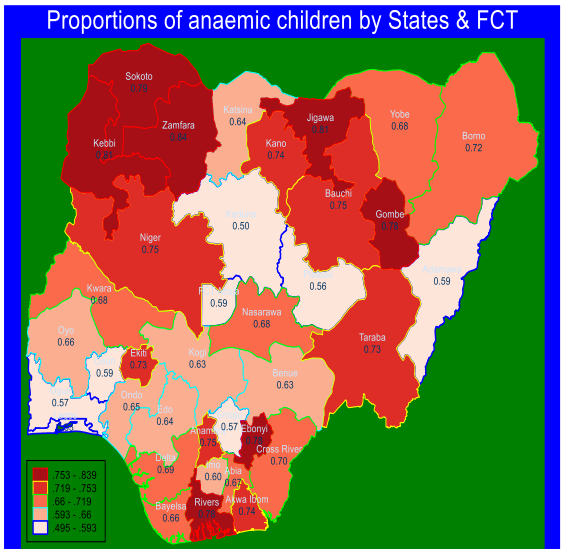
Research question 2

Are there variations in the proportion of children in each of the three outcomes of anaemia, malaria, and malnutrition across the states and regional levels?

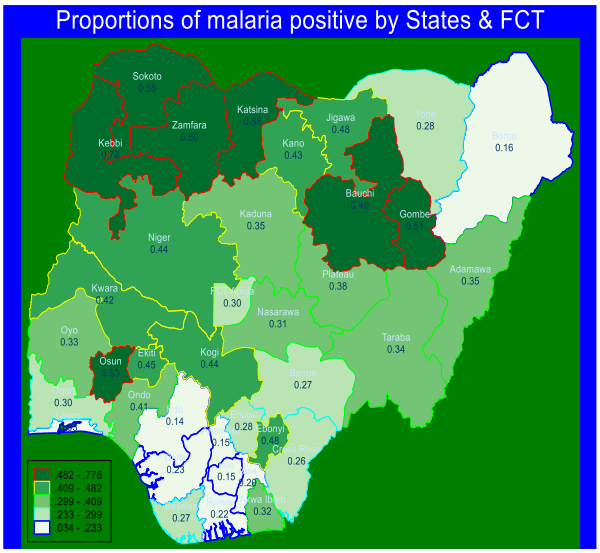
5.2.1 Spatial distribution of proportions of the three outcome variables by states

Figure 5.1 presents the spatial variations in the proportion of each of the three outcome variables by states and FCT. Map (Fig. 5.1a) shows Nigeria's proportion of anaemic children. Zamfara state, with 0.84 (266/317), had the highest proportion of anaemic children in Nigeria, followed by Jigawa state, 0.81 (286/351). Only three states, Kaduna, Bauchi, Adamawa, (and FCT), from northern Nigeria, had a proportion of anaemic children in the lowest quintile, with Kaduna, 0.50 (283/572), having the lowest proportion of anaemic children in the country. In

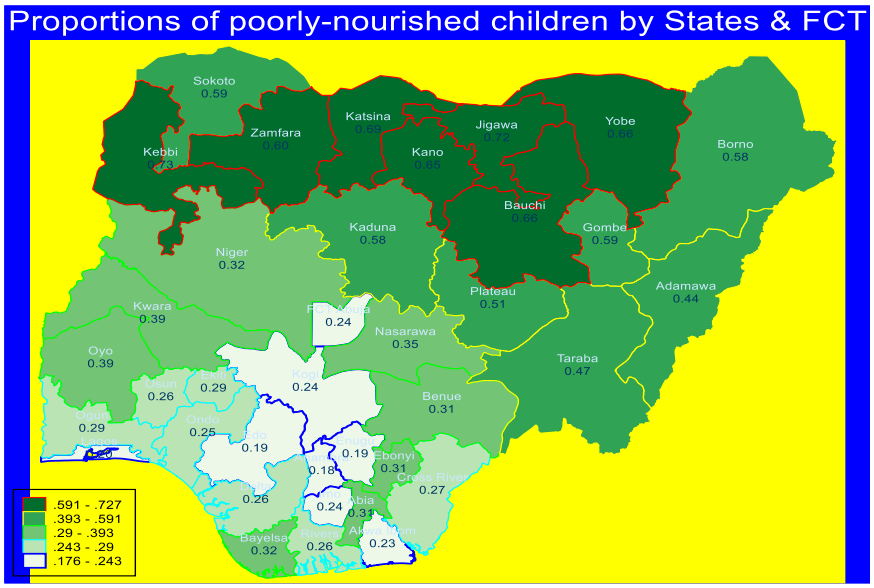
the case of malaria (Fig. 5.1b), the proportion of malaria-positive children was highest (topmost quintile) among those living in the north-west region (Sokoto, Zamfara, Kebbi, Katsina), including two states from the north-east region (Bauchi and Gombe), and Osun state (in South-west), while children living in the south-east region were least prone to malaria attack. Also, for malnutrition (Fig. 5.1c), the proportions of poorly nourished children were generally highest in northern Nigeria- Kebbi, Zamfara, Katsina, Kano, Jigawa, Bauchi and Gombe states. Edo and Lagos states are among the states with the least poorly nourished children.



(a): Anaemia



(b): Malaria



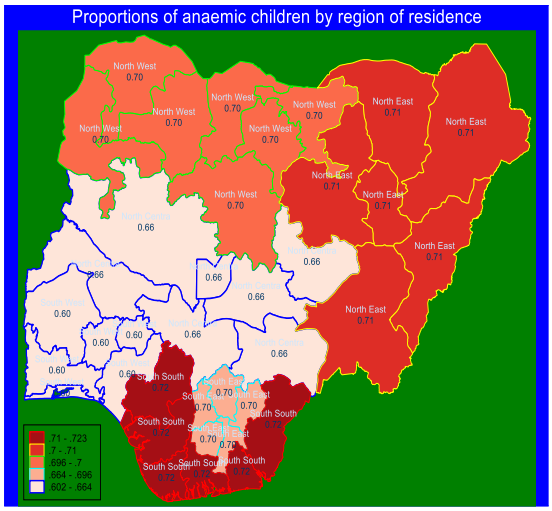
(c): Poorly nourished

Figure 5 1 Spatial maps describing the proportions of the outcome variables by states & FCT

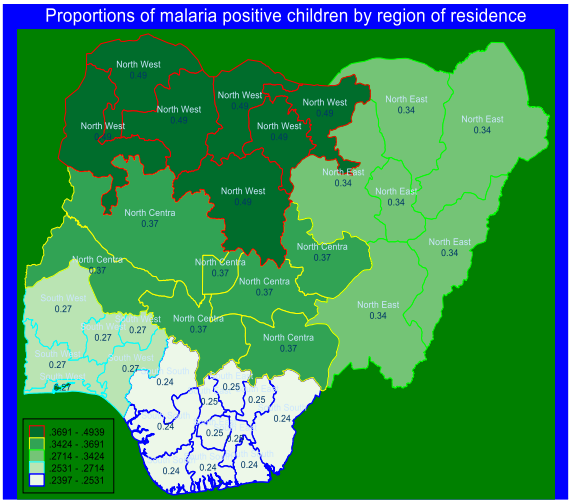
Source: Data computed from Nigeria DHS 2018

5.2.2 Spatial distribution of proportions of the three outcome variables by regions

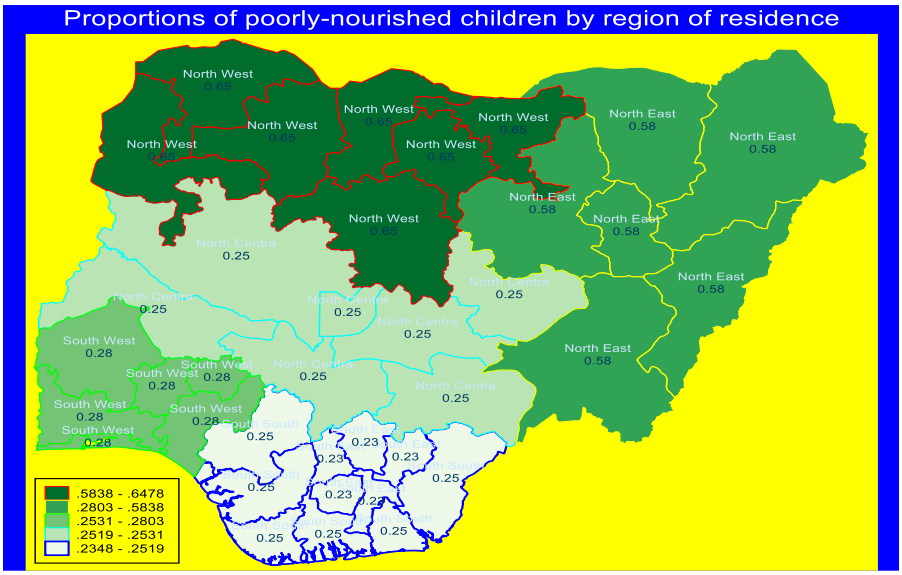
Figure 5.2a represents the spatial distribution of anaemic children over the six geopolitical zones of Nigeria. North-east had the highest proportion of anaemic children, 0.71. In comparison, only the North-central and South-west geopolitical zones had a proportion of anaemic children below the national average of 0.68. On the other hand, North-west, 0.49 recorded the highest proportion of malaria-positive children aged 6-59 months in Nigeria, while the South-south geopolitical zones recorded the lowest, 0.24. Also, North-west geopolitical zones had the highest proportion of poorly nourished children aged 6-59 months in Nigeria, followed by the North-east region with a proportion of 0.58. The south-east geopolitical zone had the lowest, 0.23.



(a) Anaemia



(b) Malaria



(c) Poorly nourished

Figure 5 2 Spatial representation of the three outcomes across the regions

Source: Data computed from Nigeria DHS 2018

5.3 Distributions of the three outcome variables

Research question 3

What is the independent prevalence of the three outcomes of anaemia, malaria, and malnutrition, and concerning the individual and contextual characteristics among children aged 6-59 months in Nigeria?

Three childhood diseases, anaemia, malaria, and malnutrition, whose data were objectively measured using the standard WHO protocols selected from the 2018 NDHS were considered for this study. This section presented the distribution of each of the three outcome variables in graphical format, followed by their prevalence concerning the individual and contextual characteristics classified under child-, parental-, household-, community-, and state-related variables, which were presented in tabular format.

5.3.1 Prevalence of anaemia

A range of anaemia indicators in the 2018 NDHS was used to establish the anaemia status of the children. These indicators (severe, moderate, mild, and not anaemic) were classified according to haemoglobin levels of less than 7.0 grams per decilitre, between 7.0 and 9.9 grams per decilitre, 10.0 and 10.9 grams per decilitre, and 11 grams per decilitre or higher, respectively. Figure 5.3 (a & b) present the distribution of anaemia status among children aged 6-59 months in Nigeria.

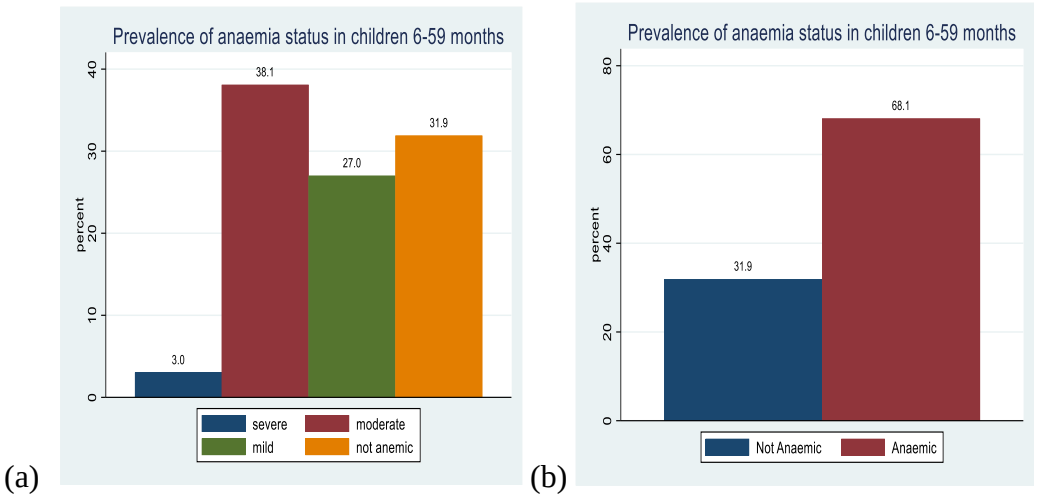


Figure 5 3 Prevalence of anaemia status among children aged 6-59 months in Nigeria: (a) by indicators (b) composite status.

As displayed on the chart, only 3% (307/10222), 95%CI (2.70-3.36) of the children were severely anaemic, while 32% (3260/10222), 95%CI (31.0-32.8) were without anaemia. However, in this analysis, anaemia status was dichotomised into two categories: anaemic

(severe, moderate, & mild), and not anaemic. Figure 5.3b shows that the number of children anaemic was 68.1% (6961/10222), 95%CI (67.87-69.67).

Similarly, the anaemia status, as displayed in Figure 5.4a, shows that the highest percentage of children aged 6-59 months by region of residence in Nigeria (20.4%), were anaemic. They reside in North-West geopolitical zone of the country, while the lowest percentage (2.9%) is among those that do not have anaemia. They live in South-South geopolitical zone of Nigeria. Also, in Figure 5.4b, out of the 68.1% of anaemic children, 41% reside in rural areas, and 27% reside in urban areas. At the same time, Figure 5.4c reports that 35.6% are male children. Of the 32% of children aged 6-59 months in Nigeria that are not anaemic, the percentage increases as the age increases (Figure 5.4d).

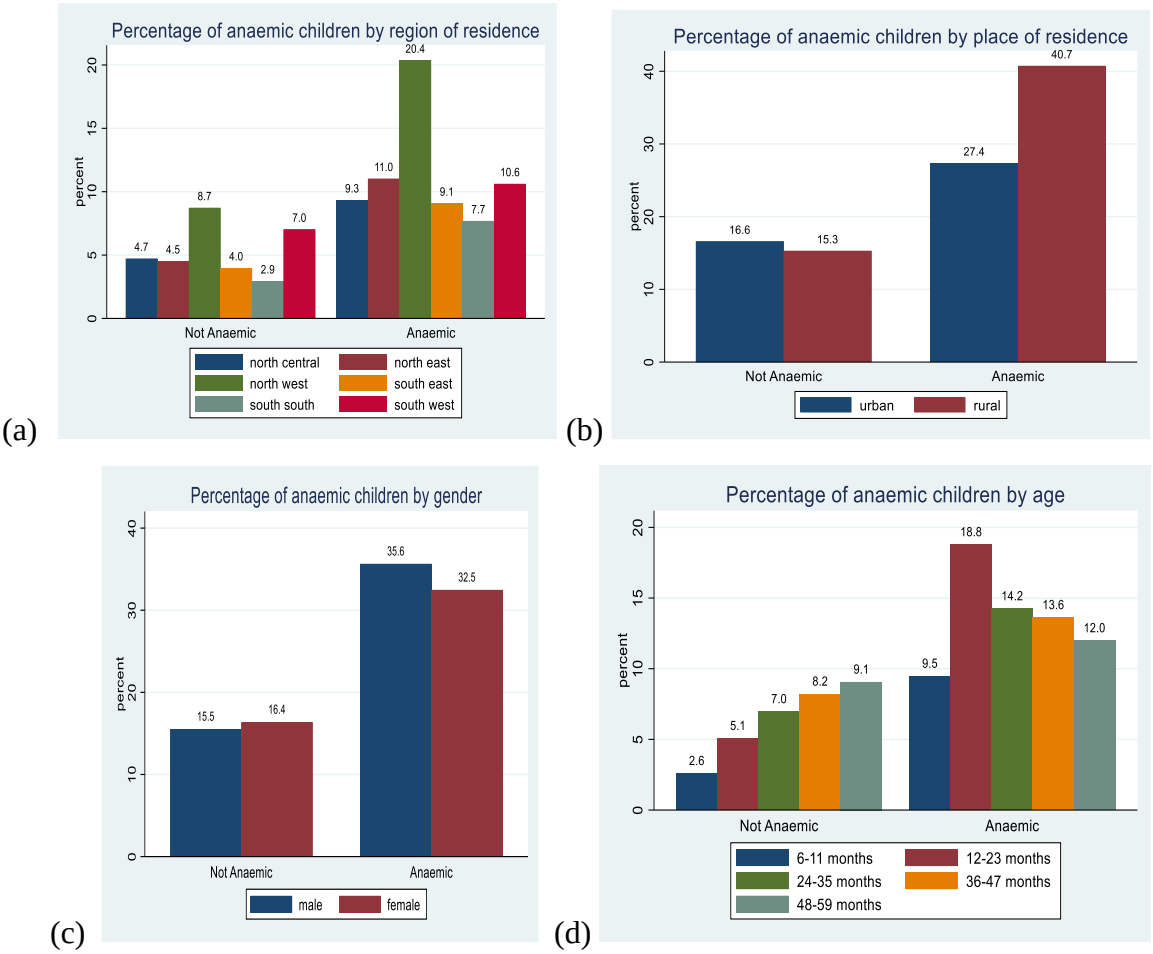


Figure 5 4 Prevalence of anaemia status among children aged 6-59 months in Nigeria (a) by region of residence (b) by place of residence (c) by child's sex (d) by child's age.

5.3.2 Prevalence of malaria

In this study, the malaria status of the child was assessed through the rapid diagnostic test (RDT) of the blood sample taken from children in the household where the men's questionnaire was administered (one-third of all the households used in the survey). Figure 5.5 shows the

distribution of malaria statuses using RDT and thick blood smear tests. There were about 35.5% (3618/10186), 95%CI (34.59-36.45) of the children who had *mRDT* positive, while 22% (1650/7442), 95%CI (21.24-23.13) had malaria positive using blood smear (from a smaller sample size).

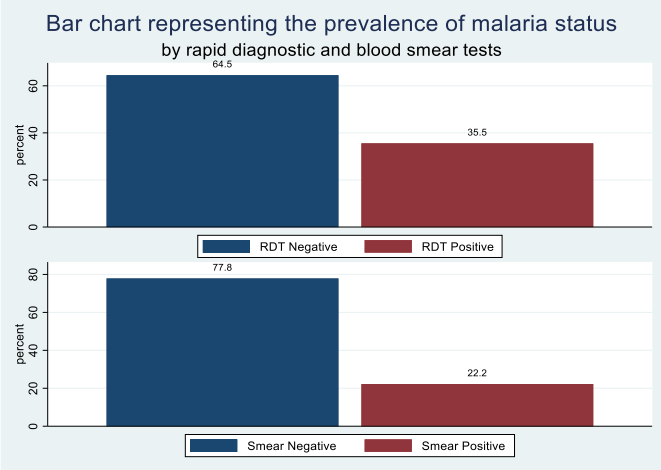


Figure 5 5 Distribution of malaria statuses using RDT and thick blood smear tests

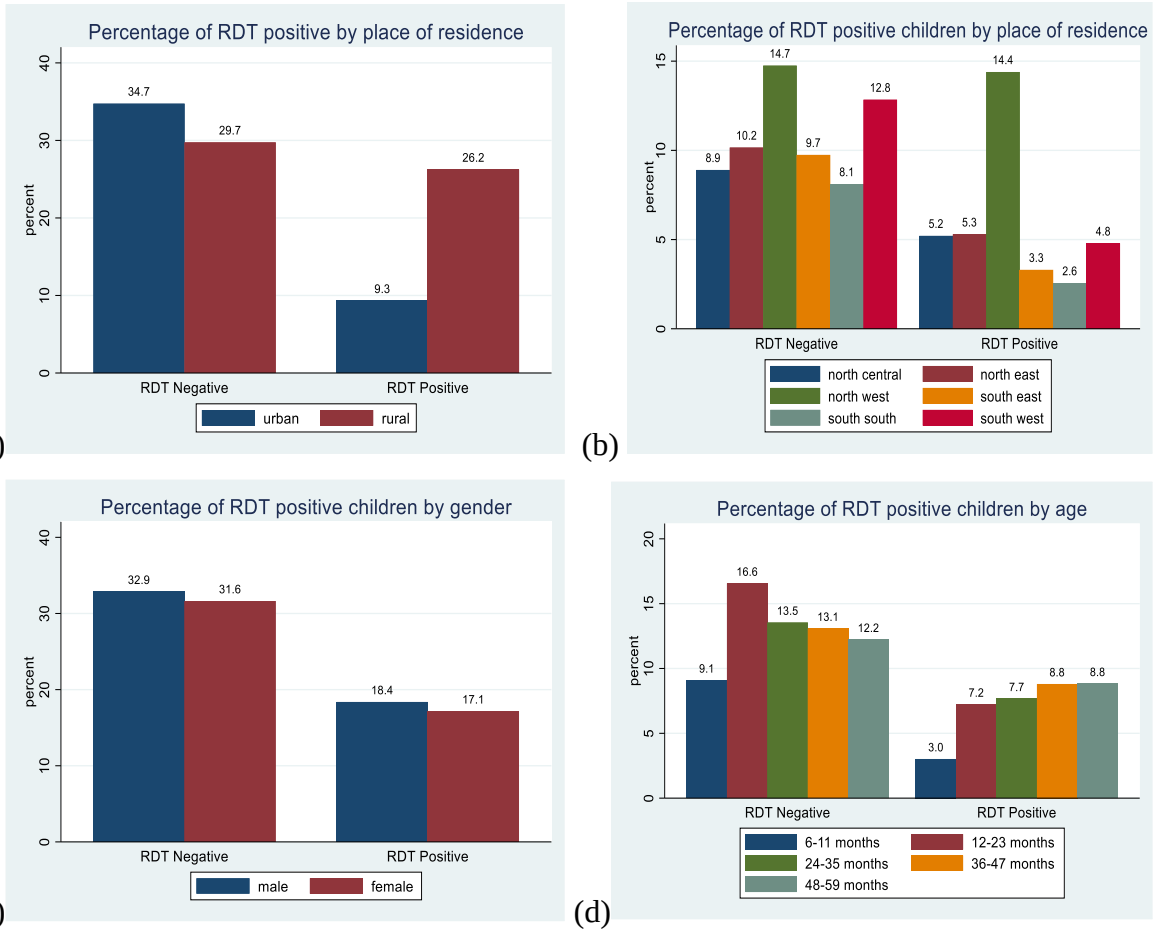


Figure 5 6 Prevalence of malaria status among children aged 6-59 months in Nigeria (a) by place of residence (b) by region of residence (c) by child's sex (d) by child's age

Furthermore, the malaria status shown in Figure 5.6a reveals that 26.2% of children aged 6-59 months in Nigeria who were malaria positive reside in rural areas. Similarly, 14.4% of children captured for RDT and residing in North-West geopolitical zones of Nigeria were malaria positive compared to 14.7% from the same malaria-negative region of residence (Figure 5.6b). Also, out of 51% of the male children, 18.4% were shown to contract malaria fever (Figure 5.6c). At the same time, Figure 5.6d shows that the same number of children (8.8%) were malaria positive in the age categories, 36-47 months and 48-59 months.

5.3.3 Prevalence of malnutrition

Four indicators were used to establish the nutrition status of the children: stunting, wasting, underweight, and overweight. Children with any of these indicators were classified as '1', and absence was classified as '0'. The 'composite of anthropometric failure' was used to classify the children as poorly nourished if the child had any indicators and represented as '1', and well-nourished otherwise. Figure 5.7 indicates that 56.6% (5931/10481), 95%CI (55.63-57.53) of the children are well nourished. In addition, about 38% (3942/10481), 95%CI (36.7-38.5) of the children aged 6-59 months in Nigeria are stunted, 7% (709/10481), 95%CI (6.30-7.26) are wasted, 22% (2296/10481), 95%CI (21.12-22.71) are underweight, while about 2% (172/10481), 95%CI (1.42-1.91) are overweight.

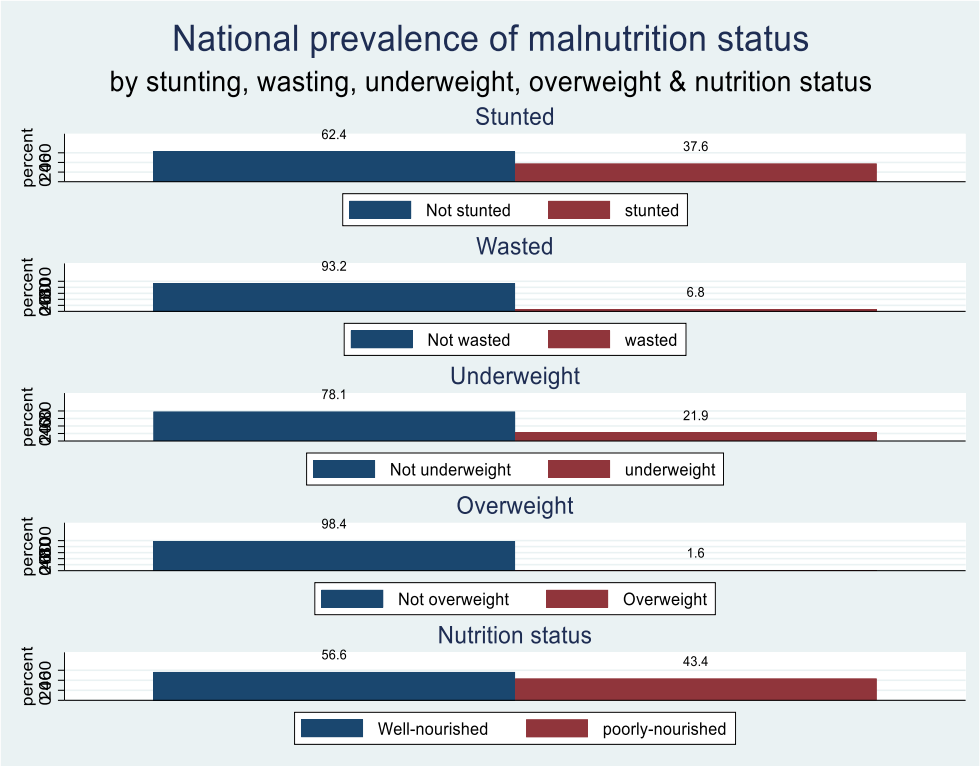


Figure 5 7 Prevalence of malnutrition status by indicators

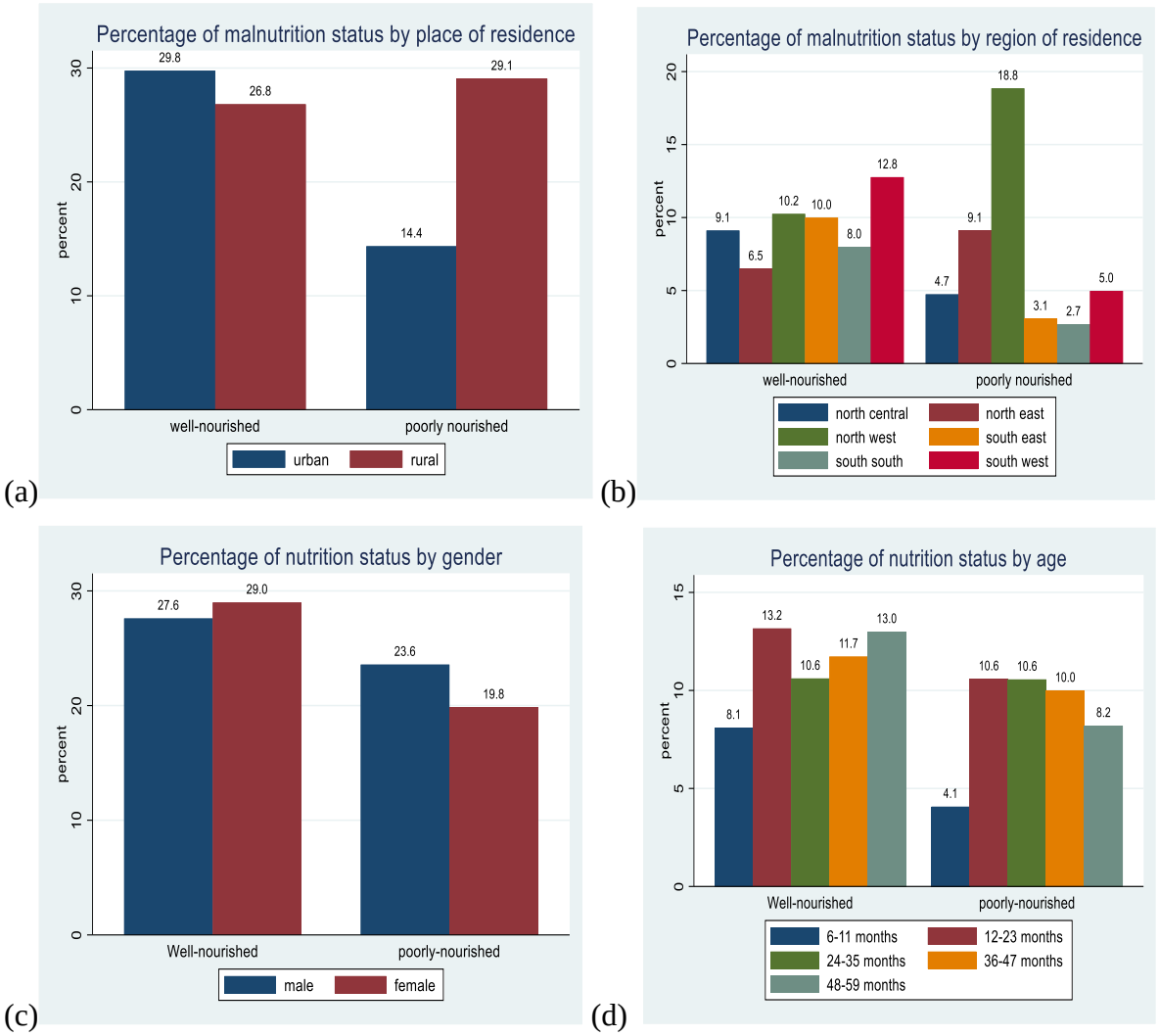


Figure 5 8 Prevalence of malnutrition status by (a) place of residence (b) region of residence (c) child's sex (d) child's age

Similarly, the malnutrition status by some selected characteristics is displayed in Figure 5.8 (a-d). Figure 5.8a reveals that 29.8% of children aged 6-59 months in Nigeria were well nourished and lived in urban areas, while 29.1% were poorly nourished and resided in rural areas. Additionally, 18.8% of all the children captured for malnutrition indices and residing in North-West geopolitical zones of Nigeria were poorly nourished compared to 9.1% of children residing in the North-East. Also, out of 51% of the male children, 23.6% were poorly nourished (Figure 5.8c). In comparison, Figure 5.8d shows that the same number of children (10.6%) were poorly nourished in the 2nd and 3rd-year categories.

5.4 Distribution of participants across the three outcomes by factors

Table 5.6 shows the distribution of the participants across the three outcome variables concerning individual and contextual characteristics.

5.4.1 Distribution of anaemia, malaria, and malnutrition by variables

5.4.1.1 Child-related characteristics of anaemia

A weighted sample of 10,222 children aged 6-59 months in Nigeria was captured for anaemia in the 2018 NDHS. Table 5.6 and the anaemia panel show that there were more male children, 51.2% (5230/10222), than female children. Likewise, the proportion of children anaemic was higher for male children, 69.7% (3643/5230), compared to their female counterparts, 66.5% (3318/4992). The sample also contained more children in the 12-23 months age band, 23.8% (2438/10222). Approximately the same proportion of children anaemic was recorded in both 6-11 months, 78.5% (968/1233), and 12-23 months, 78.7% (1920/2438), age bands. Children in the age band, 48-59 months, 57% (1225/2151), were the least anaemic. Furthermore, there were 78.7% (7948/10096) averaged birth size children in the sample, out of which 67.5% (5366/7948) were anaemic, while 28.4% (347/1223) were not anaemic. With the number of children in the sample, 15.2% (1553/10222), the 7th and above birth order were the least represented, and disproportionately the one with the highest proportion of anaemic children, 73.5% (1142/1553). In the preceding birth interval of 25-35 months, 71% (2055/2895) had the highest proportion of anaemic children. Children who took vitamin A supplements, 66.5% (3228/4854), within the last six months before the survey had a lower proportion of anaemic children than those who never took. Unexpectedly, the proportion of children still breastfeeding, 80.4% (2976/2584), being anaemic is higher than their counterparts in 'never breastfed', 64.4% (110/171) and 'ever breastfed, not currently breastfeeding', 63.9% (4775/7467). About 71% (7265/10170) of children in the survey had not been dewormed in the six months before the survey. Also, 26.4% (2701/10220) contracted fever in the last two weeks prior to the survey. Similarly, 72% (1202/1662) of those children who reported having cough, and 75.7% (1026/1255) of the children who reported having diarrheal, were found anaemic. More than half of the children in the sample were delivered at home, but the proportion of those delivered elsewhere (e.g., marketplace, farm, or on a journey, etc.) being anaemic was highest, 76% (152/200).

5.4.1.2 Child-related characteristics of malaria

Similarly, the results in Table 5.6 (malaria panel) include the description of the proportion of children who were malaria positive. A weighted sample of 10,185 children aged 6-59 months in Nigeria was involved in a rapid diagnostic test for malaria (*mRDT)* in the 2018 NDHS. Male children were more in the sample, 51.2% (5217/10185), than female children. Also, the proportion of malaria-positive male children, 35.9% (1871/5217), is almost the same as their

female counterparts, 35.2% (1747/4968). The sample also contained more children in the 12-23 months, 23.78% (2422/10185). The highest proportion of malaria-positive children was recorded among those aged 48-59 months, 41.9 (898/2143). Furthermore, 78.7% (7915/10185) averaged birth-size children in the sample, out of which 35.7% (2822/7915) were malaria positive. With the number of children in the sample, 34.2% (3483/10185), the 2nd or 3rd birth order were the most represented, while 7th or above had the highest proportion of malaria-positive children, 47.8% (740/1549). Among the preceding birth intervals, 25-35 months, 38.5% (1109/2884) had the highest proportion of malaria children. Also, children who took vitamin A supplements in the last six months before the survey, 29.0% (1399/4832), had a lower proportion of malaria-positive children than those who never took them. Expectedly, the proportion of children who never breastfed, 40.2% (696/171), being malaria positive is higher than their counterparts in 'still breastfeeding', 29.9% (769/2572) and 'ever breastfed, not currently breastfeeding', 37.4% (2780/7441). About 71% (7235/10185) of children in the survey had not been dewormed in the six months before the survey. The proportion of malaria-positive children among those who had diarrhoea in the last two weeks before the survey was 43.3% (585/1350). The proportion of children in the sample delivered at home and are malaria positive was highest, 44.8% (2394/5348), compared with those who were delivered in a public health facility, 28.2% (840/2977), or in a private health facility, 19.6% (326/1660).

Table 5 6 Distribution and association of child-related characteristics on the three outcomes (Anaemia, malaria, malnutrition)

	Anaemia			Malaria			Malnutrition		
Variables	**N (%)**	**Not Anaemic N (%)**	**Anaemic N (%)**	**N (%)**	**Negative N (%)**	**Positive N (%)**	**N (%)**	**Well-nourished N (%)**	**Poorly nourished N (%)**
Child's sex		**χ2 (1) =11.88, P = 0.0040**			**χ2 (1) = 0.55, P = 0.5163**			**χ2 (1) = 31.37, P<0.0001**	
Male	5230(51.16)	1587(30.34)	3643(69.66)	5217(51.22)	3346(64.14)	1871(35.86)	5363(51.17)	2892(53.93)	2471(46.07)
Female	4992(48.84)	1674(33.52)	3318(66.48)	4968(48.78)	3221(64.84)	1747(35.16)	5118(48.83)	3038(59.37)	2080(40.63)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Child's age in group		**χ2 (4) = 344.80, P<0.0001**						**χ2 (4) = 116.88, P<0.0001**	
6-11 months	1233(12.06)	265(21.46)	968(78.54)	1232(12.1)	925(75.09)	307(24.91)	1276(12.17)	849(66.55)	427(33.45)
12-23 months	2438(23.85)	518(21.27)	1920(78.73)	2422(23.78)	1686(69.62)	736(30.38)	2488(23.74)	1379(55.43)	1109(44.57)
24-35 months	2168(21.21)	712(32.84)	1456(67.16)	2160(21.21)	1379(63.86)	780(36.14)	2219(21.17)	1112(50.11)	1107(49.89)
36-47 months	2231(21.83)	839(37.6)	1392(62.4)	2228(21.88)	1332(59.78)	896(40.22)	2276(21.72)	1229(53.98)	1048(46.02)
48-59 months	2151(21.04)	926(43.05)	1225(56.95)	2143(21.04)	1245(58.08)	898(41.92)	2221(21.19)	1362(61.31)	860(38.69)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Child's birth size		**χ2 (2) = 8.21, P = 0.0580**						**χ2 (2) = 65.11, P<0.0001**	
Large	925(9.16)	295(31.94)	629(68.06)	923(9.17)	631(68.35)	292(31.65)	950(9.18)	615(64.71)	335(35.29)
Average	7948(78.72)	2582(32.48)	5366(67.52)	7915(78.68)	5094(64.35)	2822(35.65)	8141(78.69)	4645(57.06)	3496(42.94)
Small	1223(12.11)	347(28.37)	876(71.63)	1222(12.15)	764(62.56)	457(37.44)	1255(12.13)	600(47.84)	655(52.16)
Total	10096(100)	3224(31.93)	6872(68.07)	10060(100)	6489(64.5)	3571(35.5)	10346(100)	5861(56.64)	4486(43.36)
Childbirth order		**χ2 (3) = 51.80, P<0.0001**						**χ2 (3) = 221.15, P<0.0001**	
1st	1951(19.09)	728(37.33)	1223(62.67)	1945(19.1)	1363(70.06)	582(29.94)	2012(19.2)	1275(63.36)	737(36.64)
2nd or 3rd	3494(34.18)	1142(32.68)	2352(67.32)	3483(34.2)	2388(68.56)	1095(31.44)	3602(34.37)	2213(61.42)	1390(38.58)
4-6th	3223(31.53)	979(30.36)	2245(69.64)	3207(31.49)	2008(62.59)	1200(37.41)	3294(31.43)	1789(54.29)	1506(45.71)
7th+	1553(15.19)	411(26.48)	1142(73.52)	1549(15.21)	809(52.21)	740(47.79)	1572(15)	655(41.65)	917(58.35)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Preceding birth interval		**χ2 (4) = 56.71, P<0.0001**						**χ2 (4) = 122.41, P<0.0001**	

None	1951 (19.12)	728 (37.3)	1223 (62.7)	1945(19.13)	1363(70.06)	582 (29.94)	2012(19.24)	1275(63.36)	737 (36.64)
8-24 months	2196(21.52)	657(29.93)	1539(70.07)	2191(26.65)	1356(61.91)	835(38.09)	2263(26.78)	1171(51.77)	1091(48.23)
25-35 months	2895(28.37)	840(29.02)	2055(70.98)	2884(35.09)	1775(61.54)	1109(38.46)	2970(35.15)	1566(52.73)	1404(47.27)
36-59 months	2363(23.16)	724(30.63)	1639(69.37)	2351(28.6)	1515(64.43)	836(35.57)	2404(28.45)	1349(56.12)	1055(43.88)
60+ months	798(7.82)	303(38)	495(62)	795(9.67)	544(68.41)	251(31.59)	811(9.6)	555(68.34)	257(31.66)
Total	10203(100)	2524(30.59)	5727(69.41)	10166(100)	5190(63.13)	3031(36.87)	10460 (100)	4641(54.94)	3807(45.06)
Took Vitamin A supplements		**χ2 (1) = 11.27, P = 0.0114**						**χ2 (1) = 196.73, P<0.0001**	
No	5323(52.3)	1618(30.4)	3705(69.6)	5309(52.35)	3106(58.5)	2203(41.5)	5443(52.16)	2722(50.01)	2721(49.99)
Yes	4854(47.69)	1627(33.51)	3228(66.49)	4832(47.65)	3433(71.04)	1399(28.96)	4992(47.84)	3178(63.65)	1814(36.35)
Total	10178(100)	3245(31.89)	6932(68.11)	10141(100)	6539(64.47)	3603(35.53)	10435(100)	5900(56.54)	4535(43.46)
Took Iron supplements		**χ2 (1) = 2.86, P = 0.1861**						**χ2 (1) = 98.70, P<0.0001**	
No	8255(81.03)	2604(31.54)	5652(68.46)	8224(81.01)	5183(63.03)	3041(36.97)	8443(80.83)	4577(54.21)	3866(45.79)
Yes	1933(18.97)	648(33.53)	1285(66.47)	1928(18.99)	1367(70.9)	561(29.1)	2002(19.17)	1331(66.47)	671(33.53)
Total	10188(100)	3252(31.92)	6936(68.08)	10152(100)	6550(64.52)	3602(35.48)	10445(100)	5908(56.56)	4537(43.44)
Duration of breastfeeding		**χ2 (2) = 238.00, P<0.0001**						**χ2 (2) = 4.78, P = 0.2231**	
Ever breastfed, not currently breastfeeding	7467(73.05)	2692(36.05)	4775(63.95)	7441(73.06)	4662(62.65)	2780(37.35)	7648(72.97)	4374(57.2)	3274(42.8)
Never breastfed	171(1.67)	61(35.57)	110(64.43)	171(1.68)	102(59.77)	69(40.23)	175(1.67)	91(52.33)	83(47.67)
Still breastfeeding	2584(25.28)	507(19.64)	2076(80.36)	2572(25.25)	1803(70.1)	769(29.9)	2658(25.36)	1465(55.11)	1193(44.89)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Child took deworming drug in last 6months		**χ2 (1) = 48.45, P<0.0001**						**χ2 (1) = 342.52, P<0.0001**	
No	7265(71.44)	2169(29.86)	5095(70.14)	7235(71.4)	4330(59.85)	2905(40.15)	7436(71.3)	3785(50.9)	3651(49.1)
Yes	2905(28.56)	1075(37)	1830(63)	2898(28.6)	2204(76.03)	695(23.97)	2993(28.7)	2118(70.79)	874(29.21)
Total	10170(100)	3244(31.9)	6925(68.1)	10133(100)	6534(64.48)	3600(35.52)	10429(100)	5903(56.6)	4526(43.4)
Child had Fever in last 2 weeks before the survey		**χ2 (1) = 123.29, P<0.0001**						**χ2 (1) = 70.33, P<0.0001**	
No	7519(73.57)	2630(34.98)	4889(65.02)	7487(73.52)	5201(69.47)	2286(30.53)	7727(73.74)	4561(59.02)	3167(40.98)
Yes	2701(26.43)	630(23.34)	2070(76.66)	2696(26.48)	1366(50.67)	1330(49.33)	2751(26.26)	1369(49.78)	1381(50.22)

Total	10220(100)	3260(31.9)	6959(68.1)	10183(100)	6567(64.49)	3615(35.51)	10478(100)	5930(56.6)	4548(43.4)
Child had cough in last 2 weeks before the survey		**χ2 (1) = 16.10, P = 0.0009**						**χ2 (1) = 2.78, P = 0.1451**	
No	8558(83.74)	2800(32.72)	5758(67.28)	8525(83.72)	5489(64.38)	3036(35.62)	8768(83.67)	4930(56.24)	3837(43.76)
Yes	1662(16.26)	460(27.69)	1202(72.31)	1658(16.28)	1078(65.03)	580(34.97)	1711(16.33)	1000(58.42)	712(41.58)
Total	10220(100)	3260(31.9)	6960(68.1)	10183(100)	6567(64.49)	3616(35.51)	10479(100)	5930(56.59)	4549(43.41)
Child had diarrheal in last 2 weeks before the survey		**χ2 (1) = 41.51, P<0.0001**						**χ2 (1) = 145.58, P<0.0001**	
No	8865(86.75)	2931(33.07)	5934(66.93)	8832(86.74)	5801(65.68)	3031(34.32)	9098(86.83)	5357(58.87)	3742(41.13)
Yes	1355(13.26)	329(24.29)	1026(75.71)	1350(13.26)	765(56.68)	585(43.32)	1380(13.17)	574(41.57)	806(58.43)
Total	10219(100)	3260(31.9)	6959(68.1)	10182(100)	6566(64.49)	3616(35.51)	10478(100)	5930(56.6)	4548(43.4)
Place of child's delivery		**χ2 (3) = 138.28, P<0.0001**						**χ2 (3) = 800.97, P<0.0001**	
Home	5365(52.48)	1459(27.2)	3905(72.8)	5348(52.51)	2953(55.22)	2394(44.78)	5494(52.42)	2413(43.92)	3081(56.08)
Public facility	2989(29.24)	1083(36.23)	1906(63.77)	2977(29.23)	2137(71.8)	840(28.2)	3058(29.18)	2037(66.62)	1021(33.38)
Private facility	1668(16.32)	670(40.17)	998(59.83)	1660(16.3)	1334(80.38)	326(19.62)	1712(16.33)	1316(76.86)	396(23.14)
Elsewhere	200(1.96)	48(23.95)	152(76.05)	200(1.96)	142(71.08)	58(28.92)	217(2.07)	165(75.93)	52(24.07)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)

5.4.1.3 Child-related characteristics of malnutrition

On the part of malnutrition, Table 5.6 (malnutrition panel) shows that a weighted sample of 10,481 children aged 6-59 months in Nigeria was captured in the 2018 NDHS. There were more male children, 51.2% (5363/10481), than female children. Likewise, the proportion of poorly nourished children was higher for male children, 46.1% (2471/5363), compared to their female counterparts, 40.6% (2080/5118). The sample captured more children in the 12-23 months age band, 23.7% (2488/10481). The proportion of poorly nourished children was highest for children aged 24-35 months, 49.9% (1107/2219), followed by children aged 36-47 months, 46% (1048/2276). Children aged 6-11 months, 33.5% (427/1276), were the least poorly nourished. In addition, the proportion of poorly nourished children in the small birth group, 52.2% (655/10481), was the highest, while 47.8% (600/1255) were well-nourished. The preceding birth interval of 8-24 months, 48.23% (1091/2263), had the highest proportion of poorly nourished children in the sample. Children who did not take vitamin A supplements, 50% (2721/5443) within the last six months before the survey were proportionally higher among the poorly nourished children compared with those who took the supplement. Furthermore, the proportion of children 'never breastfed', 47.7% (83/175), being poorly nourished is higher than their counterparts in 'ever breastfed', 42.8% (3274/7648) and 'still breastfeeding', 44.9% (1193/2658). Similarly, 58.4% (1000/1711) of those children who reported having cough, and 41.6% (574/1380) of the children who reported having diarrheal, were well nourished.

5.4.2.1 Parental-related characteristics of anaemia

Table 5.7 (anaemia panel) shows that children of mothers aged 15-24 years; not currently working-class mothers; who had their first baby at the age 10-24 years; had no education; and currently living with a partner were respectively having the highest proportion of 73% (1509/2055), 70% (2106/2990), 69% (6000/8605), 75% (2984/3984), 68% (6072/8889) of being anaemic. The proportion of children whose mothers did not sleep under a bed net the night before the anaemic survey was 65% (3063/4684). Similarly, the proportion of anaemic children whose mothers did not attend ante-natal care during their pregnancy was highest, 77.7% (1044/1344), compared with those whose mothers had 1-3 visits, 76% (735/961), and 4 & above, 68% (2799/4092). Also, the proportion of children whose mothers are Muslims, 71% (4013/5671), that are anaemic, was higher than any other religious status. About 40% (4077/10222) of the children in the sample are Hausa/Fulani/Kanuri/Seribiri ethnic group, and 72% (2920/4077) of these were anaemic.

Furthermore, the proportion of children of anaemic mothers was 58% (5875/10090), out of which 74% (4363/5875) of the children were also anaemic. Similarly, 76% (676/888) of children of underweight mothers were anaemic, while 58% (506/873) of children of the obese mother were anaemic. As was reported for the case of children whose mothers do not have any education, children whose fathers do not have any form of education have the highest proportion of anaemic children, 76% (2198/2884).

5.4.2.2 Parental-related characteristics of malaria

Also, in Figure 5.7 (malaria panel), children of mothers aged 15-24 years, 38.7% (784/2049), not currently working-class mothers, 37.7% (1123/2978), had their first baby aged 10-24 years 38.5% (3299/8578), no education 50.8% (2018/3970), and currently living with a partner, 36.0 (3194/8862) were being malaria positive. The proportions of malaria-positive children whose mothers had low autonomy and did sleep under a bed net the night before the survey was 41% (2124/5071), and 39.7% (2189/5514), respectively. The proportion of malaria-positive children whose mothers did not attend ante-natal care during their pregnancy was highest, 46.7% (627/1342), compared with those whose mothers had 1-3 visits, 35.5% (329/954), and 4 & above, 26.8% (1092/4079). In the same way, the proportion of malaria-positive children whose mothers are Muslims, 42.3% (2389/5655), was higher than for any other religious status. About 45.3% (1841/4067) of the children out of the 39.9% (4067/10185) in the sample representing the Hausa/Fulani/Kanuri/Seribiri ethnic group were malaria positive. Furthermore, the proportion of malaria-positive children of the anaemic mother was 39.8% (2328/5847). Similarly, 15.8% (137/869) of the children of underweight mothers were malaria positive, while 39.4% (2092/5311) of the children of mothers with normal body mass index were malaria positive.

5.4.2.3 Parental-related characteristics of malnutrition

Similarly, among the parental-related variables in the malnutrition panel in Table 5.7, children of mothers aged 15-24 years, not currently working-class mothers, who had their first baby aged 10-24 years, had no education, and currently living with a partner were respectively having the highest proportion of 48.9% (1043/2132), 49.5% (1527/3084), 46.7% (4119/8822), 62.1% (2536/4087), 44.7% (4079/9117), of being poorly nourished. The proportion of poorly nourished children whose mothers have low autonomy was 52.9% (2761/5223). Also, the proportion of poorly nourished children whose mothers did not attend ante-natal care during their pregnancy was highest, 58.1% (803/1383), compared with those whose mothers had 1-3 visits, 53.4% (529/991), and '4 & above', 36.6% (1531/2651). In addition, the proportion of

poorly nourished children whose mothers are Muslims, 56.3% (3282/5832), was higher, followed by children of 'traditionalist & others', 37.1% (25/66). About 62.9% (2636/4190) of the children of Hausa/Fulani/Kanuri/Seribiri mothers were poorly nourished.

Furthermore, the proportion of poorly nourished children of anaemic mothers was 45.9% (2730/5946). Similarly, children of mothers who did not take iron tablets during their children's pregnancies had a proportion of poorly nourished children, 50.8% (936/1840). Also, the proportion of poorly nourished children of underweight mothers was highest, 60.5% (543/899), while 24.3% (214/882) of children of the obese mother were poorly nourished. Finally, the proportion of poorly nourished children whose fathers do not work and do not have any education was 48.1% (150/311) and 62.1% (1853/2984), respectively.

Table 5 7 Distribution and association of parental-related characteristics on the three outcomes (Anaemia, malaria, malnutrition)

	Anaemia			**Malaria**			**Malnutrition**		
Variables	**N (%)**	**Not Anaemic N (%)**	**Anaemic N (%)**	**N (%)**	**Negative N (%)**	**Positive N (%)**	**N (%)**	**Well-nourished N (%)**	**Poorly nourished N (%)**
Maternal age group in 10years		**χ2 (2) = 34.62, P<0.0001**			**χ2 (2) = 14.59, P = 0.0095**			**χ2 (2) = 32.95, P = 0.0001**	
15-24 years	2055(20.1)	545(26.55)	1509(73.45)	2049(20.12)	1265(61.73)	784(38.27)	2132(20.34)	1090(51.11)	1043(48.89)
25-34 years	5283(51.68)	1737(32.88)	3546(67.12)	5262(51.66)	3481(66.15)	1781(33.85)	5427(51.78)	3159(58.22)	2267(41.78)
35 years+	2884(28.21)	978(33.89)	1907(66.11)	2874(28.22)	1821(63.38)	1052(36.62)	2922(27.88)	1681(57.55)	1240(42.45)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Mother/Caregiver currently working		**χ2 (1) = 10.69, P = 0.0126**			**χ2 (1) = 8.83, P = 0.0380**			**χ2 (1) = 65.72, P<0.0001**	
No	2990(29.25)	883(29.55)	2106(70.45)	2978(29.24)	1855(62.28)	1123(37.72)	3084(29.42)	1557(50.5)	1527(49.5)
Yes	7232(70.75)	2377(32.87)	4855(67.13)	7207(70.76)	4712(65.39)	2494(34.61)	7397(70.58)	4373(59.12)	3024(40.88)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Age of mother at first birth		**χ2 (2) = 65.30, P<0.0001**			**χ2 (2) = 203.78, P<0.0001**			**χ2 (2) = 242.26, P<0.0001**	
10-24	8605(84.18)	2605(30.28)	6000(69.72)	8578(84.22)	5279(61.55)	3299(38.45)	8822(84.17)	4704(53.32)	4119(46.68)
25-36	1590(15.55)	643(40.47)	946(59.53)	1580(15.51)	1266(80.16)	313(19.84)	1628(15.53)	1203(73.88)	425(26.12)
37-49	27(0.26)	12(42.35)	16(57.65)	27(0.27)	22(79.4)	6(20.6)	30(0.29)	24(79.27)	6(20.73)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Maternal/caregiver highest educational level		**χ2 (3) = 264.90, P<0.0001**			**χ2 (3) = 929.69, P<0.0001**			**χ2 (3) = 1119.82, P<0.0001**	
No education	3984(38.97)	1000(25.1)	2984(74.9)	3970(38.98)	1951(49.16)	2018(50.84)	4087(38.99)	1551(37.94)	2536(62.06)
Primary	1646(16.1)	475(28.85)	1171(71.15)	1643(16.13)	985(59.93)	658(40.07)	1688(16.11)	948(56.13)	741(43.87)
Secondary	3609(35.31)	1294(35.86)	2315(64.14)	3598(35.33)	2750(76.44)	847(23.56)	3688(35.19)	2611(70.79)	1077(29.21)
Higher	983(9.62)	491(49.99)	492(50.01)	974(9.56)	881(90.42)	93(9.58)	1017(9.7)	821(80.76)	196(19.24)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Mother is currently residing with husband/partner		**χ2 (1) = 1.20, P = 0.3892**			**χ2 (1) = 7.43, P = 0.0291**			**χ2 (1) = 31.36, P<0.0001**	
Living with her partner	8889(91.01)	2818(31.7)	6072(68.3)	8862(91.05)	5668(63.96)	3194(36.04)	9117(91.04)	5038(55.26)	4079(44.74)
Staying elsewhere	877(8.98)	294(33.51)	583(66.49)	871(8.95)	598(68.62)	273(31.38)	897(8.96)	583(65.03)	314(34.97)

Total	9767(100)	3112(31.86)	6655(68.14)	9733(100)	6266(64.37)	3468(35.63)	10014(100)	5621(56.14)	4392(43.86)
Maternal autonomy level		**χ2 (1) = 44.08, P<0.0001**			**χ2 (1) = 178.05, P<0.0001**			**χ2 (1) = 376.73, P<0.0001**	
Low autonomy	5082(49.72)	1464(28.81)	3618(71.19)	5071(49.79)	2947(58.12)	2124(41.88)	5223(49.83)	2462(47.14)	2761(52.86)
More autonomy	5140(50.28)	1796(34.94)	3344(65.06)	5114(50.21)	3620(70.79)	1494(29.21)	5258(50.17)	3468(65.97)	1790(34.03)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Maternal/caregiver slept under mosquito bed net		**χ2 (1) = 29.19, P<0.0001**			**χ2 (1) = 91.02, P<0.0001**			**χ2 (1) = 174.16, P<0.0001**	
No	4684(45.82)	1621(34.61)	3063(65.39)	4671(45.86)	3242(69.4)	1429(30.6)	4816(45.95)	3059(63.53)	1757(36.47)
Yes	5538(54.18)	1639(29.6)	3898(70.4)	5514(54.14)	3325(60.31)	2189(39.69)	5665(54.05)	2871(50.69)	2794(49.31)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Ante-Natal Care visits during pregnancy of the child		**χ2 (2) = 55.65, P<0.0001**			**χ2 (2) = 186.0, P<0.0001**			**χ2 (2) = 238.20, P<0.0001**	
None	1344(21.01)	300(22.34)	1044(77.66)	1342(21.05)	715(53.29)	627(46.71)	1383(21.1)	580(41.94)	803(58.06)
1-3 visits	961(15.02)	226(23.52)	735(76.48)	954(14.96)	624(65.46)	329(34.54)	991(15.12)	462(46.64)	529(53.36)
4 and above visits	4092(63.96)	1293(31.6)	2799(68.4)	4079(63.98)	2987(73.23)	1092(26.77)	4182(63.8)	2651(63.4)	1531(36.6)
Total	6398(100)	1819(28.44)	4578(71.56)	6375(100)	4326(67.87)	2048(32.13)	6555(100)	3693(56.34)	2862(43.66)
Mother's religious status		**χ2 (3) = 41.10, P<0.0001**			**χ2 (3) = 255.02, P<0.0001**			**χ2 (3) = 888.51, P<0.0001**	
Catholic	1028(10.06)	360(34.99)	668(65.01)	1027(10.08)	754(73.39)	273(26.61)	1050(10.02)	788(75.04)	262(24.96)
Other Christian	3458(33.83)	1220(35.27)	2239(64.73)	3438(33.76)	2509(72.96)	930(27.04)	3533(33.71)	2552(72.22)	982(27.78)
Islam	5671(55.48)	1658(29.24)	4013(70.76)	5655(55.52)	3266(57.75)	2389(42.25)	5832(55.64)	2550(43.72)	3282(56.28)
Traditionalist & others	64(0.63)	22(34.84)	42(65.16)	64(0.63)	39(60.39)	25(39.61)	66(0.63)	42(62.92)	25(37.08)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Maternal ethnicity		**χ2 (3) = 66.78, P<0.0001**			**χ2 (3) = 325.93, P<0.0001**			**χ2 (3) = 1148.48, P<0.0001**	
Hausa/Fulani/Kanuri/Seribiri	4077(39.88)	1157(28.38)	2920(71.62)	4067(39.93)	2226(54.74)	1841(45.26)	4190(39.98)	1555(37.1)	2636(62.9)
Ibos	1656(16.2)	529(31.94)	1127(68.06)	1650(16.2)	1273(77.12)	377(22.88)	1701(16.23)	1321(77.68)	380(22.32)
Yoruba	1497(14.64)	596(39.78)	902(60.22)	1490(14.63)	1068(71.68)	422(28.32)	1538(14.67)	1074(69.86)	463(30.14)
Others	2991(29.26)	979(32.72)	2013(67.28)	2978(29.24)	2001(67.18)	977(32.82)	3052(29.12)	1980(64.89)	1071(35.11)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)

Mother took iron tablets during pregnancy		**χ2 (1) = 10.14, P = 0.0188**			**χ2 (1) = 55.83, P<0.0001**			**χ2 (1) = 56.42, P<0.0001**	
No	1784(27.48)	459(25.74)	1324(74.26)	1778(27.48)	1086(61.07)	692(38.93)	1840(27.66)	904(49.14)	936(50.86)
Yes	4709(72.52)	1401(29.75)	3308(70.25)	4692(72.52)	3322(70.8)	1370(29.2)	4812(72.34)	2857(59.37)	1955(40.63)
Total	6493(100)	1860(28.65)	4633(71.35)	6470(100)	4408(68.13)	2062(31.87)	6652(100)	3761(56.54)	2891(43.46)
Mother's Anaemia status		**χ2 (1) = 245.14, P<0.0001**			**χ2 (1) = 128.01, P<0.0001**			**χ2 (1) = 29.71, P<0.0001**	
Not Anaemic	4215(41.77)	1707(40.49)	2508(59.51)	4206(41.84)	2991(71.12)	1214(28.88)	4252(41.69)	2531(59.53)	1721(40.47)
Anaemic	5875(58.23)	1512(25.74)	4363(74.26)	5847(58.16)	3519(60.18)	2328(39.82)	5946(58.31)	3216(54.09)	2730(45.91)
Total	10090(100)	3219(31.9)	6871(68.1)	10053(100)	6510(64.76)	3543(35.24)	10198(100)	5747(56.36)	4451(43.64)
Maternal body weight status		**χ2 (3) = 106.63, P<0.0001**			**χ2 (3) = 273.05, P<0.0001**			**χ2 (3) = 390.19, P<0.0001**	
Normal	5331(60.84)	1592(29.85)	3739(70.15)	5311(60.82)	3219(60.61)	2092(39.39)	5401(60.77)	2878(53.29)	2523(46.71)
Underweight	888(10.13)	212(23.83)	676(76.17)	885(10.14)	513(58.04)	371(41.96)	899(10.12)	355(39.54)	543(60.46)
Overweight	1670(19.06)	636(38.08)	1034(61.92)	1668(19.1)	1246(74.68)	422(25.32)	1704(19.17)	1198(70.32)	506(29.68)
Obese	873(9.96)	367(42.03)	506(57.97)	869(9.95)	732(84.22)	137(15.78)	882(9.92)	668(75.73)	214(24.27)
Total	8763(100)	2806(32.03)	5956(67.97)	8732(100)	5710(65.39)	3022(34.61)	8887(100)	5100(57.39)	3786(42.61)
Paternal Work Status		**χ2 (1) = 4.47, P = 0.1120**			**χ2 (1) = 0.29, P = 0.7133**			**χ2 (1) = 2.87, P = 0.2099**	
No	305(2.98)	80(26.33)	225(73.67)	304(2.98)	191(63.01)	112(36.99)	311(2.97)	162(51.89)	150(48.11)
Yes	9916(97.01)	3180(32.07)	6737(67.93)	9881(97.02)	6376(64.53)	3505(35.47)	10170(97.03)	5769(56.73)	4400(43.27)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Partner education status		**χ2 (3) = 199.51, P<0.0001**			**χ2 (3) = 718.72, P<0.0001**			**χ2 (3) = 699.76, P<0.0001**	
No education	2884(29.93)	686(23.78)	2198(76.22)	2872(29.9)	1369(47.65)	1504(52.35)	2984(30.2)	1131(37.91)	1853(62.09)
Primary education	1425(14.79)	419(29.38)	1006(70.62)	1423(14.82)	817(57.4)	606(42.6)	1444(14.61)	759(52.54)	685(47.46)
Secondary education	3752(38.93)	1279(34.08)	2474(65.92)	3742(38.96)	2725(72.82)	1017(27.18)	3833(38.79)	2512(65.52)	1322(34.48)
Tertiary education	1576(16.35)	689(43.73)	887(56.27)	1566(16.31)	1294(82.59)	273(17.41)	1620(16.39)	1160(71.63)	460(28.37)
Total	9637(100)	3072(31.88)	6565(68.12)	9604(100)	6204(64.6)	3400(35.4)	9882(100)	5562(56.29)	4320(43.71)

5.4.3.1 Household-related characteristics of anaemia

In Table 5.8, the result shows that the proportion of children from the poorest households that are anaemic is very high, 81% (1532/1898). The proportion of anaemic children decreases as the household wealth index increases. Also, the proportions of anaemic children from a household without electricity, with unimproved drinking water, and unimproved toilet facilities, were 76% (3277/4310), 74% (2281/3095), 75% (3454/4622), respectively. Similarly, children from a household built with the unimproved floor, roof, or wall materials had a higher proportion of anaemic than their counterparts in households built with improved materials. The proportion of anaemic children from a female-headed household was lower, 67% (733/1095) than those from male-headed households.

5.4.3.2 Household-related characteristics of malaria

Also, the malaria panel in Table 5.8 shows that the proportion of malaria-positive children increases as the household wealth index decreases. The result shows that the proportion of children from the wealthiest household that is malaria positive is 9.8% (197/2020). Also, the proportion of malaria-positive children from a household headed by someone aged 56 years+ or above was highest, 39.8% (524/1319). The household with only one sleeping room had the lowest proportion of malaria-positive children, 30.5% (855/2807). Similarly, children from a household built with an unimproved source of drinking water, 48% (1477/3079), toilet facility, 48.9% (2251/4607), had a higher proportion of being malaria positive compared with their counterparts in a household with the improved source of drinking water and toilet facility, respectively. The proportion of malaria-positive children from a male-headed household was higher, 36% (3273/9098) than those from female-headed households. Interestingly, the proportion of malaria-positive children from a household where the youngest child's stool is not disposed of properly, 34.9% (1257/3606), is like the counterpart where such stool is disposed of correctly, 34.5% (967/2803).

5.4.3.3 Household-related characteristics of malnutrition

As with the other two outcome variables in Table 5.8, the proportion of poorly nourished children decreases as the household wealth index increases. Also, the proportions of poorly nourished children from a 4-bedroom household, a household without electricity, with unimproved drinking water, unimproved toilet facilities, were respectively 50.5% (514/1018), 54% (2384/4414), 56.1% (1791/3196), 51.4% (2434/4737). Also, a household using biofuel for cooking had a higher proportion of poorly nourished children, 46.6% (4295/9225). Similarly, children from households built with unimproved floor, roof, or wall materials had a

higher proportion of being poorly nourished than their counterparts in households built with improved materials. The proportion of poorly nourished children from a male-headed household was 44.4% (4155/9357), compared with those children from female-headed households.

Table 5 8 Distribution and association of household-related characteristics on the three outcomes (Anaemia, malaria, malnutrition)

	Anaemia			**Malaria**			**Malnutrition**		
Variables	**N (%)**	**Not Anaemic N (%)**	**Anaemic N (%)**	**N (%)**	**Negative N (%)**	**Positive N (%)**	**N (%)**	**Well-nourished N (%)**	**Poorly nourished N (%)**
Household wealth index		**χ2 (4) = 391.21, P<0.0001**			**χ2 (4) =1240.51, P<0.0001**			**χ2 (4) = 994.65, P<0.0001**	
Poorest	1898(18.57)	366(19.29)	1532(80.71)	1893(18.59)	809(42.73)	1084(57.27)	1954(18.64)	713(36.47)	1241(63.53)
Poorer	1995(19.52)	499(25.04)	1495(74.96)	1989(19.53)	1004(50.47)	985(49.53)	2027(19.34)	865(42.68)	1162(57.32)
Middle	2151(21.04)	718(33.4)	1433(66.6)	2139(21)	1335(62.42)	804(37.58)	2197(20.96)	1225(55.76)	972(44.24)
Richer	2154(21.07)	731(33.93)	1423(66.07)	2144(21.05)	1596(74.47)	547(25.53)	2212(21.1)	1481(66.95)	731(33.05)
Richest	2024(19.8)	945(46.71)	1078(53.29)	2020(19.83)	1823(90.25)	197(9.75)	2091(19.95)	1647(78.77)	444(21.23)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Household Head age group		**χ2 (3) = 3.48, P = 0.5367**			**χ2 (3) = 27.14, p<0.0026**			**χ2 (3) = 10.72, P = 0.0980**	
Less 34 years	2838(27.76)	873(30.77)	1965(69.23)	2828(27.77)	1825(64.52)	1003(35.48)	2936(28.01)	1635(55.7)	1301(44.3)
35-44 years	3959(38.73)	1302(32.88)	2658(67.12)	3946(38.74)	2648(67.11)	1298(32.89)	4046(38.6)	2360(58.32)	1686(41.68)
45-55 years	2100(20.54)	664(31.63)	1436(68.37)	2091(20.53)	1300(62.15)	792(37.85)	2158(20.59)	1171(54.27)	987(45.73)
56 years+	1324(12.95)	421(31.78)	903(68.22)	1319(12.95)	794(60.24)	524(39.76)	1340(12.79)	764(57.03)	576(42.97)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Children under 5 slept under mosquito bed net last night		**χ2 (3) = 48.15, P<0.0001**			**χ2 (3) = 104.81, P<0.0001**			**χ2 (3) = 151.49, P<0.0001**	
No child	1320(13.01)	426(32.26)	894(67.74)	1317(13.02)	1351(12.98)	816(60.37)	1351(12.98)	1320(13.01)	426(32.26)
All children	4734(46.64)	1497(31.63)	3236(68.37)	4715(46.63)	4841(46.52)	2523(52.11)	4841(46.52)	4734(46.64)	1497(31.63)
Some children	1000(9.85)	229(22.9)	771(77.1)	996(9.85)	1017(9.77)	487(47.93)	1017(9.77)	1000(9.85)	229(22.9)
No net in household	3096(30.51)	1073(34.66)	2023(65.34)	3084(30.5)	3198(30.73)	2050(64.12)	3198(30.73)	3096(30.51)	1073(34.66)
Total	10149(100)	3225(31.78)	6924(68.22)	10112(100)	10406(100)	5876(56.47)	10406(100)	10149(100)	3225(31.78)
Number of children under-5 years in household		**χ2 (2) = 28.42, P = 0.0002**			**χ2 (2) = 103.78, P<0.0001**			**χ2 (2) = 111.21, P<0.0001**	
0-3	9099(89.01)	2979(32.74)	6120(67.26)	9070(89.05)	9340(89.11)	5452(58.37)	9340(89.11)	9099(89.01)	2979(32.74)
4-6	1059(10.36)	261(24.65)	798(75.35)	1051(10.32)	1077(10.28)	454(42.2)	1077(10.28)	1059(10.36)	261(24.65)
7th+	64(0.63)	21(32.01)	44(67.99)	64(0.63)	65(0.62)	25(38.34)	65(0.62)	64(0.63)	21(32.01)

Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	10481(100)	5931(56.59)	10481(100)	5931(56.59)	4550(43.41)
Number of bedrooms in household		**χ2 (4) = 1.26, P = 0.9405**			**χ2 (4) = 47.58, P<0.0001**			**χ2 (4) = 117.03, P<0.0001**	
One-room	2814(27.53)	895(31.8)	1919(68.2)	2807(27.56)	1952(69.55)	855(30.45)	2910(27.76)	1881(64.65)	1028(35.35)
Two rooms	3498(34.22)	1115(31.87)	2383(68.13)	3490(34.27)	2221(63.65)	1268(36.35)	3578(34.14)	1971(55.09)	1607(44.91)
Three rooms	2044(20)	666(32.58)	1378(67.42)	2030(19.93)	1239(61.03)	791(38.97)	2091(19.95)	1105(52.84)	986(47.16)
Four rooms	988(9.67)	317(32.09)	671(67.91)	981(9.63)	604(61.57)	377(38.43)	1018(9.71)	504(49.52)	514(50.48)
Five+ rooms	878(8.59)	268(30.48)	610(69.52)	877(8.61)	551(62.8)	326(37.2)	884(8.43)	470(53.11)	415(46.89)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Household had electricity		**χ2 (1) = 217.23, P<0.0001**			**χ2 (1) = 590.90, P<0.0001**			**χ2 (1) = 341.57, P<0.0001**	
No	4310(42.66)	1034(23.98)	3277(76.02)	4296(42.68)	2186(50.9)	2109(49.1)	4414(42.6)	2030(45.98)	2384(54.02)
Yes	5793(57.33)	2193(37.86)	3600(62.14)	5771(57.33)	4296(74.44)	1475(25.56)	5948(57.4)	3822(64.25)	2127(35.75)
Total	10104(100)	3227(31.94)	6877(68.06)	10066(100)	6482(64.39)	3584(35.61)	10362(100)	5851(56.47)	4511(43.53)
Source of drinking water		**χ2 (1) = 63.73, P<0.0001**			**χ2 (1) = 298.76, P<0.0001**			**χ2 (1) = 297.91, P<0.0001**	
Unimproved drinking water	3095(30.28)	814(26.3)	2281(73.7)	3079(30.23)	1601(52.01)	1477(47.99)	3196(30.49)	1405(43.95)	1791(56.05)
Improved drinking water	7127(69.72)	2446(34.32)	4680(65.68)	7106(69.77)	4966(69.88)	2140(30.12)	7285(69.51)	4526(62.13)	2759(37.87)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Type of toilet facility		**χ2 (1) = 169.71, P<0.0001**			**χ2 (1) = 650.38, P<0.0001**			**χ2 (1) = 222.94, P<0.0001**	
Unimproved toilet factories	4622(45.22)	1168(25.27)	3454(74.73)	4607(45.23)	2357(51.15)	2251(48.85)	4737(45.2)	2303(48.61)	2434(51.39)
Improved toilet factories	5600(54.78)	2092(37.36)	3508(62.64)	5578(54.77)	4210(75.49)	1367(24.51)	5744(54.8)	3628(63.16)	2116(36.84)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Type of cooking fuel		**χ2 (1) = 205.47, P<0.0001**			**χ2 (1) = 384.85, P<0.0001**			**χ2 (1) = 309.69, P<0.0001**	
Electricity & Gas	1213(11.87)	606(49.93)	608(50.07)	1211(11.89)	1088(89.85)	123(10.15)	1252(11.95)	998(79.76)	253(20.24)
Biofuel	9006(88.13)	2653(29.46)	6353(70.54)	8971(88.11)	5477(61.06)	3494(38.94)	9225(88.05)	4930(53.45)	4295(46.55)
Total	10219(100)	3259(31.89)	6960(68.11)	10182(100)	6565(64.48)	3617(35.52)	10477(100)	5929(56.59)	4548(43.41)
Floor Materials		**χ2 (1) = 152.06, P<0.0001**			**χ2 (1) = 329.83, P<0.0001**			**χ2 (1) = 488.55, P<0.0001**	
Unimproved floor materials	2885(28.22)	658(22.81)	2227(77.19)	2878(28.26)	1460(50.73)	1418(49.27)	2971(28.35)	1175(39.55)	1796(60.45)

Improved floor materials	7337(71.78)	2602(35.47)	4735(64.53)	7307(71.74)	5107(69.89)	2200(30.11)	7510(71.65)	4756(63.33)	2754(36.67)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Roof Materials		**χ2 (1) = 51.28, P<0.0001**			**χ2 (1) = 87.80, P<0.0001**			**χ2 (1) = 152.16, P<0.0001**	
Unimproved roof materials	1132(11.07)	255(22.52)	877(77.48)	1125(11.05)	583(51.85)	542(48.15)	1160(11.07)	460(39.64)	700(60.36)
Improved roof materials	9090(88.93)	3005(33.06)	6085(66.94)	9060(88.95)	5984(66.05)	3076(33.95)	9320(88.92)	5471(58.7)	3850(41.3)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Wall materials		**χ2 (1) = 175.32, P<0.0001**			**χ2 (1) = 638.88, P<0.0001**			**χ2 (1) = 579.49, P<0.0001**	
Unimproved wall materials	3282(32.11)	755(23)	2527(77)	3265(32.06)	1535(47)	1731(53)	3367(32.12)	1334(39.62)	2033(60.38)
Improved wall materials	6940(67.89)	2505(36.1)	4434(63.9)	6919(67.93)	5032(72.73)	1887(27.27)	7114(67.88)	4597(64.62)	2517(35.38)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Sex of household head		**χ2 (1) = 0.79, P = 0.4591**			**χ2 (1) = 7.82, P = 0.0283**			**χ2 (1) = 34.54, P<0.0001**	
Male	9127(89.29)	2898(31.75)	6229(68.25)	9098(89.33)	5824(64.02)	3273(35.98)	9357(89.28)	5202(55.6)	4155(44.4)
Female	1095(10.71)	362(33.08)	733(66.92)	1087(10.67)	743(68.32)	344(31.68)	1124(10.72)	728(64.81)	395(35.19)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Shared toilet facilities		**χ2 (1) = 0.11, P = 0.8216**			**χ2 (1) = 8.36, P = 0.0691**			**χ2 (1) = 24.51, P = 0.0005**	
No	4781(61.64)	1624(33.97)	3157(66.03)	4761(61.62)	3157(66.32)	1603(33.68)	4915(61.75)	2640(53.72)	2274(46.28)
Yes	2975(38.36)	1000(33.6)	1976(66.4)	2966(38.38)	2064(69.58)	902(30.42)	3044(38.25)	1813(59.56)	1231(40.44)
Total	7756(100)	2624(33.83)	5132(66.17)	7727(100)	5221(67.57)	2506(32.43)	7959(100)	4454(55.96)	3505(44.04)
Household has mosquito bed net for sleeping		**χ2 (1) = 18.22, P = 0.0015**			**χ2 (1) = 65.71, P<0.0001**			**χ2 (1) = 110.68, P<0.0001**	
No	3123(30.55)	1089(34.87)	2034(65.13)	3111(30.54)	2187(70.29)	924(29.71)	3225(30.77)	2072(64.24)	1154(35.76)
Yes	7098(69.44)	2171(30.59)	4927(69.41)	7074(69.46)	4381(61.93)	2693(38.07)	7256(69.23)	3859(53.19)	3397(46.81)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Number of people in household		**χ2 (3) = 32.08, P = 0.0006**			**χ2 (3) = 159.22, P<0.0001**			**χ2 (3) = 300.94, P<0.0001**	
2-3	982(9.61)	329(33.54)	653(66.46)	980(9.62)	698(71.2)	282(28.8)	1014(9.67)	615(60.67)	399(39.33)
4-6	4851(47.46)	1651(34.03)	3200(65.97)	4836(47.48)	3322(68.7)	1514(31.3)	5001(47.71)	3174(63.47)	1826(36.53)

7-9	2472(24.18)	758(30.65)	1715(69.35)	2462(24.17)	1521(61.79)	941(38.21)	2512(23.97)	1335(53.12)	1178(46.88)
10+	1917(18.75)	522(27.25)	1394(72.75)	1908(18.73)	1026(53.8)	881(46.2)	1954(18.64)	807(41.29)	1147(58.71)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Youngest child's stool disposed Properly		**χ2 (1) = 0.02, P = 0.9240**			**χ2 (1) = 0.10, P = 0.8208**			**χ2 (1) = 56.06, P<0.0001**	
No	3621(56.26)	1032(28.49)	2590(71.51)	3606(56.26)	2348(65.13)	1257(34.87)	3710(56.26)	1989(53.6)	1721(46.4)
Yes	2815(43.74)	806(28.63)	2009(71.37)	2803(43.74)	1837(65.52)	967(34.48)	2884(43.74)	1812(62.82)	1072(37.18)
Total	6436(100)	1838(28.55)	4598(71.45)	6409(100)	4185(65.3)	2224(34.7)	6594(100)	3801(57.64)	2794(42.36)
Frequency of watching television		**χ2 (2) = 228.63, P<0.0001**			**χ2 (2) = 751.11, P<0.0001**			**χ2 (2) = 856.25, P<0.0001**	
Not at all	5057(49.47)	1289(25.49)	3768(74.51)	5046(49.54)	2609(51.71)	2437(48.29)	5185(49.47)	2200(42.43)	2985(57.57)
Less than once a week	1990(19.47)	656(32.95)	1334(67.05)	1984(19.48)	1421(71.62)	563(28.38)	2036(19.43)	1352(66.39)	684(33.61)
At least once a week	3175(31.06)	1315(41.44)	1859(58.56)	3154(30.97)	2537(80.42)	618(19.58)	3260(31.1)	2379(72.97)	881(27.03)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)

5.4.4.1 Community-related characteristics of anaemia

Results in Figure 5.9 show that children from the community whose household wealth level is below the median (low) have a higher proportion of anaemic children, 75.7% (3536/4669). In addition, children whose proportion of community distance to any health facility is 'no big problem' is low have a higher proportion of anaemic children, 72.5% (3422/4721). Similarly, children from the community where the proportion of maternal education is high have less than the national proportion of anaemic children, 63.4% (3286/5183).

5.4.4.2 Community-related characteristics of malaria

Also, from the malaria panel of Table 5.9, children from the community whose household wealth level is below the median (low), have a higher proportion of malaria-positive children, 51.7% (2404/4647). In addition, children with a low proportion of community distance to any health facility are 'no big problem' and have a higher proportion of malaria-positive children, 43.4% (2038/4702). Similarly, children from the community where the proportion of maternal education is high have a lower proportion of malaria-positive children, 47.6% (2390/5025).

5.4.4.3 Community-related characteristics of malnutrition

Table 5.9 (malnutrition panel) shows that children from the community where the proportion of household wealth level is above the median (high), have a higher proportion of well-nourished children, 69.4% (3956/5698). Also, children whose community distance to any health facility is 'no big problem' is low have a higher proportion of poorly nourished children, 48.5% (2353/4852). In addition, the proportion of poorly nourished children from a community with a low proportion of community maternal education level is 59.2% (3050/5156). Similarly, children from the community where the proportion of 'community household with no bed net' is low have a proportion of poorly nourished children, 52.7% (2693/5107).

Table 5 9 Distribution and association of community-related characteristics on the three outcomes (Anaemia, malaria, malnutrition)

	Anaemia			**Malaria**			**Malnutrition**		
Variables	**N (%)**	**Not Anaemic N (%)**	**Anaemic N (%)**	**N (%)**	**Negative N (%)**	**Positive N (%)**	**N (%)**	**Well-nourished N (%)**	**Poorly nourished N (%)**
Community wealth level		**χ2 (1) = 229.84, P<0.0001**			**χ2 (1) = 977.40, P<0.0001**			**χ2 (1) = 835.29, P<0.0001**	
Low	4669(45.68)	1133(24.26)	3536(75.74)	4647(45.63)	2243(48.27)	2404(51.73)	4783(45.63)	1975(41.29)	2808(58.71)
High	5553(54.32)	2128(38.32)	3425(61.68)	5537(54.36)	4324(78.08)	1214(21.92)	5698(54.37)	3956(69.42)	1742(30.58)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Proportion of community distance to health facility is no big problem		**χ2 (1) = 77.11, P<0.0001**			**χ2 (1) = 233.12, P<0.0001**			**χ2 (1) = 94.78, P<0.0001**	
Low	4721(46.18)	1299(27.52)	3422(72.48)	4702(46.17)	2664(56.65)	2038(43.35)	4852(46.29)	2499(51.5)	2353(48.5)
High	5501(53.82)	1961(35.65)	3540(64.35)	5483(53.83)	3903(71.2)	1579(28.8)	5629(53.71)	3432(60.97)	2197(39.03)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Proportion of community maternal education level		**χ2 (1) = 107.11, P<0.0001**			**χ2 (1) = 625.72, P<0.0001**			**χ2 (1) = 1020.16, P<0.0001**	
Low	5039(49.3)	1363(27.05)	3676(72.95)	5025(49.34)	2635(52.44)	2390(47.56)	5156(49.19)	2106(40.85)	3050(59.15)
High	5183(50.7)	1897(36.61)	3286(63.39)	5160(50.66)	3932(76.21)	1228(23.79)	5325(50.81)	3824(71.82)	1500(28.18)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Proportion of community households with no bed net		**χ2 (1) = 22.32, P = 0.0049**			**χ2 (1) = 210.75, P<0.0001**			**χ2 (1) = 350.34, P<0.0001**	
Low	4999(48.9)	1483(29.66)	3516(70.34)	4982(48.92)	2861(57.43)	2121(42.57)	5107(48.73)	2414(47.28)	2693(52.72)
High	5223(51.1)	1777(34.03)	3446(65.97)	5203(51.08)	3706(71.23)	1497(28.77)	5374(51.27)	3516(65.43)	1858(34.57)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)

5.4.5.1 State-related characteristics of anaemia

Furthermore, Table 5.10 reveals that the proportion of anaemic children decreases as the deprivation of multidimensional poverty index (MPI) of the state of residence decreases. For example, the proportion of anaemic children from highly deprived MPI states was 76.4% (649/850), compared with 63% (1254/1992) from the lowest deprived MPI states. Nevertheless, as the human development index (HDI) of the state of residence increases, the proportion of anaemic children decreases from 72.2% (1556/2157) for the lowest HDI to 55.2% (395/715) for the highest HDI. However, the proportion of anaemic children associated state gender inequality index (GII) did not show a similar pattern as with MPI or HDI. The highest proportion of anaemic children, 73.3% (923/1260), was associated with the states with the highest GII, followed by children from the state with average GII, 69.7% (682/979).

The results also show that South-south has the highest proportion of anaemic children, 72.3% (786/1087), compared with children from North-central, 66.4% (954/1437), and South-west with the lowest proportion, 60.2% (1085/1803). In addition, the proportion of anaemic children from rural areas, 72.7% (4164/5728), was higher than their counterparts in urban areas, 62,3% (2798/4494).

5.4.5.2 State-related characteristics of malaria

Similarly, from the malaria panel (Table 5.10), the proportion of malaria-positive children is highest in the state with above averagely deprived multidimensional poverty index (MPI), 46.4% (1434/3093), followed by the states with highly deprived MPI, 43.2% (366/847). Similarly, children from the states with low human development index (HDI) recorded the highest proportion of positive malaria cases, 46.4% (1120/2416), compared with children from the states of residence with the highest HDI, 8.67% (62/716). However, the proportion of malaria-positive children associated state gender inequality index (GII) decreases as the GII increases. The highest proportion of malaria-positive children, 73.8% (2074/2727), was associated with the states with the lowest GII.

The results also show that North-west has the highest proportion of malaria-positive children, 49.4% (1465/2967), followed by children from the North-central, 36.9% (530/1436), and South-south recorded the lowest proportion, 24% (260/1085). Furthermore, the proportion of malaria-positive children from rural areas, 46.9% (2671/5700), was higher than their counterparts in urban areas, 21.1% (947/4485).

5.4.5.3 State-related characteristics of malnutrition

Table 5.10 also shows that the proportion of poorly nourished children decreases as the deprivation of multidimensional poverty index (MPI) of the state of residence decreases. The proportion of poorly nourished children from highly deprived MPI states dropped from 66.5% (597/899) to 23.1% (476/2062) for children from the lowest deprived MPI states. Also, as the human development index (HDI) of the state of residence increases, the proportion of poorly nourished children decreases from 63.7% (1423/2232) for the lowest HDI to 21.9% (166/754) for the highest HDI. However, the proportion of poorly nourished children associated with the state gender inequality index (GII) indicates that the higher the GII, the higher the proportion of poorly nourished children. The highest proportion of poorly nourished children, 59.9% (798/1333), was associated with the states with the highest GII, while children from the state with the lowest GII, 26.2% (736/2810).

The results also show that North-west has the highest proportion of poorly nourished children, 64.8% (1976/3050), followed by children from the North-east, 58.4% (954/1635), and the lowest proportion was for children from the South-east, 23.5% (321/1368). In addition, the proportion of poorly nourished children from rural areas, 52.0% (3046/5857), was higher than their counterparts in urban areas, 32.5% (1504/4624).

Table 5 10 Distribution and association of state-related characteristics on the three outcomes (Anaemia, malaria, malnutrition)

	Anaemia			**Malaria**			**Malnutrition**		
Variables	**N (%)**	**Not Anaemic N (%)**	**Anaemic N (%)**	**N (%)**	**Negative N (%)**	**Positive N (%)**	**N (%)**	**Well-nourished N (%)**	**Poorly nourished N (%)**
Multidimensional poverty index by state (MPI)		**χ2 (4) = 96.03, P<0.0001**			**χ2 (4) = 364.70, P<0.0001**			**χ2 (4) = 1213.44, P<0.0001**	
Highly Deprived	850(8.32)	200(23.58)	649(76.42)	847(8.32)	481(56.79)	366(43.21)	899(8.58)	302(33.55)	597(66.45)
Above averagely deprived	3104(30.37)	853(27.49)	2251(72.51)	3093(30.37)	1659(53.65)	1434(46.35)	3168(30.23)	1173(37.04)	1994(62.96)
Averagely Deprived	2327(22.76)	763(32.8)	1563(67.2)	2319(22.77)	1500(64.68)	819(35.32)	2359(22.51)	1468(62.25)	890(37.75)
Mildly Deprived	1950(19.08)	706(36.2)	1244(63.8)	1939(19.04)	1395(71.94)	544(28.06)	1994(19.02)	1402(70.3)	592(29.7)
Lowest Deprived	1992(19.49)	737(37.03)	1254(62.97)	1988(19.52)	1533(77.11)	455(22.89)	2062(19.67)	1586(76.91)	476(23.09)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Human development index by state (HDI)		**χ2 (4) = 79.55, P = 0.0001**			**χ2 (4) = 456.50, P<0.0001**			**χ2 (4) = 1161.02, P<0.0001**	
Lowest HDI	2157(21.1)	601(27.85)	1556(72.15)	2150(21.11)	1220(56.73)	930(43.27)	2232(21.3)	810(36.27)	1423(63.73)
Low HDI	2420(23.67)	717(29.64)	1702(70.36)	2416(23.72)	1297(53.65)	1120(46.35)	2464(23.51)	1005(40.8)	1459(59.2)
Average HDI	2239(21.9)	719(32.12)	1520(67.88)	2223(21.83)	1511(67.98)	712(32.02)	2271(21.67)	1508(66.41)	763(33.59)
High HDI	2690(26.32)	903(33.56)	1788(66.44)	2680(26.31)	1886(70.39)	793(29.61)	2759(26.32)	2019(73.18)	740(26.82)
Highest HDI	715(6.99)	320(44.76)	395(55.24)	716(7.03)	654(91.32)	62(8.68)	754(7.19)	589(78.02)	166(21.98)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Gender inequality index by state (GII)		**χ2 (4) = 21.49, P = 0.0353**			**χ2 (4) = 348.78, P<0.0001**			**χ2 (4) = 764.51, P<0.0001**	
Lowest GII	2732 (26.73)	921(33.73)	1810(66.27)	2727(26.77)	2033 (74.55)	694 (25.45)	2810(26.81)	2074 (73.81)	736 (26.19)
Low GII	1177 (11.51)	384 (32.65)	792 (67.35)	1171(11.50)	910 (77.71)	261 (22.29)	1206(11.51)	855 (70.9)	351 (29.1)
Average GII	979 (9.55)	297 (30.33)	682 (69.67)	977(9.60)	605 (61.95)	372 (38.05)	986 (9.41)	548 (53.57)	438 (44.43)
High GII	4073 (39.85)	1321 (32.42)	2753 (67.58)	4054(39.80)	2282 (56.30)	1772 (43.70)	4145 (39.55)	1918 (46.28)	2227(53.72)
Highest GII	1260 (12.33)	337 (26.74)	923 (73.26)	1256(12.33)	737 (58.66)	519 (41.34)	1333 (12.72)	535 (40.14)	798 (59.86)
Total	10222 (100)	3260 (3189)	6962 (68.11)	10185 (100)	6567 (64.48)	3618 (35.52)	10481 (100)	5931 (56.59)	4550 (43.41)
Region of residence		**χ2 (5) = 74.73, P<0.0001**			**χ2 (5) = 428.79, P<0.0001**			**χ2 (5) = 1313.74, P<0.0001**	
North-central	1437(14.06)	483(33.59)	954(66.41)	1436(14.1)	906(63.09)	530(36.91)	1451(13.84)	955(65.79)	496(34.21)

North-east	1589(15.54)	461(29.05)	1127(70.95)	1573(15.44)	1034(65.76)	539(34.24)	1635(15.6)	680(41.62)	954(58.38)
North-west	2973(29.08)	891(29.99)	2081(70.01)	2967(29.13)	1502(50.61)	1465(49.39)	3050(29.1)	1074(35.22)	1976(64.78)
South-east	1334(13.05)	406(30.44)	928(69.56)	1328(13.04)	992(74.69)	336(25.31)	1368(13.05)	1047(76.52)	321(23.48)
South-south	1087(10.63)	301(27.68)	786(72.32)	1086(10.66)	826(76.03)	260(23.97)	1118(10.67)	837(74.81)	282(25.19)
South-west	1803(17.64)	718(39.81)	1085(60.19)	1794(17.61)	1307(72.86)	487(27.14)	1859(17.74)	1338(71.97)	521(28.03)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)
Type of place of residence		**χ2 (1) = 126.25, P<0.0001**			**χ2 (1) = 724.32, P<0.0001**			**χ2 (1) = 397.70, P<0.0001**	
Urban	4494(43.96)	1697(37.75)	2798(62.25)	4485(44.04)	3538(78.89)	947(21.11)	4624(44.12)	3119(67.47)	1504(32.53)
Rural	5728(56.04)	1563(27.3)	4164(72.7)	5700(55.96)	3029(53.14)	2671(46.86)	5857(55.88)	2811(48)	3046(52)
Total	10222(100)	3260(31.89)	6962(68.11)	10185(100)	6567(64.48)	3618(35.52)	10481(100)	5931(56.59)	4550(43.41)

5.5 Individual and contextual factors associated with the three outcome variables

Research Question 4:

What are the differences between groups in the individual and contextual characteristics concerning the three outcomes of anaemia, malaria, and malnutrition among children 6-59 months in Nigeria?

As per the study design, all the variables were classified as categorical. To answer the above question, a chi-square statistic was used to establish the association between the individual and contextual characteristics with each of the three outcomes. Tables 5.6-5.10 also contained the results of the associations between the characteristics classified as a child-, parental-, household-, community-, and states-related, respectively, with anaemia, malaria, and malnutrition among children aged 6-59 months in Nigeria.

5.5.1 Associations of child-related characteristics

Table 5.6 also displays the associations between child-related variables and the three outcome variables. The child's sex was significantly associated with anaemia, with male more likely to be anaemic than the female children ($\chi2$ (1) =11.88, P = 0.0040) and for malnutrition, male children were significantly more likely to be poorly nourished than the female children, ($\chi2$ (1) = 31.37, P<0.0001), but not significantly associated with malaria status ($\chi2$ (1) = 0.55, P = 0.5163) among children aged 6-59 months in Nigeria. The child's age, birth order, and preceding birth interval were significantly associated with the three outcomes. However, the child's birth size was not statistically significantly associated with anaemia and malaria but was significantly associated with malnutrition ($\chi2$ (2) = 65.12, P<0.0001), with children born with small birth size more likely to be poorly nourished compared with children born either average of large birth size. The child having taken vitamin A supplements and dewormed in the last six months before the survey was statistically significantly associated with the three outcomes. But the child taken iron supplements in the last six months before the survey was associated with malaria ($\chi2$ (1) = 42.17, P<0.0001) and malnutrition ($\chi2$ (1) = 98.70, P<0.0001). Those who took iron supplements were less likely to be malaria positive or poorly nourished but was not associated with anaemia ($\chi2$ (1) = 2.86, P = 0.1861). Similarly, the difference in fever and diarrheal statuses in the last two weeks before the survey was statistically significantly associated with the three outcomes. Having cough in the last two weeks before the survey was found to be significantly associated with anaemia ($\chi2$ (1) = 16.10, P = 0.0009), with having reported having cough more likely to be anaemic compared with children who did

not have cough, but not significantly associated with malaria ($\chi2$ (1) = 0.25, P = 0.6851) and malnutrition ($\chi2$ (1) = 2.78, P = 0.1451).

5.5.2 Associations of parental-related characteristics

Moreover, Table 5.7 shows that the variations in some numbers of maternal characteristics were simultaneously statistically associated with the three outcome variables. Differences in maternal age group, currently working status, age group at first birth, highest educational status, maternal autonomy level, ante-natal care visit during the child's pregnancy, maternal religious status, maternal ethnicity, maternal anaemia status, body weight status, and paternal education status were statistically significantly associated with the three outcomes. However, the results show that mother currently residing with a partner is not significantly associated with anaemia ($\chi2$ (1) = 1.20, P = 0.3892), but significantly associated with malaria ($\chi2$ (1) = 7.43, P = 0.0291) and malnutrition ($\chi2$ (1) = 31.36, P<0.0001), with children of mothers currently living with partners more likely to be malaria positive and poorly nourished when compared with children whose mothers stay elsewhere. Also, paternal work status was not statistically associated with the three outcomes of interest.

5.5.3 Associations of household-related characteristics

Differences in household wealth indices were found to be statistically associated with anaemia ($\chi2$ (4) = 391.21, P<0.0001), malaria ($\chi2$ (4) =1240.51, P<0.0001), and malnutrition ($\chi2$ (4) = 994.65, P<0.0001), such that, the richer the households, the less likely the children will cohabit with either of the three diseases. (See Table 5.8). All household-related characteristics considered in this study were significantly associated with the malnutrition status of the children aged 6-59 months in Nigeria, except the household head age group ($\chi2$ (3) = 10.72, P = 0.0980). Similarly, only variations in shared toilet facilities ($\chi2$ (1) = 8.36, P = 0.0691), and younger child's stool disposal status ($\chi2$ (1) = 0.10, P = 0.8208), were not statistically significantly associated with malaria status of children aged 6-59 months in Nigeria. However, variations in age group of household head ($\chi2$ (3) = 3.48, P = 0.5367), number of bedrooms in the household ($\chi2$ (4) = 1.28, P = 0.9405), sex of household head ($\chi2$ (1) = 0.79, P = 0.4591), household shared toilet facilities ($\chi2$ (1) = 0.11, P = 0.8216), younger child's stool disposal status ($\chi2$ (1) = 0.02, P = 0.9240), were also reported as not statistically associated with anaemia status of children aged 6-59 months in Nigeria. However, children from households that use electricity & gas as source of cooking fuel were significantly less likely to either be anaemic, ($\chi2$ (1) = 205.47, P<0.0001), or malaria positive ($\chi2$ (1) = 384.85, P<0.0001) or poorly nourished ($\chi2$ (1) = 309.69, P<0.0001) when compared with children from the households that

use biofuel for cooking. Similarly, but unexpectedly, children residing in households having mosquito bed net for sleeping where significantly more likely to be anaemic, ($\chi2$ (1) = 18.22, P = 0.0015), malaria positive, ($\chi2$ (1) = 65.71, P<0.0001), and poorly nourished ($\chi2$ (1) = 110.68, P<0.0001), when compared with their counterparts living in households without mosquito bed net

5.5.4 Associations of community-related characteristics

All the community-related variables considered in this study, community wealth status, the proportion of community distance to a health facility is no big problem, the proportion of community maternal education level and proportion of community household with no bed net were statistically significantly associated with the outcomes, anaemia, malaria, and malnutrition (Results shown in Table 5.9)

5.5.5 Associations of state-related characteristics

Similarly, in Table 5.10, the variations in all the states-related variables were statistically significantly associated with the three outcomes of interest. For instance, multidimensional poverty index (MPI) was significantly associated with anaemia, showing that the less deprived in MPI, the less likely the children from such state will be anaemic, ($\chi2$ (4) = 96.03, P<0.0001), while, for malaria, children from above averagely deprived states were more likely to be malaria positive compared to other statuses ($\chi2$ (4) = 364.70, P<0.0001), and for malnutrition, children living in a state that is highly deprived multidimensionally in poverty, the more likely they are poorly nourished when compared to other children from other states ($\chi2$ (4) = 1213.44, P<0.0001). Also, the gender inequality index was statistically significantly associated with anaemia among children aged 6-59 months in Nigeria at 5% significance but was not at a 1% significance level.

5.6 The Chapter Summary

With the presentation of a sample description of the variables utilised in the study, the first level of the study of the quantitative methods attempted to address research questions 1 through 4. It detailed the fundamental traits for each variable considered in the study. This objective was effectively achieved with the secondary analysis of two integrated data (2018 NDHS & NHDR). The analysis includes a thorough investigation of the independent associations between the baseline traits classified into child-, parental-, household-, community-, and area-related factors with each of the outcomes (anaemia, malaria, and malnutrition)

Chapter 6 Quantitative analysis 2

6.0 Introduction

This chapter answers question five using multilevel logistic analysis of predictors of the three outcome variables of anaemia, malaria, and malnutrition separately. Following an extensive array of characteristics associated with the likelihood of children 6-59 months in Nigeria contracting any of the three outcome variables, the chapter's opening section discussed the multicollinearity problem and how to solve it. The findings of the multilevel analyses of anaemia, malaria, and malnutrition among children aged 6-59 months in Nigeria are presented in the second half.

Question 5
What are the independent effects of individual and contextual risk factors on the outcomes of anaemia, malaria, and malnutrition among children 6-59 months of age in Nigeria?

6.1 Analysis of predictors of the outcome variables

The last section performed a bivariate analysis of associations between the various characteristics and outcome variables. As much as bivariate analysis is essential to establish the associations or relationships between two variables, it has some pitfalls. Firstly, it only considered the association between an independent variable with a dependent variable of interest without accounting for other critical confounding variables (Kawo, Asfaw and Yohannes, 2018; DJS Research, 2022). Secondly, the chi-square test conducted can be sensitive to sample size. This study involved a large sample with small categories which might portray seemingly trivial relations to look statistically significant (Department of Sociology, 2022). Thirdly, the established associations neither connote causal nor predictor effects or the strength of these predictions (Department of Sociology, 2022). To take care of the drawbacks of chi square's bivariate analysis mentioned above and to answer question 5, this chapter presents the results of the multilevel logistic regression analysis of the individual and contextual determinants of each of the three outcome variables, anaemia, malaria, and malnutrition among children aged 6-59 months in Nigeria. The first part of the chapter considered checking for multicollinearity problem and resolving it. The second part presents the results of a multilevel analysis of anaemia, followed by a multilevel analysis of malaria, and then the analysis of malnutrition among children aged 6-59 months in Nigeria.

6.2 Multicollinearity check

A pre-estimation procedure was performed to check for the existence of multicollinearity among the predictors that were extracted from the bivariate analysis. Since the analysis of the

predictors of the three outcome variables was carried out independently using the logistic regression method, the multicollinearity check using 'collin' command in STATA was done once for all the predictor variables. Variables whose variance inflation factor (VIF) was greater than five were considered a potential multicollinearity problem. Three variables (household had mosquito net (VIF=11.65), under-five slept under a mosquito net (VIF=6.55), and household wealth quintile (VIF=6.55)) had VIF greater than 5 out of 58 variables considered for multicollinearity checks with mean VIF=2.20. However, nine variables (source of drinking water, type of toilet facility, type of cooking fuel used in the household, household had television, main floor materials, main roofing materials, main wall materials, shared toilet facility, and disposal of youngest child's stool), which were part of the indicators for the derivation of household wealth index, and 'household had mosquito net'(which has a strong inverse correlation with 'children under-5 years slept under bed net the night before the survey'), making up ten variables that were dropped for analysis. The mean VIF for the 48 variables retained was 1.85. (See table in appendix A.1)

6.2.1 Resolving additional collinearity problem

Furthermore, it was observed that during the analysis, the estimate for a category in the 'preceding birth interval' (60 months and above) was always omitted for the collinearity problem. Several diagnostic checks were carried out to detect where the problem was. From the original data set, the preceding birth intervals only captured data ranging from 8 to 236 months, with 19.4% (2,036/10451), children missing (invariably, this was suspected to be the children who were first born or the only child in the household and would not be included in the preceding birth interval), subsequently, these children will be removed from the overall analysis (via listwise deletion in STATA). Further checks on the data set, it was found that among the birth order variable (ranging from 1 to 16), children who are in the first order were 2,015 (invariably, these one will be missing among the preceding birth interval since they do not have any birth before them), so the analysis incorporated these set of children into the preceding birth interval variable and classified them as 'none'. Therefore, the birth order variable was dropped from the analysis to resolve the collinearity problem.

6.3 Multilevel analysis of anaemia

The first part of this analysis is titled: Individual, household, and area predictors of anaemia among children aged 6–59 months in Nigeria. *Public Health in Practice 3* 2022, 100229, available online on: https://www.sciencedirect.com/science/article/pii/S2666535222000052 was published in January 2022, and a copy of the publication is attached herein appendix C.5.

The publication used a single-level multiple logistic regression analysis to determine the risk factors of anaemia among children aged 6-59 months in Nigeria. The paper presented the results of both the adjusted odds ratios and predicted probabilities but reported and discussed in detail the results from the adjusted predicted probabilities of being anaemic among children aged 6-59 months in Nigeria at each mean of the predictor's category holding other variables constant at their means. However, this current study considered the hierarchical nature of the data set and applied a multilevel mixed-effect logistic regression to determine the risk factors associated with being anaemic among children 6-59 months of age in Nigeria.

6.3.1 Variables selection

The study applied the forward and backward stepwise selection methods at $p>0.20$ and $p<0.2$, respectively, and combined the outcomes of both forward and backward stepwise methods. In addition, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) post-estimation from the logistic analyses of the chosen variables were used to assess the goodness of fit from these three methods.

Table 6 1 Evaluation of goodness of fit for variables selection methods in anaemia

Goodness of fit	Backward stepwise	Forward stepwise	Backward + forward
AIC	8548.46	8478.6	8483
BIC	9015.22	8938.8	8957

The variables selected using the forward stepwise selection method yielded the least of both AICs and BICs. A total of 25 variables includes, child's sex, age, preceding birth order, the child took iron pills/syrup, duration of breastfeeding, deworming, malaria status, nutritional status, fever, and the child's place of delivery. Others are maternal highest education level, mother currently residing with a partner, maternal religious status, body mass index, anaemia status, and paternal highest educational level. Also included were household socioeconomic status (wealth quintile index), under-five slept under the bed net the night before the survey, number of under-5 years in the household, number of bedrooms in the household, sex of household head, household size, the state human development index, the state gender inequality index, and household region of residence. These variables were grouped into child-, parental-, household-, and state-related variables. Unfortunately, none of the community-related variables was among the selected factors for further analysis.

6.3.2 Model Set-up

Given the complex/hierarchical nature of the data sets, such that children/parental/household in individual units at Level-1 (since children from the same parent and household tend to be more similar than children from other households because they share the same characteristics)

(Obasohan *et al.*, 2021b), are nested in communities/clusters at Level-2 and nested in states at Level-3, multiple multilevel mixed-effects logistic regression models were fitted to determine the predictors of anaemia status among 6–59 months of age in Nigeria. Also, a likelihood ratio test was carried out to establish that the three-level model was more appropriate than the two-level model (the likelihood-ratio test is LR $\chi 2 = 99.38$, $p < 0.001$ for Level-2 nested in Level-3).

6.3.3 Model Building

The study built five multilevel logistic models. Model 1 is a null model (or empty model), with no predictors. The essence is to measure the variations across the communities and the states. Model 2 included only child-related variables; Model 3, had model 2 adjusted for/parental-related variables, while Model 4 contained level-1 factors only (i.e., household-related variables were added to Model 3; Model 5 (full model) was derived for all the selected variables including the area-related variables (level-3 variables). The goodness of fit was determined using log-likelihood (LLH), Akaike's information criteria (AIC) and Bayesian information criteria (BIC), such that the model with the highest LLH and lowest AIC and/or BIC was chosen as the best fit (Obasohan *et al.*, 2021b).

6.3.3.1 Multilevel model results

This section describes the results from the analysis using multilevel mixed-effects logistic regression. A weighted number of 7896 children had complete information for the included variables and were analysed. There were 1361 communities (level 2) with an average of 6 persons per community, nested in 37 states with the number of children per state ranging between 95 and 373 and an average of 214 children.

A Measure of Variation (Random Effects)

Model 1 is an empty model with no predictors and shows that the random effect of the proportions of the total variations due to differences in the communities and the states were, respectively, 0.494 and 0.157, while the variance due to individual level is 3.29 ($\pi 2/3$), which is fixed for logit. Therefore, the variations in the prevalence of anaemia status due to the three-level factors were assessed through an intrastate correlation coefficient of 0.0398 (95% CI: 0.023–0.069) and intracommunity correlation coefficient of 0.1652 (95% CI: 0.134–0.202), indicating that 3.98% and 16.52% of the total variation in the odds of being anaemic among children 6-59 months in Nigeria were respectively due to state and community levels.

Table 6 2 Multilevel multivariate models of predictors of anaemia with adjusted odds ratios (AOR) among children aged 6–59 months in Nigeria

	(Model 5) N=7896		
Variables	**AOR**	**P-value**	**(95%CI)**
Child's sex			
Male	1		
Female	0.83	0.001	(0.748-0.932)
Child's age in group			
6-11 months	1		
12-23 months	0.91	0.377	(0.729-1.127)
24-35 months	0.52	<0.0001	(0.39-0.683)
36-47 months	0.41	<0.0001	(0.311-0.546)
48-59 months	0.30	<0.0001	(0.227-0.402)
Preceding birth interval			
None	1		
8-24 months	1.31	0.004	(1.089-1.587)
Duration of breastfeeding			
Ever breastfed, not currently breastfeeding	1		
Never breastfed	0.82	0.367	(0.531-1.264)
Still breastfeeding	1.36	0.006	(1.093-1.68)
Malaria status			
Negative	1		
Positive	3.7	<0.0001	(3.218-4.251)
Nutritional status			
Well-nourished	1		
Poorly nourished	1.31	<0.0001	(1.159-1.484)
Child had Fever in last 2 weeks before the survey			
No	1		
Yes	1.26	0.001	(1.102-1.45)
Maternal/caregiver highest educational level			
No education	1		
Higher	0.73	0.028	(0.547-0.966)
Mother's religious status			
Catholic	1		
Islam	1.47	0.005	(1.124-1.915)
Mother's Anaemia status			
Not Anaemic	1		
Anaemic	1.74	<0.0001	(1.552-1.949)
Household wealth index			
Poorest	1		
Poorer	0.94	0.58	(0.765-1.161)
Middle	0.75	0.009	(0.599-0.928)
Richer	0.68	0.002	(0.538-0.867)
Richest	0.63	0.001	(0.48-0.833)
Children under 5 slept under mosquito bed net last night			
No child	1		
No net in household	0.83	0.047	(0.685-0.998)
Region of residence			
North-central	1		
South-east	1.96	0.004	(1.236-3.104)
South-south	2.46	<0.0001	(1.544-3.926)
Intercept	2.06	0.068	(0.947-4.484)
Random effect			
Community-level variance	0.2042		(0.124-0.337)
State-level variance	0.0717		(0.036-0.142)
VPC: community-level			
VPC: state-level			
ICC: community-level	0.077		(0.053-0.112)
ICC: state-level	0.02		(0.010-0.039)
MOR: community			
MOR: state	1.291		(1.198-1.432)

AOR: adjusted odds ratios, ICC: intraclass correlation coefficient, VPC: variance partition coefficient, MOR: Median odds ratios, AIC: Akaike information criterion (given a set of candidate models for the data, the preferred model is the one with the minimum AIC value), BIC: Bayesian information criterion

The variance partition coefficient (VPC) at the state level corresponds with the ICC at the state level (0.0398). However, the VPC at the community level is 0.1254, signifying that 12.54% of the total variance is collectively attributed to both the state and community levels.

The performance of the models for the goodness of fit was achieved using the most negligible value of AIC and the highest LLH. Model 5 contains all the variables in the analysis, with the

smallest AIC = 8478.3 and LLH = -4173.3. From the choice model (Model 5) in Table 6.2 (the results for all the models are displayed in Appendix A.2). The ICC at the community level has dropped from 0.117 in the null model to 0.077 (95% CI: 0.053-0.112), meaning the correlation between two children/individuals (unit of analysis) within the same community and the same state is 0.077, and the ICC at state-level dropped from 0.042 to 0.020 (95% CI: 0.020–0.039), and both had remained significant.

Similarly, in model 5, the median odds ratio (MOR) computed for states was 1.291, indicating the mean difference of the risk of being anaemic for two children with the same level-1 characteristics and picked randomly from two states. In more practical terms, it means there is a 30% increased risk of a child being anaemic if he/she moves from one state to another with an increased risk of anaemia. Also, MOR=1.54 at the community level signifies there is a 54% increased risk of a child being anaemic if he/she moves to another community with a higher risk of anaemia.

Measures of Association (Fixed Effects)

Table 6.2 also includes the results of the adjusted odds ratios (AOR) for each of the variables considered in the analysis after adjusting for other variables in the model. Model 5 (the choice model with the least AIC) represents the model fitting all the variables selected for analysis: child's sex, age is older than two years, preceding birth interval is between 8-24 months, the child is still breastfeeding, malaria and malnutrition statuses, had fever two weeks before the survey, mother/caregiver had higher education, she is a Muslim, the mother is anaemic, household wealth is middle and above, no net in the household and the regions of residence is south-east and South-south, were statistically significant predictors of anaemia status among children 6–59 months of age in Nigeria. The child's iron supplement, deworming statuses, place of child's delivery, mother residing with a partner, mother's body weight status, partner's education level, number of under-five years in the household, the number of bedrooms, and people in the household, sex of household head, human development index, and gender inequality index were not statistically significant predictors of anaemia among children aged 6-59 months in Nigeria.

Furthermore, the odds of a child whose mother has a higher education (AOR=0.73, 95%CI 0.547-0.966) is less likely to be anaemic compared with a child of a mother without any formal education. The results further reveal that as the household wealth quintile increases, the odds of children from such households decrease significantly compared to children from the poorest household when other variables are constant.

With respect to a variable 'number of children under-five years who slept under bed nets', implies that children from households without mosquito bed nets have 0.17 reduced odds of being anaemic compared with children from households without under-five years of slept under a mosquito bed net. The odds of children aged 6-59 months from South-south geopolitical zones of Nigeria are 2.46 times more likely to be anaemic compared with children from North-central geopolitical zones.

6.4 Multilevel analysis of malaria status

A part of the study titled: Individual and contextual factors associated with malaria among children 6–59 months in Nigeria: A multilevel mixed-effect logistic model approach. *Int. J. Environ. Res. Public Health* **2021**, *18*, 11234. https://doi.org/10.3390/ijerph182111234 was published in October 2021. The full text of the publication has been attached herein the Appendix C.4

This current analysis was performed on the same data but with reclassifications of maternal education and household wealth index and addition variable (state gender inequality index) in line with other outcome variables and applied the same multilevel multivariate mixed effects logistic regression analysis.

6.4.1 Multivariable Multilevel Models of Predictors of Malaria Fever Status

In the first instance, all the variables that serve as proxies for nutritional status and household wealth were excluded from the multilevel analysis. Furthermore, a multicollinearity test (See section 6.2) checks for highly correlated predictors. It also used a forward stepwise variable selection procedure by entering all variables statistically associated with the malaria status of children 6–59 months of age in Nigeria at a 5% significance level, and removal was by $p > 0.20$. Because of this, 26 variables (child's sex and age, birth size, duration of breastfeeding, anaemia status, nutritional status, fever status, deworming, maternal education status, paternal education and work status, maternal religion, ethnicity, anaemia status, household wealth, household head age group, under-five slept under a bed net, number of bedrooms, low cluster wealth level, cluster distance to a health facility is no big problem, state multidimensional poverty index, state human development index, state gender inequality index, region of residence, and place of residence), were finally retained for the multilevel model building.

6.4.2 Multilevel Model Results

A Measure of Variation (Random Effects)

Model 1 is the null model (no predictors) with the fixed effect showing that the proportions

of the total variations due to differences in the communities and the states were 1.305 and 0.614, while the variance due to individual level is 3.29 ($\pi^2/3$), which is fixed for logit. Therefore, the variations in the prevalence of malaria status due to the three-level factors were assessed through an intrastate correlation coefficient of 0.1188 (95% CI: 0.73–0.184) and intracommunity correlation coefficient of 0.368 (95% CI: 0.32–0.42), indicating that 11.9% and 36.8% of the total variation in the odds of malaria positive were respectively due to state and community levels. The variance partition coefficient (VPC) at the state level corresponds with the ICC at the state level. However, the VPC at the community level is 0.025, meaning that 2.5% of the total variance is collectively attributed to both the state and community levels. However, from the chosen model (Model 6) in Table 6.3, the ICC at the community level has dropped from 36.8% in the null model to 18% (95% CI:14–22%), meaning the correlation between two children/individuals (unit of analysis) within the same community and the same state is 0.21, and the ICC at state-level dropped from 11.88% to 2.6% (95% CI: 1.3–5.2%), both had remained significant. The performance of models was established using AIC and likelihood ratio. Improvements in model fit was achieved at Model 6 (full model), with AIC = 8058, BIC= 8594, and log-likelihood = −3952.

Measures of Association (Fixed Effects)

Table 6.3 shows the results of the adjusted odds ratios (AOR) for each of the variables considered in the analysis after adjusting for the rest variables. Model 2 represents the model fitting with child-related variables only: age, sex, birth size, prebirth intervals, the child's duration of breastfeeding, fever two weeks before the survey, dewormed in the last six months before the survey, the anaemic status of the child, and nutrition status. The child's age, the child’s duration of breastfeeding, the child is dewormed, the child is anaemic and has a fever were statistically significant risk factors of being malaria positive. Also, maternal education, ethnicity, maternal is anaemic, is obese, household wealth, the age of household head, the number of children under-five years in the household, the sex of household head, the proportion of community distance to a health facility is no big problem is high, living in a state that is above averagely deprived MDPI, high HDI, states with low gender inequality index, living in north-east zone of Nigeria, and place of residence were statistically significant predictors of malaria status among children 6–59 months of age in Nigeria. The child's sex, birth size, preceding birth intervals, nutritional status, maternal age group, age at first birth, paternal work status, and education status, the number of under-five years who slept under a bed net the night before the survey, and the number of bedrooms and number of people in the household were

not statistically significant predictors. However, after including all the predictor variables (Model 6), the significant status of the child-specific factors (model 2) remains.

Table 6 3 Multilevel multivariate logistic models of predictors of malaria with adjusted odds ratios (AOR) among children 6-59 months in Nigeria

	Model 6 (N=7808) **(Level 1, 2, 3 variables)**		
Individual variables	**AOR**	**p-value**	**95% CI**
Child's sex			
Male	1		
Female	0.93	0.252	(0.83-1.05)
Child's age in group			
6-11 months	1		
12-23 months	1.31	0.015	(1.05-1.62)
24-35 months	1.83	<0.001	(1.37-2.45)
36-47 months	2.41	<0.001	(1.79-3.23)
48-59 months	2.8	<0.001	(2.07-3.78)
Child's birth size			
Large	1		
Average	0.93	0.521	(0.76-1.15)
Small	0.97	0.832	(0.75-1.27)
Preceding birth interval			
None	1		
8-24 months	0.95	0.636	(0.76-1.18)
25-35 months	0.98	0.828	(0.79-1.21)
36-59 months	0.97	0.796	(0.77-1.22)
60+ months	0.89	0.45	(0.66-1.2)
Duration of breastfeeding			
Ever breastfed, not currently breastfeeding	1		
Never breastfed	1.44	0.144	(0.88-2.34)
Still breastfeeding	0.63	<0.001	(0.5-0.79)
Child took deworming drug in last 6months			
No	1		
Yes	0.76	0.001	(0.64-0.89)
Malnutrition status			
Well-nourished	1		
Poorly nourished	1.05	0.443	(0.92-1.2)
Anaemia status			
Not anaemic	1		
Anaemic	3.83	<0.001	(3.3-4.44)
Child had Fever in last 2 weeks before the survey			
No	1		
Yes	2.03	<0.001	(1.77-2.33)
Maternal age group in 10 years			
15-24 years	1		
25-34 years	1.02	0.812	(0.85-1.24)
35 years+	1.21	0.117	(0.95-1.54)
Age of mother at first birth			
10-24 years	1		
25-36 years	0.87	0.226	(0.7-1.09)
37-49 years	0.45	0.206	(0.13-1.54)
Maternal/caregiver highest educational level			
No education	1		
Primary	0.85	0.127	(0.69-1.05)
Secondary	0.74	0.008	(0.6-0.93)
Higher	0.45	<0.001	(0.31-0.66)
Maternal ethnicity			
Hausa/Fulani/Kanuri/Seribiri	1		
Ibo	1	0.998	(0.59-1.69)
Yoruba	1.68	0.016	(1.1-2.57)
Others	1.31	0.032	(1.02-1.67)
Mother's Anaemia status			
Not Anaemic	1		
Anaemic	1.23	0.001	(1.09-1.4)
Maternal body mass index			
Normal	1		
Underweight	0.89	0.251	(0.73-1.08)
Overweight	0.86	0.105	(0.72-1.03)
Obese	0.72	0.011	(0.55-0.93)
Paternal Work Status			
No	1		
Yes	1.3	0.164	(0.9-1.9)
Partner education status			
No education	1		
Primary education	0.95	0.622	(0.76-1.17)
Secondary education	0.83	0.078	(0.68-1.02)
Tertiary education	0.87	0.298	(0.66-1.13)
Household wealth index			
Poorest	1		
Poorer	0.9	0.325	(0.74-1.11)
Middle	0.69	0.002	(0.55-0.87)
Richer	0.6	<0.001	(0.46-0.78)
Richest	0.26	<0.001	(0.18-0.36)
Household Head age group			

Less 34 years	1		
35-44 years	0.83	0.03	(0.7-0.98)
45-55 years	0.9	0.312	(0.72-1.11)
56 years+	1.04	0.771	(0.81-1.32)
Children under 5 slept under mosquito bed net last night			
No child	1		
All children	0.89	0.237	(0.72-1.08)
Some children	1.17	0.231	(0.9-1.52)
No net in household	0.98	0.85	(0.80, 1.21)
Number of under-5 in household			
0-3	1		
4-6th	1.29	0.038	(1.01-1.64)
7th+	1.38	0.404	(0.64-2.97)
Number of bedrooms in household			
One-room	1		
Two rooms	1.04	0.659	(0.88-1.23)
Three rooms	1.08	0.458	(0.88-1.34)
Four rooms	0.92	0.511	(0.71-1.19)
Five+ rooms	0.78	0.109	(0.58-1.06)
Sex of household head			
Male	1		
Female	0.78	0.024	(0.62-0.97)
Number of people in household			
2-3	1		
04-6	1.01	0.949	(0.78-1.3)
07-9	0.96	0.809	(0.72-1.3)
10+	1.03	0.852	(0.73-1.47)
Proportion of community distance to health facility is no big problem			
Low	1		
High	0.78	0.006	(0.65-0.93)
Multidimensional Poverty Index by State MPI			
Highly Deprived	1		
Above averagely deprived	2.08	0.011	(1.19-3.64)
Averagely Deprived	1.25	0.569	(0.58-2.71)
Mildly Deprived	1.18	0.689	(0.52-2.68)
Lowest Deprived	0.94	0.897	(0.35-2.51)
Human Development Index by State HDI			
Lowest HDI	1		
Low HDI	1.5	0.13	(0.89-2.53)
Average HDI	1.81	0.076	(0.94-3.5)
High HDI	2.66	0.016	(1.2-5.88)
Highest HDI	1.47	0.402	(0.6-3.6)
Gender Inequality Index by State GII			
Lowest GII	1		
Low GII	0.56	0.032	(0.33-0.95)
Average GII	1.16	0.593	(0.67-2.02)
High GII	1.34	0.242	(0.82-2.17)
Highest GII	1.63	0.113	(0.89-2.99)
Region of residence			
North-central	1		
North-east	0.44	0.015	(0.22-0.85)
North-west	1.3	0.488	(0.62-2.74)
South-east	1.32	0.457	(0.64-2.71)
South-south	0.7	0.265	(0.38-1.31)
South-west	1.55	0.208	(0.78-3.07)
Type of place of residence			
Urban	1		
Rural	1.98	<0.001	(1.63-2.41)
Intercept	0.04	<0.001	(0.01-0.14)
Random effect			
Community-level variance	0.63		(0.48-0.81)
State-level variance	0.10		(0.05-0.21)
VPC: community-level	0.16		
VPC: state-level	0.02		
ICC: community-level	0.18		(0.15-0.22)
ICC: state-level	0.03		(0.01-0.05)
MOR: community	2.13		(1.94-2.42)
MOR: state	1.35		(1.24-1.55)

AOR: Adjusted Odds Ratios, ICC: Intraclass Correlation Coefficient, VPC: Variance Partition Coefficient, AIC: Akaike Information Criterion (Given a set of candidate models for the data, the preferred model is the one with the minimum AIC value)

The odds of a child having malaria increased as the child's age increased. The odds of children between the age of 48–59 months experiencing malaria fever were 2.8 times the odds of children 6–11 months of age (AOR = 2.8, 95% CI: 2.07–3.78). Children who were still breastfeeding (AOR = 0.63, 95% CI: 0.50–0.79), and dewormed (AOR = 0.76, 95% CI: 0.64–

0.89), had 37% and 24% reduced odds of contracting malaria infection, respectively relative to their reference category.

In addition, the higher the maternal educational attainment, the less likely the children will contract malaria fever. Children whose mothers (AOR = 0.45, 95% CI: 0.31–0.66) had higher education has 55% reduced odds of being malaria fever positive. The wealthier the household, the less likely the child can be malaria positive. Children living in the wealthiest households have 74% reduced odds of contracting malaria parasites compared to children from the poorest households. Within the community-related variables, children from a community with a high proportion of mothers who said distance to the nearest health centre is "no big problem" had lower odds of malaria fever positive. The result from among the area-specific variables shows that children from the states that are 'above averagely deprived in multidimensional poverty index are significantly two folds more likely to have malaria when compared with children from the states with the highest deprived (AOR = 2.08, 95% CI: 1.19–3.64).

Similarly, children residing in states with high human development index were more than two and a half folds more likely to contract malaria fever when compared with children from the state with lowest human development index. Also, children living in North East geopolitical zones were less likely to have malaria fever when compared with children from the North central geopolitical zone. On the contrary, children from rural areas (AOR = 1.98, 95% CI: 1.63–2.41) were more likely to suffer from malaria infection than children from urban areas.

6.5 Multilevel analysis of malnutrition status

As part of the study, a paper titled: Spatial disparities in prevalence and socioeconomic predictors of malnutrition among children under-five years in Nigeria was presented at the Royal Statistical Society (RSS) international conference held in Aberdeen, United Kingdom, between 2-6 September 2022. The full text of the presentation has been attached herein, the Appendix D.1. The analysis for this presentation focused on children aged under-five years in Nigeria. In contrast, this thesis focused on the subset of children aged 6-59 months in Nigeria (see section 4.4.1.1 for the reasons). Therefore, the content of the multilevel multivariate mixed effect logistic analysis of predictors of malnutrition among children aged 6-59 months in Nigeria is presented in the following section.

6.5.1 Multilevel Multivariate Models of Predictors of Malnutrition Status

In the first instance, a multicollinearity test (See section 6.2) was conducted to check for highly correlated predictors. The study examined the variable selection using the backward and forward stepwise procedures by testing all 48 variables that scaled through the multicollinearity

checks. The removal was by $p \geq 0.20$ for backward, and entry was $p < 0.20$ for stepwise forward methods, also combined the outcomes of both forward and backward stepwise methods. Furthermore, check the goodness of fits (Table 6.4) from these three methods using AIC and BIC post-estimation from the logistic analyses of the variables selected for each stepwise method. Combining the backward and forward stepwise variables yielded the least AIC (9124.917).

Table 6 4 Evaluation of goodness of fit for variables selection methods in malnutrition

Goodness of fit	Backward stepwise	Forward stepwise	Backward + forward
AIC	9262.6	9154.846	9124.917
BIC	9729.8	9635.162	9639.811

Given above, 31 potential variables (child's age, sex, birth size, preceding birth interval, child took iron syrup in the last six months before the survey, duration of breastfeeding, malaria status, anaemia status, cough status, diarrhoeal status, and child's place of delivery, mother lives with partner, maternal education status, maternal ethnic group, maternal religious status, paternal education status, maternal body weight status, maternal anaemia status, household wealth, household head age group, number of bedrooms, low cluster wealth level, cluster distance to a health facility is no big problem, low cluster maternal education level, low cluster household with bed net, state human development index, state gender inequality index, region of residence, and place of residence), were finally retained for the multilevel model building.

6.5.2 Model Set-up

Given the complex/hierarchical nature of the data sets, such that children/parental/household in individual units at Level-1 (since children from the same parent, and household tend to be more similar than children from other households because they share the same characteristics) (Obasohan *et al.*, 2021b), are nested in communities/clusters at Level-2 and nested in states at Level-3, multiple multilevel logistic regression models were fitted to determine the predictors of malnutrition status among 6–59 months of age in Nigeria. Furthermore, a likelihood ratio test was carried out to establish that the three-level model was more appropriate than the two-level model (the likelihood-ratio test is LR $\chi 2 = 448.73$, $p < 0.001$ for Level-2 nested in Level-3).

6.5.3 Model Building

The analysis built six multilevel logistic models. Model 1 is a null model (or empty model) with no predictors. The essence is to measure the variations across the communities and the states. Model 2 included only child-related variables; model 3 adjusted model 2 for parental-

related covariates, while model 4 (level-1 factors only), model 2, was adjusted for both parental- and household-related variables. Model 5 contains level-1 and level-2 factors only; that is, community-related variables were added to Model 4; Model 6 (full model) was derived for all the selected variables, including the area-related variables (level-3 variables). Intra-class correlation coefficients (both the communities and the states), variance partition coefficients (both for the communities and states), and median odds ratios (MOR) were the post-estimation techniques used to evaluate the models. The goodness of fit was determined using Log-likelihood (LLH), Akaike's information criteria (AIC) and Bayesian information criteria (BIC), such that the model with the highest LLH and lowest AIC and/or BIC was chosen as the best fit (Obasohan *et al.*, 2021b)

6.5.3.1 Multilevel Model Results

This section presents the results from the analysis using multilevel mixed-effects logistic regression. To consider appropriate balance in the number of cases while comparing the models for fit, a total of 7770 children with complete information for the included variables were analysed. These result into 1361 communities (level 2) with an average of 6 persons per community, nested in 37 states with the number of children having data for malnutrition per state ranging between 92 and 373 and on average of 210 children per state.

A Measure of Variation (Random Effects)

Model 1 is the null model (no predictors) with the random effect showing that the proportions of the total variations due to differences in the communities and the states were, respectively, 0.322 (95%CI: 0.234 to 0.443) and 0.595 (95%CI: 0.367 to 0.966), while the variance due to individual level is 3.29 ($\pi^2/3$), which is fixed for logit. Therefore, the variations in the prevalence of malnutrition status among children aged 6-59 months in Nigeria due to the three-level factors were assessed through an intrastate correlation coefficient of 0.1415 (95% CI: 0.092–0.210) and intracommunity correlation coefficient of 0.218 (95% CI: 0.165–0.281), indicating that 14.15% and 21.8% of the total variation in the odds of malnutrition were respectively due to state and community levels. Therefore, the variance partition coefficient (VPC) at the state level corresponds with the ICC at the state level. However, the VPC at the community level is 0.076, meaning that 7.6% of the total variance is collectively attributed to both the state and community levels.

The performance of models was established using AIC and likelihood ratio. Improvements in model fit were achieved at Model 6 (full model), with AIC = 9118.5 and log-likelihood = −4490.3. Therefore, this study interpreted the results of model 6. From this chosen model

(Model 6) in Table 6.5, the ICC at the community level in the null model has dropped from 21.8% to 4.6% (95% CI:17–25%), meaning the correlation between two children/individuals (unit of analysis) within the same community and the same state is 0.046, and the ICC at state-level also dropped from 14.1% to 0.1% (95% CI: 0.1–4.4%), both had remained significant.

The variance partition coefficient (VPC) is the same as the ICC at the state level (0.002). Nevertheless, the VPC at the community level is 0.045, meaning that 4.5% of the total variance is collectively attributed to both the state and the community levels.

Similarly, in model 6, the median odds ratio (MOR) computed for states was 1.077, signifying that there exist a mean difference of the risk of being poorly nourished for two children with the same level-1 characteristics and picked randomly from two states. It means there is a 7.7% increased risk of a child being poorly nourished if he/she moves from one state to another state of increased risk of poorly nourished. Additionally, there is a 46% increased risk of a child being poorly nourished if he/she moves to another community with a higher risk of being poorly nourished.

Measures of Association (Fixed Effects)

Table 6.5 presents the results of the adjusted odds ratios (AOR) for the variables used in the analysis after adjusting for the other variables in the model. Model 6 represented the model with the best fit and contained all the variables from the three levels (individual variables at level 1, community variables at level 2 and state/area variables at level 3). Variables at level-1 are child's age, sex, birth size, preceding birth interval; the child took iron syrup in the last six months before the survey, anaemia status, the child had diarrhoea in the last two weeks before the survey, mother currently works, maternal education status, maternal ethnicity, paternal education status, maternal body weight status, household wealth, and several bedrooms in the household were statistically significant predictors of malnutrition among children 6-59 months of age in Nigeria. Among the community-related variables (level 2-related), cluster distance to a health facility is no big problem and was a statistically significant predictor of malnutrition. Gender inequality index and region of residence among the area variables were also significant predictors of malnutrition. On the other hand, the child who took iron syrup in the last six months before the survey, the child's duration of breast-feeding status, malaria RDT status, the child had cough two weeks before the survey, and place of delivery were not statistically significant predictors of malnutrition. Also, maternal religious status, maternal anaemia status, household head age group, number of people in the household, community wealth status, the proportion of community maternal education status, proportion of community households with

no net, and type of place of residence, were not statistically significant predictors of malnutrition among children aged 6-59 months in Nigeria.

The odds of female children being poorly nourished (AOR=0.74, 95% CI 0.67-0.82) are significantly lower than their male counterparts. Also, the odds of children aged 24-35 months developing malnutrition were 2.22 times the odds of children 6–11 months of age (AOR = 2.22, 95% CI: 1.72–2.86). The smaller the birth size of the children is, the more likely they will be poorly nourished. Children who were born with average birth size (AOR = 1.26, 95% CI: 1.05–1.51), and born with small birth size (AOR = 1.79, 95% CI: 1.45–2.26), had 26% and 79% increased odds of contracting malnutrition when compared with children born with large birth size. Anaemic children (AOR = 1.33, 95% CI: 1.18–1.51) and those who had diarrhoeal (AOR = 1.27, 95% CI: 1.08–1.49) two weeks preceding the survey were more prone to being poorly nourished compared with children who do not have any of these conditions.

Similarly, children of working-class mothers have increased odds (AOR = 1.14, 95% CI: 1.01–1.29) of being poorly nourished compared with children whose mothers do not work. The educational levels attained by mothers and fathers are inversely proportional to the odds of their children being poorly nourished. Children of mothers with secondary education (AOR = 0.71, 95% CI: 0.58–0.86), tertiary education (AOR = 0.51, 95% CI: 0.38–0.70), and fathers with tertiary education (AOR = 0.78, 95% CI: 0.62–0.98), were respectively, 29%, 49%, and 22% reduced odds of being poorly nourished compared with children whose mothers and fathers do not have any formal education. The results also show that the richer the household, the less likely the children will be poorly nourished compared with their counterparts in the poorest household. Also, the odds of children residing in a 3-bedroom household (AOR = 1.23, 95% CI: 1.02–1.47) are 1.23 times more likely to be poorly nourished than children residing in a one-bedroom household. Furthermore, among the community-related variables, children from a community where the proportion of the community distance to the nearest health centre is not a big problem are high; there are 17% reduced odds of being poorly nourished compared with children from a community with a low proportion. Moreover, from the area-related variables, the odds of children from a state where the gender inequality index is low (AOR = 1.45, 95% CI: 1.14–1.85) is significantly 1.45 times more likely to be poorly nourished when compared with children from the state with lowest gender inequality index. The odds of children from the North-east (AOR = 2.27, 95% CI: 1.77–2.94), and the North-west (AOR = 3.11, 95% CI: 2.40–4.14), are 127% and 211% significantly more likely to be poorly nourished respectively.

Table 6 5 Multilevel multivariate logistic models of predictors of malnutrition with adjusted odds ratios (AOR) among children 6-59 months in Nigeria

	Model 6 (N=7770): Level 1, 2, & 3 variables (Model 5 + area-related)		
Variables	**AOR**	**P-value**	**95%CI**
Child's sex			
Male	1		
Female	0.742	<0.0001	(0.669, 0.824)
Child's age in group			
6-11 months	1		
12-23 months	1.664	<0.0001	(1.381, 2.005)
24-35 months	2.219	<0.0001	(1.722, 2.858)
36-47 months	1.791	<0.0001	(1.384, 2.318)
48-59 months	1.276	0.068	(0.982, 1.659)
Child's birth size			
Large	1		
Average	1.260	0.014	(1.049, 1.514)
Small	1.790	<0.0001	(1.419, 2.26)
Preceding birth interval			
None	1		
8-24 months	1.311	0.004	(1.091, 1.575)
60+ months	0.757	0.024	(0.594, 0.964)
Anaemia status			
Not anaemic	1		
Anaemic	1.332	<0.0001	(1.178, 1.506)
Child had diarrheal in last 2 weeks before the survey			
No	1		
Yes	1.267	0.004	(1.08, 1.488)
Mother/Caregiver currently working			
No	1		
Yes	1.140	0.042	(1.005, 1.294)
Maternal/caregiver highest educational level			
No education	1		
Secondary	0.709	0.001	(0.583, 0.863)
Higher	0.513	<0.0001	(0.378, 0.696)
Maternal ethnicity			
Hausa/Fulani/Kanuri/Seribiri	1		
Ibos	0.633	0.034	(0.415, 0.966)
Mother's Anaemia status			
Not Anaemic	1		
Anaemic	1.096	0.100	(0.983, 1.223)
Maternal body weight status			
Normal	1		
Underweight	1.266	0.008	(1.063, 1.506)
Overweight	0.710	<0.0001	(0.611, 0.824)
Obese	0.596	<0.0001	(0.481, 0.737)
Partner education status			
No education	1		
Tertiary education	0.780	0.031	(0.623, 0.977)
Household wealth index			
Poorest	1		
Richest	0.732	0.040	(0.543, 0.986)
Number of bedrooms in household			
One-room	1		
Two rooms	1.191	0.020	(1.028, 1.38)
Three rooms	1.227	0.026	(1.024, 1.469)
Four rooms	1.336	0.011	(1.068, 1.673)
Proportion of community distance to health facility is no big problem			
Low	1		
High	0.867	0.033	(0.761, 0.988)
Proportion of community households with no bed net			
Low	1		
High	0.972	0.678	(0.848, 1.113)
Gender inequality index by state (GII)			
Lowest GII	1		
Low GII	1.454	0.002	(1.144, 1.849)
Region of residence			
North-central	1		
North-east	2.272	<0.0001	(1.773, 2.912)
North-west	3.111	<0.0001	(2.339, 4.138)
Intercept	0.316	<0.0001	(0.182, 0.547)
Random effect			
Community-level variance	0.155		(0.089, 0.270)
State-level variance	0.006		(0.000, 0.159)
VPC: community-level	0.045		
VPC: state-level	0.002		
ICC: community-level	0.047		
ICC: state-level	0.002		
MOR: community	1.456		1.329, 1.641
MOR: state	1.077		1.014, 1.463

AOR: Adjusted Odds Ratios, ICC: Intraclass Correlation Coefficient, VPC: Variance Partition Coefficient, AIC: Akaike Information Criterion (Given a set of candidate models for the data, the preferred model is the one with the minimum AIC value)

6.6 The Chapter Summary

The quantitative analyses presented in the Chapter were the second level of the statistical analysis that provided answers to research question 5. A one-time multicollinearity check was done and resolved for use in all the outcome variables. Besides, variable selections were carried out for each of the outcome variables. Sections 6.3 – 6.5 presented multilevel analyses for anaemia, malaria, and malnutrition. The findings show that the predictors of each outcome of interest span across the child-, parental-, household-, community-, and area-related characteristics presenting the possibility of overlaps in the determinants of MAMM. At the third level of statistical analysis in this study, the following Chapter is set to establish if there are multiple overlaps in the determinants of MAMM.

Chapter 7 Quantitative analysis 3

7.0 Introduction

This section presents the results of the analysis of prevalence and associations of predictors of multimorbidity to answers question 6. It starts by using graphs to illustrate the prevalence of MAMM in section 7.1, followed by analysing associations of the predictors with multimorbidity in section 7.2. Next, the spatial prevalence of MAMM was given via the map descriptions across the states & FCT and regions of residence in Nigeria. Next, an analysis of the predictors of MAMM using the multilevel mixed effect ordinal logistic regression models were presented in section 7.4. Finally, the multiple imputation method given in section 7.5 was used to check the missing mechanism and the effects on the analysis results.

Research question 6

What are the prevalence and differences between groups in the individual and contextual characteristics concerning the number of occurrences of MAMM among children 6-59 months in Nigeria?

7.1 Prevalence of multimorbidity

The interactions between the three diseases (anaemia, malaria, and malnutrition) were considered as the state of multimorbidity of common childhood diseases among children aged 6-59 months in Nigeria. Multimorbidity of childhood diseases was assessed using the counts of the interactions between the three outcome variables. Figure 7.1, the composite of 3 diseases, shows the distribution of the three diseases' possible interactions and their counts. There were more children cohabiting with anaemia only, 22.5% (2293/10183), 95%CI (21.72-23.34), compared with malaria only, 3% (308/10183), 95%CI (2.71-3.38), and malnutrition only, 9% (897/10183), 8.27-9.38). There are 16.9% (1721/10183), 95%CI (16.19-17.65) and 17.4% (1767/10183), 95%CI (16.64-18.10), almost equally many children in the sample who cohabit with the three disorders and those who do not.

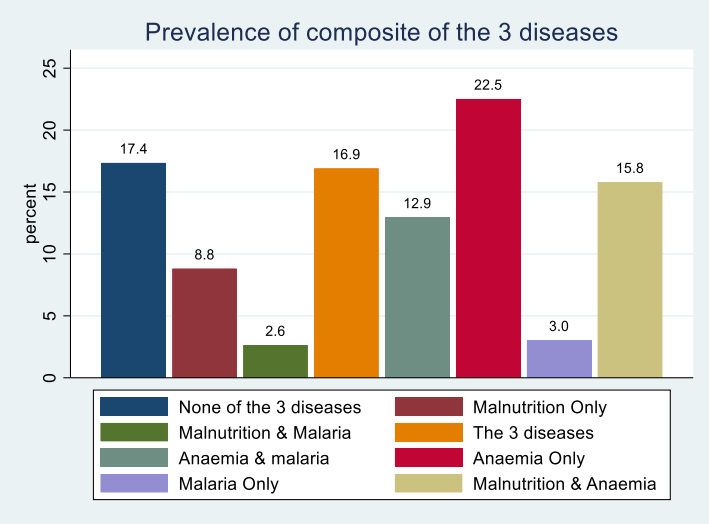


Figure 7 1 : Distribution of prevalence of composite of 3 diseases

Figure 7.2 shows the prevalence of multimorbidity among children aged 6-59 months in Nigeria.

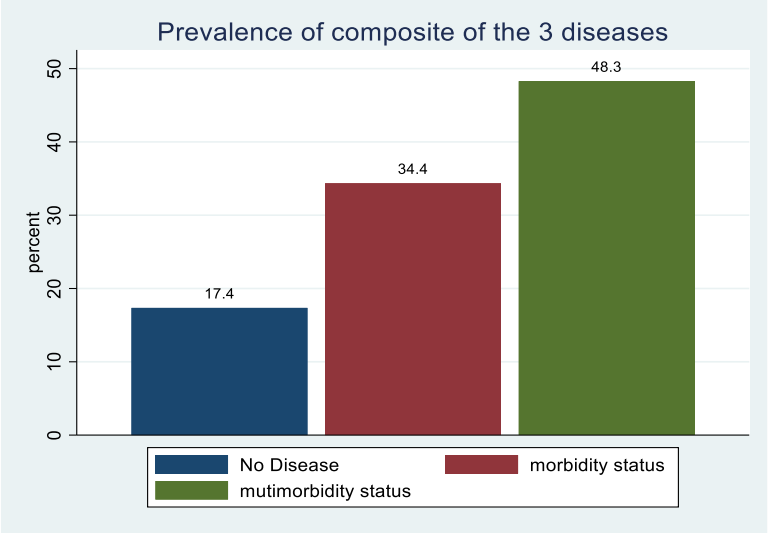
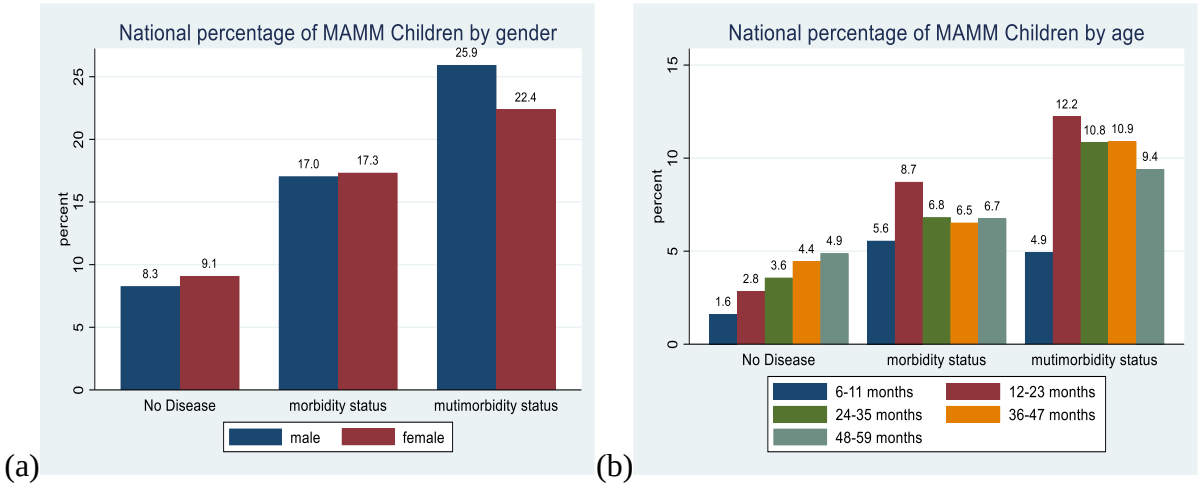


Figure 7 2 Distribution of national prevalence of multimorbidity

The statuses show that the percentage of children with none of the outcome diseases, 'no disease' was 17.4% (1767/10183), 95%CI (16.63-18.10), while 48.3% (4917/10183), 95%CI (47.32-49.26) had two or more of the disease outcomes (multimorbidity), and 34.4% (3498/10183), 95%CI (33.44-35.29) had morbidity status (only one of the diseases). More children aged 6-59 months in Nigeria cohabit with two or more diseases than with one morbidity.

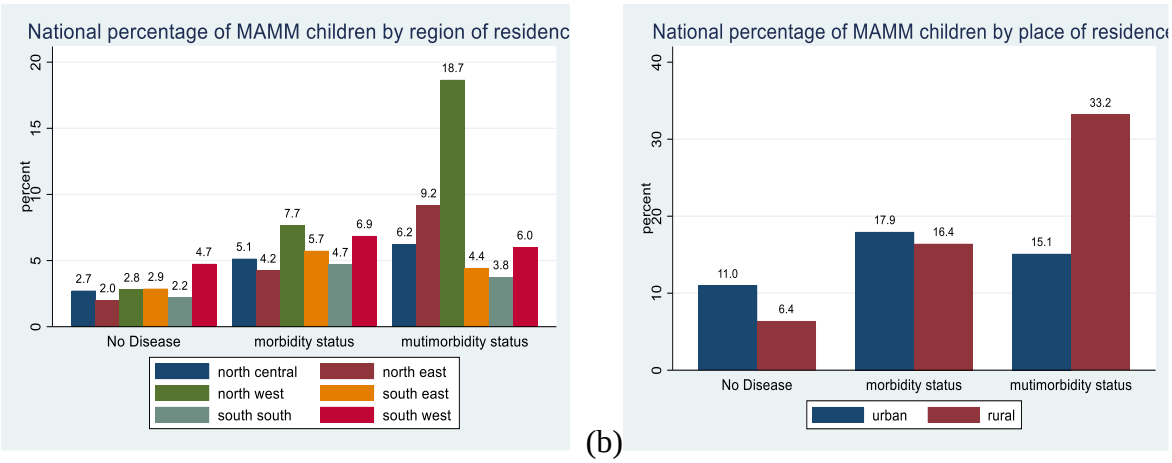


(a) (b)

Figure 7 3 Distribution of national percentage of MAMM children by (a) sex and (b) age

The data reported in Fig. 7.3a reveals that MAMM varies by sex. Male children were more prone to an increased MAMM prevalence than female children. Also, the prevalence of 'no disease' increases almost proportionally as age increases. The prevalence of MAMM was highest among children aged 12-23 months (Fig 7.3b).

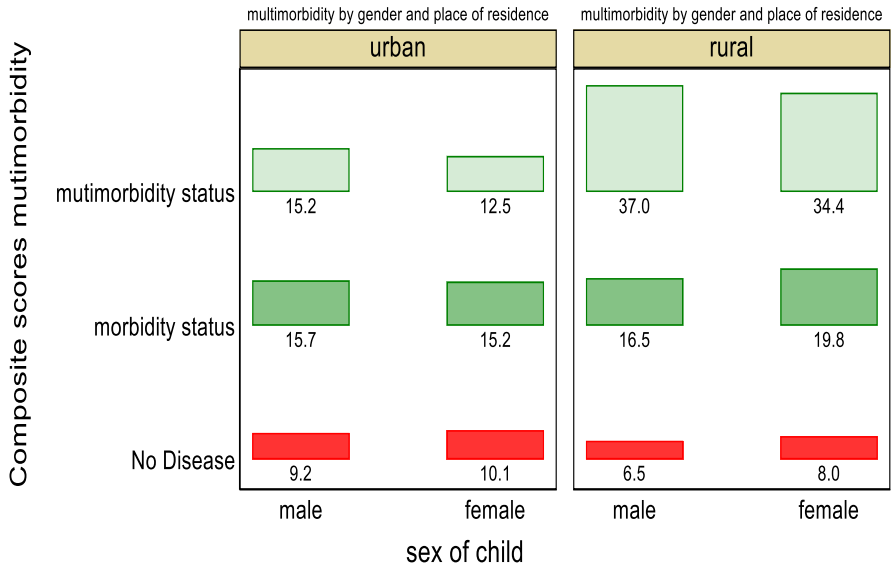
Similarly, the highest percentage of children aged 6-59 months in Nigeria found sick of MAMM lived in the North-west geopolitical zones of Nigeria (18.7%), followed by children from the North-East geopolitical zone (9.2%).



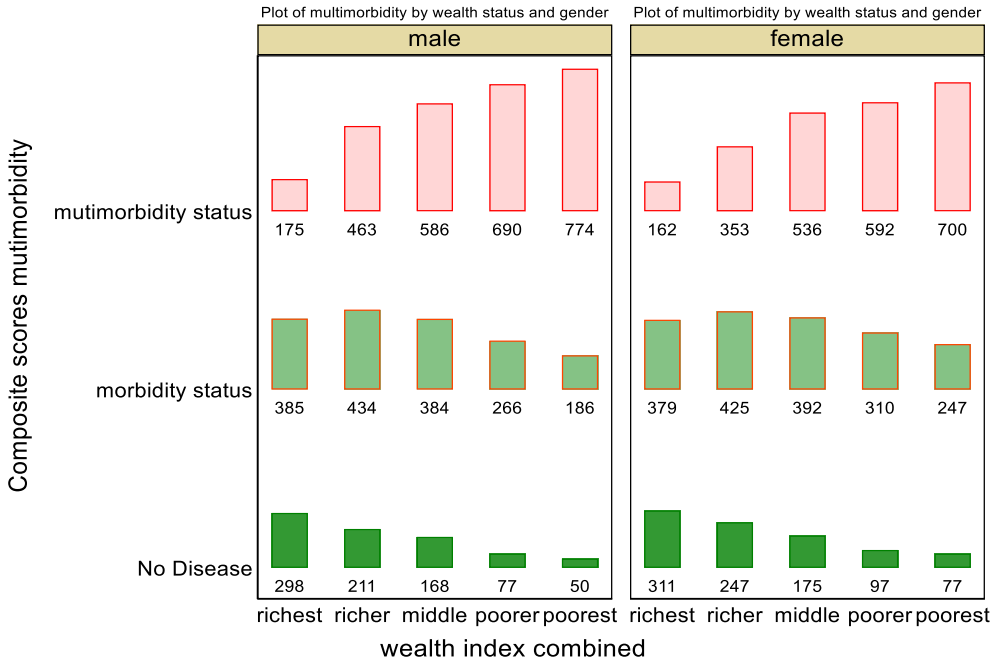
(a) (b)

Figure 7 4 Distribution of national percentage of MAMM children by (a) region (b) place of residence

Also, in Fig 7.4b, the percentage of children in Nigeria cohabiting with two or more diseases of anaemia, malaria, and malnutrition from the rural area is more than two folds the number of those residing in an urban area.



(a)



(b)

Figure 7 5 : Percentage of MAMM children (a) by sex and place of residence (b) by wealth index and sex

Fig. 7.5 displays a three-dimensional distribution between MAMM, sex, and place of residence. Fig 7.5a shows that children are cohabiting with two or more diseases of anaemia, malaria, and malnutrition, with the highest percentage being males (37%) from rural areas. Furthermore, female children living in urban areas without any of the three diseases had the highest percentage (10.1%). On the other hand, the 'tabulation plot' in Fig 7.5b shows that the highest number of children (774) cohabiting with MAMM reside in the poorest household.

7.2 Association of individual, contextual characteristics and multimorbidity status

7.2.1 Child-related characteristics

In consideration of MAMM, Table 7.1 presents the distributions and the associations of child-related variables on the MAMM among children aged 6-59 months in Nigeria. There were 51.2% (5217/10184) of male children in the sample of multimorbidity. Therefore, the proportion of children with two or more diseases was higher for male children, 50.62% (2641/5217), compared to their female counterparts, 45.8% (2277/4967). There were more children in the 12-23 months age group, 23.8% (2422/10184), and had the highest proportion of children with two or more diseases (multimorbidity), 51.4% (1245/2422). followed by children in the age band 24-35 months, 51.1% (1102/2160). In addition, children with an average birth size of 78.7% (7914/10059) were more represented in the sample, such that the proportion of those with multimorbidity among the small birth size group, 55.1% (673/1222), was the highest, followed by those with average birth size 47.8% (3785/7914). Children with birth order 7th and above 63% (976/1549), have the highest proportion of MAMM. The preceding birth interval of 25-35 months had the highest number, 28.4% (2884/10164) in the sample, and the highest proportion, 52.9% (1525/2884), of children with multimorbidity in the sample. Similarly, children who did not take vitamin A supplements, 55.2% (2928/5309), iron supplements, 50.2% (4128/8224), or deworming, 53.9% (3899/7235) within the last six months before the survey were proportionally higher among the children cohabiting with two or more of the diseases compared with those who took the supplements

Table 7 1 Distribution of child-related characteristics and their association with MAMM status

		Multimorbidity status		
Variables	**Total**	**None of the diseases**	**One disease only**	**Two or more the diseases**
	N (%)	**N (%)**	**N (%)**	**N (%)**
Child-related characteristics				
Child's sex		**$\chi 2$ (2) = 25.03, p=0.0002**		
Male	5217(51.23)	841(16.13)	1734(33.25)	2641(50.62)
Female	4967(48.77)	926(18.64)	1764(35.52)	2277(45.84)

Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Child's age in group		**χ2 (8) = 205.55, p<0.0001**		
6-11 months	1232(12.1)	165(13.35)	566(45.91)	502(40.74)
12-23 months	2422(23.78)	289(11.95)	888(36.66)	1245(51.39)
24-35 months	2160(21.21)	363(16.82)	694(32.13)	1102(51.05)
36-47 months	2227(21.87)	452(20.32)	664(29.83)	1110(49.85)
48-59 months	2143(21.04)	498(23.23)	687(32.06)	958(44.71)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Child's birth size		**χ2 (4) = 38.28, P<0.0001**		
Large	923(9.18)	190(20.63)	343(37.13)	390(42.23)
Average	7914(78.68)	1387(17.53)	2741(34.64)	3785(47.83)
Small	1222(12.15)	177(14.52)	371(30.37)	673(55.11)
Total	10059(100)	1755(17.45)	3455(34.35)	4849(48.2)
Childbirth order		**χ2 (6) = 242.19, P<0.0001**		
1st	1944(19.09)	449(23.09)	689(35.42)	807(41.49)
2nd or 3rd	3483(34.2)	662(19.01)	1315(37.77)	1506(43.23)
4-6th	3207(31.49)	492(15.35)	1086(33.86)	1629(50.78)
7th+	1549(15.21)	164(10.58)	409(26.38)	976(63.04)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Preceding birth interval		**χ2 (8) = 135.23, P<0.0001**		
None	1944(19.13)	449(23.09)	689(35.42)	807(41.49)
8-24 months	2191(21.55)	319(14.56)	736(33.58)	1136(51.87)
25-35 months	2884(28.38)	435(15.07)	924(32.05)	1525(52.88)
36-59 months	2351(23.13)	383(16.28)	827(35.16)	1141(48.55)
60+ months	795(7.82)	177(22.23)	317(39.88)	301(37.89)
Total	10164(100)	1762(17.33)	3492(34.36)	4910(48.31)
Took Vitamin A supplements		**χ2 (2) = 212.37, P<0.0001**		
No	5309(52.36)	757(14.26)	1624(30.59)	2928(55.15)
Yes	4831(47.64)	1004(20.77)	1853(38.36)	1974(40.87)
Total	10140(100)	1761(17.37)	3477(34.29)	4902(48.35)
Took Iron supplements		**χ2 (2) = 67.80, P<0.0001**		
No	8224(81.02)	1347(16.38)	2748(33.42)	4128(50.2)
Yes	1927(18.98)	416(21.62)	737(38.25)	773(40.13)
Total	10150(100)	1764(17.38)	3485(34.34)	4902(48.29)
Duration of breastfeeding		**χ2 (4) = 119.28, P<0.0001**		
Ever breastfed, not currently breastfeeding	7440(73.06)	1474(19.82)	2448(32.9)	3518(47.29)
Never breastfed	171(1.68)	19(11)	68(39.89)	84(49.11)
Still breastfeeding	2572(25.26)	274(10.65)	983(38.22)	1315(51.13)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Child took deworming drug in last 6months		**χ2 (2) = 348.84, P<0.0001**		
No	7235(71.41)	1033(14.28)	2302(31.82)	3899(53.89)
Yes	2897(28.59)	729(25.16)	1173(40.5)	995(34.33)
Total	10132(100)	1762(17.39)	3476(34.31)	4894(48.3)
Child had Fever in last 2 weeks before the survey		**χ2 (2) = 281.15, P<0.0001**		

No	7485(73.52)	1473(19.68)	2764(36.93)	3248(43.39)
Yes	2696(26.48)	294(10.9)	735(27.25)	1667(61.85)
Total	10181(100)	1767(17.36)	3499(34.36)	4915(48.28)
Child had cough in last 2 weeks before the survey		**χ2 (2) = 0.96, P=0.7103**		
No	8524(83.71)	1488(17.45)	2939(34.48)	4097(48.07)
Yes	1658(16.29)	280(16.85)	560(33.78)	819(49.36)
Total	10182(100)	1767(17.36)	3499(34.36)	4916(48.28)
Child had diarrheal in last 2 weeks before the survey		**χ2 (2) = 142.48, P<0.0001**		
No	8831(86.74)	1638(18.55)	3126(35.39)	4067(46.06)
Yes	1350(13.26)	129(9.56)	373(27.64)	848(62.8)
Total	10181(100)	1767(17.36)	3499(34.37)	4915(48.28)
Place of child's delivery		**χ2 (6) =794.52, P<0.0001**		
Home	5348(52.51)	572(10.69)	1543(28.86)	3233(60.45)
Public facility	2975(29.22)	672(22.58)	1163(39.08)	1141(38.34)
Private facility	1660(16.3)	490(29.52)	701(42.25)	469(28.23)
Elsewhere	200(1.97)	34(16.83)	91(45.59)	75(37.59)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)

7.2.1 Parental-related characteristics

Similarly, Table 7.2 describes the distribution and association of the parental-related characteristics, children of mothers aged 15-24 years, not currently working-class mothers, who had their first baby aged 10-24 years, had no education, and currently living with a partner were respectively having the highest proportion of 54.4% (1115/2049), 53.4% (1590/2978), 51.8% (4446/8578), 67.7% (2687/3970), 49% (4343/8861), of being cohabiting with multimorbidity. The results also revealed that the proportion of children cohabiting with multimorbidity was higher among mothers who slept under a mosquito bed net the night before the survey when compared with those whose mothers did not. Also, the proportion of children whose mother with no ante-natal care record/visit during the pregnancy of the child, is a Muslim, of Hausa/Fulani/Kanuri/Seribiri ethnicity, did not take iron tablets during pregnancy of the child. She is anaemic, were consistently higher compared with other children in other groups/categories.

Table 7 2 Distribution of parental-related characteristics and their association with MAMM status

Parental-related characteristics				
Maternal age group in 10 years		**χ2 (4) = 62.21, P<0.0001**		
15-24 years	2049(20.12)	247(12.06)	687(33.53)	1115(54.41)
25-34 years	5261(51.66)	988(18.78)	1831(34.8)	2442(46.42)
35 years+	2874(28.22)	532(18.51)	981(34.14)	1361(47.35)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Mother/Caregiver currently working		**χ2 (2) = 44.71, P<0.0001**		
No	2978(29.24)	449(15.07)	939(31.55)	1590(53.38)

Yes	7206(70.76)	1318(18.3)	2559(35.52)	3328(46.19)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Age of mother at first birth		**χ2 (4) = 330.39, P<0.0001**		
10-24 years	8578(84.23)	1294(15.08)	2838(33.09)	4446(51.83)
25-36 years	1578(15.5)	463(29.32)	653(41.37)	463(29.31)
37-49 years	27(0.27)	11(39.12)	8(28.3)	9(32.58)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Maternal/caregiver highest educational level		**χ2 (6) = 1417.75, P<0.0001**		
No education	3970(38.98)	332(8.37)	951(23.95)	2687(67.68)
Primary	1643(16.14)	221(13.45)	581(35.35)	841(51.2)
Secondary	3597(35.32)	832(23.13)	1542(42.88)	1223(34)
Higher	974(9.56)	382(39.23)	425(43.64)	167(17.13)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Mother is currently residing with husband/partner		**χ2 (2) = 20.09, P=0.0022**		
Living with her partner	8861(91.05)	1479(16.69)	3039(34.3)	4343(49.02)
Staying elsewhere	871(8.95)	195(22.41)	298(34.22)	378(43.37)
Total	9732(100)	1674(17.2)	3337(34.29)	4721(48.51)
Maternal autonomy level		**χ2 (2) = 358.15, P<0.0001**		
Low autonomy	5070(49.78)	635(12.52)	1529(30.15)	2907(57.34)
More autonomy	5114(50.21)	1133(22.15)	1970(38.53)	2011(39.32)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Maternal/caregiver slept under mosquito bed net		**χ2 (2) = 175.43, P<0.0001**		
No	4670(45.85)	964(20.65)	1777(38.06)	1928(41.29)
Yes	5514(54.14)	803(14.56)	1722(31.22)	2990(54.22)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Ante-Natal Care visits during pregnancy of the child		**χ2 (4) = 314.09, P<0.0001**		
None	1342(21.06)	120(8.97)	333(24.81)	889(66.21)
1-3 visits	954(14.96)	112(11.76)	289(30.31)	552(57.93)
4 and above visits	4078(63.97)	775(19.01)	1656(40.62)	1646(40.37)
Total	6374(99.99)	1008(15.81)	2278(35.75)	3088(48.44)
Mother's religious status		**χ2 (6) = 595.20, P<0.0001**		
Catholic	1027(10.09)	241(23.43)	442(43.03)	344(33.54)
Other Christian	3438(33.76)	835(24.28)	1378(40.09)	1225(35.63)
Islam	5654(55.52)	682(12.07)	1651(29.2)	3321(58.73)
Traditionalist & others	64(0.63)	9(14.57)	28(42.81)	27(42.62)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Maternal ethnicity		**χ2 (6) = 737.24, P<0.0001**		
Hausa/Fulani/Kanuri/Seribiri	4067(39.94)	407(10)	1070(26.3)	2591(63.69)
Ibo	1650(16.2)	404(24.49)	710(43.04)	536(32.47)
Yoruba	1488(14.62)	392(26.34)	562(37.73)	535(35.93)
Others	2978(29.24)	564(18.94)	1157(38.86)	1256(42.19)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Mother took iron tablets during pregnancy		**χ2 (2) = 90.87, P<0.0001**		
No	1778(27.49)	245(13.78)	508(28.54)	1026(57.68)

Yes	4690(72.51)	791(16.87)	1814(38.67)	2085(44.46)
Total	6469(100)	1036(16.02)	2321(35.88)	3111(48.1)
Mother's Anaemia status		**χ2 (2) = 269.34, P<0.0001**		
Not Anaemic	4206(41.84)	997(23.7)	1534(36.47)	1675(39.83)
Anaemic	5847(58.16)	761(13.02)	1930(33.01)	3156(53.97)
Total	10053(100)	1758(17.49)	3464(34.46)	4831(48.06)
Maternal body weight status		**χ2 (6) = 518.14, P<0.0001**		
Normal	5311(60.82)	776(14.62)	1757(33.09)	2777(52.29)
Underweight	885(10.13)	84(9.48)	233(26.35)	568(64.17)
Overweight	1668(19.1)	429(25.72)	689(41.3)	550(32.98)
Obese	869(9.95)	255(29.39)	405(46.62)	208(23.99)
Total	8732(100)	1544(17.69)	3085(35.32)	4103(46.99)
Paternal Work Status		**χ2 (2) = 6.04, P=0.2041**		
No	304(2.98)	37(12.09)	112(36.88)	155(51.02)
Yes	9880(97.01)	1731(17.52)	3387(34.28)	4763(48.21)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Partner education status		**χ2 (6) = 969.76, P<0.0001**		
No education	2872(29.91)	231(8.04)	651(22.66)	1990(69.3)
Primary education	1423(14.82)	183(12.84)	485(34.1)	755(53.06)
Secondary education	3741(38.95)	775(20.72)	1514(40.47)	1452(38.81)
Tertiary education	1566(16.31)	471(30.1)	651(41.55)	444(28.35)
Total	9603(100)	1660(17.29)	3301(34.38)	4641(48.33)

7.2.3 Household-related characteristics

Table 7.3 shows that the proportion of children with two or more diseases decreases as the household wealth index increases. The highest proportion was children from the poorest households, 73.6% (1393/1893). Also, the proportion of children with multimorbidity from a household headed by middle-aged (35-44 years) is the lowest, 45.2% (1783/3946), compared to other households in the survey. Additionally, the proportion of children with multimorbidity from households without electricity, with unimproved drinking water, and unimproved toilet facilities, were respectively 63.2% (2715/4296), 62.6% (1927/3079), 61.4% (2828/4607) higher.

Table 7 3 : Distribution of household-related characteristics and their association with MAMM status

Household-related characteristics				
Household wealth index		**χ2 (8) = 1635.53, P<0.0001**		
Poorest	1893(18.59)	109(5.73)	392(20.7)	1393(73.57)
Poorer	1989(19.53)	166(8.33)	555(27.9)	1268(63.77)
Middle	2139(21)	328(15.35)	753(35.19)	1058(49.46)
Richer	2144(21.05)	445(20.75)	876(40.85)	823(38.4)
Richest	2019(19.83)	720(35.66)	924(45.75)	376(18.6)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)

Household Head age group		**χ2 (6) = 29.79, P=0.0040**		
Less 34 years	2827(27.76)	469(16.6)	952(33.66)	1406(49.75)
35-44 years	3946(38.75)	720(18.25)	1443(36.57)	1783(45.18)
45-55 years	2091(20.54)	338(16.17)	699(33.43)	1054(50.4)
56 years+	1319(12.95)	240(18.17)	405(30.7)	674(51.12)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Children under 5 slept under mosquito bed net last night		**χ2 (6) = 176.44, P<0.0001**		
No child	1316(13.02)	250(19)	451(34.24)	615(46.75)
All children	4715(46.64)	744(15.78)	1549(32.86)	2422(51.37)
Some children	996(9.85)	114(11.42)	269(26.97)	613(61.61)
No net in household	3083(30.5)	635(20.6)	1211(39.27)	1238(40.13)
Total	10110(100)	1743(17.24)	3479(34.41)	4888(48.35)
Number of under-5 in household		**χ2 (4) = 131.82, P<0.0001**		
0-3	9068(89.04)	1656(18.26)	3210(35.4)	4202(46.34)
4-6th	1051(10.32)	104(9.88)	268(25.49)	679(64.63)
7th+	64(0.63)	8(11.98)	20(31.77)	36(56.24)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Number of bedrooms in household		**χ2 (8) = 56.35, P<0.0001**		
One-room	2806(27.55)	563(20.07)	1042(37.14)	1201(42.79)
Two rooms	3489(34.26)	593(16.98)	1187(34.03)	1709(48.99)
Three rooms	2030(19.93)	334(16.44)	660(32.54)	1036(51.02)
Four rooms	981(9.64)	143(14.62)	321(32.75)	517(52.63)
Five+ rooms	877(8.61)	134(15.31)	287(32.79)	455(51.91)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Household had electricity		**χ2 (2) = 700.88, P<0.0001**		
No	4296(42.68)	418(9.73)	1163(27.07)	2715(63.2)
Yes	5770(57.32)	1328(23.02)	2289(39.67)	2153(37.31)
Total	10065(100)	1746(17.35)	3452(34.29)	4867(48.36)
Source of drinking water		**χ2 (2) = 391.35, P<0.0001**		
Unimproved drinking water	3079(30.23)	300(9.74)	851(27.65)	1927(62.61)
Improved drinking water	7105(69.77)	1468(20.65)	2647(37.26)	2990(42.08)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Type of toilet facility		**χ2 (2) = 616.17, P<0.0001**		
Unimproved toilet factories	4607(45.24)	489(10.61)	1290(28.01)	2828(61.38)
Improved toilet factories	5576(54.76)	1279(22.93)	2208(39.6)	2089(37.47)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Type of cooking fuel		**χ2 (2) = 655.49, P<0.0001**		
Electricity & Gas	1210(11.88)	464(38.33)	535(44.26)	211(17.42)
Biofuel	8971(88.12)	1304(14.53)	2962(33.02)	4705(52.45)
Total	10181(100)	1767(17.36)	3497(34.35)	4916(48.29)
Floor Materials		**χ2 (2) = 599.36, P<0.0001**		
Unimproved floor materials	2878(28.26)	210(7.29)	746(25.92)	1922(66.79)
Improved floor materials	7306(71.74)	1557(21.32)	2753(37.68)	2996(41)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)

Roof Materials		**χ2 (2) = 184.38, P<0.0001**		
Unimproved roof materials	1125(11.05)	101(8.99)	268(23.85)	756(67.17)
Improved roof materials	9059(88.95)	1666(18.39)	3230(35.66)	4162(45.94)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Wall materials		**χ2 (2) = 800.39, P<0.0001**		
Unimproved wall materials	3265(32.06)	255(7.81)	781(23.91)	2230(68.28)
Improved wall materials	6918(67.93)	1512(21.86)	2718(39.29)	2688(38.85)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Sex of household head		**χ2 (2) = 20.61, P=0.0007**		
Male	9096(89.32)	1528(16.8)	3124(34.34)	4444(48.85)
Female	1087(10.67)	239(21.98)	375(34.46)	473(43.56)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Shared toilet facilities		**χ2 (2) = 11.81, P=0.0464**		
No	4761(61.62)	878(18.43)	1615(33.93)	2268(47.63)
Yes	2965(38.38)	586(19.75)	1089(36.74)	1290(43.51)
Total	7726(100)	1463(18.94)	2705(35.01)	3558(46.05)
Household has mosquito bed net for sleeping		**χ2 (2) = 125.96, P<0.0001**		
No	3111(30.55)	647(20.8)	1221(39.25)	1243(39.95)
Yes	7073(69.45)	1120(15.84)	2278(32.2)	3675(51.96)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Number of people in household		**χ2 (6) = 247.76, P<0.0001**		
0-3	979(9.61)	195(19.95)	354(36.18)	429(43.86)
4-6	4836(47.48)	985(20.37)	1802(37.27)	2048(42.36)
7-9	2462(24.17)	372(15.1)	842(34.21)	1248(50.69)
10+	1907(18.73)	215(11.28)	500(26.22)	1192(62.5)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Youngest child's stool disposed Properly		**χ2 (2) = 10.87, P=0.0428**		
No	3606(56.26)	535(14.83)	1266(35.11)	1805(50.06)
Yes	2803(43.74)	461(16.45)	1055(37.62)	1287(45.93)
Total	6409(100)	996(15.54)	2321(36.21)	3092(48.25)
Frequency of watching television		**χ2 (4) = 1152.14, P<0.0001**		
Not at all	5046(49.55)	462(9.15)	1349(26.73)	3236(64.12)
Less than once a week	1984(19.48)	401(20.2)	807(40.65)	777(39.15)
At least once a week	3153(30.96)	905(28.69)	1343(42.6)	905(28.71)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)

7.2.4 Community-related characteristics

Similarly, Table 7.4 reveals that the children from the community whose household wealth level is below the median (high), have a higher proportion of multimorbidity children, 66.4% (3086/4647). Also, children whose community distance to any health facility is 'no big problem' is low have a higher proportion of multimorbidity children, 48.5% (2353/4852). Also, the proportion of children cohabiting with multimorbidity from a community with a lower than the median proportion of community maternal education level is 63.6% (3194/5025). Also,

children from the community where the proportion of 'community household with no bed net' is lower than the median have a proportion of multimorbidity children, 56.9% (2833/4982).

Table 7 4 : Distribution of community-related characteristics and their association with MAMM status

Community-related characteristics				
Proportion of community wealth level		**χ2 (2) = 1183.2950, P<0.0001**		
Low	4647(45.63)	387(8.34)	1174(25.26)	3086(66.4)
High	5536(54.36)	1380(24.92)	2325(41.99)	1832(33.08)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Proportion of community distance to health facility is no big problem		**χ2 (2) = 245.3836, P<0.0001**		
Low	4702(46.17)	629(13.38)	1417(30.14)	2656(56.48)
High	5481(53.82)	1138(20.76)	2082(37.98)	2262(41.26)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Proportion of community maternal education level		**χ2 (2) = 972.8534, P<0.0001**		
Low	5025(49.34)	494(9.83)	1337(26.6)	3194(63.56)
High	5158(50.65)	1273(24.68)	2162(41.91)	1723(33.41)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Proportion of community households with no bed net		**χ2 (2) = 298.7991, P<0.0001**		
Low	4982(48.92)	661(13.27)	1488(29.86)	2833(56.87)
High	5202(51.08)	1106(21.26)	2011(38.67)	2084(40.07)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)

7.2.5 State-related characteristics

Table 7.5 displays that the proportion of multimorbidity in children decreases as the deprivation of the multidimensional poverty index (MPI) of the state of residence decreases. The proportion of children cohabiting with multimorbidity from highly deprived MPI states dropped from 68.8% (582/847) to 29.2% (579/1987) for children from the lowest deprived MPI states. Similarly, as the human development index (HDI) of the state of residence increases, the proportion of multimorbidity children decreases from 65% (1397/2150) for the lowest HDI to 20.2% (144/715) for the highest HDI. However, the proportion of multimorbidity children associated with the state gender inequality index (GII) indicates that the higher the GII, the higher the proportion of children with multimorbidity. The results also show that North-west has the highest proportion of multimorbidity children, 64.0% (1900/2967), followed by children from the North-east, 59.5% (936/1573), and the lowest proportion was for children from the South-east, 34% (452/1328). In addition, the proportion of multimorbidity children from urban areas, 34.3% (1538/4483), was lower than their counterparts in rural areas, 59.3% (3379/5700).

Table 7 5 Distribution of area-related characteristics and their association with MAMM status

Area-related characteristics				
Multidimensional Poverty Index by State (MPI)		**χ2 (8) = 913.2766, P<0.0001**		
Highly Deprived	847(8.32)	57(6.7)	208(24.54)	582(68.75)
Above averagely deprived	3093(30.37)	309(9.98)	791(25.59)	1992(64.43)
Averagely Deprived	2319(22.77)	402(17.36)	884(38.14)	1032(44.51)
Mildly Deprived	1939(19.04)	487(25.11)	720(37.16)	732(37.73)
Lowest Deprived	1987(19.51)	512(25.8)	895(45.04)	579(29.16)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Human Development Index by State (HDI)		**χ2 (8) = 860.4636, P<0.0001**		
Lowest HDI	2150(21.11)	201(9.35)	552(25.68)	1397(64.97)
Low HDI	2416(23.73)	267(11.06)	690(28.56)	1459(60.39)
Average HDI	2223(21.83)	442(19.9)	846(38.08)	934(42.02)
High HDI	2680(26.31)	600(22.37)	1096(40.92)	984(36.71)
Highest HDI	715(7.02)	257(35.97)	314(43.88)	144(20.15)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Gender Inequality Index by State (GII)		**χ2 (8) = 551.0941, P<0.0001**		
Lowest GII	2726(26.77)	660(24.23)	1129(41.42)	936(34.35)
Low GII	1171(11.5)	266(22.71)	507(43.26)	398(34.03)
Average GII	977(9.59)	165(16.91)	301(30.79)	511(52.3)
High GII	4054(39.81)	557(13.74)	1222(30.13)	2275(56.13)
Highest GII	1256(12.33)	119(9.46)	341(27.13)	796(63.41)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Region of residence		**χ2 (10) = 761.2519, P<0.0001**		
North-central	1436(14.1)	277(19.29)	523(36.43)	636(44.28)
North-east	1573(15.44)	204(13)	433(27.5)	936(59.49)
North-west	2967(29.13)	286(9.65)	781(26.31)	1900(64.04)
South-east	1328(13.04)	292(22.01)	584(43.97)	452(34.02)
South-south	1086(10.66)	224(20.61)	480(44.21)	382(35.19)
South-west	1793(17.61)	483(26.95)	698(38.93)	612(34.12)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)
Type of place of residence		**χ2 (2) = 682.0256, P<0.0001**		
Urban	4483(44.02)	1117(24.92)	1828(40.77)	1538(34.31)
Rural	5700(55.97)	650(11.4)	1671(29.31)	3379(59.28)
Total	10184(100)	1767(17.35)	3499(34.36)	4918(48.29)

On the chi square analysis of the associations of the variables considered in this study, all except “Child had cough in last 2 weeks before the survey”, ($\chi2$ (2) = 0.9606, P=0.7103), and “paternal work status”, ($\chi2$ (2) = 6.0370, P=0.2041), were statistically significantly associated with multimorbidity of children aged 6-59 months in Nigeria

7.3 Spatial proportion of multimorbidity across states and regional levels of Nigeria

Research question 7:

Are there variations in the multimorbidity of two or more of anaemia, malaria, and malnutrition among children aged 6-59 months across Nigeria's states and geopolitical regions?

7.3.1 Spatial proportions of the multimorbidity of two or more diseases by states

Figure 7.6 presents the spatial variations in the proportion of multimorbidity of two or more diseases of anaemia, malaria, and malnutrition by states and FCT. It reveals that the proportion of children cohabiting with '2 or more diseases' in Nigeria was highest in Kebbi state with 0.83 (95% CI:0.78-0.86), followed by Jigawa state, 0.73 (95% CI: 0.69-0.78). Ebonyi state has the highest proportion, 0.55 (95% CI: 0.50-0.59), of children having concurrent two or more diseases of anaemia, malaria, and malnutrition among the states in the southern part of Nigeria. Also, the map (Fig 7.6) shows that the three states with the lowest proportions of MAMM in Nigeria are Edo state, 0.31 (95% CI: 0.24-0.40), Anambra state, 0.26 (95% CI: 0.22-0.31), and Lagos state, 0.14 (95% CI: 0.10-0.18). FCT has 0.36 (95% CI: 0.30-0.42).

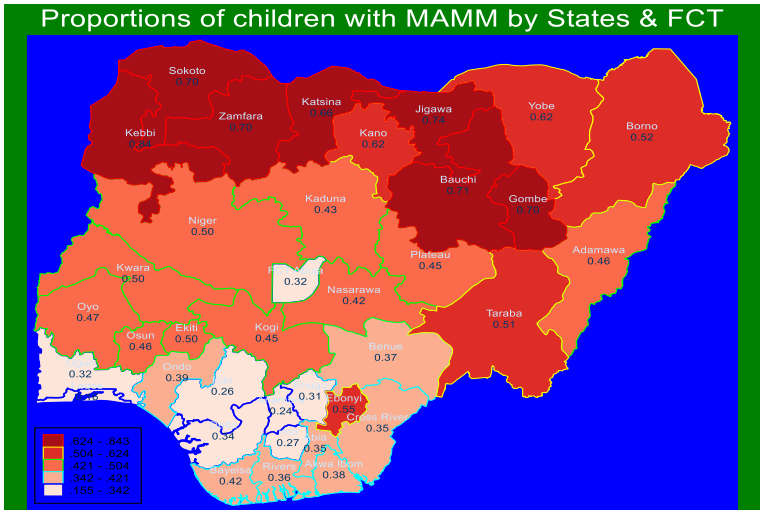


Figure 7 6 Spatial maps describing the proportions of children with two or more diseases by states & FCT

Source: Data computed from Nigeria DHS 2018.

7.3.2 Spatial distribution of proportions of children with two or more diseases by regions

Figure 7.7 represents the spatial distribution of children cohabiting with two or more diseases of anaemia, malaria, and malnutrition over the six geopolitical zones of Nigeria. North-west had the highest proportion of children with multimorbidity, 0.65 (95% CI: 0.62-0.67), followed by North-east geopolitical zones with a 0.59 (95% CI: 0.56-0.62) proportion of children living with two or more of anaemia, malaria, and malnutrition in Nigeria. All the geopolitical zones in the southern part of Nigeria had similar distributions of multimorbidity and below the

national average of 0.48 (95% CI: 0.47-0.49), including North-central with a proportion of 0.44 (95% CI: 0.41-0.47).

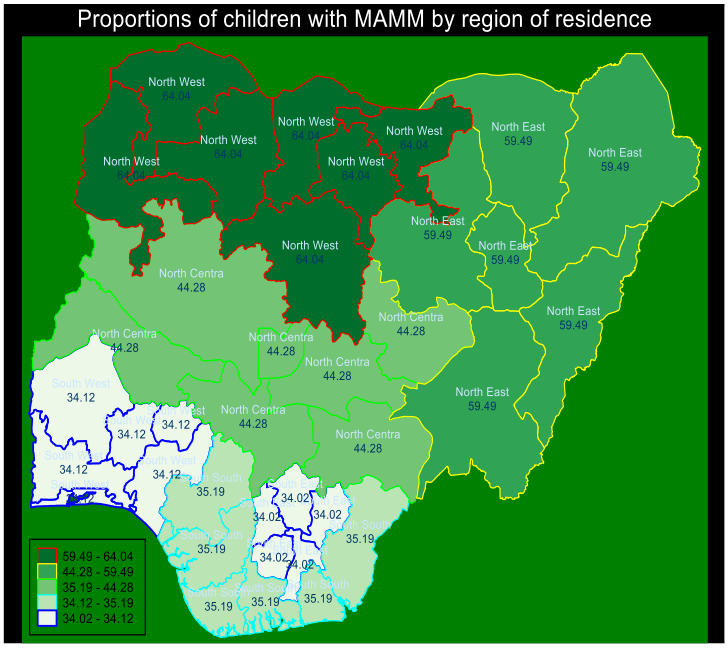


Figure 7 7 Spatial maps describing the proportions of children with two or more diseases by region

Source: Data computed from Nigeria DHS 2018

7.4 Multilevel analysis of multimorbidity status

A multicollinearity check was carried out in section 6.2, and 47 variables were extracted. Furthermore, three variables which formed the proxies for multimorbidity, anaemia, malaria, and malnutrition, were excluded before the next stage of the analysis evaluated using variable selection methods to avoid over- or under-fitting across child-, parental-, and household-—community-, and area-related factors.

7.4.1 Variables selection

This study applied both backwards and forward stepwise variable selection methods. It recognised the many controversies surrounding using stepwise regression methods (koteletje, 2020; Sribney, 2022). Some major limitations of using stepwise regression modeling as given by Frank Harrell (2001) were summarised in (Flom, 2018) as follows:

1. R-square values are excessively skewed (i.e., High)
2. The claimed distribution of the F statistics is missing.
3. The parameter estimations have too tiny standard errors.
4. The confidence intervals around the parameter estimates are therefore too small.
5. Because of multiple comparisons, p-values are overly low and challenging to adjust.
6. Parameter estimations have an asymmetry with respect to zero.
7. Collinearity issues are aggravated.

Despite these shortfalls, stepwise regression as a means of variable selection is still the most popular method in the circle of researcher to date (Smith, 2018). However, using these methods here is not an end to the analysis but a means of obtaining a model that will be most beneficial and economical (koteletje, 2020), using reasonable threshold p-values and applying an appropriate model followed by measures of goodness of fit. Therefore, it adopted backwards and forward stepwise selection methods with a threshold of p=0.20 (Kawo, Asfaw and Yohannes, 2018). Also acknowledged is that both methods produce different sets of variables, then subject the two sets of variables and combine the two sets into the goodness of fit to determine which sets of variables will likely yield the best fit.

Table 7 6 Evaluation of goodness of fit for variables selection methods in multimorbidity

Goodness of fit	Backward stepwise	Forward stepwise	Backward + forward
AIC	14011.16	14229.48	14010.87
BIC	14477.58	14655.13	14498.15

In Table 7.6, the AIC for the variables derived from combining those derived from the two stepwise methods yielded the least (14,010.87) compared with the other two sets of variables. To this end, 28 variables classified into child-related (child's sex, child's age in group, child's birth size, child's preceding birth interval, child took iron supplements, child's duration of breastfeeding, child took deworming drug in last 6months, child had fever in last 2 weeks before the survey, child's place of delivery), parental-related (maternal/caregiver highest educational level, mother is currently residing with husband/partner, mother's religious status, mother's anaemia status, maternal body weight status, paternal work status, partner education status), household-related (household wealth index, children under 5 slept under mosquito bed net last night, the sex of household head, number of people in household), community-related (proportion of community wealth level, proportion of community distance to health facility is no big problem, proportion maternal community education level), and area-related (multidimensional poverty index by state (MPI), human development index by state (HDI), gender inequality index by state (GII), geopolitical region of residence, and type of place of residence), were included in the analysis.

7.4.2 Multilevel mixed effect ordinal logistic regression models

The proportionality assumption was checked through a naïve method, showing that it was not violated. The predicted mean multimorbidity of the full model was 0.170, while the predicted mean multimorbidity of the partial model (after the variables that violated the proportionality assumptions were removed) was 0.166. The null hypothesis that the difference between these

two means was not significantly different from zero at $p<0.05$ was not rejected ($p=0.0729$). So, it concludes that the proportionality assumption was not violated. Therefore, multilevel mixed effect ordinal logistic regression was used to answer research question eight.

Question 8:

What are the multiple overlaps in the associations of individual and contextual factors with the MAMM among children 6-59 months in Nigeria?

The first instance confirmed that the 2-level model was significantly nested within a 3-level model using a likelihood ratio test with $\chi^2= 293.65$, $p<0.0001$. Therefore 3-level multilevel mixed effect ordinal logistic regression was carried out to evaluate research question eight.

7.4.3 Model building

This section, 11 models were evaluated (Tables 4.10 & 4.11). To properly account for model comparison for the goodness of fit, an equal sample size was created using all the variables included from stepwise variable selection to retain only the participants having complete data in all the variables. To achieve this, it applied the 'predict method' and excluded those participants with partial data in all the variables. To this end, the weighted sample size is 7,794 children at level 1 nested in 1,360 communities at level 2, with an average of 6 children per community, and are, in turn, nested in 37 states at level 3 with an average of 210 children per state.

7.4.3.1 Model comparison and fit

Table 7.7 reports the first part of the analysis, where 11 models were fitted and compared. Model 0 contained no covariate (variance component model), but models 8, 4, and 5 considered multimorbidity of children aged 6-59 months in Nigeria as a function of levels 1, 2, and 3 factors only, respectively. However, model 10, which contained all the level 1, 2, and 3 variables (full model), combined was adjudged the model of best fit with the highest log-likelihood (-6935.4) and least AIC (14010.9), therefore chosen for further analysis. Also, the likelihood ratio test (1076.4), $p<0.0001$ of the variance component model indicates that the multilevel mixed effect ordinal logistic model is better than a single-level ordinal logistic model.

Table 7 7 Model fit comparison

Model	No of covariates	Log-likelihood	AIC	BIC
Model 0	No covariate	-7415.6	14839.3	14867.1
Model 1	9 (child-related)	-7254.5	14555	14715.1
Model 2	7 (parental-related)	-7148.2	14334.4	14466.6
Model 3	4 (household factors)	-7186.8	14403.56	14508
Model 4	3 (level-2 factors only)	-7273	14559.9	14608.7
Model 5	5 (level-3 factors only)	-7318.4	14680.7	14833.9
Model 6	16 (model 1 & 2 factors)	-7036.1	14148.23	14412.8
Model 7	13 (model 1 & 3 factors)	-7072.8	14213.6	14450.3
Model 8	20 (Level-1 factors only)	-6964	14026.1	14367.2
Model 9	23 (level-1 & 2 factors only)	-6955.6	14015.4	14377.3
Model 10	28 (level 1, 2, & 3 factors)	-6935.4	14010.9	14498.2

7.4.3.2 Variance component analysis

Table 7.8 describes the variations in the prevalence of MAMM corresponding to the state (level 3), and community (level 2). For model 0 (null model), with no covariates, the variance component coefficient (VPC) at the state level is 0.099. meaning that differences across the state explain 10% of the total variability in the proportion of MAMM among children aged 6-59 months (level 3). This is the same as the intrastate correlation coefficient (ICC), which signifies that the correlation between two children within the same state but in different communities is 0.099 (95% CI: 0.06-0.15).

Table 7 8 Distribution of random effect components

Model	**Community level variance**	**State-level variance**	**ICC at the community level**	**ICC at the state level**	**VPC at the community level**	**VPC at the state level**
Model 0	0.87	0.46	0.289	0.099	0.188	0.099
Model 1	0.67	0.22	0.214	0.053	0.160	0.053
Model 2	0.44	0.1	0.142	0.027	0.115	0.027
Model 3	0.45	0.11	0.144	0.028	0.117	0.028
Model 4	0.58	0.14	0.179	0.035	0.145	0.035
Model 5	0.72	0.04	0.187	0.01	0.178	0.01
Model 6	0.4	0.08	0.128	0.022	0.106	0.022
Model 7	0.41	0.09	0.133	0.024	0.108	0.024
Model 8	0.33	0.07	0.107	0.018	0.089	0.018
Model 9	0.33	0.07	0.109	0.019	0.089	0.019
Model 10	0.33	0.01	0.094	0.003	0.091	0.003

On the other hand, the VPC and ICC of model 0 at the community level (level 2), in a three-level model, are not usually the same (Obasohan et al 2021b). The VPC at level 2 (community) is 0.188, signifying that 18.8% of the total variability in the proportion of MAMM is attributable to the community. However, ICC at the community level is 0.289 (95% CI: 0.25-

0.33), suggesting that the correlation between two children/individuals (unit of analysis) within the same community and the same state is 28.9%. The sizes of ICCs at level-2 and level-3 are substantial (greater than 5%), which is large enough to validate further the need for a multilevel analysis over a single-level model (Heck, Thomas and Tabata, 2014).

Furthermore, from the chosen model (model 10), the intrastate and intracommunity correlations drop from 0.46 and 0.87 in the null model (model 0) to 0.01 and 0.33 in the model containing all 28 covariates, respectively. Also, between-state and between-community variabilities drop from 0.46 and 0.10 in the null model to 0.01 and 0.003 in the full-level model (containing level 1, 2, and 3 covariates), respectively. Again, this indicates that the distribution of all the variables across the states and communities differs significantly.

In Table 7.9, a measure of odds for cluster variance was computed using the median odds ratios. For the choice model (model 10), the median odds ratio (MOR) computed for states was 1.10, meaning that the mean difference of the risk of MAMM for any two children having the same individual predictors and selected at random from two states. It signifies a 10% increased risk of a child contracting '2 or more diseases' if he/she moves from one state to another with an increased risk of multimorbidity. Similarly, there is a 72% increased risk of a child contracting '2 or more diseases if he/she moves to another community with a higher risk of MAMM.

7.4.3.3 Fixed Effect Analysis

In section 7.4.2, the test of proportional odds assumptions was reported as not being violated. Given this, the effect sizes for the two categories: (1 & 2 or more diseases) versus 0; and (2 or more diseases) versus (0 & 1 disease) remain the same for each level of predictors, resulting in one model interpretation (Cornish *et al.,* 2013). Therefore, how the findings from model 10 are reported was at the authors' discretion.

Table 7.9 reports the chosen model 10 (level 1, 2, & 3 covariates), and two other models: 8 (level 1 covariates only), & 9 (level 1 & 2 covariates only), to show changes that may have occurred in the significance values over adjusting for more variables across the different levels. The results of other models (1 to 7) are displayed in Appendix A.5. For example, model 10 reveals that the child's age, sex, birth size, pre-birth interval, the child was dewormed in the last six months before the survey, the child had a fever in the last two weeks before the survey, the maternal education status, religious status, anaemia status, body weight index status, paternal education status, the household wealth status, proportion of community distance to a health facility is no big problem, state human development index (HDI), gender inequality index by state (GII), region of residence, and place of residence were significant predictors of

the proportional odds of a child cohabiting with MAMM versus the combined of 0/1 diseases among children 6-59 months of age in Nigeria compared with their respective reference category.

Table 7 9 Multilevel Ordinal logistic regression analysis of the individual, community, and state level risk factors for MAMM

	Model 8 (N=7794) (Level 1 covariates only)			Model 9 (N=7794) (Level 1 & 2 covariates only)			Model 10 (N=7794) (Level 1, 2, & 3 covariates)		
	AOR	**p-value**	**95% CI**	**AOR**	**p-value**	**95% CI**	**AOR**	**p-value**	**95% CI**
Child's sex									
Male	1.00			1.00			1.00		
Female	0.73	<0.001	(0.67-0.8)	0.73	<0.001	(0.67-0.81)	0.73	<0.001	(0.67-0.80)
Child's age in group									
6-11 months	1.00			1.00			1.00		
12-23 months	1.39	<0.001	(1.18-1.65)	1.39	<0.001	(1.18-1.65)	1.39	<0.001	(1.18-1.65)
24-35 months	1.26	0.048	(1-1.57)	1.24	0.057	(0.99-1.56)	1.25	0.05	(1.00-1.57)
36-47 months	1.10	0.428	(0.87-1.38)	1.09	0.439	(0.87-1.37)	1.1	0.41	(0.88-1.38)
48-59 months	0.88	0.261	(0.7-1.1)	0.87	0.233	(0.69-1.09)	0.87	0.24	(0.69-1.10)
Child's birth size									
Large	1.00			1.00			1.00		
Average	0.99	0.863	(0.84-1.16)	0.99	0.894	(0.84-1.16)	0.98	0.79	(0.83-1.15)
Small	1.26	0.035	(1.02-1.56)	1.26	0.033	(1.02-1.56)	1.26	0.04	(1.02-1.56)
Preceding birth interval									
None	1.00			1.00			1.00		
8-24 months	1.36	<0.001	(1.16-1.6)	1.37	<0.001	(1.17-1.61)	1.37	<0.001	(1.17-1.62)
25-35 months	1.09	0.262	(0.94-1.28)	1.10	0.232	(0.94-1.29)	1.11	0.20	(0.95-1.29)
36-59 months	1.01	0.951	(0.86-1.18)	1.01	0.862	(0.86-1.19)	1.02	0.81	(0.87-1.20)
60+ months	0.93	0.467	(0.75-1.14)	0.93	0.494	(0.76-1.14)	0.93	0.50	(0.76-1.15)
Child took Iron supplements									
No	1.00			1.00			1.00		
Yes	1.04	0.585	(0.91-1.19)	1.04	0.555	(0.91-1.19)	1.03	0.65	(0.90-1.18)
Duration of breastfeeding									
Ever breastfed, not currently breastfeeding	1.00			1.00			1.00		
Never breastfed	1.23	0.301	(0.83-1.82)	1.20	0.353	(0.81-1.79)	1.19	0.39	(0.80-1.76)
Still breastfeeding	0.96	0.661	(0.81-1.15)	0.95	0.591	(0.8-1.14)	0.96	0.63	(0.80-1.14)
Child was dewormed in last 6 months before the survey									
No	1.00			1.00			1.00		
Yes	0.83	0.004	(0.73-0.94)	0.83	0.004	(0.73-0.94)	0.84	0.01	(0.74-0.96)

Child had fever in last 2 weeks before the survey									
No							1.00		
Yes	1.56	<0.001	(1.39-1.75)	1.56	<0.001	(1.39-1.75)	1.57	<0.001	(1.40-1.77)
Place of child's delivery									
Home	1.00			1.00			1.00		
Public facility	0.90	0.13	(0.79-1.03)	0.92	0.205	(0.8-1.05)	0.93	0.26	(0.81-1.06)
Private facility	0.88	0.14	(0.74-1.04)	0.89	0.168	(0.75-1.05)	0.88	0.14	(0.74-1.04)
Elsewhere	1.03	0.871	(0.72-1.46)	1.02	0.896	(0.72-1.46)	1.01	0.94	(0.71-1.44)
Maternal/caregiver highest educational level									
No education							1.00		
Primary	0.83	0.035	(0.7-0.99)	0.84	0.044	(0.7-1)	0.84	0.043	(0.70-0.99)
Secondary	0.69	<0.001	(0.58-0.82)	0.69	<0.001	(0.57-0.83)	0.68	<0.001	(0.57-0.82)
Higher	0.45	<0.001	(0.35-0.57)	0.45	<0.001	(0.34-0.58)	0.45	<0.001	(0.35-0.58)
Mother staying with a partner									
Staying with partner	1.00			1.00			1.00		
staying elsewhere	0.94	0.502	(0.77-1.14)	0.94	0.569	(0.78-1.15)	0.94	0.52	(0.77-1.14)
Mother's religious status									
Catholic	1.00			1.00			1.00		
Other Christian	1.08	0.395	(0.9-1.3)	1.10	0.324	(0.91-1.32)	1.12	0.22	(0.93-1.36)
Islam	1.23	0.066	(0.99-1.53)	1.28	0.032	(1.02-1.6)	1.37	0.01	(1.08-1.74)
Traditionalist & others	0.96	0.898	(0.54-1.71)	0.97	0.907	(0.54-1.71)	1	0.99	(0.56-1.78)
Mother's Anaemia status									
Not Anaemic							1.00		
Anaemic	1.61	<0.001	(1.46-1.78)	1.61	<0.001	(1.46-1.78)	1.6	<0.001	(1.45-1.77)
Maternal body mass index									
Normal	1.00			1.00			1.00		
Underweight	1.16	0.1	(0.97-1.38)	1.16	0.091	(0.98-1.39)	1.18	0.07	(0.99-1.40)
Overweight	0.76	<0.001	(0.67-0.86)	0.76	<0.001	(0.67-0.87)	0.77	<0.001	(0.67-0.87)
Obese	0.70	<0.001	(0.59-0.83)	0.71	<0.001	(0.6-0.84)	0.71	<0.001	(0.60-0.84)
Paternal work status									
Not working	1.00			1.00			1.00		
Working	1.24	0.134	(0.94-1.66)	1.23	0.157	(0.92-1.64)	1.21	0.20	(0.91-1.61)
Partner education status									
No education	1.00			1.00			1.00		
Primary education	0.97	0.76	(0.81-1.17)	0.99	0.878	(0.82-1.19)	0.97	0.76	(0.81-1.17)
Secondary education	0.88	0.149	(0.74-1.05)	0.90	0.211	(0.76-1.06)	0.9	0.22	(0.76-1.07)
Tertiary education	0.79	0.028	(0.64-0.98)	0.81	0.045	(0.65-1)	0.81	0.05	(0.66-1.00)

Household wealth index									
Poorest	1.00			1.00			1.00		
Poorer	0.82	0.038	(0.69-0.99)	0.86	0.121	(0.72-1.04)	0.86	0.12	(0.72-1.04)
Middle	0.58	<0.001	(0.48-0.71)	0.69	0.001	(0.56-0.85)	0.69	<0.001	(0.56-0.86)
Richer	0.43	<0.001	(0.35-0.53)	0.54	<0.001	(0.43-0.69)	0.56	<0.001	(0.44-0.72)
Richest	0.28	<0.001	(0.22-0.36)	0.36	<0.001	(0.27-0.47)	0.38	<0.001	(0.29-0.50)
Under-5 slept under a bed net									
No child	1.00			1.00			1.00		
All children	0.94	0.415	(0.8-1.1)	0.93	0.372	(0.79-1.09)	0.93	0.37	(0.79-1.09)
Some children	1.12	0.304	(0.91-1.38)	1.11	0.327	(0.9-1.37)	1.12	0.27	(0.91-1.39)
No net in household	0.92	0.344	(0.79-1.09)	0.93	0.351	(0.79-1.09)	0.94	0.46	(0.80-1.11)
Sex of household head									
Male	1.00						1.00		
Female	0.96	0.707	(0.79-1.18)	0.95	0.638	(0.78-1.17)	0.95	0.62	(0.78-1.16)
Number of people in household									
2-3	1.00			1.00			1.00		
4-6	0.89	0.225	(0.73-1.08)	0.89	0.22	(0.73-1.07)	0.88	0.20	(0.73-1.07)
7-9	0.99	0.897	(0.8-1.22)	0.98	0.861	(0.79-1.22)	0.97	0.79	(0.78-1.20)
10+	1.14	0.266	(0.9-1.44)	1.13	0.31	(0.89-1.43)	1.12	0.36	(0.88-1.41)
Community wealth level									
Low				1.00			1.00		
High				0.74	0.002	(0.61-0.9)	0.79	0.02	(0.65-0.96)
Proportion of community distance to health facility is no big problem									
Low				1.00			1.00		
High				0.86	0.029	(0.75-0.98)	0.86	0.03	(0.75-0.98)
Proportion of community maternal education level									
Low				1.00			1.00		
High				1.10	0.332	(0.91-1.33)	1.10	0.34	(0.90-1.34)
State multidimensional poverty index (SMPI)									
Highly deprived							1.00		
Above averagely deprived							1.28	0.11	(0.95-1.73)
Averagely Deprived							0.72	0.11	(0.48-1.07)
Mildly Deprived							0.69	0.09	(0.45-1.06)
Lowest Deprived							0.67	0.12	(0.41-1.11)

State human development index (HDI)									
Lowest HDI							1.00		
Low HDI							1.25	0.12	(0.94-1.65)
Average HDI							1.27	0.17	(0.90-1.80)
High HDI							1.51	0.04	(1.01-2.28)
Highest HDI							1.13	0.60	(0.72-1.78)
Gender inequality index by state (GII)									
Lowest GII							1.00		
Low GII							0.76	0.05	(0.58-1.00)
Average GII							1.25	0.13	(0.94-1.67)
High GII							1.03	0.83	(0.80-1.32)
Highest GII							1.30	0.11	(0.94-1.80)
Region of residence									
North-central							1.00		
North-east							0.68	0.03	(0.49-0.96)
North-west							1.12	0.56	(0.77-1.62)
South-east							1.56	0.01	(1.13-2.15)
South-south							1.52	0.01	(1.09-2.12)
South-west							1.61	<0.001	(1.16-2.23)
Type of place of residence									
Urban							1.00		
Rural							1.23	<0.001	(1.06-1.42)
Odds of cluster variance									
MOR (States)	1.29		(1.19-1,41)	1.29		(1.20-1.43)	1.10		(1.03-1.31)
MOR (Community)	1.73		(1.61-1.88)	1.73		(1.61-1.89)	1.73		(1.61-1.89)

AOR: Adjusted odds ratios, MOR: Median odds ratios. CI: Confidence interval

Individual-level predictors of multimorbidity

From model 10 in Table 7.9, the proportional odds of female children cohabiting with '2 or more diseases' versus the combined of '0/1 disease only' are 0.27 (95% CI: 0.67-0.80, p=0.001), lower when compared to male children, relative to other predictors being held constant. Likewise, the proportional odds of children aged 12-23 months having 'two or more diseases' versus a combined of '0/1 diseases' are 1.39 (95% CI: 1.18-1,65), times higher when compared to children aged 6-11 months with all other variables held constant. A child born as perceived small size by the mother had statistically significant proportional odds of 1.26 (95% CI: 1.02-1.56, p=0.04), times of having at least 'one disease' versus 'no disease' compared to children who were born perceived large by their mothers while accounting for other predictors. Also, the higher the pre-birth interval, the lower the odds of developing '2 or more diseases' versus a

combined of '0/1 diseases' conditional on other confounding factors. Children with 8-24 months pre-birth interval were less protective (AOR=1.37, p<0.001) in contracting '2 or more diseases' versus combined of '0/1 diseases' compared to children without preceding birth interval (none) relative to other covariates. Children who were dewormed within six months before the survey; contracted fever two weeks before the survey had proportional odds of 0.84 (95% CI: 0.74-0.96, p=0.01) times lower, and 1.57 (95% CI: 1.40-1.77, p<0.001), times more, respectively of having '2 or more diseases' versus combined of '0/1 diseases' compared to children who were never in any such conditions.

Furthermore, the odds of children contracting multimorbidity of '2 or more of anaemia, malaria, and malnutrition versus combined odds of 'no or one disease' decreases significantly as the maternal highest educational level increases. For instance, children whose mothers have higher education levels have a more than two folds reduced proportional odds (AOR=0.45, 95% CI: 0.35-0.58) of cohabiting with '2 or more diseases' versus combined odds of having '0/1 disease' when compared with children whose mothers do not have any formal education. Also, children of Muslim mothers had significant proportional odds of 0.37 (95% CI: 1.08-1.74), more of contracting '2 or more diseases' versus '0/1 disease' compared with children whose mothers are Catholics. However, the proportional odds were not significant in a model with only level-1 covariates (model 8). Additionally, children whose mothers are anaemic; overweight, or obese had 0.6 increased odds, 0.23, or 0.29 reduced odds, of cohabiting with '2 or more diseases' versus a combined odds of '0/1 disease', respectively, when compared with children whose mothers are neither 'not anaemic' nor have 'normal body mass index'.

For household wealth quintiles, the results reveal that the higher the wealth quintile, the less likely the proportional odds of the children 6-59 months of age from the households of contracting '2 or more diseases' versus the combined odds of '0/1 disease'. Children from the middle, richer, and richest classes have reduced statistically significantly proportional odds of 0.31, 0.44, and 0.62, respectively, of being sick of '2 or more diseases' versus combined odds of '0/1 disease' when compared with children from the poorest household wealth quintile. While considering model 8 (individual level only covariates), comparing the proportional odds for children in the poorer households with those in the poorest household wealth quintile, it was statistically significant. However, these relationships were no longer significant after adjusting for the community-level covariates (model 9) and state-level covariates (model 10).

Community level predictors of multimorbidity

Out of the three community (level 2) covariates in this analysis, two were statistically significant predictors of MAMM among children 6-59 months of age in Nigeria. Children from a community where the proportion of the wealth level is high (median and above) had reduced proportional odds of 0.79 (95% CI: 0.65-0.96), times of contracting multimorbidity of '2 or more diseases' versus 0/1 disease when compared with children from a community with low (less than the median) wealth level. Similarly, children living in a community where the proportion of the community distance to a health facility is 'no big problem' is high (median and above) have 0.14 reduced proportional odds of contracting '2 or more diseases' versus '0/1 disease' compared with other children from the communities with low proportion relative to other covariates in the model.

State-level predictors of multimorbidity

Out of the five state-level covariates adjusted for in model 10 analysis, state multidimensional poverty index (SMPI) was not a statistically significant predictor of MAMM among children 6-59 months of age in Nigeria, conditional other covariates. However, children from the states where the human development index is in the high quintile have statistically significant harmful proportional odds of contracting '2 or more diseases' versus 0/1 disease when compared with children from the state where human development index is at the lowest quintile. Similarly, children from the states where the gender inequality index (GII) is low have reduced proportional odds of 0.24 of contracting multimorbidity versus '0/1 disease' when compared with children from the state where GII is the lowest quintile. Also, concerning the region of residence, only the proportional odds of contracting '2 or more diseases' versus the combined of '0/1 disease' for children from the North-west is not statistically significant when compared with children from the North-central geopolitical zone of Nigeria. Finally, children from rural areas have increased proportional odds of 0.23 (95% CI: 1.06-1.42), more of cohabiting with '2 or more diseases' versus the combined odds of '0/1 disease' when compared with children from urban areas.

7.5 Resolving the missing data

Most of the apparent missingness in the interactions of the three outcome diseases is due to the survey design because the cases were taken from different children across the households. For instance, the group of children's anthropometric measurements used to determine the indicators of nutrition status were extracted from one-third of the households surveyed aged 0-59 months. However, biomarkers used to determine malaria and anaemia statuses were also taken from

one-third of the households where the men's questionnaire was administered and among children aged 6-59 months (National Population and I. C. F. International, 2019). Furthermore, data for anaemia was stored in 'kids recode file (KR)', while malaria and nutrition were recorded in the 'households recode file (PR)'. These multiple files necessitated the merger of the two files (KR & PR). Therefore, it suspects that the missingness format concerning other predictor variables may not be systematic and that analysing complete observation data did not introduce biases in the estimates. However, it used multiple imputations (MI) to confirm this. Firstly, Stata's 'misstable' summarise command determined how many missing values were among the variables initially selected for analysis.

Table 7 10 Distribution of missingness

Variable	Missing	Observed	Percentage
Outcome (multimorbidity)	301	10150	2.88
Birth size	141	10310	1.35
Preceding birth interval	21	10430	0.20
Children under 5 slept under mosquito bed net	88	10363	0.84
Child took iron syrup	33	10418	0.32
Child was dewormed	55	10396	0.53
Child had fever 2 weeks before the survey	3	10448	0.03
Currently residing with husband/partner	533	9913	5.10
Maternal anaemia status	291	10160	2.78
Maternal body weight	1610	8841	15.41
Paternal education status	652	9799	6.24

7.5.1 Checking for missingness mechanism

The highest missing value was associated with maternal BMI. So, it first establishes a binary variable that indicates if the maternal BMI variable is observed (=1) or missing (=0) in order to study which characteristics are predictive of missingness in the maternal BMI variable (Bartlett and Carpenter, 2013). Therefore, it fits a logistic model for maternal BMI missingness status with other variables having missing values as covariates, and in addition, the sex of the child (which has no missing values).

The results in Table 7.11 demonstrates that there is substantial evidence that the likelihood of maternal BMI observation is independently correlated with both Preceding birth intervals above two years, some children slept under bed nets the night before the survey, mother staying elsewhere, and mother had anaemia, signifying that there is no evidence that the missing values in maternal BMI are missing completely at random (MCAR). However, there is no proof that the sex of the child and other covariates in the model are related to this risk, conditional on

other variables. Given this situation, it is assumed that maternal body weight status data is missing at random (MAR) or not at random (MNAR).

Table 7 11 Analysis of missingness mechanism

Variable	Coefficient	SE	p-values
Sex of the child			
Female	-0.019	0.060	0.757
Multimorbidity			
One disease only	0.124	0.095	0.189
Two or more diseases	-0.161	0.091	0.077
Birth size			
Medium	-0.037	0.104	0.721
Small	-0.024	0.131	0.856
Preceding birth intervals			
8-24 months	0.028	0.088	0.750
25-35 months	0.381	0.088	0.000
36-59 months	0.474	0.094	0.000
60+ months	0.775	0.150	0.000
Children under 5 slept under mosquito bed net last night			
All children	-0.028	0.094	0.765
Some children	0.299	0.130	0.021
No net in household	0.105	0.100	0.295
Child took iron syrup			
Yes	0.066	0.083	0.422
Child was dewormed			
Yes	-0.106	0.075	0.159
Child had fever			
Yes	-0.101	0.067	0.130
Currently residing with husband/partner			
Staying elsewhere	0.352	0.112	0.002
Maternal anaemia status			
Anaemic	-0.259	0.063	0.000
Paternal education status			
Primary	0.113	0.096	0.238
Secondary	0.151	0.078	0.053
Tertiary	0.168	0.100	0.093

Now that the missingness in maternal BMI is not MCAR, caution must be exercised in analysing the complete records, which might introduce biases in the results. However, an

exemption could arise if this missingness is not a function of the outcome variable while accounting for other covariates (Bartlett and Carpenter, 2013) (This was the situation at hand). To justify this, it first took the logistic regression of missingness status in maternal BMI conditional on other covariates and sex of the child without adding the outcome variable. It then investigated the model's predictive power using the area under the curve (AUC). The number of observations was 9243, and AUC was 0.5917. Next, it added the outcome variable to the model, resulting in 9129 observations, and AUC was 0,5995. The Wald test p-value for the outcome variable was not significant, and there was no substantial increase in the AUC (from 0.5917 to 0.5995). This represents a non-significant improvement for these models and demonstrates that, even when considering the sex of the child and other covariates with missing values, multimorbidity status remains a no predictor of missingness in maternal BMI. Therefore, analysing the complete records will not introduce any biases as such.

Secondly, it considered the missingness mechanism to be MAR and produced multiple imputations of the missing data by employing the method of the chained equation, also referred to as full conditional specification (Bartlett and Carpenter, 2013). Table 7.12 shows the results of the imputed data for the variables with missing values, and all the missing data were imputed entirely.

Table 7 12 Distribution of imputed data

Variable	Complete	Incomplete	Imputed	Total
Outcome (multimorbidity)	10150	301	301	10451
Birth size	10310	141	141	10451
Preceding birth interval	10430	21	21	10451
Children under 5 slept under mosquito bed net last night	10363	88	88	10451
Child took iron syrup	10418	33	33	10451
child was dewormed	10396	55	55	10451
Child had fever	10448	3	3	10451
Currently residing with husband/partner	9918	533	533	10451
Maternal anaemia status	10160	291	291	10451
Maternal body weight	8841	1610	1610	10451
Paternal education status	9799	652	652	10451

Model 10 was the chosen model of best fit (complete observations) in the analysis of MAMM. Considering the missingness to be MAR, it performs multiple imputations (The result is attached in Appendix A.6).

The following were observed:

1. MI estimation technique is not presently available for multilevel mixed effect ordinal logistic regression in STATA 17 (the current version).
2. The analysis to perform MI estimates were 'forced', using "cmbok' option in MI estimation.
3. There was not much difference in the significance of the variables inputted compared with when it used complete cases.
4. The ICCs could not be generated; except they could be computed manually
5. Model fit using AICs & BICs could not be performed as there was no likelihood information in the estimation results.

Hence, coupled with the large sample size (7989), it justifies using complete observation instead of multiple imputation estimates.

7.6 The Chapter Summary

The quantitative analyses presented in this Chapter covered the third level of the statistical analysis that provided answers to research questions 6 – 8, which correspond to the main aim of this study, to investigate the multiple overlaps in the impact of individual and contextual variables on the prevalence of the multimorbidity's of anaemia, malaria, and malnutrition among children aged 6 to 59 months in Nigeria. First, the variable selection was carried out for MAMM variable. It answered the question of the prevalence of MAMM, spatial map prevalence of MAMM across the states & FCT, and geopolitical zones in Nigeria. The multilevel analyses of the predictors of MAMM across the child-, parental-, household-, community-, and area-related characteristics revealed the presence of multiple overlaps in the determinants of MAMM

Chapter 8 Quantitative analysis 4

8.0 Introduction

This Chapter covers the fourth level of the statistical analysis and provides the answer to research question 9. This approach is a further analysis of multilevel mixed effect ordinal logistic analysis of predictors of MAMM among children aged 6-59 months in Nigeria which was considered in the previous Chapter while accounting for the interaction effects of some individual-level covariates.

Research question 9

What are the interaction effects of a child's sex, age, and household socioeconomic status on the impact of individual and contextual risk factors of MAMM among children 6-59 months of age in Nigeria?

In other to answer research question 9, the results obtained in model 10 and reported in the preceding Chapter were further investigated to understand the changes in the significance of individual and contextual predictors of MAMM while accounting for the intersectionality of child's sex, age, and household wealth quintiles (proxy of household socioeconomic status).

The three individual-level variables (child's sex, age, and household wealth quintiles) were classified into four possible interaction groups to include, including three 2-way and one 3-way classification: child's sex and wealth status; child's sex and age; child's age and wealth status; and child's sex, age, and wealth status. In the scoping review of multimorbidity of childhood diseases, it was found that child's age, sex, and household wealth status were the most common predictors of all the diseases examined in the extracted. Five additional models (models 11 – 15) were created in this scenario. Model 11 includes model 10 conditional interaction between child's sex and wealth status; model 12 includes model 10 and interaction of child's sex and age; model 13 involves model 10 and the interactions between child's age and wealth status; model 14 has model 10 accounting the three 2-way interactions of child's sex, age, and household wealth status. Finally, model 15 includes model 14 and the 3-way interactions between a child's sex, age, and household wealth quintiles. Two approaches were adopted to interpret the interaction effects. (i) By examining the significance of the interaction terms, as displayed in Table 8.4 models 11-15, while accounting for model 10. (ii) By visual inspection of the plots

8.1 Model comparison and fit

Table 8.1 shows the model comparison indicators. Model 13, which contains all the model 10 covariates and accounts for the interactions between a child's age and wealth status, was adjudged the best fit model in this category using the least AIC (13977.3) and the best combination of log-likelihoods and BICs. Interestingly, model 13 (AIC= 13977.3), compared with model 10 (AIC=14010.9), improved in terms of goodness of fit.

Table 8 1Distribution of model fit

Model	Number of covariates	Log-likelihood	AIC	BIC
Model 11	Model 10 covariates + child's sex * wealth status	-6933.6	14015.1	14530.2
Model 12	Model 10 covariates + child's sex * age	-6933.4	14014.8	14529.9
Model 13	Model 10 covariates + child's age * wealth status	-6902.6	13977.3	14575.9
Model 14	Model 10 covariates + child's sex * wealth status + child's sex * age + child's age * wealth status	-6898.5	13985.03	14639.4
Model 15	Model 14 covariates + child's sex * age * wealth status	-6890.8	14001.6	14767.4

8.2 Variance component analysis

Table 8.2 compares the distributions of random effect components of model 10 and model 13. The results show that no significant changes occurred in all the indicators except the variance partition component (VPC) at the community level, where it drops from 0.091 in model 10 to 0.088 in model 13; this is because there was a 0.01 drop in community level variance. However, the 0.088 in model 13 implies that 8.8% of the total variability in the proportion of MAMM is attributable to the community when the interaction term between a child's age and wealth status is accounted.

Table 8 2 : Distribution of random effect components for chosen models

Model	**Community level variance**	**State-level variance**	**ICC at community level**	**ICC at state level**	**VPC at community level**	**VPC at state level**
Model 0	0.87	0.46	0.289	0.099	0.188	0.099
Model 10	0.33	0.01	0.094	0.003	0.091	0.003
Model 13	0.32	0.01	0.094	0.003	0.088	0.003

8.3 Fixed effect components

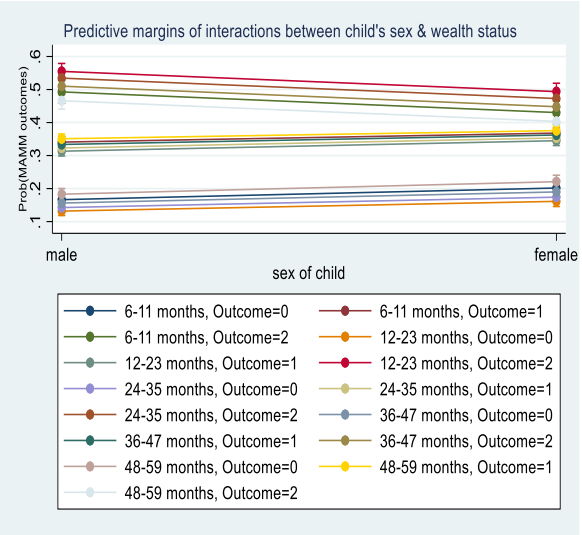
Table 8.4 contains the results of the fixed effect components of the further analysis done on model 10, accounting for all the possible ways a child's sex, age, and household wealth status interact. Going by the goodness of fit comparison (Table 8.1), models 13, 14, and 15 were

improvements on model 10, but model 13 was the best fit. Therefore, it fully reported the effects of intersectionality as contained in model 13 alongside model 10. Now to directly answer research question 9 stated above, it presents the results as follows:

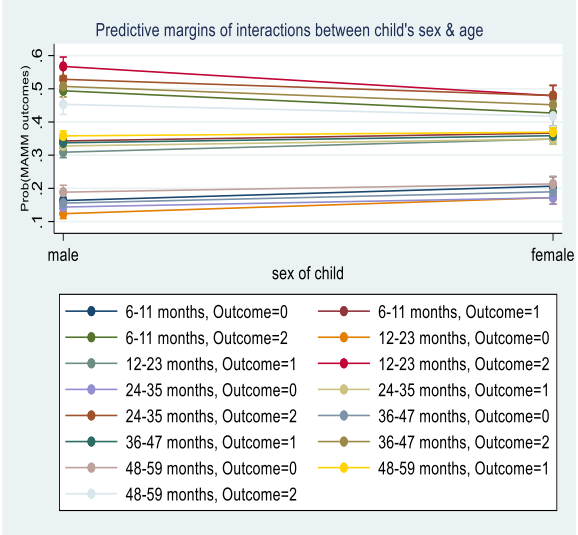
8.3.1 Accounting for interactions between child's sex and wealth status

In Table 8.4, model 11 shows no significant interaction effect of a child's sex and household wealth status on MAMM among children aged 6-59 months in Nigeria after accounting for model 10 covariates. However, in model 11, there were further drops in the proportional odds in the child's sex and household wealth status compared to model 10 (See Table 8.3).

Furthermore, interaction plots are necessary for a more straightforward interpretation (Dawson, 2014). Fig. 8.1(a) illustrates the predictive margins plot of the interaction between a child's sex and wealth quintiles on MAMM among children aged 6-59 months in Nigeria. The interpretations are to visualise the existence of or none of the interaction effects. The parallel lines indicate the non-presence of interaction effects between a child's sex and household wealth quintiles. The effect of a child's sex on MAMM does not vary by the household wealth quintile. In other words, the household wealth status does not moderate the relationship between the child's sex and MAMM.



(a) interaction between child's sex and wealth quintiles



(b) interaction between child's sex and age

Figure 8 1 Predictive margins plot of interaction effects

8.3.2 Accounting for interactions between child's sex and age

Model 12 presents the result when it accounts for the two-way interaction between a child's sex and age and shows no significant interaction effects after adjusting for model 10 covariates. It is also observed that the main effects of the child's sex and age in model 10 did not improve significantly in model 12. Similarly, Fig. 8.1 (b) illustrates the predictive margins plot of the interaction between a child's sex and age on MAMM among children aged 6-59 months in

Nigeria. The interpretations are to visualise the existence of or none of the interaction effects. The non-intersection of the lines indicates the non-presence of interaction effects between a child's sex and age. Therefore, the effect of a child's sex on MAMM does not vary by child's age. In other words, the child's age does not moderate the relationship between the child's sex and MAMM.

8.3.3 Accounting for interactions between child's age and wealth status

Table 8.4 contains the results from models 10, 13, 14, and 15. However, model 13 describes the results of further analysing model 10 and account for the two-way interaction between a child's age and household wealth quintile in multimorbidity of '2 or more diseases' of anaemia, malaria, and malnutrition among children aged 6-59 month in Nigeria. Some categories in this interaction display statistically significant effects on the outcome of interest, while, some categories of child's age that were not significant in model 10 have become outright significant, and those that were significant in wealth status were no longer significant it indicates that uncertainty may exist on how relevant the main effects (child's age and wealth status) are when no other covariates are accounted for in the model (Stat Trek, 2022). Interestingly, these two implications have been taken care of in the model. Model 13 is the best fit compared with other models created in this study (AIC=13977.3), and other individuals and contextual predictors have been adjusted for in the model. So, the two-way interaction effects of a child's age and wealth status are relevant in the model prediction. Thus, the variation in MAMM over a child's age differs depending on the household wealth quintile (Moran, 2017).

Table 8.4 (Model 13) shows that the proportional odds of children aged 24-35 months cohabiting with '2 or more diseases' versus combined of '0/1 disease' and living in the wealthiest households were significantly 0.66 lower than the odds for children aged 24-35 months and reside in poorest households when other covariates in model 10 are held constant. Similarly, the proportional odds of children who are aged 34-47 months and live in the middle, richer, and richest household wealth quintiles were statistically significantly 0.59 (95% CI: 0.35-0.99), 0.49 (95% CI: 0.29-0.83), and 0.21 (95% CI: 0.12-0.36), respectively times the odds of contracting '2 or more diseases' versus combining of '0/1 disease' when compared with children aged 34-47 months and live in poorest household wealth quintile. Also, the two-way interactions between a child's age and wealth status reveal that children aged 48-59 months from the middle and richest classes have reduced statistically significantly proportional odds of 0.42 and 0.73, respectively, of being sick of '2 or more diseases' versus combined odds of

'0/1 disease' when compared with children aged 48-59 months and live in the poorest household wealth quintile relative to the model 10 covariates.

Sometimes, interpretations of interaction effects could be challenging for odds ratios in ordinal logistic regression models (The Stata Forum, 2017). However, an intuitive way to present this seems complicated to understand the situation (Williams, 2021a, 2021b) is here presented in Table 8.3 and Figure 8.2 showing the output of margins of the predictive effect of interaction between child's age and wealth status and MAMM after adjusting for model 10 covariates. Figure 8.2 shows that some of the lines' intersections (non-parallel) indicate the existence of interaction effects. For instance, in the band of 'none of the diseases' and '2 or more diseases', the effects of the richest household vary at different points in the child's age band.

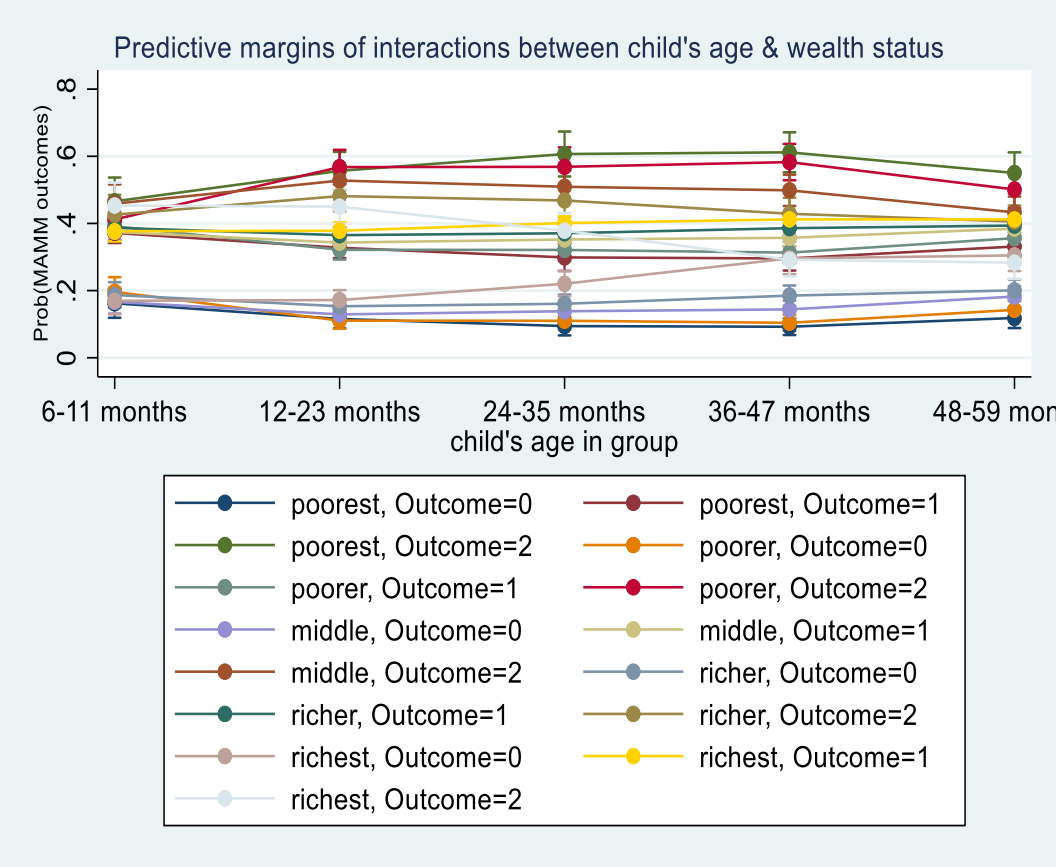


Figure 8 2 Predictive margins plot of interaction effects of child's age & wealth status

Combining Table 8.3 and Fig. 8.2, in the 'none of the diseases' group, for instance, a child living in the richest household and aged 48-59 months has a probability of 0.31 of staying healthy from MAMM compared with a child of the same age but resides in the poorest household with a probability 0.12 of being healthy from MAMM. Similarly, children aged 36-47 months living in the poorest households have the probability of 0.11, 0.18, and 0.32 above the probability of

children of the same age. Still, they live in the middle, richer, and richest households of contracting MAMM while all other model 10 covariates are held constant.

Another way these interaction effects could be viewed (Table 8.3) is by seeing the effects in each outcome category. For instance, the probability of children staying healthy from MAMM for each child's age group is highest for children living in the richest households. A similar pattern is observed in the morbidity (one disease only) group. However, the design changed where the probability of children of all ages cohabiting with two or more diseases decreases as the wealth quintile increases. So, in general, the results reflect those children from the richest household with an increase in age had the slightest tendency to contract MAMM compared to children living in the poorest household across the child's age.

Table 8 3 Average adjusted probability for interactions of child's age and wealth status

	None of the disease					One disease only					Two or more diseases				
	6-11	**11-23**	**24-35**	**35-47**	**47-59**	**6-11**	**11-23**	**24-35**	**35-47**	**47-59**	**6-11**	**11-23**	**24-35**	**35-47**	**47-59**
Poorest	0.162	0.116	0.094	0.092	0.119	0.372	0.328	0.299	0.296	0.331	0.466	0.557	0.607	0.612	0.550
Poorer	0.196	0.111	0.110	0.104	0.143	0.392	0.322	0.321	0.313	0.356	0.412	0.568	0.569	0.583	0.501
Middle	0.166	0.129	0.138	0.144	0.182	0.375	0.343	0.352	0.357	0.385	0.459	0.528	0.509	**0.499***	**0.433***
Richer	0.187	0.153	0.161	0.185	0.201	0.387	0.365	0.371	0.386	0.394	0.426	0.482	0.468	**0.429***	0.406
Richest	0.170	0.172	0.220	0.296	0.305	0.377	0.378	0.401	0.412	0.412	0.454	0.450	**0.378***	**0.292***	**0.283***

However, model 14, which includes model 10 covariates and all the possible two-way interactions between a child's sex, age, and wealth status, did not show any more improvement in the significant effects of the child's age and wealth status over what was attained in model 13. Furthermore, the three-way interaction between a child's sex, age and wealth status considered in model 15 did not yield any significant effects on children contracting '2 or more diseases' versus combining '0/1 disease' when compared with their respective reference categories conditional all the covariates in model 14.

Table 8 4 Interactions between child's age, sex, and wealth status accounting for Model 10 covariates

				Model 10 + interactions of child's sex and wealth status			Model 10 + interactions of child's sex and age			Model 10 + interactions of Child's age and wealth status			Model 10 +2-way of Child's sex, age, and wealth status			Model 10 + all interactions of Child's sex, age, and wealth		
	Model 10			Model 11			Model 12			Model 13			Model 14			Model 15		
Child's sex	AOR	p-value	95% CI	AOR	p-value	95% CI	AOR	p-value	95% CI	AOR	p-value	95% CI	AOR	p-value	95% CI	AOR	p-value	95% CI
Male	1.00			1.00			1.00			1.00			1.00			1.00		
Female	0.73	<0.001	(0.67-0.80)	0.66	0.001	(0.52-0.84)	0.70	0.005	(0.55-0.9)	0.73	<0.001	(0.67-0.8)	0.65	0.01	(0.47-0.9)	0.73	0.31	(0.4-1.35)
Child's age in group																		
6-11 months	1.00			1.00			1.00			1.00			1.00			1.00		
12-23 months	1.39	<0.001	(1.18-1.65)	1.39	<0.001	(1.17-1.65)	1.47	0.001	(1.17-1.85)	1.56	0.022	(1.07-2.28)	1.65	0.02	(1.08-2.51)	1.83	0.04	(1.03-3.24)
24-35 months	1.25	0.05	(1.00-1.57)	1.25	0.055	(0.99-1.56)	1.20	0.209	(0.9-1.59)	2.00	0.003	(1.27-3.18)	1.94	0.01	(1.18-3.18)	2.96	0.00	(1.45-6.04)
36-47 months	1.1	0.41	(0.88-1.38)	1.10	0.429	(0.87-1.38)	1.07	0.634	(0.81-1.42)	2.06	0.001	(1.33-3.18)	2.02	0.00	(1.26-3.25)	1.89	0.05	(1-3.57)
48-59 months	0.87	0.24	(0.69-1.10)	0.87	0.231	(0.69-1.09)	0.81	0.14	(0.61-1.07)	1.51	0.064	(0.98-2.34)	1.40	0.16	(0.87-2.24)	1.36	0.32	(0.74-2.52)
Household wealth index																		
Poorest	1.00			1.00			1.00			1.00			1.00			1.00		
Poorer	0.86	0.12	(0.72-1.04)	0.87	0.3	(0.68-1.13)	0.86	0.114	(0.72-1.04)	0.77	0.207	(0.51-1.16)	0.77	0.26	(0.49-1.21)	0.88	0.68	(0.47-1.63)
Middle	0.69	<0.001	(0.56-0.86)	0.63	0.001	(0.49-0.83)	0.69	0.001	(0.56-0.86)	0.97	0.874	(0.64-1.47)	0.88	0.58	(0.56-1.38)	0.93	0.81	(0.51-1.69)
Richer	0.56	<0.001	(0.44-0.72)	0.53	<0.001	(0.4-0.71)	0.56	<0.001	(0.44-0.71)	0.82	0.379	(0.53-1.27)	0.77	0.29	(0.48-1.24)	0.78	0.43	(0.42-1.44)
Richest	0.38	<0.001	(0.29-0.50)	0.34	<0.001	(0.24-0.47)	0.38	<0.001	(0.29-0.5)	0.94	0.802	(0.59-1.51)	0.82	0.45	(0.5-1.36)	0.97	0.92	(0.5-1.87)
Interaction effects																		
Sex and wealth status																		
				1.00									1.00			1.00		
Female and poorer				0.97	0.877	(0.7-1.35)							0.97	0.85	(0.7-1.35)	0.77	0.52	(0.34-1.74)
Female and middle				1.19	0.276	(0.87-1.62)							1.18	0.30	(0.86-1.61)	1.08	0.85	(0.49-2.37)
Female and richer				1.11	0.514	(0.81-1.51)							1.10	0.53	(0.81-1.5)	1.12	0.79	(0.51-2.45)
Female and richest				1.25	0.167	(0.91-1.72)							1.28	0.13	(0.93-1.76)	0.94	0.88	(0.41-2.16)
Sex and age																		

							1.00						1.00			1.00		
Female and 12-23 months							0.90	0.488	(0.66-1.22)				0.88	0.42	(0.65-1.2)	0.73	0.42	(0.34-1.57)
Female and 24-35 months							1.10	0.561	(0.8-1.52)				1.07	0.69	(0.77-1.48)	0.52	0.15	(0.21-1.27)
Female and 36-47 months							1.06	0.702	(0.77-1.46)				1.04	0.82	(0.75-1.43)	1.17	0.71	(0.52-2.64)
Female and 48-59 months							1.18	0.32	(0.85-1.62)				1.15	0.38	(0.84-1.58)	1.23	0.61	(0.55-2.76)
Age and wealth status																		
12-23 months and poorer										1.38	0.23	(0.82-2.32)	1.39	0.22	(0.82-2.33)	1.12	0.78	(0.52-2.4)
12-23 months and middle										0.9	0.67	(0.54-1.48)	0.91	0.70	(0.55-1.5)	0.86	0.70	(0.41-1.81)
12-23 months and richer										0.84	0.499	(0.51-1.39)	0.84	0.51	(0.51-1.39)	0.91	0.79	(0.44-1.87)
12-23 months and richest										0.63	0.08	(0.37-1.06)	0.64	0.09	(0.38-1.08)	0.44	0.04	(0.21-0.96)
24-35 months and poorer										1.08	0.80	(0.61-1.92)	1.08	0.78	(0.61-1.93)	0.65	0.35	(0.27-1.59)
24-35 months and middle										0.64	0.11	(0.37-1.1)	0.64	0.11	(0.37-1.11)	0.38	0.02	(0.16-0.88)
24-35 months and richer										0.61	0.078	(0.36-1.06)	0.62	0.08	(0.36-1.06)	0.42	0.04	(0.18-0.96)
24-35 months and richest										0.34	0.00	(0.19-0.6)	0.34	0.00	(0.19-0.6)	0.20	0.01	(0.08-0.48)
36-47 months and poorer										1.13	0.67	(0.65-1.94)	1.13	0.65	(0.66-1.95)	1.23	0.62	(0.54-2.81)
36-47 months and middle										0.59	0.05	(0.35-0.99)	0.59	0.05	(0.35-0.99)	0.64	0.25	(0.29-1.37)
36-47 months and richer										0.49	0.007	(0.29-0.83)	0.49	0.01	(0.29-0.83)	0.50	0.08	(0.23-1.09)
36-47 months and richest										0.21	0.00	(0.12-0.36)	0.21	0.00	(0.12-0.36)	0.25	0.01	(0.11-0.56)
48-59 months and poorer										1.03	0.92	(0.6-1.77)	1.03	0.90	(0.6-1.78)	0.96	0.92	(0.44-2.12)
48-59 months and middle										0.58	0.04	(0.35-0.98)	0.59	0.05	(0.35-0.99)	0.67	0.29	(0.31-1.42)
48-59 months and richer										0.60	0.051	(0.36-1)	0.60	0.06	(0.36-1.01)	0.68	0.30	(0.32-1.42)
48-59 months and richest										0.27	0.00	(0.16-0.47)	0.27	0.00	(0.16-0.47)	0.25	0.01	(0.11-0.54)
Sex, age and wealth status																		
Female, 12-23 months and poorer																1.50	0.44	(0.53-4.27)
Female, 12-23 months and middle																1.08	0.88	(0.4-2.96)

Female, 12-23 months and richer																0.82	0.69	(0.3-2.21)
Female, 12-23 months and richest																2.03	0.18	(0.72-5.74)
Female, 24-35 months and poorer																2.40	0.15	(0.74-7.78)
Female, 24-35 months and middle																2.47	0.11	(0.81-7.5)
Female, 24-35 months and richer																1.87	0.27	(0.62-5.65)
Female, 24-35 months and richest																2.49	0.12	(0.79-7.86)
Female, 36-47 months and poorer																0.87	0.81	(0.29-2.64)
Female, 36-47 months and middle																0.88	0.81	(0.31-2.51)
Female, 36-47 months and richer																0.96	0.94	(0.34-2.73)
Female, 36-47 months and richest																0.75	0.60	(0.25-2.25)
Female, 48-59 months and poorer																1.13	0.83	(0.38-3.36)
Female, 48-59 months and middle																0.76	0.61	(0.27-2.16)
Female, 48-59 months and richer																0.77	0.63	(0.27-2.18)
Female, 48-59 months and richest																1.21	0.73	(0.41-3.57)

8.4 Summary and comparison of four models/outcomes and risk factors

This section summarises the factors associated with and the predictors of the four outcome variables. Section 8.4.1 examines the factors commonly associated with anaemia, malaria, malnutrition, and multimorbidity. Also, section 8.4.2 presents the summary and comparisons of the predictors of the outcome variables from their respective choice models

8.4.1 Comparison of bivariate associations between the risk factors and outcomes

Table 8.5 shows that among the child-related variables, the child's age, birth order, preceding birth interval, took vitamin A supplements, was dewormed, had fever, and place of delivery was statistically significantly associated with the four outcomes of interest in this study. All variables listed from serial numbers 1 to 43 were simultaneously associated with anaemia, malaria, malnutrition, and multimorbidity. The child's sex was associated with anaemia, malnutrition and multimorbidity, but not malaria fever among children aged 6-59 months in Nigeria. Similarly, a child's duration of breastfeeding was associated with anaemia, malaria, and multimorbidity but not malnutrition.

Table 8 5 Bivariate associations between the risk factors and outcomes (Anaemia status, Malaria status, malnutrition status and multimorbidity status) and their statistical significance

		Anaemia status	**Malaria status**	**Malnutrition status**	**Multimorbidity status**
	Variables	**Not Anaemic and Anaemic**	**Negative & Positive**	**Well-nourished & poorly nourished**	**no disease, one disease only & two or more diseases**
S/N	**Sample size**	**10,222**	**10,185**	**10,481**	**10,184**
1.	Child's age in group	Yes	Yes	Yes	Yes
2.	Childbirth order	Yes	Yes	Yes	Yes
3.	Preceding birth interval	Yes	Yes	Yes	Yes
4.	Took vitamin A supplements	Yes	Yes	Yes	Yes
5.	The child took deworming drug in last 6months	Yes	Yes	Yes	Yes
6.	The child had fever in last 2 weeks before the survey	Yes	Yes	Yes	Yes
7.	Child had diarrheal in last 2 weeks before the survey	Yes	Yes	Yes	Yes
8.	Place of child's delivery	Yes	Yes	Yes	Yes
9.	Maternal age group in 10 years	Yes	Yes	Yes	Yes
10.	Mother/caregiver currently working	Yes	Yes	Yes	Yes
11.	Age of mother at first birth	Yes	Yes	Yes	Yes
12.	Maternal/caregiver highest educational level	Yes	Yes	Yes	Yes

13.	Maternal autonomy level	Yes	Yes	Yes	Yes
14.	Maternal/caregiver slept under mosquito bed net	Yes	Yes	Yes	Yes
15.	Ante-natal care visits during pregnancy of the child	Yes	Yes	Yes	Yes
16.	Mother's religious status	Yes	Yes	Yes	Yes
17.	Maternal ethnicity	Yes	Yes	Yes	Yes
18.	The mother took iron tablets during pregnancy	Yes	Yes	Yes	Yes
19.	Mother's anaemia status	Yes	Yes	Yes	Yes
20.	Maternal body weight status	Yes	Yes	Yes	Yes
21.	Partner education status	Yes	Yes	Yes	Yes
22.	Household wealth index	Yes	Yes	Yes	Yes
23.	Children under 5 slept under mosquito bed net last night	Yes	Yes	Yes	Yes
24.	Number of under-5 in household	Yes	Yes	Yes	Yes
25.	Household had electricity	Yes	Yes	Yes	Yes
26.	Source of drinking water	Yes	Yes	Yes	Yes
27.	Type of toilet facility	Yes	Yes	Yes	Yes
28.	Type of cooking fuel	Yes	Yes	Yes	Yes
29.	Floor materials	Yes	Yes	Yes	Yes
30.	Roof materials	Yes	Yes	Yes	Yes
31.	Wall materials	Yes	Yes	Yes	Yes
32.	The household has a mosquito bed net for sleeping	Yes	Yes	Yes	Yes
33.	Number of people in household	Yes	Yes	Yes	Yes
34.	Frequency of watching television	Yes	Yes	Yes	Yes
35.	Community wealth level	Yes	Yes	Yes	Yes
36.	The proportion of community distance to health facility is no big problem	Yes	Yes	Yes	Yes
37.	Proportion of community maternal education level	Yes	Yes	Yes	Yes
38.	Proportion of community households with no bed net	Yes	Yes	Yes	Yes
39.	Multidimensional poverty index by state (MPI)	Yes	Yes	Yes	Yes

40.	Human development index by state (HDI)	Yes	Yes	Yes	Yes
41.	Gender inequality index by state (GII)	Yes	Yes	Yes	Yes
42.	Region of residence	Yes	Yes	Yes	Yes
43.	Type of place of residence	Yes	Yes	Yes	Yes
44.	Child's sex	Yes	No	Yes	Yes
45.	Took iron supplements	No	Yes	Yes	Yes
46.	Duration of breastfeeding	Yes	Yes	No	Yes
47.	Mother is currently residing with their husband/partner	No	Yes	Yes	Yes
48.	Number of bedrooms in household	No	Yes	Yes	Yes
49.	Sex of household head	No	Yes	Yes	Yes
50.	Child's birth size	No	No	Yes	Yes
51.	Household head age group	No	Yes	No	Yes
52.	Shared toilet facilities	No	No	Yes	Yes
53.	The youngest child's stool disposed Properly	No	No	Yes	Yes
54.	Child had cough in last 2 weeks before the survey	Yes	No	No	No
55.	Paternal work status	No	No	No	No

Furthermore, a child's birth size and household sharing toilet facilities with others are associated with malnutrition and multimorbidity but not with anaemia and malaria. The child had a cough in the last two weeks before the survey, which was only associated with anaemia, but not with malaria, malnutrition and multimorbidity. Paternal work status was the only variable not associated with any outcome variables.

8.4.2 Comparison of strength and direction of risk factors for the outcome variables

Table 8.6 shows that child's age was a common predictor for all four outcome variables. With 6-11 months as the reference category for a child's age, the result shows that an increase in age is significantly protective for anaemia status but harmful for malaria, malnutrition and multimorbidity. For instance, the odds of children 12-23 months being anaemic is 0.91 times the odds of children 6-11 months, but the odds are 1.28, 1.66, and 1.39 times the odds of children 6-11 months being malaria positive, poorly nourished, and cohabiting with '2 or more diseases', respectively. On the other hand, children currently breastfeeding were significantly

more likely to be anaemic, not very harmful as poorly nourished, and having '2 or more diseases', but significantly protective against contracting malaria fever, when compared with ever breastfed, not currently breastfeeding children.

The result also shows that maternal educational attainment is a common predictor for all the outcome variables. Children of mothers with higher education are statistically significantly protective against being anaemic, malaria positive or poorly nourished, or cohabiting with '2 or more diseases' compared to children without formal education. Similarly, household wealth status is a common predictor for all the outcomes of interest. Children from the richest household wealth quintile are significantly protective from being anaemic, malaria positive, poorly nourished, or have '2 or more diseases' compared with children from the poorest household wealth quintile. In addition, the result shows that children of obese mothers were significantly protective against malaria, malnutrition, and multimorbidity but not significant in being anaemic compared to children of mothers of normal body mass index. Finally, it is worthy of note that the geopolitical zone of residence was a common predictor for all the outcomes of interest. Specifically, being children from the South-east (AOR=1the .96, $p<0.04$), and South-south (AOR=2.46, $p<0.001$) significantly harmful being anaemic, and respectively, (AOR=1.56, $p<0.01$), and (AOR=1.52, $p<0.01$) for multimorbidity when compared with children from North-central geopolitical zone of Nigeria.

Table 8 6 The strength and direction of the multivariable associations (Odds Ratio and 95% Confidence Intervals) between the risks factor and outcomes

(Anaemia status, malaria status, Malnutrition status, and multimorbidity status)

	Anaemia (N=7896)-Model 5 (Level 1 & 3 factors only)			Malaria (N=7808)-Model 6 (Level 1, 2 & 3 factors only)			Malnutrition (N=7770)-Model 6 (Level 1, 2 & 3 factors only)			Multimorbidity (N=7794)-Model 10 (Level 1, 2, & 3 factors only)		
Variables	**AOR**	**p-value**	**95% CI**	**AOR**	**p-values**	**95% CI**	**AOR**	**p-value**	**95% CI**	**AOR**	**p-value**	**95% CI**
Child-related characteristics												
Child's sex												
Male	1			1			1			1		
Female	0.83†	0.001	0.748, 0.932	0.93	0.252	(0.83-1.05)	0.742†	<0.0001	0.669, 0.824	0.73†	<0.001	0.67, 0.80
Child's age in group												
6-11 months	1			1			1			1		
12-23 months	0.91†	0.377	0.729, 1.127	1.31‡	0.015	(1.05-1.62)	1.664‡	<0.0001	1.381, 2.005	1.39‡	<0.001	1.18, 1.65
24-35 months	0.52†	<0.0001	0.39, 0.683	1.83‡	<0.001	(1.37-2.45)	2.219‡	<0.0001	1.722, 2.858	1.25‡	0.05	1.00, 1.57
36-47 months	0.41†	<0.0001	0.311, 0.546	2.41‡	<0.001	(1.79-3.23)	1.791‡	<0.0001	1.384, 2.318	1.1	0.41	0.88, 1.38
48-59 months	0.3†	<0.0001	0.227, 0.402	2.8‡	<0.001	(2.07-3.78)	1.276	0.068	0.982, 1.659	0.87	0.24	0.69, 1.10
Child's birth size												
Large				1			1			1		
Average				0.93	0.521	0.76, 1.15	1.26‡	0.014	1.049, 1.514	0.98	0.79	0.83, 1.15
Small				0.97	0.832	0.75, 1.27	1.79‡	<0.0001	1.419, 2.26	1.26‡	0.04	1.02, 1.56
Preceding birth interval												

None	1			1			1			1		
8-24 months	1.31‡	0.004	1.089, 1.587	0.95	0.636	0.76, 1.18	1.311‡	0.004	1.091, 1.575	1.37‡	<0.001	1.17, 1.62
25-35 months	1.15	0.133	0.959, 1.372	0.98	0.828	0.79, 1.21	1.015	0.872	0.85, 1.211	1.11	0.2	0.95, 1.29
36-59 months	1.11	0.276	0.922, 1.331	0.97	0.796	0.77, 1.22	0.841	0.065	0.701, 1.011	1.02	0.81	0.87, 1.20
60+ months	0.95	0.692	0.751, 1.209	0.89	0.45	0.66, 1.2	0.757	0.024	0.594, 0.964	0.93	0.5	0.76, 1.15
Malaria RTD status												
Negative	1						1					
Positive	3.7‡	<0.0001	3.218, 4.251				1.071	0.261	0.95, 1.207			
Anaemia status												
Not anaemic				1			1					
Anaemic				3.83‡	<0.001	(3.31-4.44)	1.332‡	<0.0001	1.178, 1.506			
Malnutrition status			,									
Well-nourished	1			1								
Poorly nourished	1.31‡	<0.0001	1.159, 1.484	1.05	0.443	(0.92, 1.2)						
Took Iron supplements												
No	1						1			1		
Yes	1.09	0.272	0.933, 1.277				1.13	0.095	0.979, 1.304	1.03	0.65	0.90, 1.18
Duration of breastfeeding			,			,						
Ever breastfed, not currently breastfeeding	1			1			1			1		

Never breastfed	0.82	0.367	0.531, 1.264	1.44	0.144	(0.88-2.34)	1.185	0.437	0.773, 1.815	1.19	0.39	0.80, 1.76
Still breastfeeding	1.36‡	0.006	1.093, 1.68	0.63†	<0.001	(0.5-0.79)	0.974	0.79	0.801, 1.184	0.96	0.63	0.80, 1.14
Child took deworming drug in last 6months	,											
No	1			1						1		
Yes	0.89	0.145	0.769, 1.039	0.77†	0.001	(0.64-0.89)				0.84†	0.01	0.74, 0.96
Child had Fever in last 2 weeks before the survey	,											
No	1			1						1		
Yes	1.26‡	0.001	1.102, 1.45	2.03‡	<0.001	(1.77-2.3)				1.57‡	<0.001	1.40, 1.77
Child had cough in last 2 weeks before the survey	,											
No							1					
Yes							0.899	0.149	0.779, 1.039			
Child had diarrheal in last 2 weeks before the survey	,											
No							1					
Yes							1.267‡	0.004	1.08, 1.488			
Place of child's delivery	-											
Home	1						1			1		
Public facility	0.94	0.419	0.805, 1.095				0.934	0.351	0.809, 1.078	0.93	0.26	0.81, 1.06

Private facility	0.95	0.629	0.776, 1.166				0.853	0.119	0.698, 1.042	0.88	0.14	0.74, 1.04
Elsewhere	1.3	0.235	0.843, 2.008				0.718	0.12	0.473, 1.09	1.01	0.94	0.71, 1.44
Parental-related characteristics												
Maternal age group in 10 years												
15-24 years				1								
25-34 years				1.02	0.812	(0.85, 1.24)						
35 years+				1.21	0.117	(0.95, 1.54)						
Mother/Caregiver currently working												
No							1					
Yes							1.14‡	0.042	1.005, 1.294			
Age of mother at first birth												
10-24 years				1								
25-36 years				0.87	0.226	(0.7, 1.09)						
37-49 years				0.45	0.206	(0.13, 1.54)						
Maternal/caregiver highest educational level	-											
No education	1			1			1			1		
Primary	0.95	0.618	0.78, 1.159	0.85	0.127	(0.69-1.05)	0.972	0.753	0.812, 1.163	0.84†	0.043	0.70, 0.99

Secondary	0.89	0.242	0.724, 1.085	0.74†	0.008	(0.6-0.93)	0.709†	0.001	0.583, 0.863	0.68†	<0.001	0.57, 0.82
Higher	0.73†	0.028	0.547, 0.966	0.45†	<0.001	(0.31-0.66)	0.513†	<0.0001	0.378, 0.696	0.45†	<0.001	0.35, 0.58
Mother is currently residing with husband/partner	-											
Living with her partner	1									1		
Staying elsewhere	0.85	0.155	0.677, 1.064							0.94	0.52	0.77, 1.14
Mother's religious status	-											
Catholic	1						1			1		
Other Christian	1.14	0.241	0.917, 1.41				1.107	0.358	0.891, 1.375	1.12	0.22	0.93, 1.36
Islam	1.47‡	0.005	1.124, 1.915				1.203	0.179	0.919, 1.575	1.37‡	0.01	1.08, 1.74
Traditionalist & others	1.11	0.748	0.584, 2.117				1.029	0.931	0.539, 1.966	1	0.99	0.56, 1.78
Maternal ethnicity												
Hausa/Fulani/Kanuri/Seribiri				1			1					
Ibo				1	0.998	(0.59-1.69)	0.633†	0.034	0.415, 0.966			
Yoruba				1.68‡	0.016	(1.1-2.57)	1.187	0.31	0.853, 1.651			
Others				1.31	0.032	(1.02-1.67)	0.831	0.079	0.677, 1.021			
Mother's Anaemia status												
Not Anaemic	1			1			1			1		
Anaemic	1.74‡	<0.0001	1.552, 1.949	1.23‡	0.001	(1.09-1.41)	1.096	0.1	0.983, 1.223	1.6‡	<0.001	1.45, 1.77
Maternal body mass index	-											

Normal	1			1			1			1		
Underweight	1.13	0.251	0.92, 1.378	0.89	0.251	(0.73-1.08)	1.266‡	0.008	1.063, 1.506	1.18	0.07	0.99, 1.40
Overweight	0.98	0.812	0.845, 1.141	0.86	0.105	(0.72-1.03)	0.71†	<0.0001	0.611, 0.824	0.77†	<0.001	0.67, 0.87
Obese	0.96	0.694	0.79, 1.17	0.72†	0.011	(0.55-0.93)	0.596†	<0.0001	0.481, 0.737	0.71†	<0.001	0.60, 0.84
Paternal Work Status												
No				1						1		
Yes				1.30	0.164	0.9, 1.9				1.21	0.2	0.91, 1.61
Partner education status	-											
No education	1			1			1			1		
Primary education	0.95	0.631	0.769, 1.173	0.95	0.622	(0.76-1.17)	1.017	0.861	0.842, 1.228	0.97	0.76	0.81, 1.17
Secondary education	0.99	0.942	0.818, 1.205	0.83	0.078	(0.68-1.02)	0.965	0.686	0.81, 1.148	0.9	0.22	0.76, 1.07
Tertiary education	0.86	0.221	0.681, 1.093	0.87	0.298	(0.66-1.13)	0.78†	0.031	0.623, 0.977	0.81†	0.05	0.66, 1.00
Household-related variables												
Household wealth index	-											
Poorest	1			1			1			1		
Poorer	0.94	0.58	0.765, 1.161	0.9	0.325	(0.74-1.11)	0.943	0.509	0.792, 1.122	0.86	0.12	0.72, 1.04
Middle	0.75†	0.009	0.599, 0.928	0.69†	0.002	(0.55-0.87)	0.97	0.776	0.787, 1.195	0.69†	<0.001	0.56, 0.86
Richer	0.68†	0.002	0.538, 0.867	0.6†	<0.001	(0.46-0.78)	0.797	0.078	0.62, 1.026	0.56†	<0.001	0.44, 0.72
Richest	0.63†	0.001	0.48, 0.833	0.26†	<0.001	(0.18-0.36)	0.732†	0.04	0.543, 0.986	0.38†	<0.001	0.29, 0.50
Household Head age group												

Less 34 years				1			1					
35-44 years				0.83†	0.03	(0.7, 0.98)	0.946	0.447	0.821, 1.091			
45-55 years				0.90	0.312	(0.72, 1.11)	0.863	0.096	0.725, 1.026			
56 years+				1.04	0.771	(0.81, 1.32)	0.922	0.427	0.755, 1.127			
Children under 5 slept under mosquito bed net last night	,											
No child	1			1						1		
All children	0.9	0.254	0.748, 1.08	0.89	0.237	(0.72, 1.08)				0.93	0.37	0.79, 1.09
Some children	1.07	0.596	0.835, 1.369	1.17	0.231	(0.9, 1.52)				1.12	0.27	0.91, 1.39
No net in household	0.83†	0.047	0.685, 0.998	0.98	0.85	(0.80, 1.21)				0.94	0.46	0.80, 1.11
Number of under-5 in household	-											
0-3	1			1								
4-6th	1.19	0.153	0.938, 1.501	1.29‡	0.038	1.01, 1.64						
7th+	0.88	0.703	0.442, 1.734	1.38	0.404	0.64, 2.97						
Number of bedrooms in household	-											
One-room	1			1			1					
Two rooms	0.95	0.501	0.813, 1.107	1.04	0.659	0.88, 1.23	1.191‡	0.02	1.028, 1.38			
Three rooms	0.88	0.195	0.732, 1.066	1.08	0.458	0.88, 1.34	1.227‡	0.026	1.024, 1.469			

Four rooms	0.83	0.129	0.658, 1.055	0.92	0.511	0.71, 1.19	1.336‡	0.011	1.068, 1.673			
Five+ rooms	0.9	0.419	0.684, 1.171	0.78	0.109	0.58, 1.06	1.158	0.253	0.9, 1.49			
Sex of household head			,									
Male	1			1						1		
Female	1.15	0.243	0.909, 1.458	0.78†	0.024	0.62, 0.97				0.95	0.62	0.78, 1.16
Number of people in household		-										
2-3	1			1			1			1		
4-6	1.01	0.9	0.809, 1.272	1.01	0.949	0.78, 1.3	0.84	0.112	0.678, 1.041	0.88	0.2	0.73, 1.07
7-9	1.09	0.516	0.84, 1.416	0.96	0.809	0.72, 1.3	0.928	0.553	0.724, 1.189	0.97	0.79	0.78, 1.20
10+	1.21	0.229	0.886, 1.66	1.03	0.852	0.73, 1.47	1.008	0.956	0.761, 1.335	1.12	0.36	0.88, 1.41
Community-related variables												
Proportion of community wealth level												
Low							1			1		
High							0.845	0.089	0.696, 1.026	0.79†	0.02	0.65, 0.96
Proportion of community distance to health facility is no big problem	,											
Low				1			1			1		
High				0.79†	0.006	(0.65-0.93)	0.867†	0.033	0.761, 0.988	0.86†	0.03	0.75, 0.98
Proportion of community maternal education level	,											

Low							1			1		
High							1.135	0.205	0.933, 1.381	1.1	0.34	0.90, 1.34
Proportion of community households with no bed net	,											
Low							1					
High							0.972	0.678	0.848, 1.113			
Area-related variables												
Multidimensional Poverty Index by State MPI	,											
Highly Deprived				1						1		
Above averagely deprived				2.08‡	0.011	(1.19-3.64)				1.28	0.11	0.95, 1.73
Averagely Deprived				1.25	0.569	(0.58-2.71)				0.72	0.11	0.48, 1.07
Mildly Deprived				1.18	0.689	(0.52-2.68)				0.69	0.09	0.45, 1.06
Lowest Deprived				0.94	0.897	(0.35-2.51)				0.67	0.12	0.41, 1.11
Human Development Index by State HDI	-											
Lowest HDI	1			1						1		
Low HDI	1.09	0.679	0.714, 1.678	1.5	0.13	(0.89-2.53)				1.25	0.12	0.94, 1.65
Average HDI	1.07	0.809	0.633, 1.796	1.81‡	0.076	(0.94-3.5)				1.27	0.17	0.90, 1.80
High HDI	0.88	0.666	0.479, 1.6	2.66‡	0.016	(1.2-5.88)				1.51‡	0.04	1.01, 2.28
Highest HDI	0.86	0.671	0.429, 1.726	1.47	0.402	(0.6-3.6)				1.13	0.6	0.72, 1.78

Gender Inequality Index by State GII	-											
Lowest GII	1			1			1			1		
Low GII	0.9	0.611	0.615, 1.331	0.56†	0.032	(0.33-0.95)	1.454‡	0.002	1.144, 1.849	0.76†	0.05	0.58, 1.00
Average GII	1.04	0.864	0.664, 1.628	1.16	0.593	(0.67-2.02)	1.066	0.634	0.819, 1.388	1.25	0.13	0.94, 1.67
High GII	0.87	0.46	0.592, 1.268	1.34	0.242	(0.82-2.17)	0.814†	0.077	0.647, 1.023	1.03	0.83	0.80, 1.32
Highest GII	0.84	0.497	0.519, 1.375	1.63	0.113	(0.89-2.99)	1.042	0.777	0.783, 1.387	1.3	0.11	0.94, 1.80
Region of residence			,									
North-central	1			1			1			1		
North-east	0.81	0.407	0.502, 1.322	0.44†	0.015	(0.22-0.85)	2.272‡	<0.0001	1.773, 2.912	0.68†	0.03	0.49, 0.96
North-west	0.74	0.287	0.427, 1.287	1.3	0.488	(0.62-2.74)	3.111‡	<0.0001	2.339, 4.138	1.12	0.56	0.77, 1.62
South-east	1.96‡	0.004	1.236, 3.104	1.32	0.457	(0.64-2.71)	1.106	0.652	0.714, 1.712	1.56‡	0.01	1.13, 2.15
South-south	2.46‡	<0.0001	1.544, 3.926	0.7	0.265	(0.38-1.31)	0.979	0.885	0.734, 1.306	1.52‡	0.01	1.09, 2.12
South-west	1.22	0.333	0.813, 1.841	1.55	0.208	(0.78-3.07)	1.093	0.566	0.807, 1.481	1.61‡	<0.001	1.16, 2.23
Type of place of residence												
Urban				1			1			1		
Rural				1.98‡	<0.001	(1.63-2.41)	1.01	0.899	0.869, 1.173	1.23‡	<0.001	1.06, 1.42

†: decreased odds (protective effects); ‡: **increased odds (harmful effects); AOR: Adjusted odds ratio**

8.5 The Chapter Summary

This Chapter answered the final research question in this study and covered the fourth level of statistical analysis. The process was an extension of the preceding Chapter's multilevel mixed effect ordinal logistic analysis of predictors of MAMM among Nigerian children aged 6-59 months, which considered the interaction effects of child's age, sex, and household wealth on the multiple overlaps in the determinants of MAMM in Nigeria. The model which incorporated interaction effects of a child's age and wealth status into covariates of model 10 stood out to produce a better fit among the models formulated in this study. In addition, the Chapter ended by comparing the bivariate association across the four outcome variables and the strength and direction of predictors across anaemia, malaria, malnutrition, and MAMM.

Chapter 9 Discussion and conclusion

9.0 Introduction

The results of this study offer new evidence in the individual and contextual determinants of multimorbidity of anaemia, malaria, and malnutrition (MAMM) among children aged 6-59 months in Nigeria. Identifying the risk factors is also quite concerning because there is a paucity of knowledge regarding the origins, indicators, and prevention of this new health disorder (multimorbidity) in children. In the past, most studies conducted in Nigeria and many other least developed nations of the world examined this newly emerging public health condition in adults and children by treating the components separately as distinct disease conditions using conventional analytical techniques. However, because these illnesses are related and part of the same ecological epidemiology system, they may share risk variables such as socioeconomic status, demographics, and the environment. The intricate interactions between these illnesses and variations in individual and contextual predictors present the biggest challenge to doctors, researchers, and healthcare professionals, creating critical gaps in our understanding of multimorbidity in health and having grave ramifications for policies aiming to reduce such gaps. This thesis sought to address these difficulties by applying statistical technique, which promotes the necessity to comprehend the interdependence of disease structures. Health research in developing countries is seeing empirical studies that use an appropriate method to explore simultaneous occurrences of diseases in child health. However, the scoping review results in Chapter 3 show that very few of these studies are in the SSA in general and in Nigeria in particular. This study used the combined data sets from two nationally representative surveys to answer the following research questions: What **are the** individual and contextual risk factors associated with anaemia, malaria, and malnutrition and their cooccurrence among children aged 6-59 months in Nigeria?

However, in more specific terms, the study addressed the following sub-questions in four stages:

1. What are the descriptions of individual and contextual characteristics of children aged 6-59 months in Nigeria at baseline (response rates), as captured in 2018 NDHS?
2. Are there variations in the proportion of children in each of the three outcomes of anaemia, malaria, and malnutrition across the states and the regions
3. What is the independent prevalence of the three outcomes of anaemia, malaria, and malnutrition concerning the individual and contextual characteristics among children 6-59 months of age in Nigeria?

4. What are the differences between groups in the individual and contextual characteristics concerning the three outcomes of anaemia, malaria, and malnutrition among children 6-59 months in Nigeria?
5. What are the independent effects of individual contextual factors on the outcomes of anaemia, malaria, and malnutrition among children 6-59 months of age in Nigeria?
6. What are the prevalence and differences between groups in the individual and contextual characteristics concerning the number of occurrences of MAMM among children 6-59 months in Nigeria?
7. Are there variations in the MAMM across the states and the regions?
8. What are the multiple overlaps in the associations of individual and contextual factors with the MAMM among children 6-59 months in Nigeria?
9. What are the interaction effects of a child's sex, age, and household socioeconomic status on the impact of individual and contextual risk factors of MAMM among children 6-59 months of age in Nigeria?

9.1 Summary of the focus of Chapters

The preceding chapters (5-8) present the results of different statistical analysis approaches that looked at how individual and contextual predictors interact to explain the occurrence of anaemia, malaria, and malnutrition in various categories among children aged 6-59 months in Nigeria. The study proposed nine specific research questions wrapped into four analysis phases to fully explain the relationships between the selected predictors and the outcomes of interest using the merged data set of two nationally representative surveys. At the first level (Chapter 5), baseline descriptive and bivariate analyses were conducted to explain and describe the various predictors used and their relationships with the outcome variables while classifying them into child-, parental-, household-, community-, and state-related variables. In doing so, research questions 1 – 4 were answered. At the second level (Chapter 6), the multivariate analyses of each of the three disease indicators (anaemia, malaria, and malnutrition) for multimorbidity among children aged 6-59 months in Nigeria were conducted. In doing so, it answered research question 5. The third level (Chapter 7) addressed research questions (6 – 8), which represent the primary focus of the thesis. It covered the analysis of associations, spatial map descriptions of prevalence, and multilevel mixed effects ordered logistic regression of predictors of the MAMM. By examining how the individual variables at level 1 nested in the community at level 2 and nested in the state at level 3 affect the cooccurrence of multiple diseases and perceived that some child's demographic variables (age and sex) will interact with

household socioeconomic status (represented by household wealth status) to modify these relationships with MAMM, the fourth level of analysis (Chapter 8) was conducted.

The final part of this chapter starts with an update of the scoping review of the literature (from Chapter 3) to capture new 'hot of the press' research published since the first review was conducted, followed by discussions to answer the research questions, and comparing the results of MAMM with previous studies. Next, a section on the strength and limitations of the current study will be outlined, followed by issues for future research, recommendations, and conclusions.

9.2 Update on scoping reviews of literature

Having carried out scoping review of past studies on the four outcomes of interest: anaemia, malaria, malnutrition, and multimorbidity of childhood diseases at the start of this thesis (Chapter 3), it becomes imperative to update the review in the light of some new papers that may become available. Therefore, this section begins with the updates on anaemia literature, followed by malaria literature, and then malnutrition papers (Risk factors and the directions of effects in the three outcomes are in Appendix A.7).

9.2.1 Scoping review update on anaemia among children aged under-five years in SSA

A supplementary scoping review was conducted to identify additional literature on determinants of anaemia among children under-five years in SSA. These were papers published since the first scoping review (including papers published between 22 June 2020 and 27 March 2022). Having used the same search **terms** as in the previous critique **(Obasohan *et al.*, 2020a)**, a total of 83 additional studies were extracted (PubMed had 27 papers, Scopus had 0 papers, Web of Science had 17, CNAHL had 1; Medline (Ovid) had one paper, and DHS publications, had 37 additional papers). Only 30 papers were screened for abstract and full-text reading, and 14 papers were included in the review. The results are presented **in** different classifications of the predictor variables as follows:

9.2.1.1 Child-related variables

The studies showed that, as in the previous review, the child's age is the most crucial predictor of anaemia. All 13 studies that found a child's age as a predictor of anaemia reported that as the age of the child increases, the child becomes more protective against becoming anaemic. That is, the odds of being anaemic are lower for older children than younger children (Elmardi *et al.*, 2020; Gebremeskel *et al.*, 2020; Ag *et al.*, 2021; Iddrisu Amadu *et al.*, 2021; Anjorin and Yaya, 2021; Anteneh and Van Geertruyden, 2021; Aregbeshola, Onifade and Awuviry-Newton,

2021; Barry *et al.*, 2021; Heinrichs *et al.*, 2021; Jember *et al.*, 2021; Tesema, Tessema, *et al.*, 2021; Tesema, Worku, *et al.*, 2021; Eshete *et al.*, 2022).

Similarly, the higher the birth order, the more likely it is for a child to become anaemic. However, a child firstborn in the household is more protected from being anaemic. For instance, Aragbeshola et al. and Tesema et al. found that children who are more than seventh birth order have 90% and 23%, respectively, higher odds compared with children of the first order when all other variables are held constant (Aregbeshola, Onifade and Awuviry-Newton, 2021; Tesema, Worku, *et al.*, 2021). Also, children who had a fever (Gebremeskel *et al.*, 2020; Anteneh and Van Geertruyden, 2021; Aregbeshola, Onifade and Awuviry-Newton, 2021; Jember *et al.*, 2021), and those who had diarrhoeal (Aregbeshola, Onifade and Awuviry-Newton, 2021; Tesema, Worku, *et al.*, 2021), two weeks before the survey took place were more likely to be anaemic than those children who neither had fever nor diarrhoeal. Additionally, having an adverse nutritional status, such as being stunted (Gebremeskel *et al.*, 2020; Anteneh and Van Geertruyden, 2021; Jember *et al.*, 2021; Tesema, Tessema, *et al.*, 2021; Tesema, Worku, *et al.*, 2021), being wasted (Anteneh and Van Geertruyden, 2021; Aregbeshola, Onifade and Awuviry-Newton, 2021; Tesema, Worku, *et al.*, 2021) and being underweight (Anteneh and Van Geertruyden, 2021; Tesema, Tessema, *et al.*, 2021; Tesema, Worku, *et al.*, 2021) have harmful effect to a child being anaemic.

9.2.1.2 Parental-related variables

Among the parental-related factors, the mother's age is a significant predictor of anaemic children. Children born to older mothers were less likely to be anaemic when compared to children born to younger mothers. For instance, the review shows that children of mothers aged 15-24 years, (AOR=1.38, 95% CI=1.22, 1.56), 25-29 years, (AOR=1.16, 95% CI=1.05, 1,27), and 30-34 years, (AOR=1.14, 95% CI=1.05, 1.25) are more likely to contract anaemia compared with children of mothers aged 35-49 years. Furthermore, children of working-class mothers were reported to be more protective of anaemia than children of the non-working class. However, Eshete et al. 2022 (though borderline significance) reported a contrary result (AOR=1.25, 95% CI=1.006, 1.5), that children of the non-working class were more protective compared to children of working-class mothers (Eshete *et al.*, 2022). Furthermore, the more educated mothers become, their children are protected from being anaemic. Expectedly, the anaemia status of mothers was a significant predictor of children being anaemic. All the studies (Elmardi *et al.*, 2020; Gebremeskel *et al.*, 2020; Anteneh and Van Geertruyden, 2021; Aregbeshola, Onifade and Awuviry-Newton, 2021; Heinrichs *et al.*, 2021; Tesema, Worku, *et*

al., 2021; Eshete *et al.*, 2022), reported that children born to anaemic mother are more likely to be anaemic compared with children born to non-anaemic mothers, except, Anjorin and Yaya (Anjorin and Yaya, 2021), that reported otherwise.

9.2.1.3 Household-related variables

Household wealth is another major determinant of the anaemia status of children under five years of age in SSA. The wealthier the households are, the more likely the children from such homes will be anaemic compared to children from the poorest household. For instance, Eshete et al. 2022 reported that the odds of children living in the richest household being anaemic is 46% (AOR=0.54, 95% CI=0.4, 0.73), less likely compared with the odds of children living in the poorest household (Eshete *et al.*, 2022). Similarly, Tesema et al. 2021 found the harmful effects of being anaemic among children living in the poorest households (AOR=1.39, 95% CI=1.33, 1.45), poor households (AOR=1.32, 95% CI=1.25, 1.37), middle households (AOR=1.20, 95% CI=1.15, 1.25) and rich households (AOR=1.15, 95% CI=1.11, 1.20) compared with children living in richest households (Tesema, Worku, *et al.*, 2021).

9.2.1.4 Community-related variables

Two significant community-related predictors (place of residence and community wealth status) were reported in the papers reviewed. Elmadi *et al.* 2020 concluded that the odds of being anaemic for children living in camps are 63% less likely than for those living in rural areas (Elmardi *et al.*, 2020). Also, Heinrichs 2021 reported the significant harmful effect of being anaemic for children living in rural areas compared to children living in urban areas (Heinrichs *et al.*, 2021). Both Eshete et al. 2022, and Gebremeskel et al. 2020 found that children living in high community wealth areas are less prone to being anaemic when compared with children living in the low community wealth area (Gebremeskel *et al.*, 2020; Eshete *et al.*, 2022).

9.2.2 Scoping review update on malaria among children aged under-five years in SSA

This section reports the results of a supplementary scoping review conducted to identify additional literature on malaria determinants among children under-five years in SSA. These papers have been published since the first scoping review on malaria (including articles published between 1 January 2021 and 27 June 2022). Having used the exact search as in the previous review (Obasohan *et al.*, 2021a), a total of 77 additional studies were extracted (PubMed had four papers, Scopus had 0 papers, Web of Science had 2, CNAHL had 0; Medline (Ovid) had two papers, and DHS publications, had 69 additional papers). After removing irrelevant papers and duplicate publications, nine studies were screened for the abstract and full text read. Only four papers met the inclusion criteria, and five were removed for various

reasons: the paper was 'variable specific' only (that is, the analysis of malaria was concerning an index variable) (Woolley *et al.*, 2022). Two papers were not related to an analysis of predictors (Oyibo *et al.*, 2021; Iddrisu and Moyer, 2022), one paper that was related to comorbidity (Taylor *et al.*, 2021), and another paper that considered multimorbidity cases (Mann, Swahn and McCool, 2021). The results from the included papers are presented in the following section

9.2.2.1 Child-related variables

The result shows that the only two studies that found a child's age as a predictor of malaria indicated that they grow more exposed to being malaria positive as a child ages. In other words, older children have an increased risk of being malaria positive than younger ones. Aheto et al. reported that the odds of children aged 48 months and above having more than 4-folds (AOR=4.28, 95% CI= 3.19, 5.77), higher odds of being malaria positive compared to children less than two years (Aheto *et al.*, 2021). Similarly, in Democratic Republic of Congo (DRC) Emina et al found that the odds of children aged 12-23 months, (AOR=1.71, 95% CI=1.25, 2.36), 24-35 months, (AOR=2.68, 95% CI= 2.02, 3.54), 36-47 months, (AOR=3.36, 95% CI= 2.53, 3.46), and 48-59 months, (AOR=3.42, 95% CI= 2.53, 4.62), were significantly higher compared to the odds of children aged 6-11 months (Emina, Doctor and Yé, 2021). One study using posterior means for linear effects found that male children are less likely to contract malaria fever than female children (Nzabakiriraho and Gayawan, 2021). Not anaemic children are less likely to be malaria-positive (Aheto *et al.*, 2021).

9.2.2.2 Parental-related variables

Amongst the parental-related variables, maternal education status was the only significant factor identified in the captured papers. Compared to children whose moms have no formal education, those whose mothers have at least a primary education are less likely to contract malaria (Emina, Doctor and Yé, 2021; Nzabakiriraho and Gayawan, 2021; Oguoma *et al.*, 2021).

9.2.2.3 Household-related variables

Furthermore, on the part of household-related variables, compared to children from the poorest homes, those from at least poorer households have a lower risk of having malaria (Aheto *et al.*, 2021; Emina, Doctor and Yé, 2021; Nzabakiriraho and Gayawan, 2021; Oguoma *et al.*, 2021). Children from households where at least some under-five years slept under a net the night before the survey have a lower odds of being malaria positive (Nzabakiriraho and Gayawan, 2021). The higher the number of people in a household, the more likely the children will

contract malaria fever. Oguoma et al. found that children living in a household with more than seven people are 47% more likely to contract malaria fever than children from a household with less than five persons (Oguoma *et al.,* 2021). The higher the number of children aged under-five years in a home, the more harmful it is to contract malaria fever (Aheto *et al.*, 2021). Children from homes where package water is the primary source of drinking water are more protected from malaria. In contrast, those from homes that depend on wells/spring, river/stream, and rainwater as a source of drinking water were more likely to contract malaria fever compared to children using piped water.

9.2.2.4 Community-related variables

On the community-related variables, variations in the place of residence were found to be a predictor of contracting malaria fever. Compared to children from rural areas, children from urban environments have a lower risk of contracting malaria (Aheto *et al.*, 2021; Nzabakiriraho and Gayawan, 2021; Oguoma *et al.*, 2021).

9.2.3 Scoping review update on malnutrition among children aged under-five years in SSA

Additionally, a supplementary scoping review of related literature on the determinants of malnutrition in children under the age of five in SSA was done. These were published following the initial scoping review (including papers published between 22 June 2020 and 27 March 2022). Three hundred eighty-seven new studies were extracted using the same search strategy as in the previous review **(Obasohan *et al.*, 2020b);** PubMed had 166 papers, Scopus had 0, Web of Science had 63, CNAHL had 7, and DHS publications had 151 more papers. A total of 68 papers were retrieved from databases into the reference manager after considering the titles and abstracts. After removing the duplicate copies (14), for not meeting the inclusion criteria (29), 25 papers were reviewed.

Stunting, wasting, and underweight were the three generally used comprehensive indicators of malnutrition in the texts reviewed. Since some variables better-explained chronic rather than acute malnutrition, most papers concentrated on stunted children (2 SD of height-for-age below the median value). This height-for-age index (stunting) is the most trustworthy indicator since it is less subject to temporary food shortages typical in developing countries (N.-B. Kandala *et al.*, 2011). If the joint analysis was carried out for the three indicators, the preference for inclusion was given to stunting, wasting, or underweight. The results are presented as follows:

9.2.3.1 Child-Related Variables

The research confirmed the previous review's finding that the sex of the child is a significant predictor of malnutrition. Of the 19 studies that found the sex of the child a predictor of

malnutrition, 18 studies indicated that sex difference is more protective for female children than male children. That is, the odds of being poorly nourished are lower for female children than for male children (Hailu, Bogale and Beyene, 2020; Kassie and Workie, 2020; Khamis *et al.,* 2020; Masibo, Humwa and Macharia, 2020; Rutayisire *et al.,* 2020; Simelane, Chemhaka and Zwane, 2020; Aboagye *et al.,* 2021; Adam Birhan and Bitew Belay, 2021; Adedokun and Yaya, 2021; Fenta, Zewotir and Muluneh, 2021; Muche and Dewau, 2021; Muche *et al.,* 2021; Musuka *et al.,* 2021; Seboka *et al.,* 2021; Sserwanja *et al.,* 2021; Tesema, Yeshaw, *et al.,* 2021; Tesfaw and Fenta, 2021; Uwiringiyimana *et al.,* 2022).

Similarly, increases in the age of the child were found as the harmful effect of poorly nourishment for the children (Kassie and Workie, 2020; Khamis *et al.,* 2020; Masibo, Humwa and Macharia, 2020; Rutayisire *et al.,* 2020; Simelane, Chemhaka and Zwane, 2020; Aboagye *et al.,* 2021; Adam Birhan and Bitew Belay, 2021; Bekele and Fetene, 2021; Kebede and Aynalem, 2021; Muche and Dewau, 2021; Sserwanja *et al.,* 2021; Tesema, Yeshaw, *et al.,* 2021; Uwiringiyimana *et al.,* 2022). Also, children born with large size have decreased effects of malnutrition compared to children born small. However, one study found an increased effect for children born big (Khamis *et al.,* 2020). Finally, children who are the product of multiple births have higher odds of being poorly nourished in all the papers that reported significant effects (Hailu, Bogale and Beyene, 2020; Adam Birhan and Bitew Belay, 2021; Fenta, Zewotir and Muluneh, 2021; Kebede and Aynalem, 2021; Muche *et al.,* 2021; Tesema, Yeshaw, *et al.,* 2021; Tesfaw and Fenta, 2021). Additionally, preceding birth interval of less than 60 months has harmful effects of being poorly nourished compared with children of preceding birth intervals of more than 60 months(Bekele and Fetene, 2021; Muche *et al.,* 2021; Amoako Johnson, 2022). Similarly, children of birth order more than first-order have increased odds of being malnourished(Adam Birhan and Bitew Belay, 2021; Chikako *et al.,* 2021; Tesema, Yeshaw, *et al.,* 2021). Furthermore, some studies reported that children who had diarrhoeal two weeks before the survey had an increased odds of being poorly nourished compared with children who do not have any of the diseases (Adam Birhan and Bitew Belay, 2021; Bekele and Fetene, 2021; Chikako *et al.,* 2021; Muche *et al.,* 2021; Tesfaw and Fenta, 2021; Uwiringiyimana *et al.,* 2022), or fever(Kassie and Workie, 2020; Adam Birhan and Bitew Belay, 2021; Chikako *et al.,* 2021; Muche *et al.,* 2021). The review also found that children born in health facilities have decreased odds of being poorly nourished compared with children born at home.

9.2.3.2 Parental-related variables

Among the parental-related factors, increased mother's age has decreased significant effects on their children being malnourished. That is, children born to older mothers were less likely to be malnourished when compared to children born to younger mothers (Aboagye *et al.,* 2021; Adedokun and Yaya, 2021; Muche and Dewau, 2021; Tesema, Yeshaw, *et al.,* 2021). In addition, children of mothers who had their first birth at an older age were reported to be more protective against malnutrition than children who had their first birth at a younger age (Kassie and Workie, 2020; Tesfaw and Fenta, 2021). Furthermore, all the studies that found significance in maternal education status reported that the more educated mothers become, the more protected their children are from being malnourished.(Hailu, Bogale and Beyene, 2020; Kassie and Workie, 2020; Khamis *et al.,* 2020; Rutayisire *et al.,* 2020; Simelane, Chemhaka and Zwane, 2020; Aboagye *et al.,* 2021; Adam Birhan and Bitew Belay, 2021; Adedokun and Yaya, 2021; Amaha and Woldeamanuel, 2021; Bekele and Fetene, 2021; Chikako *et al.,* 2021; Fenta, Zewotir and Muluneh, 2021; Muche and Dewau, 2021; Muche *et al.,* 2021; Tesema, Yeshaw, *et al.,* 2021; Tesfaw and Fenta, 2021; Amoako Johnson, 2022). Similarly, higher paternal education decreases the children's odds of being poorly nourished (Rutayisire *et al.,* 2020; Bekele and Fetene, 2021; Fenta, Zewotir and Muluneh, 2021). Also, Ameghor et al. 2020 reported that children of the working class had decreased odds of being malnourished compared to children of non-working-class mothers (Amegbor, Yankey and Sabel, 2020). The maternal body mass index, an indicator of maternal nutrition status, was an essential predictor of malnutrition in under-five years in SSA. Children of mothers who are either normal, overweight or obese are more protected from being poorly nourished compared with children of thin mothers (Kassie and Workie, 2020; Khamis *et al.,* 2020; Adam Birhan and Bitew Belay, 2021; Amaha and Woldeamanuel, 2021; Chikako *et al.,* 2021; Kebede and Aynalem, 2021; Muche *et al.,* 2021; Musuka *et al.,* 2021; Tesfaw and Fenta, 2021; Uwiringiyimana *et al.,* 2022). Children whose mothers have more than four times antenatal care (ANC) visits have decreased odds of being malnourished compared with children whose mothers only attended less than four times ANC visits (Aboagye *et al.,* 2021; Adedokun and Yaya, 2021; Tesema, Yeshaw, *et al.,* 2021; Amoako Johnson, 2022).

9.2.3.3 Household-related variables

Interestingly, among the household-related characteristics, wealth status was the most reported. Out of the twenty-one studies that found wealth status as a predictor of malnutrition, twenty reported wealth status as having a protective effect on malnutrition among children under-five

years in SSA (Amegbor *et al.*, 2020; Hailu, Bogale and Beyene, 2020; Kassie and Workie, 2020; Khamis *et al.*, 2020; Masibo, Humwa and Macharia, 2020; Rutayisire *et al.*, 2020; Simelane, Chemhaka and Zwane, 2020; Aboagye *et al.*, 2021; Adam Birhan and Bitew Belay, 2021; Adedokun and Yaya, 2021; Bekele and Fetene, 2021; Chikako *et al.*, 2021; Fenta, Zewotir and Muluneh, 2021; Muche and Dewau, 2021; Muche *et al.*, 2021; Musuka *et al.*, 2021; Tesema, Yeshaw, *et al.*, 2021; Tesfaw and Fenta, 2021; Amoako Johnson, 2022; Uwiringiyimana *et al.*, 2022). This finding implies that the higher the wealth quintiles, the less likely the child will be poorly nourished. However, Wondimu & Dejene found the contrary (Wondimu and Dejene, 2022). The higher the household size, the more likely the children under five will be malnourished (Aboagye *et al.*, 2021; Tesfaw and Fenta, 2021). When the number of children under under-five in a household is higher than three, the children are at an increased odds of being poorly nourished (Kassie and Workie, 2020; Simelane, Chemhaka and Zwane, 2020; Tesfaw and Fenta, 2021). Also, children living in a household with access to an improved source of water were reported to experience protective effects of being malnourished when compared with children living in a household without access to an improved source of water (Kassie and Workie, 2020; Kebede and Aynalem, 2021; Seboka *et al.*, 2021; Uwiringiyimana *et al.*, 2022).

9.2.3.4 Community-related variables

On the community-related variables, variations in the place of residence were found to be a predictor of malnutrition status among children aged under-five years in SSA. Children living in urban areas are more protected from being malnourished than children from rural areas. (Khamis *et al.*, 2020; Adedokun and Yaya, 2021; Chikako *et al.*, 2021; Fenta, Zewotir and Muluneh, 2021; Muche and Dewau, 2021; Tesema, Yeshaw, *et al.*, 2021; Tesfaw and Fenta, 2021; Amoako Johnson, 2022) (Full text of results is in Appendix 9.B)

9.3 Discussion of Key findings

This study aimed to investigate the impact of individual and contextual variables on the prevalence of MAMM among children aged 6 to 59 months in Nigeria. The DHS data offers a reliable, sizable, and comprehensive national database that may be utilized to examine the nature of childhood diseases in Nigeria. In addition to other predictors derived from NHDR data that may help explain the area-specific heterogeneity in Nigeria's state and geopolitical zones, this study has demonstrated correlations between childhood multimorbidity and individual and contextual factors. The sections below provide an overview of the study's main conclusions from both the descriptive and multivariate analysis stages of MAMM among

children aged 6-59 months in Nigeria to answer the research questions posed in this study, as well as how the findings add to the body of literature.

Section 9.3.1 comparatively discusses the prevalence of anaemia, malaria, and malnutrition and provides answers to questions 1-4 of multimorbidity among children in Nigeria. The evidence of individual and contextual disparities in the determinants of three outcomes of interest is then highlighted in Section 9.3.2 to answer question 5 at the second level of analysis. Furthermore, section 9.3.3 discusses the results that answer questions 6-7; section 9.3.4 discusses question 8 on the determinants of MAMM among children aged 6-59 months in Nigeria. Finally, section 9.3.5 explains why the interactions of a child's demographic variables with household wealth status were seen to have moderation effects on the impact of individual and contextual factors over the MAMM among children aged 6-59 months in Nigeria to answer question 9.

9.3.1 Baseline distribution of characteristics and prevalence of anaemia, malaria, and malnutrition

Question 1

What are the descriptions of individual and contextual characteristics of children under-five in Nigeria at baseline (response rates), as captured in 2018 NDHS?

This question was answered in section 5.1.1. Percentage frequencies were derived for all the potential variables considered for the study. A weighted sample of 10481 children aged 6-59 months in Nigeria was captured for this study. The composition of male to female was at the ratio of 51 to 49, meaning there were slightly more male than female children in the data. Children in the age group 12-23 months were more represented in the survey. Almost 80% of the children were considered born with average birth size. 26.3%, 16.3%, and 13.2% of the children aged 6-59 months had fever, cough (ARI), and diarrhoea in the last two weeks before the survey, respectively. About half the number of children in this study whose mothers are between the age of 25 – 34 years, while the mothers of about 40% of the children aged 6-59 months in Nigeria do not have formal education. Furthermore, 19% of the children live in the poorest households.

Question 2

Are there variations in the proportion of children in each of the three outcomes of anaemia, malaria, and malnutrition across the states and the regions

This thesis has also provided answers to question 2 in Chapter 5 (section 5.2), that the prevalence of anaemia across the states in Nigeria was highest among children in Zamfara state, while the lowest in Kaduna and Lagos states. Malaria fever was common among children living in Sokoto, Zamfara, Kebbi, and Katsina states. On the other hand, the proportions of poorly nourished were generally highest among children from most of the states in the northern part of the country. Edo and Lagos states had Nigeria's least poorly nourished children aged 6-59 months.

The spatial description of Nigeria's regional perspectives (six geopolitical zones) shows that the highest proportion of anaemic children is from the North-East zone. North-West had the highest proportion of malaria-positive children, while South-South had the lowest prevalence. Also, North-West geopolitical zones had the highest proportion of poorly nourished children aged 6-59 months, while the South-East zone had the lowest. These findings are consistent with other study (Kandala *et al.*, 2007), who stated that after accounting for covariates, the remaining spatial effects in Nigeria reveal a distinct and robust spatial pattern at the district level, indicating that a higher prevalence of childhood morbidity is primarily found in the north-eastern states and a lower prevalence is present in the south-western states.

Question 3

What is the independent prevalence of the three outcomes of anaemia, malaria, and malnutrition concerning the individual and contextual characteristics among children 6-59 months of age in Nigeria?

To answer question 3 this thesis has also shown, in Chapter 5 (section 5.3), that the prevalence of anaemia, malaria and malnutrition among children aged 6-59 months in Nigeria in 2018 was 68.1% (6961/10,221), 36 % (3618/10186), 43% (4550/10481), respectively. Also, 18.8% of children aged 6-59 months are anaemic among the age group 12-23 months. Out of the 35.5% of children that had malaria positive in Nigeria, 26.2% reside in rural areas, while female children are less prone to contracting malaria compared to their male counterparts. Similarly, 1.6% (168/10481) of children aged 6-59 months in Nigeria are overweight. Of the 56.6% of well-nourished children aged 6-59 months in Nigeria, 29.8% reside in urban areas. Arising from the scoping reviews reported in Chapter 3 the study evidence reported that the prevalence of anaemia among children under five years in SSA countries was very high. Some of these studies reported the prevalence of as much as

between 60% and 85% (Ngnie-Teta, Receveur and Kuate-Defo, 2007; Nikoi and Anthamatten, 2013; Menon and Yoon, 2015; Moschovis *et al.*, 2018; Ntenda, Nkoka, *et al.*, 2018; Mohammed, Habtewold and Esmaillzadeh, 2019; Nambiema, Robert and Yaya, 2019). Similarly, some malaria studies generally reported a prevalence of higher than 30% (Njau *et al.*, 2013; Zgambo, Mbakaya and Kalembo, 2017; Levitz *et al.*, 2018; Berendsen *et al.*, 2019b). Also, the prevalence of malnutrition (which includes all or any of the indicators) among children in SSA countries was, on average, lower than 40%, with a small number of studies reporting higher than 40% (Ukwuani and Suchindran, 2003; Kennedy *et al.*, 2006; Ntoimo and Odimegwu, 2014).

Question 4

What are the differences between groups in the individual and contextual characteristics concerning the three outcomes of anaemia, malaria, and malnutrition among children 6-59 months in Nigeria?

To answer the above question chi-square statistic was used to establish the association between the individual and contextual characteristics with each of the three outcomes. The results are presented in chapter 5, section 5.5.

In Nigeria, in children aged 6-59 months, the sex of the child was statistically related to anaemia and malnutrition but not to the presence of malaria. Additionally, there was a clear association between the three outcomes and the child's age, birth order, and preceding birth interval. However, the child who had taken iron supplements six months before the study was linked to malnutrition and malaria but not anaemia. Differences in the three outcomes were statistically significantly associated with the maternal age group, current employment status, age at first birth, highest educational status, maternal autonomy level, antenatal care visit during the child's pregnancy, maternal ethnicity, maternal anaemia status, body weight status, and paternal education status.

Similarly, three outcomes were significantly associated with variations in household wealth indices. Furthermore, community wealth status, the proportion of community distance to a health facility is no big problem, the proportion of community maternal education level, and the proportion of community households with no bed net was statistically significantly associated with the outcomes of anaemia, malaria, and malnutrition. Multidimensional poverty index (MPI) was significantly associated with anaemia, malaria, and malnutrition.

9.3.2 Determinants of the three outcomes among children aged 6-59 months in Nigeria

Question 5

What are the independent effects of individual and contextual factors on each outcome of anaemia, malaria, and malnutrition among children 6-59 months of age in Nigeria?

The answers to these questions regarding the three outcome variables are presented in Chapter 6. From the anaemia study, the intrastate correlation coefficient of 0.0398 and intracommunity correlation coefficient of 0.1652 was used to assess the variations in the prevalence of anaemia status due to the three factors. These results showed that 3.98% and 16.52% of the total variation in the odds of being anaemic among children 6-59 months in Nigeria were due to state and community levels. Also, the results reveal that the median odds ratio (MOR) calculated for states was 1.291, meaning that if a child transfers from one state to another where anaemia is higher, there is a 30% increased risk that the child will be anaemic. Similarly, a child's chance of getting anaemic increases by 54% if they move to a community with a greater anaemia risk (MOR=1.54 at the community level). In addition, the following factors were statistically significant predictors of anaemia status among children: child's sex, age is older than two years, preceding birth interval is between 8 and 24 months, the child is still breastfeeding, malaria and malnutrition statuses, the child had fever two weeks prior to the survey, mother/caregiver had higher education, she is a Muslim, the mother is anaemic, household wealth is middle and above, no net in the household and the regions of residence are South-East and South-South. Furthermore, when all other factors are held constant, female children's odds of becoming anaemic are lower than those of male youngsters. Most of the studies reviewed for anaemia, except Immurana & Urmi; Nikoi & Anthamatten (Nikoi and Anthamatten, 2013; Immurana and Urmi, 2017), reported protective effects for female children than for males.

The likelihood of being anaemic significantly reduces as a child gets older. This finding agrees with previous studies (Elmardi *et al.,* 2020; Gebremeskel *et al.,* 2020; Ag *et al.,* 2021; Iddrisu Amadu *et al.,* 2021; Anjorin and Yaya, 2021; Anteneh and Van Geertruyden, 2021; Aregbeshola, Onifade and Awuviry-Newton, 2021; Barry *et al.,* 2021; Heinrichs *et al.,* 2021; Jember *et al.,* 2021; Tesema, Tessema, *et al.,* 2021; Tesema, Worku, *et al.,* 2021; Eshete *et al.,* 2022). Compared to a child in the first order relative to other characteristics, a child born with an interval between births of 8 to 24 months is statistically more likely to be anaemic. In addition, a child who has a mother with a higher level of education is less likely to be anaemic than a child whose mother has no formal education. The same conclusion was reached in a

previous study (Anjorin and Yaya, 2021; Aregbeshola, Onifade and Awuviry-Newton, 2021; Barry *et al.,* 2021; Tesema, Tessema, *et al.,* 2021; Tesema, Worku, *et al.,* 2021; Eshete *et al.,* 2022). When all other factors are held constant, the results further show that as the household wealth quintile increases, the odds of children from such households are much lower than those of children from the poorest households (Anjorin *et al.,* 2020; Gebremeskel *et al.,* 2020; Ag *et al.,* 2021; Anteneh and Van Geertruyden, 2021; Aregbeshola, Onifade and Awuviry-Newton, 2021; Amadu *et al.,* 2021; Jember *et al.,* 2021; Tesema, Tessema, *et al.,* 2021; Tesema, Worku, *et al.,* 2021; Eshete *et al.,* 2022). Children aged 6-59 months from Nigeria's South-South geopolitical zones are 2.46 times more likely than those from the North-Central geopolitical zones to be anaemic.

Similarly, for the malaria study, the variations in the prevalence of malaria status due to the three-level factors were assessed through the intrastate correlation coefficient and intracommunity correlation coefficient. The ICC at the state level decreased from 11.88% to 4.8%, both of which remained significant. The ICC at the community level decreased from 36.4% in the null model to 21.0%, meaning the correlation between two children/individuals (unit of analysis) within the same community and the same state is 0.21.

As a child becomes older, their chances of contracting malaria rise. Previous studies found the same results (Aheto *et al.,* 2021; Emina, Doctor and Yé, 2021). For example, the likelihood of children aged 48-59 months developing malaria fever was 2.68 times higher than those aged 6-11 months. However, with deworming and still breastfeeding, children had 39% and 25% lower risks of malaria infection, respectively. Like this, children with mothers who had their first birth after 20 years had a lower probability of contracting malaria fever than their counterparts with mothers who had their first child before turning 20 years.

Additionally, children with mothers or fathers who had completed at least a secondary education had 33% and 21%, respectively, significantly lower risks of having malaria fever. So, children of mothers who had higher education were less likely to contract malaria fever. This finding agrees with other studies (Emina, Doctor and Yé, 2021; Nzabakiriraho and Gayawan, 2021; Oguoma *et al.,* 2021). A kid's likelihood of testing positive for malaria decreases with an increased household wealth quintile. Children from a community with a high proportion of mothers who stated that the distance to the nearest health centre was "no big problem" had a lower risk of malaria fever. Compared to children from the North-Central geopolitical zone, children from the South-South geopolitical zone had a 50% lower risk of contracting malaria fever. On the other hand, compared to children from urban areas, children

from rural areas had a higher risk of contracting malaria. This finding agrees with other studies on malaria (Aheto *et al.,* 2021; Nzabakiriraho and Gayawan, 2021; Oguoma *et al.,* 2021).

Furthermore, the answer to question 5 concerning the malnutrition study is reported in section 6.5. In the random effect analysis, the intrastate correlation coefficient of 0.1415 and the intracommunity correlation coefficient of 0.218 were used to assess the variations in malnutrition status among children aged 6-59 months in Nigeria due to the three-level factors. These results showed that 14.15% and 21.8% of the total variation in the odds of malnutrition were due to state and community levels. In addition, the ICC at the state level also decreased from 14.1% to 0.1%, which was statistically significant. Also, the ICC at the community level in the null model decreased from 21.8% to 4.6% in the choice model, meaning the correlation between two children/individuals (unit of analysis) within the same community and the same state is 0.046. Similarly, model 6's median odds ratio (MOR) calculated for states was 1.077, indicating that if a child travels from one state to another where there is a greater chance of being poorly nourished, there is a 7.7% increased risk. Furthermore, moving to a community with a higher risk of malnutrition increases a child's probability of being poorly nourished by 46%.

Female children have considerably decreased odds of being poorly nourished than their male counterparts. The same findings were reported in previous studies on malnutrition (Ukwuani and Suchindran, 2003; Miller CM *et al.,* 2007; Magadi, 2011; Adekanmbi, Uthman and Mudasiru, 2013; Machisa, Wichmann and Nyasulu, 2013; Akombi, Agho, Hall, Merom, *et al.,* 2017; Amaral, Herrin and Gulere, 2017; Hv and S, 2017; Akombi *et al.,* 2019; Amare, Ahmed and Mehari, 2019; Fantay Gebru *et al.,* 2019; Nankinga, Kwagala and Walakira, 2019; Nshimyiryo *et al.,* 2019; Takele, Zewotir and Ndanguza, 2019), The risks of children aged 24-35 months suffering malnutrition were 2.22 times higher than those of children aged 6-11 months. Similar conclusions were reached in previous studies that an increase in the age of the children has a harmful effect on poor nourishment for the children (Kassie and Workie, 2020; Khamis *et al.,* 2020; Masibo, Humwa and Macharia, 2020; Rutayisire *et al.,* 2020; Simelane, Chemhaka and Zwane, 2020; Aboagye *et al.,* 2021; Adam Birhan and Bitew Belay, 2021; Bekele and Fetene, 2021; Kebede and Aynalem, 2021; Muche and Dewau, 2021; Sserwanja *et al.,* 2021; Tesema, Yeshaw, *et al.,* 2021; Uwiringiyimana *et al.,* 2022). Children who had diarrhoea two weeks before the survey, were more likely to be poorly nourished than children who did not have the illnesses. This finding is supported by previous studies (Adam Birhan and Bitew Belay, 2021; Bekele and Fetene, 2021; Chikako *et al.,* 2021; Muche *et al.,* 2021;

Tesfaw and Fenta, 2021; Uwiringiyimana *et al.,* 2022). Similarly, children of working-class mothers are more likely to be poorly nourished than children whose mothers do not work. This agrees with another study (Amegbor, Yankey and Sabel, 2020). The odds of being poorly nourished are inversely proportional to the educational status that mothers and fathers have obtained. Other studies substantiated the result on maternal education (Hailu, Bogale and Beyene, 2020; Kassie and Workie, 2020; Khamis *et al.,* 2020; Rutayisire *et al.,* 2020; Simelane, Chemhaka and Zwane, 2020; Aboagye *et al.,* 2021; Adam Birhan and Bitew Belay, 2021; Adedokun and Yaya, 2021; Amaha and Woldeamanuel, 2021; Bekele and Fetene, 2021; Chikako *et al.,* 2021; Fenta, Zewotir and Muluneh, 2021; Muche and Dewau, 2021; Muche *et al.,* 2021; Tesema, Yeshaw, *et al.,* 2021; Tesfaw and Fenta, 2021; Amoako Johnson, 2022), and for paternal educational attainment was supported in (Rutayisire *et al.,* 2020; Bekele and Fetene, 2021; Fenta, Zewotir and Muluneh, 2021). The results also show that the richer the household, the less likely the children from such a home will be poorly nourished compared with their counterparts from the poorest household. This finding agrees with other studies (Amegbor *et al.,* 2020; Hailu, Bogale and Beyene, 2020; Kassie and Workie, 2020; Khamis *et al.,* 2020; Masibo, Humwa and Macharia, 2020; Rutayisire *et al.,* 2020; Simelane, Chemhaka and Zwane, 2020; Aboagye *et al.,* 2021; Adam Birhan and Bitew Belay, 2021; Adedokun and Yaya, 2021; Bekele and Fetene, 2021; Chikako *et al.,* 2021; Fenta, Zewotir and Muluneh, 2021; Muche and Dewau, 2021; Muche *et al.,* 2021; Musuka *et al.,* 2021; Tesema, Yeshaw, *et al.,* 2021; Tesfaw and Fenta, 2021; Amoako Johnson, 2022; Uwiringiyimana *et al.,* 2022), and contrary finding with (Wondimu and Dejene, 2022).

In addition, children from communities where many residents do not consider distance to the nearest health facility to be 'no big problem' are 17% less likely to be poorly nourished than children from communities with a low proportion do exist. The odds of children from a state with a low gender inequality index being poorly nourished are significantly 1.45 times higher than those with the highest gender inequality index. The odds of children from the North-east, and the North-west, are 127% and 211%, significantly more likely to be poorly nourished, respectively. Children living in urban areas are more protected from being malnourished than children from rural areas. This result agrees with other previous studies (Khamis *et al.,* 2020; Adedokun and Yaya, 2021; Chikako *et al.,* 2021; Fenta, Zewotir and Muluneh, 2021; Muche and Dewau, 2021; Tesema, Yeshaw, *et al.,* 2021; Tesfaw and Fenta, 2021; Amoako Johnson, 2022).

9.3.3 Prevalence and analysis of individual and contextual characteristics effects on MAMM

Question 6

What are the prevalence and differences between groups in the individual and contextual characteristics for the number of occurrences of MAMM among children 6-59 months in Nigeria?

The answers to these questions are presented in Chapter 7. The scoping review on multimorbidity of childhood diseases reported the prevalence of cooccurrence of two or more diseases among children aged under-five years in SSA to vary between 1.2% (in overweight with concurrent stunting among Ghanian children) (Atsu, Guure and Laar, 2017), to 24.8% (in CIAF, and concurrent stunting and anaemia among Ethiopian children) (Geda *et al.*, 2021). However, this current study found approximately a two-fold prevalence of 48.3% of MAMM among children aged 6-59 months in Nigeria, compared with the highest prevalence in the reviews. Also, there are more children in Nigeria cohabiting with two or more diseases than those cohabiting with one disease of anaemia, malaria, and malnutrition, or none of the diseases.

The answer to the second part of the question is found in section 7.2. The proportion of children with two or more diseases was higher for male children than their female counterparts. All the variables considered for analysis except 'child had a cough in the last two weeks before the survey' and 'Paternal work statuses were statistically associated with MAMM,

This study also considered the factors that overlap the relationship with each outcome of interest. Section 8.4.1 displayed these effects. For instance, the findings showed that child's age, birth order, preceding birth interval, took vitamin A supplements, was dewormed, had a fever, and place of delivery was statistically significantly associated simultaneously with the four outcomes of interest in this study (anaemia, malaria, malnutrition, and multimorbidity). The child's sex was associated with anaemia, malnutrition and multimorbidity, but not malaria fever among children aged 6-59 months in Nigeria. The child had a cough in the last two weeks before the survey, which was only associated with anaemia, but not with malaria, malnutrition and multimorbidity. Paternal work status was the only variable not associated with any outcome variables. Overall, over 78% of the variables considered at this analysis level were significantly associated with contracting either of the four diseased conditions: anaemia, malaria, malnutrition, and multimorbidity.

Question 7

Are there variations in the MAMM across the states and the regions?

Similarly, the answer to spatial disparities across the regions and states in Nigeria are presented in section 7.3. The findings show that the proportion of children aged 6-59 months in Nigeria cohabiting with '2 or more diseases' was highest in Kebbi state, followed by Jigawa state. Also, three states, Edo state, Anambra, and Lagos states have estimated proportions of 0.31 (95% CI: 0.24-0.40), 0.26 (95% CI: 0.22-0.31), and 0.14 (95% CI: 0.10-0.18). respectively. Furthermore, North-west had the highest proportion of children with multimorbidity across the region of residence in Nigeria. All the geopolitical zones in the southern part of Nigeria (South-West, South-East, and South-South) have similar multimorbidity distributions, below the national average of 0.48 (95% CI: 0.47-0.49).

Question 8

What are the multiple overlaps in the associations of individual and contextual factors with the MAMM among children 6-59 months in Nigeria?

This current study focuses on multimorbidity of the three most common objective childhood diseases using anaemia, malaria, and malnutrition as proxies for disease cooccurrence. A three-state multilevel mixed effect ordinal logistic regression was used to find the significant predictors of cohabiting with two or more diseases among children aged 6-59 months in Nigeria. Multimorbidity studies in children had been neglected for a long time, especially in the LMICs. It is challenging to evaluate this study's findings in light of earlier research, partly because of the lack of similar studies, differences in methodological approach, the disease conditions, survey types and population settings (Park, Lee and Park, 2019). Nevertheless, this study has found significant disparities in some child-, parental-, household-, community-, and area-related risk factors on the occurrence of MAMM.

9.3.3.1 Child-related predictors of multimorbidity

The findings showed that among the child-related predictors considered in the model, child's sex, age, birth size, preceding birth intervals, deworming medication six months before the survey, having a fever in the last two weeks before the survey were significant predictors of MAMM (MAMM) among children aged 6-59 months in Nigeria. For instance, child sex is significantly protective for female children in MAMM compared to their male counterparts while holding other predictors constant. This finding implies that female children are less likely to co-inhabit with '2 or more diseases' of anaemia, malaria, and malnutrition than male children

when other covariates are held constant. This finding is supported by previous studies from the scoping review reported in Chapter 3, which revealed that female children are less likely to cohabit with multimorbidity of childhood diseases (Duah *et al.*, 2020; Geda *et al.*, 2021), but the finding is contrary in Tran et al. (Tran *et al.*, 2019) who concluded that it was more likely for a female to cohabit with '2 or more diseases. Similarly, the older the children become, the more likely they live with '2 or more diseases' of anaemia, malaria, and malnutrition. Children aged between the 1st and 3rd year are at significantly increased risk of cohabiting with MAMM compared to children less than one year. This finding is supported by a study conducted by Adedokun & Yaya (Adedokun, 2020) in a similar setting. Also, (Tran *et al.*, 2019; Geda *et al.*, 2021) supported the result, but contrary results that being older is protective for children under-five years compared with children less than one year were reported (Atsu, Guure and Laar, 2017; Duah *et al.*, 2020; Mulatya and Mutuku, 2020). The findings of this study also indicated that children born small-sized were more likely to cohabit with MAMM than large-sized children at birth. This finding did not support the conclusion made by (Adedokun, 2020), who reported that children born large are likely to have an increased risk of multimorbidity. The contrary findings are because the two studies have used different disease conditions as a proxy for multimorbidity. This study also demonstrated that children aged 6-59 months in Nigeria who experienced a fever two weeks before the survey date were much more at risk of having two or more MAMM than children who did not. This result is in line with findings from other studies (Duah *et al.*, 2020).

Furthermore, a child with a pre-birth interval of between 8 to 24 months was at increased risk of contracting '2 or more diseases' of MAMM compared to a child without no preceding birth. The apparent reason in a developing country is that being the firstborn or perhaps the only child in the home, more excellent care is given to the child. Additionally, children treated for intestinal deworming within six months before the survey also had a reduced risk of cohabiting with two or more MAMM.

9.3.3.2 Parental-related predictors of multimorbidity

The findings show that certain parental-related variables were significantly related to MAMM. For example, maternal education, maternal religion is Islam, maternal anaemia status, and body mass index. On maternal educational attainment, the results found in this study supported the hypothesis that maternal education has a negative correlation with children's health outcomes (Adedokun, 2020). Moreover, children of mothers with higher educational status had a lower risk of multimorbidity—defined as having 'two or more of anaemia, malaria, and malnutrition

compared with children of mothers with no formal education conditional upon holding other predictors constant. This finding is consistent with the conclusions of other research (Tran *et al.*, 2019; Geda *et al.*, 2021) but disagreed with the findings in (Adedokun, 2020; Mulatya and Mutuku, 2020). In addition, children whose fathers had higher education exhibited protective effects from MAMM. More excellent education for the mothers, particularly the caregivers, often improved their knowledge, attitude, and practice of typical children's diseases (Obasohan *et al.*, 2021b).

The study also discovered that, compared to a combined risk of 0/1 disease, children whose mother is a Muslim have an increased risk of MAMM compared to their counterparts whose mothers are Catholics. Also, the finding shows that children whose mothers were anaemic are at an increased risk of cohabiting with two or more MAMM. The possible explanation from previous studies is that children of anaemic mothers are more likely to be anaemic and are at high risk of poor child health outcomes (Ntenda, Nkoka, *et al.*, 2018; Obasohan *et al.*, 2022). This current study also found that children of mothers who are overweight or obese have decreased significant odds of contracting two or more MAMM versus 0/1 disease compared to children whose mothers have normal body mass index when other covariates are held constant. Also, mothers' underweight status harms their children (though not significant). Like their mothers, underweight children are more likely to be underweight and may experience adverse effects on their development and health (Razak, Finlay and Subramanian, 2013). The results of this study regarding the maternal weight spectrum contradict the theory that developing nations may be at increased risk for both underweight and overweight (Razak, Finlay and Subramanian, 2013) and have shown that overweight mother status is protective while underweight mother status is harmful. Also, according to this study, maternal obesity protects the neonate, and the mothers in this group are more likely to come from wealthy households in developing nations (Razak, Finlay and Subramanian, 2013). To accurately account for the actual position, more study is needed.

9.3.3.3 Household-related predictors of multimorbidity

Of the number of household-related variables considered in this study which includes household wealth quintiles, number of children under-five years that slept under a bed net the night before the survey, sex of household head, and the number of persons in a household, only household wealth appears significant predictor of MAMM when other predictors are held constant. A higher household socioeconomic level had a lower risk of developing '2 or more of MAMM. This finding agrees with the conclusions of (Tran *et al.*, 2019; Adedokun, 2020;

Mulatya and Mutuku, 2020). However, children from lower-income families are more likely to contract childhood diseases. This result relates to the fact that low-income families may find it challenging to purchase nutritious food that will increase their intake of nutrients and help them develop immunity to diseases (Adedokun, 2020). They may also live in impoverished or densely populated areas (Kazembe and Namangale, 2007)] and may have more children than they can reasonably care for (Adebowale *et al.,* 2020), which is likely to increase the risk of multimorbidity in children.

9.3.3.4 Community-related predictors of multimorbidity

This current study found that the higher the proportion of community wealth status, the more protective the children become of MAMM. This finding supports other studies that children from low-income households or communities have inferior health outcomes (Gupta, de Wit and McKeown, 2007). Similarly, this study reports that the higher the proportion of those in the community who affirmed that the distance to the nearest health centre is 'no big problem', the less likely the children from such a community will contract two or more of MAMM. Distance to health centres could be a significant factor in getting prompt medical attention, and delays in getting treatment for paediatric illnesses could have more severe consequences. Oldenburg et al. agree that children that have less access to primary care may be more susceptible to poor health outcomes, including mortality as a result, they may be a population for which initiatives aimed at reducing child mortality and morbidity should be prioritised (Oldenburg *et al.,* 2021). Some studies disagree with this finding (Rutherford *et al.,* 2009; Moïsi *et al.,* 2010).

9.3.3.5 Area-related predictors of multimorbidity

In this current study, five area-related variables were considered: state multidimensional poverty index (MDPI), state human development index (HDI), state gender inequality index (GII), region of residence, and place of residence. Though MDPI was not a significant predictor of MAMM, the results were exciting and informative. Children living in the above-averagely deprived state are at a higher risk of MAMM compared with children in highly deprived. Conversely, children living in the state that are averagely, mildly, and lowest deprived had reduced odds of cohabiting with MAMM when all other covariates are held constant. The non-significance of MDPI in a child's health outcomes was supported by another study that found mixed conclusions in MDPI indicators at the state level (Mohanty, 2011). Surprisingly, this current study found that children from states with high human development index were significantly more likely to cohabit with MAMM than those living in states with the lowest

HDI. This finding is contrary to the general expectation that the higher the state HDI, the less likely the children from the such a state will cohabit with adverse health outcomes (Shao *et al.*, 2019). The possible explanation for this result is that 14 out of 37 states were classified as 'high HDI', leading to high variability in MAMM in this group, compared with six states classified as 'lowest HDI' with low variability in MAMM. The high heterogeneity in MAMM across these 14 states must have resulted in their weak effects and significance. So, a non-linear impact of HDI on a child's health outcomes is therefore suspected (Wang and Arah, 2017). The reasons for this happening can be explored further in future studies.

Furthermore, this study revealed significantly reduced odds of cohabiting with MAMM for children residing in the North-East geopolitical zone of Nigeria compared with those living in the North Central zone. However, it is harmful to a child living in South-East or South-South geopolitical zones to cohabit with MAMM compared to a child residing in North-Central geopolitical zones of Nigeria when other predictors are held constant. This finding agrees with a similar study (Adedokun, 2020), that under-five mortality is often high in the Northeast and Southeast of Nigeria, but does not agree with another study (Kandala *et al.*, 2007), especially when these childhood morbidities are treated independently. Finally, place of residence was a significant predictor of MAMM. The results from this study show that children in rural areas of Nigeria were at increased risk of cohabiting with MAMM when all other covariates were held constant. This finding did not agree with another study (Tran *et al.*, 2019).

9.3.4 Overlapping determinants of anaemia, malaria, malnutrition, and multimorbidity

This study also extracted the results of the strengths and directions of multiple overlaps in the risk factors of the outcome variables (anaemia, malaria, malnutrition, and multimorbidity). The child's age, maternal educational attainment, household wealth status, and residence region significantly predict the four outcome variables. With 6-11 months as the reference category for a child's age, the result shows that an increase in age is significantly protective for anaemia status but harmful for malaria, malnutrition, and multimorbidity. In other words, older children are more likely to contract malaria fever and be poorly nourished than younger children, but older children are more protected from being anaemic. A child born with a small size is more likely to be poorly nourished and cohabit with MAMM. Children born within two years following another child were found more likely to be anaemic, poorly nourished and cohabit with two or more diseases. Also, a five-year and above pre-birth interval is significantly more protective against malnutrition than children firstborn. Malaria fever is a harmful factor for anaemia status, whereas anaemia is harmful in being both malaria positive and poorly

nourished and being poorly nourished is harmful to being anaemic. Breastfeeding children were more anaemic but less likely to contract malaria fever. Dewormed a child within six months before the survey was protective against malaria fever and multimorbidity. Children who had a fever in the last two weeks before the survey were significantly more likely to be anaemic, malaria positive and contract two or more diseases of anaemia, malaria, and malnutrition. Having diarrheal two weeks before the survey is only significantly harmful to being poorly nourished.

Similarly, children of mothers with higher education are statistically significantly protective against being anaemic, malaria positive, poorly nourished, or cohabiting with '2 or more diseases' compared with children of mothers without formal education. Also, children from the richest household wealth quintile are significantly protective from being anaemic, malaria positive, poorly nourished, or have '2 or more diseases' compared to children from the poorest household wealth quintile. Compared with ever breastfed, not currently breastfeeding children, children currently breastfeeding were significantly more likely to be anaemic, not significantly harmful effect as poorly nourished, and having "2 or more" diseases, but significantly protective against contracting malaria fever.

9.3.5 Accounting for interactions as predictors of MAMM

Question 9

What are the interaction effects of a child's sex, age, and household socioeconomic status on the impact of individual and contextual risk factors of MAMM among children 6-59 months of age in Nigeria?

To answer question 9 in this study the results were presented in Chapter 8. Interaction analyses were additional investigations on the effects of 3 two-way and one three-way interactions of a child's sex, age, and household wealth status on MAMM relative to model 10 covariates. While accounting for the interactions between a child's age and household wealth status on model 10 covariates, the results showed that in one of the two-way interactions, the effects of wealth status on MAMM vary by child's age. The implication is that children in the wealthiest households have the highest chance of maintaining their health from MAMM for each child's age group. A similar pattern was seen in the group of people with morbidity (only one disease). The likelihood of children of all age groups coexisting with two or more diseases lowers as the wealth quintile rises. Compared to children living in the poorest households across all age groups, children from the richest household had the lowest chance of getting MAMM as they became older.

The interaction studies in this thesis provide strong evidence for the intersectional character of individual-level disparities in multimorbidity among children in Nigeria. Moreover, it specifically draws attention to the partiality of results obtained from studies that only use individual characteristics models to look for patterns of individual and contextual variations in MAMM. This finding is supported by another study (Hartnell, 2011), which asserted that the results of this nature lend credence to the mounting evidence of connections between social inequalities in health described in the international literature.

As for the other 2 two-way interactions, the effects of wealth status and the child's age on MAMM did not vary by child's sex. Similarly, the result shows that the three-way interactions do not demonstrate a significant effect on MAMM relative to model 10 covariates. That is, the inequalities in the household wealth on MAMM do not vary by child's age and sex.

9.4 Strengths and limitations of the study

The data set from the 2018 NDHS, which included merged contextual characteristics from the 2018 NHDR, was used in this study. Anaemia, malaria, and malnutrition are three objectively assessed (standard WHO measurement procedures) paediatric diseases combined for the first time in DHS data collection. So, to the best of the researcher's knowledge, this study is the first joint modelling of these diseases among children aged 6-59 months in Nigeria or anywhere else that is undertaken on the national scale. Similar studies have used self-reported assessment of other disease conditions, which might have introduced bias through under or over-reporting cases. Since this was a baseline study, it took a more simplified approach by developing a composite score that indicated the order in which the combination of these diseases occurred by the generally accepted definition of multimorbidity, as the cooccurrence of two or more diseases in an individual without reference to an index disease.

Additionally, the study realised that the inferential analysis strategy would not have been the best. However, as a baseline study, this will attract the interest of more research to better understand the determinants of multimorbidity in children in LMIC. Furthermore, to account for the effects of both individual and contextual variables on multimorbidity among children in Nigeria, this study recognised the hierarchical characteristics of the data set employed and used multilevel mixed effect ordinal logistic regression modelling. Moreover, a significant contribution of this study is on the premises of intersectionality investigation made in the final model. A previous study has highlighted that data based on the idea that variations in risk factors associated with health status are independent. That additive processes do not adequately address significant health inequalities at the point of social groupings. Therefore, the partiality

of knowledge from such a perspective raises significant questions about how well future programmes can target individuals at risk of bad health outcomes (Hartnell, 2011).

Given the above, the current study added an intersectionality framework to investigate the interactions of children's demographics (age and sex) and household socioeconomic (wealth quintiles) inequalities in multimorbidity while accounting for the best fit in additive model's covariates as a way in addressing these problems. Overall, it gave a better model fit when adding the interaction terms for the child's age and household wealth quintile. Also, the data set came from a nationally representative survey with abundant evidence of hierarchy. Yet, most previous studies did not account for the multilevel structure or use the proper statistical techniques. This study applied multilevel methods to account for individual, community, and state variations.

This study is not without some limitations. First, the survey being cross-sectional, the study could only examine the associations between variables. Therefore causality could not be ascertained (Hartnell, 2011; Khatab and Kandala, 2011; Adedokun, 2020). Though longitudinal research on children could be challenging in LMICs, they are needed to explain these predictors' significance and determine causal effects over time. Secondly, the study assumed that the three diseases were of equal importance or severity (e.g., having malaria was the same as having anaemia or malnutrition). However, the fulfilments of the proportional odds assumptions have to some extent, given credence to this. Thirdly, only Nigeria is the subject of this study, which limits its relevance or capacity to be generalised to other SSA countries.

Furthermore, it is difficult to directly compare our findings to those of past research due to the methodological differences in the study setting, disease scope, and demography. Furthermore, part of the findings was that children who have contracted malaria fever are more likely to be anaemic. In contrast, children being anaemic is harmful to being both malaria positive and poorly nourished and being poorly nourished is harmful to being anaemic. Given this, endogeneity biases may have resulted in the study. However, in multimorbidity, attempts were made in the first instance to categorize the three outcomes into eight independent classes (Section 4.3.3) from where the 'none of the diseases', 'one disease only', and 'two or more diseases' classes were derived. Therefore, if endogeneity had been ignored in this investigation, we might have certified some predictors significant when they could have just as quickly been due to chance (Kandala, 2013). Possibly the wrong assumptions were drawn. This finding could be a subject of future investigation.

Moreover, this study accounted for the intersectionality of the child's demographic variables (age and sex) and household wealth status. No exhaustive investigations of all possible interactions in other predictor variables were carried out. This finding can also be a subject of future investigation. Also worthy of mention here is that this study did not consider checking if the random coefficient model in a three-level model was significantly better than the variance component and random intercept model. In addition, only the individual level that weighting was considered. These are suitable for future investigation.

9.5 Policy and study implications

9.5.1 Policy Implications

This study found that, at the time of the survey, about one in every two (48.3%) Nigerian children aged 6-59 months cohabits with two or more diseases of anaemia, malaria, and malnutrition. This result is alarming on a national scale and will likely be the case for children in Sub-Saharan Africa (SSA). It requires an urgent policy and a coordinated approach to check this from further escalation. This result shows that the situation of multimorbidity among children aged 6-59 months in Nigeria could be worst if nothing is done to reduce its prevalence and therefore becomes impossible for Nigeria to attain the SDG-3 by 2030. Some areas of urgent attention are:

1. The regional and state spatial maps reveal that some geopolitical regions and the states associated with them have high rates of diseases. For example, the North-East and North-West geopolitical zones have shared links to a high rate of insecurities for over a decade, leaving the people, especially women and children, homeless (living in internally displaced person camps). These people cannot carry out their farming activities, so they are destitute of good foods and drinking water.

   These places are also more prone than other areas to have a higher rate of multiple morbidities due to inadequate medical facilities, difficult deliveries, or even access to prompt medical attention and poverty. For instance, the World Bank has revealed that, except in the North East, the incidence of poverty decreased in all six of Nigeria's regions (United Nations Development Programme (UNDP), 2018). These spatial map descriptions of the prevalence of MAMM could be used by decision-makers to quickly target development efforts for health care, food security and poverty alleviation interventions in these areas of the high prevalence of MAMM. Ayala & Meier's article acknowledges the critical connections between the normative characteristics of the right

to health and the four main components of food security (access, availability, stability, and utilisation). It views nutrition security as influencing public health (i.e., availability, accessibility, affordability, and quality) (Ayala and Meier, 2017). Hence, success-driven efforts to end the aged-long security issues in these regions so that people already displaced can return to their homes to farm again.

2. This study recognises some child-related risk factors of children cohabiting with MAMM. Firstly, male children are more likely than female children to contract MAMM. In the past (pre-millennium development goals era), gender inequalities were seen to be at a disadvantage of female children (Adeyinka *et al.*, 2021). Still, in recent studies (Khatab and Kandala, 2011), and across the various disease spectrums in this study, female children were at an advantage. To address the disparities between genders in childhood MAMM in Nigeria community mobilisation against gender-based prejudice and gender-sensitive policies are needed.

Secondly, children between the ages of one and three years were more likely to cohabitate with MAMM. These children are transitioning from being weaned from breastfeeding into supplementary feedings. Most children at this stage would not like to eat any other food introduced rather than continue with breast milk while the mother is unwilling to give. So, nutrient-fortified meals are given to children in this age group that could help sustain the immunity from their mother's breast milk until their natural immunity is built up at a later age.

Thirdly, children born small (low birthweight) were at greater risk of MAMM when compared with children born larger birthweight. There are three primary reasons a child is born with low birth weight (LBW). This finding could be due to genetics because the parents are small, or intrauterine growth restriction (IUGR) (Philadelphia, 2014), or because the baby is born pre-term (before 37 weeks of pregnancy) (March of Dimes, 2021). To detect issues with foetal growth antenatal care is crucial and strongly encouraged for every pregnant woman. The ongoing reforms in Nigeria's health sector aim to dramatically alter the way that healthcare is delivered throughout Nigeria by increasing the accessibility, cost, quality, and availability of healthcare services via promoting private sector investment and engagement (NorthWindProject.com, 2019), making primary health care services accessible to the grassroots, especially to women and children should be the foremost priority.

In addition, this study found that children with preceding birth order of 8-24 months are more likely to cohabit with two or more of anaemia, malaria, and malnutrition. As the interval age increases, the tendency to have MAMM in children drops significantly. Therefore, it is strongly advised that would-be mothers should adequately space their children above 24 months. This recommendation is because mothers who had their next child waiting for at least two years would have recovered most of the body's nutrients and blood loss during the first pregnancy and breastfeeding (Oni and Samuel, 2016).

Finally, on child-related variables, children who were dewormed in the six months before the survey and those who had fever two weeks before the survey took place were more likely to be diagnosed with MAMM. It was recently reported that the Nigerian government had budgeted in 2021 the sum of N142.3 billion to feed about 10 million, deworming 7 million primary-level pupils in 35 states and the FCT (Akinpelu, 2020). However, this study has revealed that an estimated 38% of children of pre-school age who had not been dewormed are exposed to MAMM. So, a deworming program that will include children under-five should also be initiated. On the other hand, viral and bacterial infections are major causes of non-malaria fever among a significant number of children in Nigeria (Pondei, Kunle-Olowu and Peterside, 2013; Orimadegun *et al.*, 2022). Therefore, as part of health education at antenatal clinics, it is crucial to stress the importance of personal and environmental cleanliness initiatives. In addition, children's immunisation against infectious diseases should be monitored adequately (Obasohan, Anosike and Etsunyakpa, 2015, 2017).

3. Regarding parental-related characteristics, maternal education, religion, anaemia status, and body mass index were significant predictors of MAMM among children aged 6-59 months in Nigeria. This finding shows that as mothers' education status increases, the probability of their children cohabiting with MAMM drops. The reason is that these mothers were likely to have more robust knowledge about health care to safeguard their children better and handle these illnesses (Kandala *et al.*, 2007). Given this, girl-child education should be encouraged, especially in the northern part of the country, where MAMM is highly prevalent. On the other hand, the findings show that children born to Muslim mothers were significantly more likely to contract MAMM compared to children of mothers of Catholic origin. One of the most significant influences on behaviour, particularly the pursuit of health among Nigerians, is religion (Obasohan, 2014). Some religious organisations forbid their followers to participate in some health

interventions. Even without promoting any particular religion, a pro-religion public policy can improve the health of the populace, including that of children (Chiswick and Mirtcheva, 2010). Therefore, religious leaders should be allowed to participate in reaching evidence-based decisions to implement health intervention strategies that may directly affect their members.

4. Furthermore, children whose mothers are anaemic were 60% more likely to be anaemic than children whose mothers are not. The mechanism through which maternal anaemia status can affect children 6-59 months of age is complex. More importantly are the causes of maternal anaemia, especially during pregnancy which include poor diet (deficiencies in iron, folic acid, and vitamins), viral infections like malaria, and untreated hereditary haemoglobin abnormalities (Rahman *et al.,* 2016; Ntenda, Nkoka, *et al.,* 2018). Moreover, the anaemic mother has no proper immunity to pass on to breastfeeding children and, as such, could easily be exposed to MAMM. Therefore, public health initiatives to lower childhood MAMM should pay more attention to reducing poor nutrition and other infections among pregnant, nursing mothers and children still breastfeeding. For instance, between 2013 and 2025, the Nigerian National Policy on Food and Nutrition has as one of its goals the reduction of maternal anaemia during pregnancy by 27% (Ministry of Budget and National Planning, 2016; Obasohan *et al.,* 2022). Therefore, there should be political commitment to make this happen. The findings also revealed that children whose mothers are overweight or obese were more protected from contracting MAMM. As earlier asserted, overweight mothers in developing countries are more likely to come from wealthy homes where eating good food is no problem. Though being overweight and obese have their health challenges. However, the high rate of poverty among families in Nigeria should be addressed. This provision will enable families able to afford good nutrition sources.
5. From the group of household-related predictors, only household wealth quintiles had significant effects on childhood MAMM. However, these were no longer significant when the interaction between the child's age and wealth status was added (See section 8.3.3. These results have further displayed the existence of two major social-economic classes concerning the health status of the children (The poor and the rich). To address this situation, social security that will take care of the immediate necessities of life (food, shelter, and health) for poor households in Nigeria should be in place.

6. In the community-related characteristics, children living in communities where the proportions of wealth status and distance to a health facility are no big problem are high and were significantly protective of MAMM compared to the low categories. Just as in the individual household characteristics, an increased community wealth level can bring about the same 'ripple' effects on childhood MAMM. The community with high wealth status would usually attract good facilities like clean water, good roads, and health facilities. Therefore, programs that bring many people out of poverty will be initiated and pursued vigorously. Children living in a community where the proportion of respondents who say that 'distance to the nearest health facility is no big problem' is high has demonstrated a reduced odd of contracting MAMM. This report implies that children accessing health facilities are less likely to contract MAMM. Therefore, public health measures to lower childhood MAMM should pay more attention to increasing access to health centres through expanding the primary health care system.
7. Finally, the results show that the area-related variables, region, and place of residence were statistically significant predictors of MAMM. Children living in North-East, South-East, South-South, and South-West were more likely to cohabit with two or more of anaemia, malaria, and malnutrition than children living in North Central geopolitical zones. Efforts should be made to end the insecurity in the North-East and environmental degradation going on in South-East and South-South due to oil spillage that may have affected quite several things such as drinking water and farm produce. Children from the South-West have consistently increased odds of contracting any of the three diseases and the MAMM. This region seems more economically viable and educated, yet the children have a higher probability of cohabiting with two or more of these diseases. Finally, children residing in rural areas were more likely to be exposed to MAMM. Therefore, the public health approach should include making health care facilities closer to the people in rural areas. More importantly, health workers posted to these rural areas ensured they were well renumerated and monitored to dwell among the people.

9.5.2 Study implications

Studies on multimorbidity in the adult population worldwide, especially in High-Income Countries (HICs), are well established. However, very few studies have been carried out on the children population, especially among children under-five years. Moreover, most of the researchers involved in multimorbidity studies are based in HICs. Therefore, they have not

considered studying the cooccurrence of diseases in children because, with the efficient healthcare system that caters to the children population's health needs, multimorbidity in young children is not of many burdens. Conversely, in LMICs with a weak health care system accompanied by poverty, the health needs of children are often not taken as a priority, coupled with a lack of adequate data and researchers to conduct research that would help policymakers for informed decisions to provide integrated care for that co-inhabiting with multiple diseases makes the situation even scary.

This study is the first to examine the multiple overlaps of MAMM in Nigeria, for which nationally representative data have been made available for the first time; it serves as a baseline for other studies to build on. In addition, a recent study carried out by the Academy of Medical Sciences (Academy of Medical Sciences, 2018) has itemised the priority research needed to handle the global prevalence of multimorbidity in the adult population, which researchers in developing countries can as well see how these priority needs could be modified and adopted to stop the growing burden of childhood multimorbidity. The areas of urgent concern include:

1. A proper definition of multimorbidity that will be adaptable for the study of coexisting diseases among children in developing countries
2. The research should draw stakeholders' attention to the growing trends and prevalence of multimorbidity among children under-five years in developing countries.
3. Further research with appropriate statistical techniques to identify and describe these coexisting diseases cluster among children.
4. Research verifying the individual's behavioural, biological, demographic, and environmental determinants of multimorbidity clustering to allow for direct comparison of studies.
5. To establish a well-coordinated care approach beyond caring for individual diseases cost-effectively.

Additionally, funding bodies should show more interest in funding research on childhood multimorbidity in developing countries. This current study initiative has a baseline approach. Several alternative statistical analysis methods could be adopted to understand multimorbidity in children better while considering the model's requirement for parsimony (interpreting the results) from the available data. These methods include multivariate joint logistic regression, multinomial logistic regression, latent variables determination, and simultaneous equation model (Das, Poole and Bada, 2004; Khatab and Kandala, 2011; Gabr, 2016; Martin *et al.*, 2021). Even though this study used a more traditional frequentist method, it looked at the spatial map

distribution of prevalence of MAMM across the six geopolitical zones, the states, and the FCT. Since all predictors were categorised, some metric covariates could have had non-linear effects on MAMM if employed as-is (Khatab and Kandala, 2011; Kandala, 2014; Kandala, Manda and Tigbe, 2014); a future study might use a strictly Bayesian approach with random effect components. The method is expedient for comparing models from the standpoint of Classical and Bayesian approaches and offers a suitable model for analysis of MAMM. Furthermore, although longitudinal studies on children in LMICs may be difficult, they are required to demonstrate the importance of the predictors of MAMM and identify causal relationships across time. When longitudinal data becomes available for these diseases, a more sophisticated modelling approach on the connection between anaemia, malaria, and malnutrition can be developed to enhance integrated care for children.

9.6 Conclusion

The three illness clusters considered in this study—malaria, anaemia, and malnutrition-significantly contribute to Nigeria's child mortality. This study's objectives include determining the prevalence across states and regions in Nigeria, as well as contextual differences and numerous overlaps in the factors that influence the frequency of MAMM among children aged 6-59 months in Nigeria. According to this study, two or more diseases are present in almost one-half of Nigerian children aged 6 to 59 months. This is worrying and requires urgent response through creating and executing good policy. In addition, the results have demonstrated the need for clinicians and health care providers to evolve integrated care models suitable for managing and treating children cohabiting with multiple diseases. There is urgent need of paradigm shift in the training curriculum of medical school from the clinical guidelines of treating single disease to include handling clusters of diseases especially among children in LMICs.

References

Abebe, F. *et al.* (2020) 'Multimorbidity of chronic non-communicable diseases in low- and middle-income countries: A scoping review', *Journal of Comorbidity*, 10, p. 2235042X20961919. Available at: https://doi.org/10.1177/2235042X20961919.

Aboagye, R.G. *et al.* (2021) 'Dietary Diversity and Undernutrition in Children Aged 6-23 Months in Sub-Saharan Africa', *Nutrients*. 2021/10/24 edn, 13(10). Available at: https://doi.org/10.3390/nu13103431.

Abubakar, I. *et al.* (2022) 'The Lancet Nigeria Commission: investing in health and the future of the nation', *The Lancet*, 399(10330), pp. 1155–1200. Available at: https://doi.org/10.1016/S0140-6736(21)02488-0.

Academy of Medical Sciences (2018) 'Multimorbidity: a priority for global health research'. The Academy of Medical Sciences. Available at: https://acmedsci.ac.uk/file-download/82222577 (Accessed: 10 November 2021).

Acharya, Y. *et al.* (2020) 'Deforestation and Household- and Individual-Level Double Burden of Malnutrition in Sub-saharan Africa', *Frontiers in Sustainable Food Systems*, 4. Available at: https://doi.org/10.3389/fsufs.2020.00033.

Adam Birhan, N. and Bitew Belay, D. (2021) 'Associated risk factors of underweight among under-five children in Ethiopia using multilevel ordinal logistic regression model', *African Health Sciences*, 21(1), pp. 362–72. Available at: https://doi.org/10.4314/ahs.v21i1.46.

Adebowale, A.S. *et al.* (2020) 'Dynamics of poverty-related dissimilarities in fertility in Nigeria: 2003-2018', *Scientific African*, 9, p. e00468. Available at: https://doi.org/10.1016/j.sciaf.2020.e00468.

Adedokun, S.T. (2020) 'Correlates of childhood morbidity in Nigeria: Evidence from ordinal analysis of cross-sectional data', *Plos One*, 15(5). Available at: https://doi.org/10.1371/journal.pone.0233259.

Adedokun, S.T. and Uthman, O.A. (2020) 'Individual and contextual correlates of mosquito net use among women in Nigeria', *Malaria Journal*, 19(1), p. 138. Available at: https://doi.org/10.1186/s12936-020-03219-3.

Adedokun, S.T. and Yaya, S. (2020) 'Childhood morbidity and its determinants: evidence from 31 countries in sub-Saharan Africa', *BMJ Global Health*, 5(10). Available at: https://doi.org/10.1136/bmjgh-2020-003109.

Adedokun, S.T. and Yaya, S. (2021) 'Factors associated with adverse nutritional status of children in sub-Saharan Africa: Evidence from the Demographic and Health Surveys from 31 countries', *Matern Child Nutr*. 2021/05/08 edn, 17(3), p. e13198. Available at: https://doi.org/10.1111/mcn.13198.

Adekanmbi, V.T., Kayode, G.A. and Uthman, O.A. (2013) 'Individual and contextual factors associated with childhood stunting in Nigeria: a multilevel analysis', *Maternal & child nutrition*, 9(2), pp. 244–59. Available at: https://doi.org/10.1111/j.1740-8709.2011.00361.x.

Adekanmbi, V.T., Uthman, O.A. and Mudasiru, O.M. (2013) 'Exploring variations in childhood stunting in Nigeria using league table, control chart and spatial analysis', *BMC public health*, 13, p. 361. Available at: https://doi.org/10.1186/1471-2458-13-361.

Adeyinka, D.A. *et al.* (2021) 'Changing patterns of gender inequities in childhood mortalities during the Sustainable Development Goals era in Nigeria: findings from an artificial neural network analysis', *BMJ Open*, 11(1), p. e040302. Available at: https://doi.org/10.1136/bmjopen-2020-040302.

Adinan, J., Damian, D.J. and Msuya, S.E. (2015) 'Factors Associated with Testing and Prompt Use of Recommended Antimalarials following Malaria Diagnosis: A Secondary Analysis of 2011-12 Tanzania HIV and Malaria Indicator Survey Data', *Plos One*, 10(7), p. e0132964. Available at: https://doi.org/10.1371/journal.pone.0132964.

Ag, W. *et al.* (2021) 'Identification of Factors Influencing Anemia among Children Aged 6–59 Months in Ethiopia Using Ethiopia Demographic and Health Survey 2016 Data', *Pediatric Health, Medicine and Therapeutics*, Volume 12, pp. 161–175.

Agadjanian, V. and Prata, N. (2003) 'Civil war and child health: regional and ethnic dimensions of child immunization and malnutrition in Angola', *Soc Sci Med*, 56(12), pp. 2515–27. Available at: https://doi.org/10.1016/s0277-9536(02)00286-1.

Aheto, Justice Moses K. (2020) *Simultaneous quantile regression and determinants of under-five severe chronic malnutrition in Ghana | BMC Public Health | Full Text*. Available at: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-020-08782-7 (Accessed: 30 July 2020).

Aheto, J.M.K. *et al.* (2021) 'A predictive model, and predictors of under-five child malaria prevalence in Ghana: How do LASSO, Ridge and Elastic net regression approaches compare?', *Preventive Medicine Reports*, 23, p. 101475. Available at: https://doi.org/10.1016/j.pmedr.2021.101475.

Ajala, S. (2022) Can SDGs be Achieved in Nigeria before 2030? According to Data, not Likely. Dataphyte. URL https://www.dataphyte.com/latest-reports/sdgs/can-sdgs-be-achieved-in-nigeria-before-2030-according-to-data-not-likely/ (accessed 1.31.23).

Akinpelu, Y. (2020) 'Nigerian govt to feed, deworm children with N142.3 billion in 2021', *Premium Times Nigeria*, 14 November. Available at: https://www.premiumtimesng.com/news/more-news/426172-nigerian-govt-to-feed-deworm-children-with-n142-3-billion-in-2021.html (Accessed: 20 August 2022).

Akodu, O.S. *et al.* (2016) 'Iron deficiency anaemia among apparently healthy pre-school children in Lagos, Nigeria', *African health sciences*, 16(1), pp. 61–68. Available at: https://doi.org/10.4314/ahs.v16i1.8.

Akombi, B.J., Agho, K.E., Merom, D., Hall, J.J., *et al.* (2017) 'Multilevel Analysis of Factors Associated with Wasting and Underweight among Children Under-Five Years in Nigeria', *Nutrients*, 9(1). Available at: https://doi.org/10.3390/nu9010044.

Akombi, B.J., Agho, K.E., Hall, J.J., Merom, D., *et al.* (2017) 'Stunting and severe stunting among children under-5 years in Nigeria: A multilevel analysis', *BMC pediatrics*, 17(1), p. 15. Available at: https://doi.org/10.1186/s12887-016-0770-z.

Akombi, B.J., Agho, K.E., Hall, J.J., Wali, N., *et al.* (2017) 'Stunting, wasting and underweight in Sub-Saharan Africa: A systematic review', *International journal of environmental research and public health*, 14(8). Available at: https://doi.org/10.3390/ijerph14080863.

Akombi, B.J. *et al.* (2019) 'Trends in socioeconomic inequalities in child undernutrition: Evidence from Nigeria Demographic and Health Survey (2003 - 2013)', *PloS One*, 14(2), p. e0211883. Available at: https://doi.org/10.1371/journal.pone.0211883.

Akosu, T.J. and Afolaranmi, T. (2015) 'Association of malaria and anaemia in under five children in a rural general hospital in northern Nigeria', *Highland Medical Research Journal*, 15(2), pp. 80–82.

Alaba, O. and Chola, L. (2013) 'The social determinants of multimorbidity in South Africa', *International Journal for Equity in Health*, 12, p. 63. Available at: https://doi.org/10.1186/1475-9276-12-63.

Ali, N. *et al.* (2019) 'Sex-specific prevalence, inequality and associated predictors of hypertension, diabetes, and comorbidity among Bangladeshi adults: results from a nationwide cross-sectional demographic and health survey', *BMJ open*, 9(9), p. e029364. Available at: https://doi.org/10.1136/bmjopen-2019-029364.

Alicke, M. *et al.* (2017) 'Adolescent health in rural Ghana: A cross-sectional study on the co-occurrence of infectious diseases, malnutrition and cardio-metabolic risk factors', *PLOS ONE*, 12(7), p. e0180436. Available at: https://doi.org/10.1371/journal.pone.0180436.

Alijanzadeh, M., Asefzadeh, S. and Zare, S.A.M. (2016) 'Correlation Between Human Development Index and Infant Mortality Rate Worldwide', *Biotech Health Sci*, 3(1). Available at: https://doi.org/: 10.17795/bhs-35330.

Allison, P. (2012) 'When can you safely ignore multicollinearity?', Statistical Horizons. Available at: https://statisticalhorizons.com/multicollinearity/

Amadu, Iddrisu *et al.* (2021) 'Household cooking fuel type and childhood anaemia in sub-Saharan Africa: analysis of cross-sectional surveys of 123, 186 children from 29 countries', *BMJ Open*, 11(7), p. e048724. Available at: https://doi.org/10.1136/bmjopen-2021-048724.

Amadu, I. *et al.* (2021) 'The Joint Effect of Maternal Marital Status and Type of Household Cooking Fuel on Child Nutritional Status in Sub-Saharan Africa: Analysis of Cross-Sectional Surveys on Children from 31 Countries', *Nutrients*, 13(5). Available at: https://doi.org/10.3390/nu13051541.

Amaha, N.D. and Woldeamanuel, B.T. (2021) 'Maternal factors associated with moderate and severe stunting in Ethiopian children: analysis of some environmental factors based on 2016 demographic health survey', *Nutrition Journal*, 20(1), p. 18. Available at: https://doi.org/10.1186/s12937-021-00677-6.

Amaral, M.M., Herrin, W.E. and Gulere, G.B. (2017) 'Using the Uganda National Panel Survey to analyze the effect of staple food consumption on undernourishment in Ugandan children', *BMC Public Health*, 18(1), p. 32. Available at: https://doi.org/10.1186/s12889-017-4576-1.

Amare, Z.Y., Ahmed, M.E. and Mehari, A.B. (2019) 'Determinants of nutritional status among children under age 5 in Ethiopia: Further analysis of the 2016 Ethiopia demographic and health survey', *Globalization and Health*, 15(1). Available at: https://doi.org/10.1186/s12992-019-0505-7.

Amegbor, P.M. *et al.* (2020) 'Multilevel and spatial analyses of childhood malnutrition in Uganda: examining individual and contextual factors', *Sci Rep*. 2020/11/20 edn, 10(1), p. 20019. Available at: https://doi.org/10.1038/s41598-020-76856-y.

Amegbor, P.M., Yankey, O. and Sabel, C.E. (2020) 'Examining the Effect of Geographic Region of Residence on Childhood Malnutrition in Uganda', *Journal of Tropical Pediatrics*, 66(6), pp. 598–611. Available at: https://doi.org/10.1093/tropej/fmaa019.

Amoako Johnson, F. (2022) 'Spatiotemporal clustering and correlates of childhood stunting in Ghana: Analysis of the fixed and nonlinear associative effects of socio-demographic and socio-ecological factors', *PLOS ONE*. Edited by P. Anthamatten, 17(2), p. e0263726. Available at: https://doi.org/10.1371/journal.pone.0263726.

Amoran, O.E. *et al.* (2014) 'The influence of environmental sanitation on prevalence of malaria in a rural town in south-western Nigeria', *Nigerian journal of medicine: journal of the National Association of Resident Doctors of Nigeria*, 23(3), pp. 254–62.

Anjorin, S. and Yaya, S. (2021) 'Anaemia among under-five children: Is maternal marriage at 18th birthday and above protective? Evidence from 15 countries in Sub-Saharan Africa', *Maternal and Child Nutrition*, 17(4), p. e13226. Available at: https://doi.org/10.1111/mcn.13226.

Anjorin, S.S. *et al.* (2020) 'Undernutrition, polygynous context and family structure: a multilevel analysis of cross-sectional surveys of 350 000 mother-child pairs from 32 countries', *Bmj Global Health*, 5(10). Available at: https://doi.org/10.1136/bmjgh-2020-002637.

Anteneh, Z.A. and Van Geertruyden, J.-P. (2021) 'Spatial variations and determinants of anemia among under-five children in Ethiopia, EDHS 2005–2016', *PLOS ONE*. Edited by Y. Zhang, 16(4), p. e0249412. Available at: https://doi.org/10.1371/journal.pone.0249412.

Anumudu, C.I. *et al.* (2007) 'Epidemiological factors that promote the development of severe malaria anaemia in children in Ibadan', *African Health Sciences*, 7(2), pp. 80–85. Available at: https://doi.org/10.5555/afhs.2007.7.2.80.

Aregbeshola, B.S., Onifade, O.M. and Awuviry-Newton, K. (2021) 'Prevalence and correlates of anaemia among children aged 6 to 59 months in Nigeria', *World Nutrition*, 12(3), pp. 58–74. Available at: https://doi.org/10.26596/wn.202112358-74.

Arksey, H. and O'Malley, L. (2005) 'Scoping studies: towards a methodological framework', *International Journal of Social Research Methodology*, 8(1), pp. 19–32. Available at: https://doi.org/10.1080/1364557032000119616.

Asafo-Agyei, S.B., Antwi, S. and Nguah, S.B. (2013) 'HIV infection in severely malnourished children in Kumasi, Ghana: a cross-sectional prospective study', *BMC Pediatrics*, 13(1), p. 181. Available at: https://doi.org/10.1186/1471-2431-13-181.

Asresie, M.B., Fekadu, G.A. and Dagnew, G.W. (2020) 'Determinants of Anemia among Children Aged 6–59 Months in Ethiopia: Further Analysis of the 2016 Ethiopian Demographic Health Survey', *Advances in Public Health*, 2020, pp. 1–6. Available at: https://doi.org/10.1155/2020/3634591.

Atrash, H.K. (2013) 'Childhood mortality: still a global priority', *Journal of Human Growth and Development*, 23(3), pp. 257–260. Available at: https://doi.org/10.7322/jhgd.69513.

Atsu, B.K., Guure, C. and Laar, A.K. (2017) 'Determinants of overweight with concurrent stunting among Ghanaian children', *BMC pediatrics*, 17(1), p. 177. Available at: https://doi.org/10.1186/s12887-017-0928-3.

Austin, A.M., Fawzi, W. and Hill, A.G. (2012) 'Anaemia among Egyptian Children between 2000 and 2005: trends and predictors', *Maternal & child nutrition*, 8(4), pp. 522–32. Available at: https://doi.org/10.1111/j.1740-8709.2011.00339.x.

Ayala, A. and Meier, B.M. (2017) 'A human rights approach to the health implications of food and nutrition insecurity', *Public Health Reviews*, 38(1), p. 10. Available at: https://doi.org/10.1186/s40985-017-0056-5.

Aychiluhm, S.B. *et al.* (2020) 'Determinants of malaria among under-five children in Ethiopia: Bayesian multilevel analysis', *BMC Public Health*, 20(1), p. 1468. Available at: https://doi.org/10.1186/s12889-020-09560-1.

Azikiwe, C. *et al.* (2012) 'A comparative laboratory diagnosis of malaria: microscopy versus rapid diagnostic test kits', *Asian Pacific Journal of Tropical Biomedicine*, 2(4), pp. 307–310. Available at: https://doi.org/10.1016/S2221-1691(12)60029-X.

Babatunde, R.O. *et al.* (2011) 'Prevalence and Determinants of Malnutrition among Under-five Children of Farming Households in Kwara State, Nigeria', *Journal of Agricultural Science*, 3(3), p. p173. Available at: https://doi.org/10.5539/jas.v3n3p173.

Bamiwuye, S.O., Wet, N.D. and Adedini, S.A. (2013) 'Linkages between autonomy, poverty and contraceptive use in two sub-Saharan African countries', *African Population Studies*, 27, pp. 164–173. Available at: https://doi.org/10.11564/27-2-438.

Barry, T.S. *et al.* (2021) 'Bayesian Spatial Modeling of Anemia among Children under 5 Years in Guinea', *International Journal of Environmental Research and Public Health*, 18(12), p. 6447. Available at: https://doi.org/10.3390/ijerph18126447.

Bartlett, J. and Carpenter, J. (2013) 'Module 14: Missing Data Stata Practical', p. 7.

Bekele, S.A. and Fetene, M.Z. (2021) 'Modeling non-Gaussian data analysis on determinants of underweight among under five children in rural Ethiopia: Ethiopian demographic and

health survey 2016 evidences', *PLOS ONE*. Edited by S. Goli, 16(5), p. e0251239. Available at: https://doi.org/10.1371/journal.pone.0251239.

Belachew, A. and Tewabe, T. (2020) 'Under-five anemia and its associated factors with dietary diversity, food security, stunted, and deworming in Ethiopia: systematic review and meta-analysis', *Systematic Reviews*, 9(1). Available at: https://doi.org/10.1186/s13643-020-01289-7.

Bennett, A. *et al.* (2017) 'Population coverage of artemisinin-based combination treatment in children younger than 5 years with fever and Plasmodium falciparum infection in Africa, 2003-2015: a modelling study using data from national surveys', *Lancet Glob Health*, 5(4), pp. e418–e427. Available at: https://doi.org/10.1016/s2214-109x(17)30076-1.

Berendsen, M.L. *et al.* (2019) 'BCG vaccination is associated with reduced malaria prevalence in children under the age of 5 years in sub-Saharan Africa', *BMJ Glob Health*, 4(6), p. e001862. Available at: https://doi.org/10.1136/bmjgh-2019-001862.

Berendsen, M.L.T. *et al.* (2016) 'Non-specific Effects of Vaccines and Stunting: Timing May Be Essential', *EBioMedicine*, 8, pp. 341–348. Available at: https://doi.org/10.1016/j.ebiom.2016.05.010.

Bevans, R. (2021) *An introduction to the Akaike information criterion*, *Scribbr*. Available at: https://www.scribbr.com/statistics/akaike-information-criterion/ (Accessed: 2 February 2022).

Black, S.E. (2017) *New Evidence on the Impacts of Birth Order*, *NBER*. Available at: https://www.nber.org/reporter/2017number4/new-evidence-impacts-birth-order (Accessed: 2 October 2021).

Bramley, D. and Moody, D. (2016) *NHS England » Multimorbidity – the biggest clinical challenge facing the NHS?*, *Blog*. Available at: https://www.england.nhs.uk/blog/dawn-moody-david-bramley/ (Accessed: 20 August 2020).

Brownlee, J. (2019) 'Probabilistic Model Selection with AIC, BIC, and MDL', *Machine Learning Mastery*, 29 October. Available at: https://machinelearningmastery.com/probabilistic-model-selection-measures/ (Accessed: 2 February 2022).

Carle, A.C. (2009) 'Fitting multilevel models in complex survey data with design weights: Recommendations', *BMC Medical Research Methodology*, 9(1), p. 49. Available at: https://doi.org/10.1186/1471-2288-9-49.

CDC (2016) *What is Sickle Cell Disease? | CDC, Centers for Disease Control and Prevention*. Available at: https://www.cdc.gov/ncbddd/sicklecell/facts.html (Accessed: 26 March 2022).

CDC-Centers for Disease Control (2021) *CDC - Malaria - Malaria Worldwide - Impact of Malaria*. Available at: https://www.cdc.gov/malaria/malaria_worldwide/impact.html (Accessed: 9 July 2022).

Chikako, T.U. *et al.* (2021) 'Complex Multilevel Modelling of the Individual, Household and Regional Level Variability in Predictors of Undernutrition among Children Aged 6–59 Months in Ethiopia', *Nutrients*, 13(9), p. 3018. Available at: https://doi.org/10.3390/nu13093018.

Chiswick, B.R. and Mirtcheva, D. (2010) 'Religion and Child Health', *SSRN Electronic Journal* [Preprint]. Available at: https://doi.org/10.2139/ssrn.1686526.

Chitunhu, S. and Musenge, E. (2015) 'Direct and indirect determinants of childhood malaria morbidity in Malawi: a survey cross-sectional analysis based on malaria indicator survey data for 2012', *Malaria Journal*, 14. Available at: https://doi.org/10.1186/s12936-015-0777-1.

Cornish, R.P. *et al.* (2013) 'Socio-economic position and childhood multimorbidity: a study using linkage between the Avon Longitudinal study of parents and children and the general practice research database', *International Journal for Equity in Health*, 12(1), p. 66. Available at: https://doi.org/10.1186/1475-9276-12-66.

Das, A., Poole, W.K. and Bada, H.S. (2004) 'A repeated measures approach for simultaneous modeling of multiple neurobehavioral outcomes in newborns exposed to cocaine in utero', *American Journal of Epidemiology*, 159(9), pp. 891–899. Available at: https://doi.org/10.1093/aje/kwh114.

Dawaki, S. *et al.* (2016) 'Is Nigeria winning the battle against malaria? Prevalence, risk factors and KAP assessment among Hausa communities in Kano State', *Malaria Journal*, 15, p. 351. Available at: https://doi.org/10.1186/s12936-016-1394-3.

Dawson, J.F. (2014) 'Moderation in Management Research: What, Why, When, and How', *Journal of Business and Psychology*, 29(1), pp. 1–19. Available at: https://doi.org/10.1007/s10869-013-9308-7.

De Benoist, B. *et al.* (2008) *Worldwide prevalence of anaemia 1993-2005 of: WHO Global Database of anaemia*. Geneva: World Health Organization.

Demirchyan, A. *et al.* (2016) 'Prevalence and determinants of anaemia among children aged 0-59 months in a rural region of Armenia: a case-control study', *Public health nutrition*, 19(7), pp. 1260–1269. Available at: https://doi.org/10.1017/S1368980015002451.

Demographic and Health Survey (2021) *The DHS Program - Analysis FAQs*. Available at: https://dhsprogram.com/data/analysis-faqs.cfm (Accessed: 14 October 2021).

Demographic and Health Survey (2022) *The DHS Program - Dataset Types*. Available at: https://www.dhsprogram.com/data/Dataset-Types.cfm (Accessed: 1 August 2022).

Department of Sociology (2022) *Chi-Square - Sociology 3112 The University of utah*. Available at: https://soc.utah.edu/sociology3112/chi-square.php (Accessed: 7 April 2022).

Dey, S. and Raheem, E. (2016) 'Multilevel multinomial logistic regression model for identifying factors associated with anemia in children 6–59 months in northeastern states of India', *Cogent Mathematics*. Edited by Z. Lu, 3(1). Available at: https://doi.org/10.1080/23311835.2016.1159798.

Dhewantara, P.W., Ipa, M. and Widawati, M. (2019) 'Individual and contextual factors predicting self-reported malaria among adults in eastern Indonesia: findings from Indonesian community-based survey', *Malaria Journal*, 18(1), p. 118. Available at: https://doi.org/10.1186/s12936-019-2758-2.

DJS Research (2022) *Bivariate Research Techniques*. Available at: https://www.djsresearch.co.uk/glossary/item/Bivariate-Research-Techniques (Accessed: 7 April 2022).

Douglas Andabati Candia (2017) 'Influence of malaria on anemia levels among children less than 60 months of age', *International Journal of Advanced Research and Development*, 2(3), p. 5.

Duah, H.O. *et al.* (2020) 'Comorbid patterns of anaemia and diarrhoea among children aged under 5 years in Ghana: a multivariate complex sample logistic regression analysis and spatial mapping visualisation', *International Health*, 13(6), pp. 562–572. Available at: https://doi.org/10.1093/inthealth/ihaa099.

Duncan, G.J. *et al.* (2018) 'Maternal Age and Child Development', *Demography*, 55(6), pp. 2229–2255. Available at: https://doi.org/10.1007/s13524-018-0730-3.

Dwumoh, D., Essuman, E.E. and Afagbedzi, S.K. (2014) 'Determinant of factors associated with child health outcomes and service utilization in Ghana: Multiple indicator cluster survey conducted in 2011', *Archives of Public Health*, 72(1). Available at: https://doi.org/10.1186/2049-3258-72-42.

Ehrhardt, S. *et al.* (2006) 'Malaria, anemia, and malnutrition in african children--defining intervention priorities', *J Infect Dis*, 194(1), pp. 108–14. Available at: https://doi.org/10.1086/504688.

Elmardi, K.A. *et al.* (2020) 'Anaemia prevalence and determinants in under 5 years children: findings of a cross-sectional population-based study in Sudan', *BMC pediatrics*, 20(1), p. 538. Available at: https://doi.org/10.1186/s12887-020-02434-w.

El-Sayed, A.M. *et al.* (2010) 'Back and neck pain and psychopathology in rural sub-Saharan Africa: evidence from the Gilgel Gibe Growth and Development Study, Ethiopia', *Spine*, 35(6), pp. 684–689. Available at: https://doi.org/10.1097/BRS.0b013e3181b4926e.

Emina, J.B.O., Doctor, H.V. and Yé, Y. (2021) 'Profiling malaria infection among under-five children in the Democratic Republic of Congo', *PLOS ONE*. Edited by T.A. Smith, 16(5), p. e0250550. Available at: https://doi.org/10.1371/journal.pone.0250550.

Endris, N., Asefa, H. and Dube, L. (2017) 'Prevalence of Malnutrition and Associated Factors among Children in Rural Ethiopia', *BioMed research international*, 2017, p. 6587853. Available at: https://doi.org/10.1155/2017/6587853.

Eshete, T. *et al.* (2022) 'Geographical pattern and associated factors of anemia among children aged 6–59 months in Ethiopia: Further analysis of Ethiopian demographic and health survey 2016', *International Journal of Africa Nursing Sciences*, 16, p. 100420. Available at: https://doi.org/10.1016/j.ijans.2022.100420.

Ewusie, J.E. *et al.* (2014) 'Prevalence of anemia among under-5 children in the Ghanaian population: estimates from the Ghana demographic and health survey', *BMC Public Health*, 14, p. 626. Available at: https://dx.doi.org/10.1186/1471-2458-14-626.

Eyowas, F.A. *et al.* (2019) 'Multimorbidity of chronic non-communicable diseases and its models of care in low- and middle-income countries: a scoping review protocol', *BMJ Open*, 9(10), p. e033320. Available at: https://doi.org/10.1136/bmjopen-2019-033320.

Ezeonwu, B.U. *et al.* (2014) 'Prevalence of hematological abnormalities and malnutrition in HIV-infected under five children in Enugu', *Nigerian Journal of Clinical Practice*, 17(3), pp. 303–8. Available at: https://doi.org/10.4103/1119-3077.130230.

Fabic, M.S., Choi, Y. and Bird, S. (2012) 'A systematic review of Demographic and Health Surveys: data availability and utilization for research', *Bulletin of the World Health Organization*, 90, pp. 604–612. Available at: https://doi.org/doi: 10.2471/BLT.11.095513.

Fantay Gebru, K. *et al.* (2019) 'Determinants of stunting among under-five children in Ethiopia: A multilevel mixed-effects analysis of 2016 Ethiopian demographic and health survey data', *BMC Pediatrics*, 19(1). Available at: https://doi.org/10.1186/s12887-019-1545-0.

FDA Media (2020) *Using the PICOTS Framework to Strengthen Evidence Gathered in Clinical Trials—Guidance from the AHRQ's Evidence-based Practice Centers Program*. Available at: https://www.fda.gov/media/109448/download.

Federal Office of Statistics [Nigeria] and IRD/Macro International (1992) 'Nigeria Demographic and Health Survey 1990'. Abuja, Nigeria, and Rockville, Maryland, USA: NPC and ICF.

Fenta, H.M., Zewotir, T. and Muluneh, E.K. (2021) 'Spatial data analysis of malnutrition among children under-five years in Ethiopia', *Bmc Medical Research Methodology*, 21(1). Available at: https://doi.org/10.1186/s12874-021-01391-x.

Ferro, M.A. *et al.* (2019) 'Multimorbidity in Children and Youth Across the Life-course (MY LIFE): protocol of a Canadian prospective study', *BMJ Open*, 9(11), p. e034544. Available at: https://doi.org/10.1136/bmjopen-2019-034544.

Fissuh, Y.H. (2017) *How to test multicollinearity in binary logistic logistic regression? (Response)*, *ResearchGate*. Available at: https://www.researchgate.net/post/How_to_test_multicollinearity_in_binary_logistic_logistic_regression (Accessed: 14 June 2022).

Flom, P. (2018) Stopping stepwise: Why stepwise selection is bad and what you should use instead [WWW Document]. Medium. URL https://towardsdatascience.com/stopping-stepwise-why-stepwise-selection-is-bad-and-what-you-should-use-instead-90818b3f52df (accessed 1.9.23)

Fortin, M. *et al.* (2005) 'Multimorbidity is common to family practice: is it commonly researched?', *Canadian Family Physician Medecin De Famille Canadien*, 51, pp. 244–245.

Fried, L.P. *et al.* (2004) 'Untangling the concepts of disability, frailty, and comorbidity: implications for improved targeting and care', *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, 59(3), pp. 255–263. Available at: https://doi.org/10.1093/gerona/59.3.m255.

Fries, J.F., Bruce, B. and Chakravarty, E. (2011) 'Compression of Morbidity 1980–2011: A Focused Review of Paradigms and Progress', *Journal of Aging Research*, p. 11.

Gabr, H.M.K.M. (2016) *Investigating poverty and labour force participation among older population in Egypt: a multilevel simultaneous equations modeling approach*. d_ph. University of Birmingham. Available at: https://etheses.bham.ac.uk/id/eprint/6551/ (Accessed: 28 July 2020).

Gaston, R.T., Ramroop, S. and Habyarimana, F. (2021) 'Joint modelling of malaria and anaemia in children less than five years of age in Malawi', *Heliyon*, 7(5), p. e06899. Available at: https://doi.org/10.1016/j.heliyon.2021.e06899.

Gebremeskel, M.G. *et al.* (2020) 'Individual and community level factors associated with anemia among children 6-59 months of age in Ethiopia: A further analysis of 2016 Ethiopia demographic and health survey', *PloS One*, 15(11), p. e0241720. Available at: https://doi.org/10.1371/journal.pone.0241720.

Gebru, K.F. *et al.* (2019) 'Determinants of stunting among under-five children in Ethiopia: a multilevel mixed-effects analysis of 2016 Ethiopian demographic and health survey data', *BMC pediatrics*, 19(1), p. 176.

Geda, N.R. *et al.* (2021) 'Multiple anthropometric and nutritional deficiencies in young children in Ethiopia: a multi-level analysis based on a nationally representative data', *BMC Pediatrics*, 21(1), p. 11. Available at: https://doi.org/10.1186/s12887-020-02467-1.

Global Nutrition Report (2020) *The burden of malnutrition*. Available at: https://globalnutritionreport.org/reports/global-nutrition-report-2018/burden-malnutrition/ (Accessed: 25 June 2020).

Gup, I., Udo Nnorom and Amadi, A. (2013) 'Malaria Morbidity among Under-Five Nigerian Children: A Study of its Prevalence and Health Practices of Primary Care Givers (Mothers) in a Resource-Poor Setting of a Rural Hospital in Eastern Nigeria', *European Journal of Preventive Medicine*, 1(3), p. 50. Available at: https://doi.org/10.11648/j.ejpm.20130103.11.

Gupta, R.P.-S., de Wit, M.L. and McKeown, D. (2007) 'The impact of poverty on the current and future health status of children', *Paediatrics & Child Health*, 12(8), pp. 667–672.

Hailu, B.A., Bogale, G.G. and Beyene, J. (2020) 'Spatial heterogeneity and factors influencing stunting and severe stunting among under-5 children in Ethiopia: spatial and multilevel analysis', *Sci Rep*. 2020/10/04 edn, 10(1), p. 16427. Available at: https://doi.org/10.1038/s41598-020-73572-5.

Hartnell, S.J. (2011) *Intersections of Gender, Ethnicity, and Socioeconomic Position in Health in England: A Mixed Methods Study, White Rose eTheses Online*. Available at: https://etheses.whiterose.ac.uk/cgi/search/simple?q=ScHARR&_action_search=&_order=bytitle&basic_srchtype=ALL&_satisfyall=ALL.

Heck, R.H., Thomas, S. and Tabata, L. (2014) *Multilevel Modeling of Categorical Outcomes Using IBM SPSS*. 2nd Edition. New York: Routledge. Available at: https://www.routledge.com/Multilevel-Modeling-of-Categorical-Outcomes-Using-IBM-SPSS/Heck-Thomas-Tabata/p/book/9781848729568 (Accessed: 14 April 2021).

Heinrichs, H. *et al.* (2021) 'Anaemia and its determinants among young children aged 6-23 months in Ethiopia (2005-2016)', *Maternal & Child Nutrition*, 17(2), p. e13082. Available at: https://doi.org/10.1111/mcn.13082.

Hershey, C.L. *et al.* (2017) 'Malaria Control Interventions Contributed to Declines in Malaria Parasitemia, Severe Anemia, and All-Cause Mortality in Children Less Than 5 Years of Age in Malawi, 2000-2010', *The American Journal of Tropical Medicine and Hygiene*, 97(3_Suppl), pp. 76–88. Available at: https://doi.org/10.4269/ajtmh.17-0203.

Hill, K. *et al.* (2012) 'Child Mortality Estimation: Accelerated Progress in Reducing Global Child Mortality, 1990–2010', *PLoS Medicine*. Edited by P. Byass, 9(8), p. e1001303. Available at: https://doi.org/10.1371/journal.pmed.1001303.

Hv, D. and S, N.-S. (2017) 'Trends and Determinants of Child Growth Indicators in Malawi and Implications for the Sustainable Development Goals.', *AIMS Public Health*, 4(6), pp. 590–614. Available at: https://doi.org/10.3934/publichealth.2017.6.590.

Iddrisu, D. and Moyer, C.A. (2022) 'Using the Ghana malaria indicator survey to understand the difference between female and male-headed households and their prevention and testing for malaria among children under 5', *Malaria Journal*, 21(1), p. 112. Available at: https://doi.org/10.1186/s12936-022-04135-4.

Immurana, M. and Urmi, A. (2017) 'Socio-economic factors and child health status in Ghana', *International Journal of Health*, 5(2). Available at: https://doi.org/10.14419/ijh.v5i2.7806.

Jember, T.A. *et al.* (2021) 'Spatial variation and determinants of childhood anemia among children aged 6 to 59 months in Ethiopia: further analysis of Ethiopian demographic and health survey 2016', *BMC Pediatrics*, 21(1), p. 497. Available at: https://doi.org/10.1186/s12887-021-02901-y.

Jennings-Edquist, G. (2020) *Does the age you become a parent really matter? We asked three mums - ABC Everyday*. Available at: https://www.abc.net.au/everyday/does-the-age-you-become-a-parent-actually-matter/12742736 (Accessed: 14 October 2021).

Jones, A.D. *et al.* (2018) 'Livestock ownership is associated with higher odds of anaemia among preschool-aged children, but not women of reproductive age in Ghana', *Maternal & child nutrition*, 14(3), p. e12604. Available at: https://doi.org/10.1111/mcn.12604.

Jude, C.K., Chukwunedum, A.U. and Egbuna, K.O. (2019) 'Under-five malnutrition in a South-Eastern Nigeria metropolitan city', *African Health Sciences*, 19(4), pp. 3078–3084. Available at: https://doi.org/10.4314/ahs.v19i4.29.

Kandala, N.-B. *et al.* (2007) 'Spatial Analysis of Risk Factors for Childhood Morbidity in Nigeria', *The American Journal of Tropical Medicine and Hygiene*, 77(4), pp. 770–779. Available at: https://doi.org/10.4269/ajtmh.2007.77.770.

Kandala, N.-B. *et al.* (2008) 'Morbidity from diarrhoea, cough and fever among young children in Nigeria', *Annals of Tropical Medicine & Parasitology*, 102(5), pp. 427–445. Available at: https://doi.org/10.1179/136485908X300797.

Kandala, N.-B. *et al.* (2009) 'Diarrhoea, acute respiratory infection, and fever among children in the Democratic Republic of Congo', *Social Science & Medicine*, 68(9), pp. 1728–1736. Available at: https://doi.org/10.1016/j.socscimed.2009.02.004.

Kandala, N.-B. *et al.* (2011) 'Malnutrition among children under the age of five in the Democratic Republic of Congo (DRC): does geographic location matter?', *BMC public health*, 11, p. 261. Available at: https://doi.org/10.1186/1471-2458-11-261.

Kandala, N.B. *et al.* (2011) 'Semiparametric Analysis of the Socio-Demographic and Spatial Determinants of Undernutrition in Two African Countries', *LMU*, p. 18. Available at: https://doi.org/OI: 10.5282/ubm/epub.1626.

Kandala, N.-B. (2014) 'Spatial Variation of Predictors of Prevalent Hypertension in Sub-Saharan Africa: A Case Study of South-Africa', in N.-B. Kandala and G. Ghilagaber (eds) *Advanced Techniques for Modelling Maternal and Child Health in Africa*. Dordrecht: Springer Netherlands (The Springer Series on Demographic Methods and Population Analysis), pp. 211–237. Available at: https://doi.org/10.1007/978-94-007-6778-2_11.

Kandala, N.-B., Magadi, M.A. and Madise, N.J. (2006) 'An investigation of district spatial variations of childhood diarrhoea and fever morbidity in Malawi', *Social Science & Medicine (1982)*, 62(5), pp. 1138–1152. Available at: https://doi.org/10.1016/j.socscimed.2005.07.028.

Kandala, N.-B., Manda, S.O.M. and Tigbe, W. (2014) 'Assessing Geographic Co-morbidity Associated with Vascular Diseases in South Africa: A Joint Bayesian Modeling Approach', in N.-B. Kandala and G. Ghilagaber (eds) *Advanced Techniques for Modelling Maternal and Child Health in Africa*. Dordrecht: Springer Netherlands (The Springer Series on Demographic Methods and Population Analysis), pp. 303–320. Available at: https://doi.org/10.1007/978-94-007-6778-2_15.

Kandala, N.B.M. (2013) *Socio-demographic determinants of anaemia and nutritional status in the Democratic Republic of Congo, Uganda and Malawi*. phd. University of Southampton. Available at: https://eprints.soton.ac.uk/354347/ (Accessed: 25 July 2022).

Kassebaum, N.J. *et al.* (2014) 'A systematic analysis of global anemia burden from 1990 to 2010', *Blood*, 123(5), pp. 615–624. Available at: https://doi.org/10.1182/blood-2013-06-508325.

Kassie, G.W. and Workie, D.L. (2020) 'Determinants of under-nutrition among children under five years of age in Ethiopia', *BMC Public Health*, 20(1), p. 399. Available at: https://doi.org/10.1186/s12889-020-08539-2.

Kateera, F. *et al.* (2015) 'Malaria, anaemia and under-nutrition: three frequently co-existing conditions among preschool children in rural Rwanda', *Malaria Journal*, 14(1), p. 440. Available at: https://doi.org/10.1186/s12936-015-0973-z.

Kawo, K.N., Asfaw, Z.G. and Yohannes, N. (2018) 'Multilevel Analysis of Determinants of Anemia Prevalence among Children Aged 6-59 Months in Ethiopia: Classical and Bayesian Approaches', *Anemia*, 2018, p. 3087354. Available at: https://doi.org/10.1155/2018/3087354.

Kayode, G.A., Adekanmbi, V.T. and Uthman, O.A. (2012) 'Risk factors and a predictive model for under-five mortality in Nigeria: evidence from Nigeria demographic and health survey', *BMC Pregnancy and Childbirth*, 12, p. 10. Available at: https://doi.org/10.1186/1471-2393-12-10.

Kazembe, L.N. *et al.* (2007) 'Modelling the effect of malaria endemicity on spatial variations in childhood fever, diarrhoea and pneumonia in Malawi', *International Journal of Health Geographics*, 6(1), p. 33. Available at: https://doi.org/10.1186/1476-072X-6-33.

Kazembe, L.N. and Namangale, J.J. (2007) 'A Bayesian multinomial model to analyse spatial patterns of childhood co-morbidity in Malawi', *Eur J Epidemiol*, 22(8), pp. 545–56. Available at: https://doi.org/10.1007/s10654-007-9145-y.

Kebede, D. and Aynalem, A. (2021) 'Prevalence of undernutrition and potential risk factors among children below five years of age in Somali region, Ethiopia: evidence from 2016 Ethiopian demographic and health survey', *BMC Nutrition*, 7(1), p. 56. Available at: https://doi.org/10.1186/s40795-021-00460-0.

Kennedy, G. *et al.* (2006) 'Does living in an urban environment confer advantages for childhood nutritional status? Analysis of disparities in nutritional status by wealth and residence in Angola, Central African Republic and Senegal', *Public Health Nutrition*, 9(2), pp. 187–193. Available at: https://doi.org/10.1079/PHN2005835.

Khamis, A.G. *et al.* (2020) 'The burden and correlates of childhood undernutrition in Tanzania according to composite index of anthropometric failure', *BMC Nutrition*, 6(1), p. 39. Available at: https://doi.org/10.1186/s40795-020-00366-3.

Khatab, K. (2007) *Analysis of Childhood Diseases and Malnutrition in Developing Countries of Africa*. PhD Thesis. Ludwig{Maximilians{UniversitÄat, MÄunchen.

Khatab, K., Adegboye, O. and Mohammed, T.I. (2016) 'Social and Demographic Factors Associated with Morbidities in Young Children in Egypt: A Bayesian Geo-Additive Semi-Parametric Multinomial Model', *PLOS ONE*. Edited by C.T. Codeço, 11(7), p. e0159173. Available at: https://doi.org/10.1371/journal.pone.0159173.

Khatab, K. and Kandala, N.-B. (2011) 'Latent variable modelling of risk factors associated with childhood diseases: Case study for Nigeria', *Asian Pacific Journal of Tropical Disease*, 1(3), pp. 169–176. Available at: https://doi.org/10.1016/S2222-1808(11)60022-4.

koteletje (2020) 'Backward stepwise selection stopping rule in an ordinal logistic regression context when a model's ranking ability is of importance', *Cross Validated*. Available at: https://stats.stackexchange.com/q/488569 (Accessed: 27 April 2022).

Kuche, D. *et al.* (2020) 'Factors associated with dietary diversity and length-for-age z-score in rural Ethiopian children aged 6–23 months: A novel approach to the analysis of baseline data from the Sustainable Undernutrition Reduction in Ethiopia evaluation', *Maternal and Child Nutrition*, 16(1). Available at: https://doi.org/10.1111/mcn.12852.

Laerd Statistics (2018) *How to perform an Ordinal Regression in SPSS*. Available at: https://statistics.laerd.com/spss-tutorials/ordinal-regression-using-spss-statistics.php (Accessed: 2 August 2021).

Larissa Shamseer, D.M. (2015) 'Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation', *BMJ : British Medical Journal*, 349.

Leckie, G. *et al.* (2020) 'Partitioning variation in multilevel models for count data.', *Psychological Methods*, 25(6), pp. 787–801. Available at: https://doi.org/10.1037/met0000265.

Lee, E. (2019) 'Ordinal Logistic Regression on World Happiness Report', *evangelinelee*, 29 May. Available at: https://medium.com/evangelinelee/ordinal-logistic-regression-on-world-happiness-report-221372709095 (Accessed: 2 August 2021).

Lee, K. *et al.* (1997) 'Human development index as a predictor of infant and maternal mortality rates', *The Journal of Pediatrics*, 131(3), pp. 430–433. Available at: https://doi.org/10.1016/S0022-3476(97)80070-4.

Levac, D., Colquhoun, H. and O'Brien, K.K. (2010) 'Scoping studies: advancing the methodology', *Implementation Science*, 5(1), p. 69. Available at: https://doi.org/10.1186/1748-5908-5-69.

Levitz, L. *et al.* (2018) 'Effect of individual and community-level bed net usage on malaria prevalence among under-fives in the Democratic Republic of Congo', *Malaria Journal*, 17(1), p. 39. Available at: https://doi.org/10.1186/s12936-018-2183-y.

Lia, F. and Taylor, C. (2016) *Using Household Survey Data to Explore the Effects of Improved Housing Conditions on Malaria Infection in Children in Sub-Saharan Africa*. DHS Analytical Studies No. 61. Rockville, Maryland, USA: ICF International.

Lian, M. (2015) 'Statistical Significance of Geographic Heterogeneity Measures in Spatial Epidemiologic Studies', *Open Journal of Statistics*, 05(01), pp. 46–50. Available at: https://doi.org/10.4236/ojs.2015.51006.

Machisa, M., Wichmann, J. and Nyasulu, P.S. (2013) 'Biomass fuel use for household cooking in Swaziland: is there an association with anaemia and stunting in children aged 6-36 months?', *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 107(9), pp. 535–44. Available at: https://doi.org/10.1093/trstmh/trt055.

Macrotrends (2020) 'Nigeria Population Growth Rate 1950-2020'. Available at: https://www.macrotrends.net/countries/NGA/nigeria/population-growth-rate (Accessed: 27 July 2020).

Magadi, M.A. (2011) 'Household and community HIV/AIDS status and child malnutrition in sub-Saharan Africa: Evidence from the demographic and health surveys', *Social Science & Medicine (1982)*, 73(3), pp. 436–446. Available at: https://doi.org/10.1016/j.socscimed.2011.05.042.

Mann, D.M., Swahn, M.H. and McCool, S. (2021) ‘Undernutrition and malaria among under-five children: findings from the 2018 Nigeria demographic and health survey’, *Pathogens and Global Health*, 115(6), pp. 423–433. Available at: https://doi.org/10.1080/20477724.2021.1916729.

Maphosa, T.P. *et al.* (2020) ‘Mapping evidence on malnutrition screening tools for children under 5 years in sub-Saharan Africa: a scoping review protocol’, *Systematic Reviews*, 9(1), p. 52. Available at: https://doi.org/10.1186/s13643-020-01309-6.

March of Dimes (2021) *Low birthweight*. Available at: https://www.marchofdimes.org/complications/low-birthweight.aspx (Accessed: 19 August 2022).

Martin, G.P. *et al.* (2021) ‘Clinical prediction models to predict the risk of multiple binary outcomes: a comparison of approaches’, *Statistics in Medicine*, 40(2), pp. 498–517. Available at: https://doi.org/10.1002/sim.8787.

Masangwi, S. *et al.* (2015) ‘The Pattern of Variation between Diarrhea and Malaria Coexistence with Corresponding Risk Factors in, Chikhwawa, Malawi: A Bivariate Multilevel Analysis’, *Int J Environ Res Public Health*, 12(7), pp. 8526–41. Available at: https://doi.org/10.3390/ijerph120708526.

Masibo, P.K., Humwa, F. and Macharia, T.N. (2020) ‘The double burden of overnutrition and undernutrition in mother−child dyads in Kenya: demographic and health survey data, 2014’, *Journal of Nutritional Science*, 9, p. e5. Available at: https://doi.org/10.1017/jns.2019.39.

McCullagh, P. and Nelder, J.A. (1989) *Generalized Linear Models*. 2nd edn. Chapman & Hall/CRC.

McGeorge, S. (2012a) *Morbidity - Comorbidity and multimorbidity. What do they mean? | British Geriatrics Society*. Available at: https://www.bgs.org.uk/resources/morbidity-comorbidity-and-multimorbidity-what-do-they-mean (Accessed: 20 August 2020).

McGeorge, S. (2012b) *Morbidity - Comorbidity and multimorbidity. What do they mean? | British Geriatrics Society*. Available at: https://www.bgs.org.uk/resources/morbidity-comorbidity-and-multimorbidity-what-do-they-mean (Accessed: 20 August 2020).

McNulty, K. (2021) *Handbook of Regression Modeling in People Analytics: With Examples in R and Python*. Available at: https://peopleanalytics-regression-book.org/ord-reg.html (Accessed: 9 August 2022).

Menon, M.P. and Yoon, S.S. (2015) ‘Prevalence and Factors Associated with Anemia Among Children Under 5 Years of Age--Uganda, 2009’, *The American journal of tropical medicine and hygiene*, 93(3), pp. 521–6. Available at: https://doi.org/10.4269/ajtmh.15-0102.

Merlo, J. *et al.* (2006) ‘A brief conceptual tutorial of multilevel analysis in social epidemiology: using measures of clustering in multilevel logistic regression to investigate contextual phenomena’, *Journal of Epidemiology and Community Health*, 60(4), pp. 290–297. Available at: https://doi.org/10.1136/jech.2004.029454.

Midi, H., Sarkar, S.K. and Rana, S. (2010) 'Collinearity diagnostics of binary logistic regression model', *Journal of Interdisciplinary Mathematics*, 13(3), pp. 253–267. Available at: https://doi.org/10.1080/09720502.2010.10700699.

Miller CM *et al.* (2007) 'Emerging health disparities in Botswana: examining the situation of orphans during the AIDS epidemic.', *Social Science & Medicine*, 64(12), pp. 2476–2486. Available at: https://doi.org/10.1016/j.socscimed.2007.03.002.

Ministry of Budget and National Planning (2016) 'National Policy on Food and Nutrition in Nigeria'. Ministry of Budget and National Planning. Available at: https://nigeria.savethechildren.net/sites/nigeria.savethechildren.net/files/library/NPFN%20manual%20design%20%20v13.pdf.

Mishra, V. and Retherford, R.D. (2007) 'Does biofuel smoke contribute to anaemia and stunting in early childhood?', *Int J Epidemiol*, 36(1), pp. 117–29. Available at: https://doi.org/10.1093/ije/dyl234.

MLwiN User Forum. (2009) *VPC in three and four levels binary response models*. Available at: https://www.cmm.bris.ac.uk/forum/viewtopic.php?t=60 (Accessed: 9 June 2021).

Mofina, A. *et al.* (2020) 'Home care rehabilitation therapy services for individuals with multimorbidity: A rapid review', *Journal of Comorbidity*, 10, p. 2235042X20976282. Available at: https://doi.org/10.1177/2235042X20976282.

Mohammed, S.H., Habtewold, T.D. and Esmaillzadeh, A. (2019) 'Household, maternal, and child related determinants of hemoglobin levels of Ethiopian children: hierarchical regression analysis', *BMC pediatrics*, 19(1), p. 113. Available at: https://doi.org/10.1186/s12887-019-1476-9.

Mohammed, S.H., Larijani, B. and Esmaillzadeh, A. (2019) 'Concurrent anemia and stunting in young children: prevalence, dietary and non-dietary associated factors', *Nutrition journal*, 18(1), p. 10. Available at: https://doi.org/10.1186/s12937-019-0436-4.

Mohanty, S.K. (2011) 'Multidimensional Poverty and Child Survival in India', *PLOS ONE*, 6(10), p. e26857. Available at: https://doi.org/10.1371/journal.pone.0026857.

Moïsi, J.C. *et al.* (2010) 'Geographic access to care is not a determinant of child mortality in a rural Kenyan setting with high health facility density', *BMC Public Health*, 10, p. 142. Available at: https://doi.org/10.1186/1471-2458-10-142.

Morakinyo, O.M., Balogun, F.M. and Fagbamigbe, A.F. (2018) 'Housing type and risk of malaria among under-five children in Nigeria: evidence from the malaria indicator survey', *Malaria Journal*, 17(1), p. 311. Available at: https://doi.org/10.1186/s12936-018-2463-6.

Moran, M. (2017) *Statistical Interaction: More than the Sum of its Parts, Statistics Solutions*. Available at: https://www.statisticssolutions.com/statistical-interaction-more-than-the-sum-of-its-parts/ (Accessed: 17 August 2022).

Moschovis, P.P. *et al.* (2018) 'Individual, maternal and household risk factors for anaemia among young children in sub-Saharan Africa: a cross-sectional study', *BMJ Open*, 8(5), p. e019654. Available at: https://doi.org/10.1136/bmjopen-2017-019654.

Muche, A. *et al.* (2021) 'Predictors of stunting among children age 6-59 months in Ethiopia using Bayesian multi-level analysis', *Sci Rep*. 2021/02/14 edn, 11(1), p. 3759. Available at: https://doi.org/10.1038/s41598-021-82755-7.

Muche, A. and Dewau, R. (2021) 'Severe stunting and its associated factors among children aged 6-59 months in Ethiopia; multilevel ordinal logistic regression model', *Ital J Pediatr*. 2021/07/28 edn, 47(1), p. 161. Available at: https://doi.org/10.1186/s13052-021-01110-8.

Muchie, K.F. (2016) 'Determinants of severity levels of anemia among children aged 6–59 months in Ethiopia: further analysis of the 2011 Ethiopian demographic and health survey', *BMC Nutrition*, 2(1). Available at: https://doi.org/10.1186/s40795-016-0093-3.

Mulatya, D.M. and Mutuku, F.W. (2020) 'Assessing Comorbidity of Diarrhea and Acute Respiratory Infections in Children Under 5 Years: Evidence From Kenya's Demographic Health Survey 2014', *Journal of Primary Care & Community Health*, 11, p. 2150132720925190. Available at: https://doi.org/10.1177/2150132720925190.

Murdock, D. (2017) *What are Health Determinants? - Individuals & Society*, *Study.com*. Available at: https://study.com/academy/lesson/what-are-health-determinants-individuals-society.html (Accessed: 2 October 2021).

Mustapha, A.R. (2005) 'Ethnic Structure, Inequality and Governance of the Public Sector in Nigeria', *Centre for Research on Inequality, Human Security and Ethnicity (CRISE)*, (18), p. 18.

Musuka, G.N. *et al.* (2021) 'Mothers' HIV status and their children's nutritional status: Insights from secondary analysis of the Zimbabwe Demographic and Health Survey data (2015–2016)', *Food Science & Nutrition*, 9(10), pp. 5509–5516. Available at: https://doi.org/10.1002/fsn3.2509.

Myrskylä, M. and Fenelon, A. (2012) 'Maternal Age and Offspring Adult Health: Evidence From the Health and Retirement Study', *Demography*, 49(4), p. 10.1007/s13524-012-0132–x. Available at: https://doi.org/10.1007/s13524-012-0132-x.

Nambiema, A., Robert, A. and Yaya, I. (2019) 'Prevalence and risk factors of anemia in children aged from 6 to 59 months in Togo: analysis from Togo demographic and health survey data, 2013-2014', *BMC Public Health*, 19(1), p. 215. Available at: https://doi.org/10.1186/s12889-019-6547-1.

Nandy, S., Daoud, A. and Gordon, D. (2016) 'Examining the changing profile of undernutrition in the context of food price rises and greater inequality', *Social Science & Medicine*, 149, pp. 153–163.

Nandy, S. and Jaime Miranda, J. (2008) 'Overlooking undernutrition? Using a composite index of anthropometric failure to assess how underweight misses and misleads the assessment of undernutrition in young children', *Social Science & Medicine (1982)*, 66(9–5), pp. 1963–1966. Available at: https://doi.org/10.1016/j.socscimed.2008.01.021.

Nankinga, O., Kwagala, B. and Walakira, E. (2019) *Maternal employment and child nutritional status in Uganda*. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6922416/ (Accessed: 11 August 2020).

National Health Service (NHS) (2017) *Sickle cell disease*, *nhs.uk*. Available at: https://www.nhs.uk/conditions/sickle-cell-disease/ (Accessed: 5 July 2021).

National Malaria Elimination Program (NMEP), National Population Commission (NPopC), National Bureau, and ICF International (2016) 'Nigeria Malaria Indicator Survey [MIS8] 2015', *Abuja, Nigeria, and Rockville, Maryland, USA: NMEP, NPopC, and ICF International*.

National Population, C. and I. C. F. International (2004) 'Nigeria Demographic and Health Survey 2003', *Federal Republic of Nigeria and MeasureDHS* [Preprint].

National Population, C. and I. C. F. International (2019) *Nigeria Demographic and Health Survey 2018*. Abuja, Nigeria, and Rockville, Maryland, USA: NPC and ICF.

National Population Commission and ICF Macro (2014) Nigeria Demographic and Health Survey 2013. Abuja, Nigeria, and Rockville, Maryland, USA: NPC and ICF

National Population Commission (NPC), National Malaria Control Program (NMCP) and International (2012) Nigeria Malaria Indicator Survey [MIS8] 2010, *Abuja, Nigeria, and Rockville, Maryland, USA: NMEP, NPopC, and ICF International*.

Ngnie-Teta, I., Receveur, O. and Kuate-Defo, B. (2007) 'Risk factors for moderate to severe anemia among children in Benin and Mali: insights from a multilevel analysis', *Food and nutrition bulletin*, 28(1), pp. 76–89. Available at: https://doi.org/10.1177/156482650702800109.

Nguyen, H. *et al.* (2019) 'Prevalence of multimorbidity in community settings: A systematic review and meta-analysis of observational studies', *Journal of Comorbidity*, 9, p. 2235042X19870934. Available at: https://doi.org/10.1177/2235042X19870934.

Nigeria Finder (2022) National Health Policy in Nigeria: What Does It Entail? [WWW Document]. URL https://nigerianfinder.com/national-health-policy-in-nigeria/ (accessed 1.31.23)

Nikoi, E. and Anthamatten, P. (2013) 'Childhood anaemia in Ghana: an examination of associated socioeconomic and health factors', *African Geographical Review*, 33(1), pp. 19–35. Available at: https://doi.org/10.1080/19376812.2013.838688.

Njau, J.D. *et al.* (2013) 'Exploring the impact of targeted distribution of free bed nets on households bed net ownership, socio-economic disparities and childhood malaria infection rates: analysis of national malaria survey data from three sub-Saharan Africa countries', *Malaria Journal*, 12. Available at: https://doi.org/10.1186/1475-2875-12-245.

Njau, J.D. *et al.* (2014) 'Investigating the important correlates of maternal education and childhood malaria infections', *The American journal of tropical medicine and hygiene*, 91(3), pp. 509–19. Available at: https://doi.org/10.4269/ajtmh.13-0713.

Northern Ireland (2015) *Breastfeeding | Department of Health, Health*. Available at: https://www.health-ni.gov.uk/articles/breastfeeding (Accessed: 2 October 2021).

NorthWindProject.com (2019) ‘Proposed Health Sector Reform Aimed At Improving Availability, Accessibility, Quality, Affordability Of Health Services-Okoh’, *Bureau of Public Enterprises - BPE*, 13 May. Available at: https://www.bpe.gov.ng/proposed-health-sector-reform-aimed-at-improving-availability-accessibility-quality-affordability-of-health-services-okoh/ (Accessed: 20 August 2022).

Nshimyiryo, A. *et al.* (2019) ‘Risk factors for stunting among children under five years: a cross-sectional population-based study in Rwanda using the 2015 Demographic and Health Survey’, *BMC Public Health*, 19(1), p. 175. Available at: https://doi.org/10.1186/s12889-019-6504-z.

Ntenda, P.A.M., Nkoka, O., *et al.* (2018) ‘Maternal anemia is a potential risk factor for anemia in children aged 6-59 months in Southern Africa: a multilevel analysis’, *BMC Public Health*, 18(1), p. 650. Available at: https://doi.org/10.1186/s12889-018-5568-5.

Ntenda, P.A.M., Chuang, K.Y., *et al.* (2018) ‘Multilevel Analysis of the Effects of Individual- and Community-Level Factors on Childhood Anemia, Severe Anemia, and Hemoglobin Concentration in Malawi’, *J Trop Pediatr*, 64(4), pp. 267–278. Available at: https://doi.org/10.1093/tropej/fmx059.

Ntenda, P.A.M. *et al.* (2019) ‘Clinical malaria and the potential risk of anaemia among preschool-aged children: a population-based study of the 2015-2016 Malawi micronutrient survey’, *Infectious diseases of poverty*, 8(1), p. 95. Available at: https://doi.org/10.1186/s40249-019-0607-8.

Ntoimo, L.F.C. and Odimegwu, C.O. (2014) ‘Health effects of single motherhood on children in sub-Saharan Africa: a cross-sectional study’, *BMC public health*, 14, p. 1145. Available at: https://doi.org/10.1186/1471-2458-14-1145.

Nzabakiriraho, J.D. and Gayawan, E. (2021) ‘Geostatistical modeling of malaria prevalence among under-five children in Rwanda’, *BMC Public Health*, 21(1), p. 369. Available at: https://doi.org/10.1186/s12889-021-10305-x.

Obasohan, D.N., Karo, H.A. and Obasohan, P. (2018) ‘Socioeconomic and demographic barriers to assessing ante natal care services among women of child bearing age in Wushishi local government area, Niger State, Nigeria’, *World Journal of Pharmaceutical Research*, 7(1), pp. 1264–1271.

Obasohan, P. (2014) ‘Religion, Ethnicity and Contraceptive Use among Reproductive age Women in Nigeria’, *International Journal of MCH and AIDS (IJMA)*, 3(1). Available at: https://doi.org/10.21106/ijma.39.

Obasohan, P.E. *et al.* (2020a) ‘A Scoping Review of the Risk Factors Associated with Anaemia among Children Under Five Years in Sub-Saharan African Countries’, *International Journal of Environmental Research and Public Health*, 17(23), p. 8829. Available at: https://doi.org/10.3390/ijerph17238829.

Obasohan, P.E. (2020) ‘Comparing Weighted Markov Chain and Auto-Regressive Integrated Moving Average in the Prediction of Under-5 Mortality Annual Closing Rates in Nigeria’, *International Journal of Statistics and Probability*, 9(3), p. 13. Available at: https://doi.org/10.5539/ijsp.v9n3p13.

Obasohan, P.E. *et al.* (2020b) 'Risk Factors Associated with Malnutrition among Children Under-Five Years in Sub-Saharan African Countries: A Scoping Review', *International Journal of Environmental Research and Public Health*, 17(23), p. 8782. Available at: https://doi.org/10.3390/ijerph17238782.

Obasohan, P.E. *et al.* (2021a) 'A Scoping Review of Selected Studies on Predictor Variables Associated with the Malaria Status among Children under Five Years in Sub-Saharan Africa', *International Journal of Environmental Research and Public Health*, 18(4), p. 2119. Available at: https://doi.org/10.3390/ijerph18042119.

Obasohan, P.E. *et al.* (2021b) 'Individual and Contextual Factors Associated with Malaria among Children 6–59 Months in Nigeria: A Multilevel Mixed Effect Logistic Model Approach', *International Journal of Environmental Research and Public Health*, 18(21), p. 11234. Available at: https://doi.org/10.3390/ijerph182111234.

Obasohan, P.E. *et al.* (2022) 'Individual, household and area predictors of anaemia among children aged 6–59 months in Nigeria', *Public Health in Practice*, 3, p. 100229. Available at: https://doi.org/10.1016/j.puhip.2022.100229.

Obasohan, P.E., Anosike, B.U. and Etsunyakpa, M.B. (2015) 'Determinants of Full Immunization Coverage and Reasons for its Failure for Children in Bida Emirate Area, Niger State, Nigeria', 3(10), p. 8.

Obasohan, P.E., Anosike, B.U. and Etsunyakpa, M.B. (2017) 'Knowledge, Attitude and Practice of Immunization Processes and its Coverage in Rural Communities of Bida Emirate Area, Niger State, Nigeria', 1(1). Available at: https://doi.org/10.13140/rg.2.2.15865.98400.

Oguoma, V.M. *et al.* (2021) 'Multilevel modelling of the risk of malaria among children aged under five years in Nigeria', *Transactions of The Royal Society of Tropical Medicine and Hygiene*, 115(5), pp. 482–494. Available at: https://doi.org/10.1093/trstmh/traa092.

Ojoniyi, O.O. *et al.* (2019) 'Does education offset the effect of maternal disadvantage on childhood anaemia in Tanzania? Evidence from a nationally representative cross-sectional study', *BMC pediatrics*, 19(1), p. 89. Available at: https://dx.doi.org/10.1186/s12887-019-1465-z.

Oladeinde, B. *et al.* (2012) 'Malaria and Anemia among Children in a Low Resource Setting In Nigeria', *Iran J Parasitol*, 7(3), pp. 31–7.

Oldenburg, C.E. *et al.* (2021) 'Distance to primary care facilities and healthcare utilization for preschool children in rural northwestern Burkina Faso: results from a surveillance cohort', *BMC Health Services Research*, 21(1), p. 212. Available at: https://doi.org/10.1186/s12913-021-06226-5.

Oldfield, M. (2019) 'Tackling the multidimensionality of child poverty', *The Lancet Child & Adolescent Health*, 3(4), p. 199. Available at: https://doi.org/10.1016/S2352-4642(19)30067-7.

Oni, G. and Samuel, G. (2016) *Effect of Birth Spacing on Under-five Mortality in Nigeria: A Proximate Determinant Approach (Birth Spacing and Under-five Mortality)*.

OpenStreetMap Wiki contributors (2020) ‘WikiProject Nigeria’. OpenStreetMap Wiki. Available at: https://wiki.openstreetmap.org/wiki/WikiProject_Nigeria (Accessed: 27 July 2020).

Orimadegun, A.E. *et al.* (2022) ‘Non-Malaria Causes of Fever among under-5 Children with Negative Results for Malaria Rapid Diagnostic Test in South-Western Nigeria’, *Journal of Tropical Pediatrics*, 68(4), p. fmac061. Available at: https://doi.org/10.1093/tropej/fmac061.

Oshio, T. and Kan, M. (2014) ‘Multidimensional poverty and health: evidence from a nationwide survey in Japan’, *International Journal for Equity in Health*, 13. Available at: https://doi.org/10.1186/s12939-014-0128-9.

Osterbauer, B. *et al.* (2012) ‘Factors associated with malaria parasitaemia, malnutrition, and anaemia among HIV-exposed and unexposed Ugandan infants: a cross-sectional survey’, *Malaria Journal*, 11(1), p. 432. Available at: https://doi.org/10.1186/1475-2875-11-432.

Oyibo, W. *et al.* (2021) ‘Geographical and temporal variation in reduction of malaria infection among children under 5 years of age throughout Nigeria’, *BMJ Global Health*, 6(2), p. e004250. Available at: https://doi.org/10.1136/bmjgh-2020-004250.

Page, C.M., Patel, A. and Hibberd, P.L. (2015) ‘Does smoke from biomass fuel contribute to anemia in pregnant women in Nagpur, India? A cross-sectional study’, *PloS one*, 10(5), p. e0127890. Available at: https://doi.org/10.1371/journal.pone.0127890.

Parbey, P.A. *et al.* (2019) *Risk Factors of Anaemia among Children under Five Years in the Hohoe Municipality, Ghana: A Case Control Study*, *Anemia*. Available at: https://www.hindawi.com/journals/anemia/2019/2139717/ (Accessed: 9 April 2020).

Park, B., Lee, H.A. and Park, H. (2019) ‘Use of latent class analysis to identify multimorbidity patterns and associated factors in Korean adults aged 50 years and older’, *PLOS ONE*, 14(11), p. e0216259. Available at: https://doi.org/10.1371/journal.pone.0216259.

Pathirana, T.I. and Jackson, C.A. (2018) ‘Socioeconomic status and multimorbidity: a systematic review and meta-analysis’, *Australian and New Zealand Journal of Public Health*, 42(2), pp. 186–194. Available at: https://doi.org/10.1111/1753-6405.12762.

Philadelphia, T.C.H. of (2014) *Small for Gestational Age*. The Children’s Hospital of Philadelphia. Available at: https://www.chop.edu/conditions-diseases/small-gestational-age (Accessed: 19 August 2022).

Pondei, K., Kunle-Olowu, O.E. and Peterside, O. (2013) ‘The aetiology of non-malarial febrile illness in children in the malaria-endemic Niger Delta Region of Nigeria’, *Asian Pacific Journal of Tropical Disease*, 3(1), pp. 56–60. Available at: https://doi.org/10.1016/S2222-1808(13)60012-2.

Popay, J. *et al.* (2006) *Guidance on the Conduct of Narrative Synthesis in Systematic Reviews: A Product from the ESRC Methods Programme*. (Version 1).

Prestevez (2016) *r - How to compute intraclass correlation (ICC) for THREE-level negative binomial hierarchical model?, Cross Validated*. Available at:

https://stats.stackexchange.com/questions/174071/how-to-compute-intraclass-correlation-icc-for-three-level-negative-binomial-hi (Accessed: 11 May 2021).

Public Health England (2018) *Chapter 3: trends in morbidity and risk factors, GOV.UK*. Available at: https://www.gov.uk/government/publications/health-profile-for-england-2018/chapter-3-trends-in-morbidity-and-risk-factors (Accessed: 1 July 2021).

Rahman, M.M. *et al.* (2016) 'Maternal anemia and risk of adverse birth and health outcomes in low- and middle-income countries: systematic review and meta-analysis1,2', *The American Journal of Clinical Nutrition*, 103(2), pp. 495–504. Available at: https://doi.org/10.3945/ajcn.115.107896.

Raman, R. and Hedeker, D. (2005) 'A mixed-effects regression model for three-level ordinal response data', *Statistics in Medicine*, 24(21), pp. 3331–3345. Available at: https://doi.org/10.1002/sim.2186.

Razak, F., Finlay, J.E. and Subramanian, S.V. (2013) 'Maternal underweight and child growth and development', *The Lancet*, 381(9867), pp. 626–627. Available at: https://doi.org/10.1016/S0140-6736(13)60344-X.

Ready to Beat Malaria (RBM). (2020) *Commonwealth leaders respond to a global call to action and commit to halve malaria across the Commonwealth by 2023*. Available at: https://endmalaria.org/news/commonwealth-leaders-respond-global-call-action-and-commit-halve-malaria-across-commonwealth (Accessed: 8 June 2021).

Roomaney, R.A. *et al.* (2021) 'Multimorbidity in South Africa: a systematic review of prevalence studies', *BMJ Open*, 11:e048676., p. 11. Available at: https://doi.org/doi:10.1136/bmjopen-2021-048676.

Rozi, S. *et al.* (2016) 'Multilevel Modeling of Binary Outcomes with Three-Level Complex Health Survey Data', *Open Journal of Epidemiology*, 7(1), pp. 27–43. Available at: https://doi.org/10.4236/ojepi.2017.71004.

Rutayisire, R. *et al.* (2020) 'Trends in the Prevalence and Associated Contributing Factors of Stunting in Children Under Five Years of Age. Secondary Data Analysis of 2005, 2010 and 2014-2015 Rwanda Demographic and Health Surveys', *Rwanda Journal of Medicine and Health Sciences*, 3(1), pp. 71–85. Available at: https://doi.org/10.4314/rjmhs.v3i1.9.

Rutherford, M.E. *et al.* (2009) 'Access to health care and mortality of children under 5 years of age in the Gambia: a case–control study', *Bulletin of the World Health Organization*, 87(3), pp. 216–224. Available at: https://doi.org/10.2471/BLT.08.052175.

Sakwe, N. *et al.* (2019) 'Relationship between malaria, anaemia, nutritional and socio-economic status amongst under-ten children, in the North Region of Cameroon: A cross-sectional assessment', *PloS one*. Edited by B. Ghose, 14(6), p. e0218442. Available at: https://doi.org/10.1371/journal.pone.0218442.

Salako, L.A. *et al.* (1990) 'Malaria in Nigeria: a revisit', *Annals of Tropical Medicine and Parasitology*, 84(5), pp. 435–445. Available at: https://doi.org/10.1080/00034983.1990.11812493.

Santos, M.E. and Alkire, S. (2011) *Multidimensional Poverty Index (MPI)*. Final Draft, p. 35. Available at: https://www.ophi.org.uk/wp-content/uploads/MPI-Primer.pdf (Accessed: 18 August 2020).

Seboka, B.T. *et al.* (2021) 'Spatial Variations and Determinants of Acute Malnutrition Among Under-Five Children in Ethiopia: Evidence from 2019 Ethiopian Demographic Health Survey', *Annals of Global Health*, 87(1), p. 114. Available at: https://doi.org/10.5334/aogh.3500.

Semakula, H.M. *et al.* (2015) 'Potential of household environmental resources and practices in eliminating residual malaria transmission: a case study of Tanzania, Burundi, Malawi and Liberia', *African Health Sciences*, 15(3), pp. 819–827. Available at: https://doi.org/10.4314/ahs.v15i3.16.

Semedo, R.M. *et al.* (2014) 'Prevalence of anaemia and associated factors among children below five years of age in Cape Verde, West Africa', *Journal of health, population, and nutrition*, 32(4), pp. 646–57.

Shao, S.-Y. *et al.* (2019) 'Impact of national Human Development Index on liver cancer outcomes: Transition from 2008 to 2018', *World Journal of Gastroenterology*, 25(32), pp. 4749–4763. Available at: https://doi.org/10.3748/wjg.v25.i32.4749.

Simelane, M.S., Chemhaka, G.B. and Zwane, E. (2020) 'A multilevel analysis of individual, household and community level factors on stunting among children aged 6-59 months in Eswatini: A secondary analysis of the Eswatini 2010 and 2014 Multiple Indicator Cluster Surveys', *PLoS One*. 2020/10/31 edn, 15(10), p. e0241548. Available at: https://doi.org/10.1371/journal.pone.0241548.

Siri, J.G. (2014) 'Independent Associations of Maternal Education and Household Wealth with Malaria Risk in Children', *Ecology and Society*, 19(1). Available at: https://doi.org/10.5751/es-06134-190133.

SlidetoDoc (2021) *Lecture 5 Morbidity of population as medicalsocial problem*. Available at: https://slidetodoc.com/lecture-5-morbidity-of-population-as-medicalsocial-problem/ (Accessed: 1 July 2021).

Smith, G. (2018) Step away from stepwise. Journal of Big Data 5, 32. https://doi.org/10.1186/s40537-018-0143-6.

Smith, T. and Shively, G. (2019) 'Multilevel analysis of individual, household, and community factors influencing child growth in Nepal', *BMC Pediatrics*, 19(1), p. 91. Available at: https://doi.org/10.1186/s12887-019-1469-8.

Sommet, N. and Morselli, D. (2017) 'Keep Calm and Learn Multilevel Logistic Modeling: A Simplified Three-Step Procedure Using Stata, R, Mplus, and SPSS', *International Review of Social Psychology*, 30(1), pp. 203–218. Available at: https://doi.org/10.5334/irsp.90.

Sribney, B. (2022) *Stata | FAQ: Problems with stepwise regression*. Available at: https://www.stata.com/support/faqs/statistics/stepwise-regression-problems/ (Accessed: 27 April 2022).

Ssentongo, P. *et al.* (2019) 'Regional, racial, gender, and tumor biology disparities in breast cancer survival rates in Africa: A systematic review and meta-analysis', *PLoS ONE*, 14(11). Available at: https://doi.org/10.1371/journal.pone.0225039.

Sserwanja, Q. *et al.* (2021) 'Factors associated with childhood overweight and obesity in Uganda: a national survey', *Bmc Public Health*, 21(1). Available at: https://doi.org/10.1186/s12889-021-11567-1.

Stat Trek (2022) *Interactions in Regression*. Available at: https://stattrek.com/multiple-regression/interaction.aspx (Accessed: 8 May 2022).

Stata.com (2021) 'meologit — Multilevel mixed-effects ordered logistic regression'. Stata. Available at: https://www.stata.com/manuals13/memeologit.pdf.

StataCorp. (2021) *Stata Release 17*. College Station, TX: StataCorp LLC: Statistical Software. Available at: https://www.stata.com/manuals/me.pdf.

Sumbele, I.U. *et al.* (2015) 'Malarial anaemia and anaemia severity in apparently healthy primary school children in urban and rural settings in the Mount Cameroon area: cross sectional survey', *PloS one*, 10(4), p. e0123549. Available at: https://doi.org/10.1371/journal.pone.0123549.

Suzuki, E. (2015) *In 2015, the global child mortality rate is less than half its 1990 levels, but the MDG 4 target has not been met*. Available at: https://blogs.worldbank.org/opendata/2015-global-child-mortality-rate-less-half-its990-levels-mdg-4-target-has-not-been-met (Accessed: 25 June 2020).

Takele, K., Zewotir, T. and Ndanguza, D. (2019) 'Understanding correlates of child stunting in Ethiopia using generalized linear mixed models', *BMC Public Health*, 19(1), p. 626. Available at: https://doi.org/10.1186/s12889-019-6984-x.

Taylor, C. *et al.* (2021) 'Estimating the Fraction of Severe Malaria among Malaria-Positive Children: Analysis of Household Surveys in 19 Malaria-Endemic Countries in Africa', *The American Journal of Tropical Medicine and Hygiene*, 104(4), pp. 1375–1382. Available at: https://doi.org/10.4269/ajtmh.20-1351.

Teh, R.N. *et al.* (2018) 'Malaria parasitaemia, anaemia and malnutrition in children less than 15 years residing in different altitudes along the slope of Mount Cameroon: prevalence, intensity and risk factors', *Malaria Journal*, 17(1), p. 336. Available at: https://doi.org/10.1186/s12936-018-2492-1.

Tesema, G.A., Tessema, Z.T., *et al.* (2021) 'Geographic weighted regression analysis of hot spots of anemia and its associated factors among children aged 6-59 months in Ethiopia: A geographic weighted regression analysis and multilevel robust Poisson regression analysis', *PloS One*, 16(11), p. e0259147. Available at: https://doi.org/10.1371/journal.pone.0259147.

Tesema, G.A., Yeshaw, Y., *et al.* (2021) 'Pooled prevalence and associated factors of chronic undernutrition among under-five children in East Africa: A multilevel analysis', *PLoS One*. 2021/03/26 edn, 16(3), p. e0248637. Available at: https://doi.org/10.1371/journal.pone.0248637.

Tesema, G.A., Worku, M.G., *et al.* (2021) 'Prevalence and determinants of severity levels of anemia among children aged 6-59 months in sub-Saharan Africa: A multilevel ordinal logistic regression analysis', *PloS One*, 16(4), p. e0249978. Available at: https://doi.org/10.1371/journal.pone.0249978.

Tesfaw, L.M. and Fenta, H.M. (2021) 'Multivariate logistic regression analysis on the association between anthropometric indicators of under-five children in Nigeria: NDHS 2018', *BMC Pediatr*. 2021/04/24 edn, 21(1), p. 193. Available at: https://doi.org/10.1186/s12887-021-02657-5.

The DHS Program (2016) *Wealth Index* [WWW Document]. URL https://dhsprogram.com/topics/wealth-index/ (accessed 1.31.23)

The DHS Program (2020) *Demographic and Health Survey (DHS): What We Do-DHS Overview*. Available at: https://dhsprogram.com/What-We-Do/Survey-Types/DHS.cfm (Accessed: 6 March 2020).

The EUPATI (2022) *Risk Factors in Health and Disease: What are risk factors?* Available at: https://learning.eupati.eu/mod/book/view.php?id=215&chapterid=24 (Accessed: 10 June 2022).

The Stata Forum (2017) *Interpretation of interaction term coefficients of an ordinal logistic regression. - Statalist*. Available at: https://www.statalist.org/forums/forum/general-stata-discussion/general/1409237-interpretation-of-interaction-term-coefficients-of-an-ordinal-logistic-regression (Accessed: 15 August 2022).

The Stata Forums (2021) *meologit and parallel odds assumption - Statalist*. Available at: https://www.statalist.org/forums/forum/general-stata-discussion/general/1372125-meologit-and-parallel-odds-assumption (Accessed: 31 July 2021).

Tradingeconomics (2020) *Nigeria - Population Density (people Per Sq. Km) - 1961-2018 Data | 2020 Forecast*. Available at: https://tradingeconomics.com/nigeria/population-density-people-per-sq-km-wb-data.html (Accessed: 27 July 2020).

Tran, T.D. *et al.* (2019) 'Co-morbid anaemia and stunting among children of pre-school age in low- and middle-income countries: a syndemic', *Public Health Nutrition*, 22(1), pp. 35–43. Available at: https://doi.org/10.1017/S136898001800232X.

Tricco, A.C. *et al.* (2018) 'PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation', *Ann Intern Med*, 169(7), pp. 467–473. Available at: https://doi.org/10.7326/M18-0850.

Tugwell, P. and Knottnerus, J.A. (2019) 'Multimorbidity and Comorbidity are now separate MESH headings', *Journal of Clinical Epidemiology*, 105, pp. vi–viii. Available at: https://doi.org/10.1016/j.jclinepi.2018.11.019.

Tusting, L.S. *et al.* (2020) 'Housing and child health in sub-Saharan Africa: A cross-sectional analysis.', *PLoS Medicine*, 17(3), pp. 1–18. Available at: https://doi.org/10.1371/journal.pmed.1003055.

Ugwu, C.L.J. and Zewotir, T. (2020) 'Evaluating the Effects of Climate and Environmental Factors on Under-5 Children Malaria Spatial Distribution Using Generalized Additive Models (GAMs)', *J Epidemiol Glob Health*, 10(4). Available at: https://doi.org/10.2991/jegh.k.200814.001.

Ugwu, C.L.J. and Zewotir, T.T. (2018) 'Using mixed effects logistic regression models for complex survey data on malaria rapid diagnostic test results', *Malaria Journal*, 17. Available at: https://doi.org/10.1186/s12936-018-2604-y.

Ukwuani, F.A. and Suchindran, C.M. (2003) 'Implications of women's work for child nutritional status in sub-Saharan Africa: a case study of Nigeria', *Social Science & Medicine (1982)*, 56(10), pp. 2109–2121. Available at: https://doi.org/10.1016/s0277-9536(02)00205-8.

UNICEF (2022) *Childhood diseases*. Available at: https://www.unicef.org/health/childhood-diseases (Accessed: 9 July 2022).

UNICEF / WHO / World Bank Group (2019) *Levels and trends in child malnutrition: Key findings of the 2019 edition*. Available at: https://www.who.int/nutgrowthdb/jme-2019-key-findings.pdf?ua=1 (Accessed: 8 March 2020).

United Nations (2022) THE 17 GOALS | Sustainable Development [WWW Document]. URL https://sdgs.un.org/goals (accessed 1.31.23).

United Nations (2022) Health and population | Department of Economic and Social Affairs [WWW Document]. URL https://sdgs.un.org/topics/health-and-population (accessed 1.31.23).

United Nations (2008) United Nations Millennium Development Goals [WWW Document]. URL https://www.un.org/millenniumgoals/ (accessed 1.31.23).

United Nations Development Programme (UNDP) (2018) 'National Human Development Report 2018: Nigeria | Human Development Reports', *United Nations Development Programme (UNDP)* [Preprint]. Available at: http://hdr.undp.org/en/content/national-human-development-report-2018-nigeria (Accessed: 17 August 2020).

United Nations-Nigeria (2022) Sustainable Development Goals: Our work on Sustainable Development Goals in Nigeria [WWW Document]. URL https://nigeria.un.org/en/sdgs (accessed 1.31.23).

Uwiringiyimana, V. *et al.* (2022) 'Bayesian geostatistical modelling of stunting in Rwanda: risk factors and spatially explicit residual stunting burden', *BMC Public Health*. 2022/01/26 edn, 22(1), p. 159. Available at: https://doi.org/10.1186/s12889-022-12552-y.

Valderas, J.M. *et al.* (2009) 'Defining Comorbidity: Implications for Understanding Health and Health Services', *Annals of Family Medicine*, 7(4), pp. 357–363. Available at: https://doi.org/10.1370/afm.983.

Wagstaff, A. (2002) *Inequalities in Health in Developing Countries: Swimming against the Tide?* The World Bank (Policy Research Working Papers). Available at: https://doi.org/10.1596/1813-9450-2795.

Walters, S.J., Campbell, M.J. and Machin, D. (2021) *A text book for the health sciences*. 5th edn. Wiley.

Wang, A. and Arah, O.A. (2017) 'The impact of human development on individual health: a causal mediation analysis examining pathways through education and body mass index', *PeerJ*, 5. Available at: https://doi.org/10.7717/peerj.3053.

Wanzira, H. *et al.* (2017) 'Factors associated with malaria parasitaemia among children under 5 years in Uganda: a secondary data analysis of the 2014 Malaria Indicator Survey dataset', *Malaria Journal*, 16(1), p. 191. Available at: https://doi.org/10.1186/s12936-017-1847-3.

Wikipedia Contributors (2019) 'Demographic and Health Surveys', *In Wikipedia, The Free Encyclopedia*. Available at: https://en.wikipedia.org/w/index.php?title=Demographic_and_Health_Surveys&oldid=927617265 (Accessed: 5 March 2020).

Williams, R. (2006) 'Generalized Ordered Logit/Partial Proportional Odds Models for Ordinal Dependent Variables', *The Stata Journal*, 6(1), pp. 58–82. Available at: https://doi.org/10.1177/1536867X0600600104.

Williams, R. (2012) 'Using the Margins Command to Estimate and Interpret Adjusted Predictions and Marginal Effects', *The Stata Journal*, 12(2), pp. 308–331. Available at: https://doi.org/10.1177/1536867X1201200209.

Williams, R. (2015) 'Multicollinearity', University of Notre, available at: https://www3.nd.edu/~rwilliam/.

Williams, R. (2021a) 'Adjusted Predictions & Marginal Effects for Multiple Outcome Models & Commands (including ologit, mlogit, oglm, & gologit2)', p. 10.

Williams, R. (2021b) 'Interpreting Interaction Effects; Interaction Effects and Centering' available at: https://www3.nd.edu/~rwilliam/, p. 8.

Wondimu, H. and Dejene, K. (2022) 'Determinants of under-five malnutrition, significant changes, and policy implications in the Ethiopian Demographic Health Survey, 2019', *Discover Sustainability*, 3(1), p. 16. Available at: https://doi.org/10.1007/s43621-022-00087-6.

Woolley, K.E. *et al.* (2022) 'Cooking outdoors or with cleaner fuels does not increase malarial risk in children under 5 years: a cross-sectional study of 17 sub-Saharan African countries', *Malaria Journal*, 21(1), p. 133. Available at: https://doi.org/10.1186/s12936-022-04152-3.

World Health Organization (2008) *Closing the gap in a generation: health equity through action on the social determinants of health - Final report of the commission on social determinants of health*. Available at: https://www.who.int/publications-detail-redirect/WHO-IER-CSDH-08.1 (Accessed: 10 June 2022).

World Health Organization (2022) *Child mortality and causes of death, The Global Health Observatory*. Available at: https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/child-mortality-and-causes-of-death (Accessed: 9 July 2022).

World Health Organisation (2011) *Child mortality, WHO*. World Health Organization. Available at: https://www.who.int/pmnch/media/press_materials/fs/fs_mdg4_childmortality/en/ (Accessed: 20 August 2020).

World Health Organisation (2014) *World Malaria Report 2014*. Available at: https://www.who.int/malaria/publications/world_malaria_report_2014/en/ (Accessed: 21 February 2019).

World Health Organisation (2017) 'Prevalence of anaemia in children under 5 years'. Available at: https://www.who.int/data/maternal-newborn-child-adolescent/monitor (Accessed: 23 July 2020).

World Health Organisation (2019) *Children: reducing mortality*. Available at: https://www.who.int/news-room/fact-sheets/detail/children-reducing-mortality (Accessed: 22 July 2020).

World Health Organisation (2020) *Fact sheets - Malnutrition*. Available at: https://www.who.int/news-room/fact-sheets/detail/malnutrition (Accessed: 31 May 2020).

World Health Organization (2018) *Health inequities and their causes*. Available at: https://www.who.int/news-room/facts-in-pictures/detail/health-inequities-and-their-causes (Accessed: 10 June 2022).

World Health Organization (WHO) (2017) 'Children: Reducing Mortality.' WHO. Available at: http://www.who.int/mediacentre/factsheets/fs178/en/ (Accessed: 5 March 2018).

Yang, D. *et al.* (2020) 'Drinking water and sanitation conditions are associated with the risk of malaria among children under five years old in sub-Saharan Africa: A logistic regression model analysis of national survey data', *Journal of Advanced Research*, 21, pp. 1–13. Available at: https://doi.org/10.1016/j.jare.2019.09.001.

Yaya, S. *et al.* (2019) 'Effects of birth spacing on adverse childhood health outcomes: evidence from 34 countries in sub-Saharan Africa', *The Journal of Maternal-Fetal & Neonatal Medicine: The Official Journal of the European Association of Perinatal Medicine, the Federation of Asia and Oceania Perinatal Societies, the International Society of Perinatal Obstetricians*, pp. 1–8. Available at: https://doi.org/10.1080/14767058.2019.1576623.

ZACH (2021) 'How to Interpret Log-Likelihood Values (With Examples)', *Statology*, 31 August. Available at: https://www.statology.org/interpret-log-likelihood/ (Accessed: 1 February 2022).

Zgambo, M., Mbakaya, B.C. and Kalembo, F.W. (2017) 'Prevalence and factors associated with malaria parasitaemia in children under the age of five years in Malawi: A comparison study of the 2012 and 2014 Malaria Indicator Surveys (MISs)', *Plos One*, 12(4), p. e0175537. Available at: https://doi.org/10.1371/journal.pone.0175537.

Appendices

Appendix A: Reports from the quantitative analyses

A.1: Outputs from multicollinearity diagnostic tests

	Before				After			
Variables	VIF	SQRT VIF	Tolerance	Squared	VIF	SQRT VIF	Tolerance	Squared
Child's sex	1.04	1.02	0.9626	0.0374	1.02	1.01	0.9782	0.0218
Child's age	1.28	1.13	0.7817	0.2183	2.11	1.45	0.4734	0.5266
Child's birth size	1.06	1.03	0.9416	0.0584	1.04	1.02	0.9612	0.0388
Child's birth order	3.26	1.81	0.3067	0.6933	2.98	1.73	0.3354	0.6646
Child's preceding birth intervals	1.55	1.24	0.6470	0.353	1.40	1.18	0.7142	0.2858
Child took Vitamin A	1.50	1.22	0.6674	0.3326	1.44	1.20	0.6936	0.3064
Child took Iron supplements	1.35	1.16	0.7403	0.2597	1.35	1.16	0.7419	0.2581
Duration of breastfeeding	1.47	1.21	0.6821	0.3179	2.08	1.44	0.4819	0.5181
Child is dewormed	1.49	1.22	0.6725	0.3275	1.48	1.22	0.6770	0.323
Child's anaemia status	1.12	1.06	0.8955	0.1045	1.15	1.07	0.8679	0.1321
Malaria status	1.28	1.13	0.7824	0.2176	1.24	1.11	0.8068	0.1932
Nutrition status	1.21	1.10	0.8259	0.1741	1.19	1.09	0.8388	0.1612
Fever status	1.33	1.15	0.7513	0.2487	1.30	1.14	0.7696	0.2304
Acute respiratory infections	1.25	1.12	0.8001	0.1999	1.21	1.10	0.8245	0.1755
Child had diarrheal	1.17	1.08	0.8538	0.1462	1.14	1.07	0.8763	0.1237
Child's place of delivery	1.83	1.35	0.5463	0.4537	1.67	1.29	0.6004	0.3996
Maternal age group	2.64	1.63	0.3784	0.6216	2.75	1.66	0.3638	0.6362
Maternal work status	1.24	1.11	0.8071	0.1929	1.26	1.12	0.7923	0.2077
Maternal age at first birth	1.61	1.27	0.6228	0.3772	1.50	1.23	0.6651	0.3349
Maternal highest education status	3.64	1.91	0.2750	0.725	3.21	1.79	0.3118	0.6882
Mother lives with partner	1.78	1.33	0.5629	0.4371	1.79	1.34	0.5597	0.4403
Maternal autonomy level	1.42	1.19	0.7046	0.2954	1.42	1.19	0.7056	0.2944
Maternal slept under bed net	3.22	1.79	0.3106	0.6894	1.59	1.26	0.6288	0.3712
Maternal ante-natal care visit	2.15	1.47	0.4658	0.5342	2.30	1.52	0.4356	0.5644
Maternal religious status	2.18	1.48	0.4587	0.5413	1.78	1.34	0.5607	0.4393
Maternal ethnicity	1.79	1.34	0.5592	0.4408	1.66	1.29	0.6038	0.3962
Maternal took iron tabs during child's pregnancy	1.80	1.34	0.5541	0.4459	1.88	1.37	0.5333	0.4667
Maternal anaemia status	1.08	1.04	0.9231	0.0769	1.06	1.03	0.9445	0.0555
Maternal BMI	1.19	1.09	0.8423	0.1577	1.17	1.08	0.8511	0.1489
Paternal work status	1.09	1.04	0.9200	0.08	1.05	1.03	0.9479	0.0521
Paternal education status	2.18	1.48	0.4580	0.542	2.12	1.45	0.4725	0.5275
Household wealth status	6.55	2.56	0.1527	0.8473	4.35	2.09	0.2297	0.7703
Household age group	1.66	1.29	0.6008	0.3992	1.64	1.28	0.6105	0.3895
Children under-5 slept under bed net	6.55	2.56	0.1528	0.8472	1.53	1.24	0.6553	0.3447
Number of under-5 in household	1.48	1.22	0.6743	0.3257	1.36	1.16	0.7373	0.2627
Number of rooms for sleep	1.88	1.37	0.5327	0.4673	1.77	1.33	0.5659	0.4341
Electricity in household	2.07	1.44	0.4840	0.516	2.10	1.45	0.4756	0.5244
Improved water source	1.35	1.16	0.7413	0.2587				
Type of toilet facility	1.57	1.25	0.6359	0.3641				

Type of cooking fuel	1.56	1.25	0.6419	0.3581	
Type of floor materials	1.78	1.34	0.5609	0.4391	
Type of roof materials	1.29	1.14	0.7745	0.2255	
Type of wall materials	2.46	1.57	0.4060	0.594	
Sex of household head	1.77	1.33	0.5642	0.4358	
Shared toilet facility with others	1.35	1.16	0.7402	0.2598	
Household has bed net for sleeping	11.25	3.35	0.0889	0.9111	1.79 1.34 0.5579 0.4421
Household size	2.89	1.70	0.3456	0.6544	2.52 1.59 0.3968 0.6032
Youngest child stool disposal	1.25	1.12	0.7994	0.2006	
Frequency of watching television	2.03	1.42	0.4936	0.5064	
Proportion of community wealth level	3.49	1.87	0.2868	0.7132	3.13 1.77 0.3192 0.6808
Proportion of community distance to health facility is no big problem	1.24	1.11	0.8077	0.1923	1.27 1.13 0.7880 0.212
Proportion of community maternal education level	3.85	1.96	0.2599	0.7401	3.08 1.76 0.3245 0.6755
Proportion of community households with no bed net	1.75	1.32	0.5726	0.4274	1.52 1.23 0.6580 0.342
Multidimensional Poverty Index by State MPI	4.26	2.06	0.2349	0.7651	3.48 1.86 0.2876 0.7124
Human Development Index by State HDI	3.85	1.96	0.2598	0.7402	3.60 1.90 0.2781 0.7219
Gender Inequality Index by State GII	2.57	1.60	0.3889	0.6111	2.17 1.47 0.4604 0.5396
Region of residence	1.75	1.32	0.5713	0.4287	1.62 1.27 0.6169 0.3831
Type of place of residence	1.72	1.31	0.5806	0.4194	1.61 1.27 0.6208 0.3792
Mean VIF	2.2				1.85

A.2: Multilevel multivariate models of predictors of anaemia with adjusted odds ratios (AOR) among children aged 6–59 months in Nigeria

	Model 2 (n=7896) (Child-related factors only)			Model 3 (n=7896) (Child- & parental-related factors only)			Model 4 (n=7896) (Level-1 factors only)			Model 5 (n=7896) (Added level-3 factors only)		
Variables	**AOR**	**P-value**	**(95%CI)**	**AOR**	**P-value**	**(95%CI)**	**AOR**	**P-value**	**(95%CI)**	**AOR**	**P-value**	**(95%CI)**
Child's sex												
Male	1			1			1			1		
Female	0.85	0.002	(0.758-0.942)	0.84	0.002	(0.752-0.936)	0.84	0.001	(0.749-0.932)	0.83	0.001	(0.748-0.932)
Child's age in group			(-)			(-)			(-)			(-)
6-11 months	1			1			1			1		
12-23 months	0.92	0.464	(0.744-1.145)	0.9	0.331	(0.723-1.116)	0.9	0.328	(0.722-1.115)	0.91	0.377	(0.729-1.127)
24-35 months	0.55	<0.0001	(0.415-0.721)	0.51	<0.0001	(0.382-0.669)	0.51	<0.0001	(0.385-0.674)	0.52	<0.0001	(0.39-0.683)
36-47 months	0.44	<0.0001	(0.332-0.579)	0.41	<0.0001	(0.308-0.541)	0.41	<0.0001	(0.306-0.538)	0.41	<0.0001	(0.311-0.546)
48-59 months	0.32	<0.0001	(0.244-0.428)	0.3	<0.0001	(0.225-0.397)	0.3	<0.0001	(0.223-0.395)	0.3	<0.0001	(0.227-0.402)
Preceding birth interval							(-)				(-)	
None	1			1			1			1		
8-24 months	1.36	0.001	(1.143-1.623)	1.35	0.001	(1.129-1.611)	1.32	0.004	(1.09-1.588)	1.31	0.004	(1.089-1.587)
25-35 months	1.22	0.016	(1.038-1.443)	1.17	0.062	(0.992-1.385)	1.14	0.145	(0.955-1.367)	1.15	0.133	(0.959-1.372)
36-59 months	1.17	0.076	(0.984-1.382)	1.11	0.241	(0.933-1.318)	1.09	0.338	(0.91-1.315)	1.11	0.276	(0.922-1.331)
60+ months	0.99	0.929	(0.789-1.241)	0.94	0.621	(0.75-1.187)	0.94	0.636	(0.744-1.198)	0.95	0.692	(0.751-1.209)
Took Iron supplements												
No	1			1			1			1		
Yes	1.05	0.503	(0.903-1.232)	1.08	0.317	(0.926-1.266)	1.1	0.236	(0.94-1.286)	1.09	0.272	(0.933-1.277)
Duration of breastfeeding						(-)			(-)			(-)
Ever breastfed, not currently breastfeeding	1			1			1			1		

Never breastfed	0.83	0.384	(0.537-1.27)	0.84	0.445	(0.548-1.303)	0.84	0.431	(0.545-1.296)	0.82	0.367	(0.531-1.264)
Still breastfeeding	1.45	0.001	(1.169-1.789)	1.36	0.005	(1.094-1.68)	1.34	0.007	(1.084-1.666)	1.36	0.006	(1.093-1.68)
Child took deworming drug in last 6months												
No	1			1			1			1		
Yes	0.88	0.08	(0.755-1.016)	0.92	0.25	(0.789-1.064)	0.92	0.302	(0.795-1.074)	0.89	0.145	(0.769-1.039)
Malaria status			(-)			(-)			(-)			(-)
Negative	1			1			1			1		
Positive	4.23	<0.0001	(3.691-4.849)	3.86	<0.0001	(3.362-4.432)	3.7	<0.0001	(3.223-4.257)	3.7	<0.0001	(3.218-4.251)
Nutritional status			(-)			(-)			(-)			(-)
Well-nourished	1			1			1			1		
Poorly nourished	1.41	<0.0001	(1.251-1.594)	1.31	<0.0001	(1.154-1.476)	1.3	<0.0001	(1.146-1.467)	1.31	<0.0001	(1.159-1.484)
Child had Fever in last 2 weeks before the survey												
No	1			1			1			1		
Yes	1.27	0.001	(1.104-1.451)	1.27	0.001	(1.107-1.456)	1.26	0.001	(1.1-1.447)	1.26	0.001	(1.102-1.45)
Place of child's delivery			(-)			(-)			(-)			(-)
Home	1			1			1			1		
Public facility	0.77	<0.0001	(0.671-0.893)	0.92	0.283	(0.791-1.071)	0.95	0.479	(0.812-1.103)	0.94	0.419	(0.805-1.095)
Private facility	0.79	0.014	(0.653-0.953)	0.94	0.569	(0.774-1.152)	0.98	0.865	(0.803-1.202)	0.95	0.629	(0.776-1.166)
Elsewhere	1.11	0.636	(0.724-1.698)	1.27	0.272	(0.828-1.959)	1.32	0.207	(0.857-2.033)	1.3	0.235	(0.843-2.008)
Maternal/caregiver highest educational level						(-)			(-)			(-)
No education				1			1			1		
Primary				0.96	0.654	(0.787-1.163)	1	0.963	(0.817-1.213)	0.95	0.618	(0.78-1.159)
Secondary				0.84	0.073	(0.687-1.017)	0.93	0.463	(0.757-1.135)	0.89	0.242	(0.724-1.085)
Higher				0.66	0.003	(0.5-0.868)	0.76	0.054	(0.569-1.005)	0.73	0.028	(0.547-0.966)
Mother is currently residing with husband/partner						(-)			(-)			(-)
Living with her partner				1			1			1		
Staying elsewhere				0.95	0.591	(0.792-1.142)	0.86	0.178	(0.683-1.073)	0.85	0.155	(0.677-1.064)
Mother's religious status						(-)			(-)			(-)

Catholic				1			1			1		
Other Christian				1.1	0.392	(0.887-1.359)	1.09	0.412	(0.883-1.354)	1.14	0.241	(0.917-1.41)
Islam				1.2	0.175	(0.923-1.55)	1.22	0.14	(0.937-1.583)	1.47	0.005	(1.124-1.915)
Traditionalist & others				1.09	0.794	(0.575-2.062)	1.1	0.773	(0.579-2.086)	1.11	0.748	(0.584-2.117)
Mother's Anaemia status							(-)				(-)	
Not Anaemic				1			1			1		
Anaemic				1.78	<0.0001	(1.589-1.993)	1.76	<0.0001	(1.568-1.969)	1.74	<0.0001	(1.552-1.949)
Maternal body weight status						(-)			(-)			(-)
Normal				1			1			1		
Underweight				1.13	0.245	(0.921-1.378)	1.11	0.3	(0.909-1.362)	1.13	0.251	(0.92-1.378)
Overweight				0.97	0.67	(0.835-1.123)	0.99	0.931	(0.855-1.154)	0.98	0.812	(0.845-1.141)
Obese				0.93	0.495	(0.77-1.135)	0.97	0.729	(0.794-1.175)	0.96	0.694	(0.79-1.17)
Partner education status						(-)			(-)			(-)
No education				1			1			1		
Primary education				0.94	0.588	(0.767-1.163)	0.97	0.814	(0.789-1.204)	0.95	0.631	(0.769-1.173)
Secondary education				0.92	0.407	(0.765-1.115)	1	0.969	(0.82-1.21)	0.99	0.942	(0.818-1.205)
Tertiary education				0.76	0.016	(0.602-0.948)	0.84	0.137	(0.66-1.059)	0.86	0.221	(0.681-1.093)
Household wealth index									(-)			(-)
Poorest							1			1		
Poorer							0.97	0.745	(0.784-1.19)	0.94	0.58	(0.765-1.161)
Middle							0.78	0.026	(0.627-0.97)	0.75	0.009	(0.599-0.928)
Richer							0.72	0.007	(0.569-0.916)	0.68	0.002	(0.538-0.867)
Richest							0.66	0.003	(0.503-0.873)	0.63	0.001	(0.48-0.833)
Children under 5 slept under mosquito bed net last night									(-)			(-)
No child							1			1		
All children							0.88	0.185	(0.735-1.061)	0.9	0.254	(0.748-1.08)
Some children							1.06	0.639	(0.829-1.359)	1.07	0.596	(0.835-1.369)
No net in household							0.84	0.063	(0.694-1.01)	0.83	0.047	(0.685-0.998)

Number of children under-5 years in household									(-)			(-)
0-3							1			1		
4-6							1.19	0.147	(0.941-1.505)	1.19	0.153	(0.938-1.501)
7th+							0.88	0.719	(0.445-1.75)	0.88	0.703	(0.442-1.734)
Number of bedrooms in household									(-)			(-)
One-room							1			1		
Two rooms							0.95	0.49	(0.812-1.105)	0.95	0.501	(0.813-1.107)
Three rooms							0.88	0.192	(0.732-1.065)	0.88	0.195	(0.732-1.066)
Four rooms							0.83	0.13	(0.659-1.055)	0.83	0.129	(0.658-1.055)
Five+ rooms							0.9	0.437	(0.688-1.175)	0.9	0.419	(0.684-1.171)
Sex of household head									(-)			(-)
Male							1			1		
Female							1.18	0.163	(0.934-1.497)	1.15	0.243	(0.909-1.458)
Number of people in household									(-)			(-)
0-3							1			1		
4-6							1.03	0.802	(0.821-1.29)	1.01	0.9	(0.809-1.272)
7-9							1.11	0.435	(0.855-1.44)	1.09	0.516	(0.84-1.416)
10+							1.21	0.227	(0.886-1.66)	1.21	0.229	(0.886-1.66)
Human development index by state (HDI)												(-)
Lowest HDI										1		
Low HDI										1.09	0.679	(0.714-1.678)
Average HDI										1.07	0.809	(0.633-1.796)
High HDI										0.88	0.666	(0.479-1.6)
Highest HDI										0.86	0.671	(0.429-1.726)
Gender inequality index by state (GII)												(-)
Lowest GII										1		
Low GII										0.9	0.611	(0.615-1.331)
Average GII										1.04	0.864	(0.664-1.628)

High GII										0.87	0.46	(0.592-1.268)
Highest GII										0.84	0.497	(0.519-1.375)
Region of residence												(-)
North-central										1		
North-east										0.81	0.407	(0.502-1.322)
North-west										0.74	0.287	(0.427-1.287)
South-east										1.96	0.004	(1.236-3.104)
South-south										2.46	<0.0001	(1.544-3.926)
South-west										1.22	0.333	(0.813-1.841)
Intercept	2.17	<0.0001	(1.560-3.028)	1.84	0.005	(1.201-2.819)	2.23	0.001	(1.36-3.66)	2.06	0.068	(0.947-4.484)
Random effect												
Community-level variance	0.2808		0.189-0.416	0.2217		0.139-0.354	0.2050		0.124-0.338	0.2042		0.124-0.337
State-level variance	0.1567		0.088-0.278	0.1583		0.087-0.289	0.1739		0.095-0.318	0.0717		0.036-0.142
VPC: community-level												
VPC: state-level												
ICC: community-level	0.117		0.087-0.156	0.104		0.074-0.143	0.103		0.073-0.145	0.077		0.053-0.112
ICC: state-level	0.042		0.024-0.072	0.043		0.024-0.076	0.047		0.026-0.083	0.020		0.010-0.039
MOR: community	1.658		1.513-1.850	1.567		1.427-1.764	1.540		1.400-1.740			
MOR: state	1.459		1.327-1.653	1.461		1.325-1.670	1.488		1.342-1.712	1.291		1.198-1.432
Model fit statistic												
Log-likelihood	-4276.4			-4203.7			-4187.8			-4173.3		
AIC	8596.7			8479.4			8481.6			8478.6		
BIC	8750.1			8730.5			8851.2			8938.9		

A.3: Multilevel multivariate models of predictors of malaria with adjusted odds ratios (AOR) among children 6-59 months in Nigeria

	Model 2 (N=7808)			**Model 3** (N=7808) **(Model 2 + Parental-related factors)**			**Model 4** (N=7808) **(Model 3 + household-related factors)**			**Model 5** (N=7808) **(Model 4 + community-related factors)**		
Individual-level	**AOR**	**p-value**	**95% CI**	**AOR**	**p-value**	**95% CI**	**AOR**	**p-value**	**95% CI**	**AOR**	**p-value**	**95% CI**
Child's sex												
Male	1			1			1			1		
Female	0.95	0.426	(0.85-1.07)	0.94	0.277	(0.83-1.05)	0.94	0.276	(0.83-1.05)	0.94	0.272	(0.83-1.05)
Child's age in group												
6-11 months	1			1			1			1		
12-23 months	1.35	0.006	(1.09-1.68)	1.28	0.022	(1.04-1.59)	1.29	0.02	(1.04-1.6)	1.29	0.019	(1.04-1.6)
24-35 months	2.06	<0.001	(1.55-2.76)	1.84	<0.001	(1.37-2.46)	1.82	<0.001	(1.36-2.44)	1.82	<0.001	(1.36-2.43)
36-47 months	2.83	<0.001	(2.11-3.79)	2.47	<0.001	(1.84-3.31)	2.39	<0.001	(1.78-3.21)	2.4	<0.001	(1.79-3.22)
48-59 months	3.41	<0.001	(2.54-4.58)	2.84	<0.001	(2.11-3.82)	2.82	<0.001	(2.09-3.81)	2.82	<0.001	(2.09-3.8)
Child's birth size												
Large	1			1			1			1		
Average	1.04	0.704	(0.84-1.28)	0.99	0.916	(0.8-1.22)	0.96	0.667	(0.78-1.18)	0.96	0.704	(0.78-1.18)
Small	1.1	0.473	(0.84-1.44)	1.02	0.899	(0.78-1.33)	0.99	0.96	(0.76-1.29)	0.99	0.966	(0.76-1.3)
Preceding birth interval												
None	1			1			1			1		
8-24 months	1.05	0.603	(0.87-1.28)	0.95	0.614	(0.77-1.17)	0.94	0.58	(0.75-1.17)	0.94	0.582	(0.75-1.17)
25-35 months	1.17	0.096	(0.97-1.4)	0.98	0.881	(0.8-1.21)	0.96	0.732	(0.78-1.19)	0.96	0.731	(0.78-1.19)
36-59 months	1.17	0.102	(0.97-1.41)	0.96	0.719	(0.77-1.2)	0.96	0.73	(0.77-1.21)	0.96	0.738	(0.77-1.21)
60+ months	1.08	0.562	(0.83-1.4)	0.86	0.328	(0.65-1.16)	0.89	0.435	(0.66-1.2)	0.89	0.435	(0.66-1.2)

Duration of breastfeeding												
Ever breastfed, not currently breastfeeding	1			1			1			1		
Never breastfed	1.46	0.118	(0.91-2.34)	1.47	0.12	(0.91-2.37)	1.43	0.151	(0.88-2.31)	1.4	0.172	(0.86-2.27)
Still breastfeeding	0.71	0.003	(0.57-0.89)	0.66	<0.001	(0.53-0.82)	0.64	<0.001	(0.51-0.79)	0.63	<0.001	(0.51-0.79)
Child took deworming drug in last 6months												
No	1			1			1			1		
Yes	0.63	0	(0.54-0.74)	0.72	<0.001	(0.61-0.84)	0.75	<0.001	(0.64-0.88)	0.75	<0.001	(0.64-0.88)
Malnutrition status												
Well-nourished	1			1			1			1		
Poorly nourished	1.25	0.001	(1.1-1.43)	1.09	0.18	(0.96-1.24)	1.06	0.371	(0.93-1.21)	1.06	0.41	(0.93-1.2)
Anaemia status												
Not anaemic	1			1			1			1		
Anaemic	4.49	0	(3.87-5.21)	3.99	<0.001	(3.44-4.62)	3.83	<0.001	(3.3-4.44)	3.83	<0.001	(3.3-4.44)
Child had Fever in last 2 weeks before the survey												
No	1			1			1			1		
Yes	2.03	0	(1.77-2.33)	2.04	<0.001	(1.78-2.34)	1.99	<0.001	(1.73-2.28)	1.99	<0.001	(1.74-2.29)
Maternal age group in 10 years												
15-24 years				1			1			1		
25-34 years				0.95	0.587	(0.79-1.14)	1.01	0.881	(0.84-1.23)	1.02	0.876	(0.84-1.23)
35 years+				1.11	0.369	(0.89-1.38)	1.19	0.157	(0.94-1.52)	1.19	0.158	(0.93-1.51)

Age of mother at first birth												
10-24 years				1			1			1		
25-36 years				0.82	0.066	(0.66-1.01)	0.89	0.318	(0.72-1.11)	0.89	0.279	(0.71-1.1)
37-49 years				0.51	0.267	(0.15-1.68)	0.48	0.235	(0.14-1.61)	0.48	0.229	(0.14-1.59)
Maternal/caregiver highest educational level												
No education				1			1			1		
Primary				0.75	0.006	(0.61-0.92)	0.82	0.053	(0.67-1)	0.83	0.075	(0.68-1.02)
Secondary				0.55	<0.001	(0.44-0.68)	0.7	0.001	(0.56-0.87)	0.71	0.002	(0.57-0.88)
Higher				0.26	<0.001	(0.18-0.38)	0.41	<0.001	(0.28-0.59)	0.42	<0.001	(0.29-0.61)
Maternal ethnicity												
Hausa/Fulani/Kanuri/Seribiri				1			1			1		
Ibo				0.91	0.675	(0.59-1.41)	1.02	0.921	(0.67-1.57)	1.01	0.961	(0.66-1.56)
Yoruba				1.65	0.011	(1.12-2.42)	1.89	0.001	(1.29-2.78)	1.87	0.001	(1.27-2.75)
Others				1.47	0.001	(1.16-1.86)	1.39	0.006	(1.1-1.75)	1.36	0.01	(1.08-1.72)
Mother's Anaemia status												
Not Anaemic				1			1			1		
Anaemic				1.28	<0.001	(1.13-1.46)	1.24	0.001	(1.09-1.41)	1.24	0.001	(1.09-1.41)
Maternal body mass index												
Normal				1			1			1		
Underweight				0.92	0.387	(0.75-1.12)	0.88	0.219	(0.73-1.08)	0.89	0.244	(0.73-1.08)
Overweight				0.77	0.004	(0.65-0.92)	0.86	0.1	(0.72-1.03)	0.86	0.096	(0.72-1.03)

Obese				0.6	<0.001	(0.46-0.77)	0.71	0.01	(0.55-0.92)	0.71	0.01	(0.55-0.92)
Paternal Work Status												
No				1			1			1		
Yes				1.32	0.143	(0.91-1.91)	1.32	0.147	(0.91-1.91)	1.32	0.143	(0.91-1.92)
Partner education status												
No education				1			1			1		
Primary education				0.85	0.145	(0.69-1.06)	0.92	0.467	(0.75-1.14)	0.94	0.601	(0.76-1.17)
Secondary education				0.66	<0.001	(0.54-0.81)	0.79	0.019	(0.64-0.96)	0.81	0.035	(0.66-0.99)
Tertiary education				0.58	<0.001	(0.45-0.76)	0.83	0.171	(0.64-1.08)	0.85	0.251	(0.65-1.12)
Household wealth index												
Poorest							1			1		
Poorer							0.85	0.117	(0.7-1.04)	0.89	0.25	(0.73-1.09)
Middle							0.58	<0.001	(0.47-0.73)	0.63	<0.001	(0.5-0.79)
Richer							0.46	<0.001	(0.35-0.59)	0.5	<0.001	(0.39-0.65)
Richest							0.18	<0.001	(0.13-0.25)	0.2	<0.001	(0.15-0.28)
Household Head age group												
Less 34 years							1			1		
35-44 years							0.82	0.027	(0.69-0.98)	0.83	0.028	(0.69-0.98)
45-55 years							0.88	0.228	(0.71-1.09)	0.89	0.268	(0.72-1.1)
56 years+							1	0.989	(0.79-1.27)	1.02	0.885	(0.8-1.29)

Children under 5 slept under mosquito bed net last night												
No child							1			1		
All children							0.89	0.27	(0.73-1.09)	0.89	0.27	(0.73-1.09)
Some children							1.15	0.286	(0.89-1.49)	1.16	0.269	(0.89-1.5)
No net in household	*						0.96	0.729	(0.78-1.19)	0.702	0.78	(1.18-0.98)
Number of under-5 in household												
0-3							1			1		
4-6th							1.32	00-Jan	(1.04-1.67)	1.3	0.03	(1.03-1.66)
7th+							1.27	0.536	(0.59-2.72)	1.34	0.45	(0.63-2.87)
Number of bedrooms in household												
One-room							1			1		
Two rooms							1.07	0.449	(0.9-1.27)	1.06	0.52	(0.89-1.26)
Three rooms							1.13	0.262	(0.91-1.39)	1.11	0.311	(0.9-1.37)
Four rooms							0.97	0.812	(0.75-1.25)	0.96	0.738	(0.74-1.24)
Five+ rooms							0.83	0.215	(0.62-1.11)	0.81	0.169	(0.6-1.09)
Sex of household head												
Male							1			1		
Female							0.77	0.023	(0.62-0.96)	0.77	0.02	(0.62-0.96)
Number of people in household												
02-Mar							1			1		
04-Jun							0.99	00-Jan	(0.77-1.28)	1	0.973	(0.77-1.29)

07-Sep							0.95	00-Jan	(0.71-1.28)	0.96	0.795	(0.71-1.29)
10+							1.01	0.951	(0.71-1.44)	1.02	0.913	(0.72-1.45)
Proportion of community distance to health facility is no big problem												
Low							1			1		
High										0.73	0.001	(0.61-0.88)
_cons	0.06	0	(0.04-0.1)	0.12	<0.001		0.18	<0.001	(0.09-0.35)	0.2	<0.001	(0.1-0.38)

AOR: Adjusted Odds Ratios, ICC: Intraclass Correlation Coefficient, VPC: Variance Partition Coefficient, AIC: Akaike Information Criterion (Given a set of candidate models for the data, the preferred model is the one with the minimum AIC value)

A.4: Multilevel multivariate models of predictors of malnutrition with adjusted odds ratios (AOR) among children 6-59 months in Nigeria

	Model 3 (N=7770): Child-, and parental-related variables only			**Model 4 (N=7770): Level-1 variables (child, parental, and households)**			**Model 5 (N=7770): Level-1 & 2 variables (Model 4 + community-related)**		
Variables	**OR**	**P-value**	**95%CI**	**OR**	**P-value**	**95%CI**	**OR**	**P-value**	**95%CI**
Child's sex									
Male									
Female	0.744	<0.0001	(0.67, 0.825)	0.742	<0.0001	(0.669, 0.823)	0.743	<0.0001	(0.669, 0.825)
Child's age in group									
6-11 months									
12-23 months	1.688	<0.0001	(1.402, 2.034)	1.69	<0.0001	(1.402, 2.036)	1.688	<0.0001	(1.4, 2.034)
24-35 months	2.282	<0.0001	(1.772, 2.939)	2.282	<0.0001	(1.771, 2.941)	2.268	<0.0001	(1.759, 2.923)
36-47 months	1.854	<0.0001	(1.433, 2.397)	1.848	<0.0001	(1.428, 2.393)	1.847	<0.0001	(1.426, 2.391)
48-59 months	1.311	0.042	(1.01, 1.702)	1.318	0.039	(1.014, 1.715)	1.312	0.043	(1.008, 1.706)
Child's birth size									

Large									
Average	1.274	0.01	(1.059, 1.532)	1.256	0.016	(1.044, 1.512)	1.259	0.015	(1.046, 1.515)
Small	1.838	<0.0001	(1.454, 2.324)	1.805	<0.0001	(1.428, 2.282)	1.809	<0.0001	(1.431, 2.288)
Preceding birth interval									
None									
8-24 months	1.289	0.004	(1.085, 1.53)	1.313	0.004	(1.092, 1.579)	1.32	0.003	(1.098, 1.587)
25-35 months	0.995	0.954	(0.846, 1.171)	1.015	0.869	(0.85, 1.212)	1.019	0.834	(0.854, 1.217)
36-59 months	0.82	0.022	(0.693, 0.972)	0.839	0.061	(0.699, 1.008)	0.844	0.071	(0.703, 1.014)
60+ months	0.733	0.009	(0.581, 0.924)	0.753	0.022	(0.591, 0.96)	0.758	0.025	(0.594, 0.966)
Took Iron supplements									
No									
Yes	1.08	0.301	(0.934, 1.249)	1.096	0.216	(0.948, 1.268)	1.099	0.205	(0.95, 1.27)
Duration of breastfeeding									
Ever breastfed, not currently breastfeeding									
Never breastfed	1.173	0.464	(0.765, 1.8)	1.169	0.474	(0.762, 1.793)	1.155	0.509	(0.753, 1.771)
Still breastfeeding	1.019	0.847	(0.839, 1.239)	0.996	0.965	(0.819, 1.211)	0.988	0.907	(0.813, 1.202)
Malaria RTD status									
Negative									
Positive	1.125	0.053	(0.999, 1.267)	1.078	0.218	(0.956, 1.216)	1.07	0.271	(0.949, 1.207)
Anaemia status									
Not anaemic									
Anaemic	1.348	<0.0001	(1.193, 1.524)	1.33	<0.0001	(1.176, 1.505)	1.325	<0.0001	(1.172, 1.499)
Child had cough in last 2 weeks before the survey									
No									
Yes	0.924	0.282	(0.8, 1.067)	0.926	0.296	(0.801, 1.07)	0.932	0.34	(0.807, 1.077)
Child had diarrheal in last 2 weeks before the survey									
No									

Yes	1.269	0.004	(1.08, 1.492)	1.267	0.004	(1.078, 1.49)	1.276	0.003	(1.086, 1.501)
Place of child's delivery									
Home									
Public facility	0.889	0.108	(0.771, 1.026)	0.925	0.291	(0.801, 1.069)	0.933	0.351	(0.807, 1.079)
Private facility	0.8	0.03	(0.654, 0.978)	0.843	0.099	(0.689, 1.032)	0.843	0.099	(0.689, 1.033)
Elsewhere	0.704	0.1	(0.463, 1.07)	0.722	0.128	(0.475, 1.098)	0.717	0.12	(0.472, 1.091)
Mother/Caregiver currently working									
No									
Yes	1.151	0.031	(1.013, 1.308)	1.134	0.055	(0.997, 1.289)	1.128	0.067	(0.992, 1.282)
Maternal/caregiver highest educational level									
No education									
Primary	0.909	0.29	(0.762, 1.085)	0.94	0.495	(0.786, 1.123)	0.938	0.486	(0.783, 1.123)
Secondary	0.647	<0.0001	(0.539, 0.776)	0.713	<0.0001	(0.591, 0.859)	0.702	<0.0001	(0.576, 0.854)
Higher	0.449	<0.0001	(0.336, 0.6)	0.52	<0.0001	(0.386, 0.701)	0.512	<0.0001	(0.377, 0.695)
Mother's religious status									
Catholic									
Other Christian	1.063	0.59	(0.851, 1.329)	1.076	0.519	(0.861, 1.345)	1.093	0.435	(0.874, 1.367)
Islam	1.164	0.287	(0.881, 1.538)	1.206	0.189	(0.912, 1.594)	1.247	0.123	(0.942, 1.649)
Traditionalist & others	0.836	0.588	(0.438, 1.596)	0.868	0.668	(0.455, 1.656)	0.881	0.699	(0.462, 1.679)
Maternal ethnicity									
Hausa/Fulani/Kanuri/Seribiri									
Ibos	0.522	<0.0001	(0.365, 0.748)	0.542	0.001	(0.382, 0.768)	0.544	0.001	(0.383, 0.771)
Yoruba	0.836	0.277	(0.605, 1.155)	0.879	0.419	(0.644, 1.201)	0.889	0.456	(0.651, 1.212)
Others	0.767	0.013	(0.622, 0.945)	0.737	0.004	(0.599, 0.908)	0.733	0.003	(0.595, 0.902)
Mother's Anaemia status									
Not Anaemic									
Anaemic	1.112	0.057	(0.997, 1.241)	1.091	0.121	(0.977, 1.218)	1.088	0.132	(0.975, 1.215)

Maternal body weight status									
Normal									
Underweight	1.271	0.007	(1.067, 1.513)	1.267	0.008	(1.064, 1.508)	1.267	0.008	(1.064, 1.509)
Overweight	0.681	<0.0001	(0.587, 0.79)	0.706	<0.0001	(0.607, 0.82)	0.707	<0.0001	(0.609, 0.822)
Obese	0.572	<0.0001	(0.463, 0.706)	0.599	<0.0001	(0.484, 0.741)	0.604	<0.0001	(0.488, 0.748)
Partner education status									
No education									
Primary education	0.971	0.757	(0.806, 1.17)	1.002	0.987	(0.829, 1.21)	1.003	0.972	(0.83, 1.213)
Secondary education	0.882	0.146	(0.745, 1.045)	0.96	0.644	(0.806, 1.143)	0.968	0.719	(0.812, 1.154)
Tertiary education	0.692	0.001	(0.557, 0.859)	0.789	0.04	(0.629, 0.989)	0.797	0.05	(0.636, 1)
Household wealth index									
Poorest									
Poorer				0.895	0.215	(0.751, 1.067)	0.923	0.374	(0.773, 1.102)
Middle				0.846	0.087	(0.698, 1.025)	0.952	0.647	(0.77, 1.177)
Richer				0.639	<0.0001	(0.516, 0.791)	0.764	0.039	(0.592, 0.986)
Richest				0.571	<0.0001	(0.438, 0.743)	0.687	0.015	(0.508, 0.93)
Household Head age group									
Less 34 years									
35-44 years				0.945	0.435	(0.82, 1.089)	0.945	0.433	(0.819, 1.089)
45-55 years				0.857	0.081	(0.72, 1.019)	0.861	0.091	(0.723, 1.024)
56 years+				0.899	0.3	(0.736, 1.099)	0.913	0.373	(0.746, 1.116)
Number of bedrooms in household									
One-room									
Two rooms				1.215	0.01	(1.049, 1.408)	1.204	0.014	(1.038, 1.395)
Three rooms				1.286	0.006	(1.073, 1.541)	1.264	0.011	(1.054, 1.515)
Four rooms				1.381	0.005	(1.103, 1.729)	1.347	0.01	(1.075, 1.689)
Five+ rooms				1.207	0.144	(0.938, 1.553)	1.179	0.201	(0.916, 1.519)

Number of people in household									
0-3									
4-6				0.836	0.102	(0.674, 1.036)	0.837	0.105	(0.675, 1.038)
7-9				0.921	0.515	(0.718, 1.181)	0.921	0.518	(0.718, 1.182)
10+				1.009	0.951	(0.761, 1.337)	1.013	0.927	(0.764, 1.344)
Community wealth level									
Low									
High							0.797	0.022	(0.657, 0.967)
Proportion of community distance to health facility is no big problem									
Low									
High							0.918	0.225	(0.8, 1.054)
Proportion of community maternal education level									
Low									
High							1.103	0.329	(0.906, 1.344)
Proportion of community households with no bed net									
Low									
High							0.935	0.348	(0.813, 1.076)
Intercept	0.455	0.001	(0.281, 0.734)	0.527	0.013	(0.319, 0.872)	0.547	0.02	(0.329, 0.91)
Random effect									
Community-level variance	0.173		0.104, 0.288	0.166		0.098, 0.283	0.165		0.096, 0.282
State-level variance	0.155		0.082, 0.295	0112		0.057, 0.220	0.109		0.054, 0.219
VPC: community-level	0.048			0.047			0.046		
VPC: state-level	0.043			0.031			0.031		
ICC: community-level	0.091			0.078			0.077		
ICC: state-level	0.043			0.031			0.031		
MOR: community	1.487		1.360, 1.668	1.475		1.348, 1.661	1.473		1.344, 1.659
MOR: state	1.456		1.314, 1.679	1.376		1.256, 1.564	1.370		1.248, 1.563

Model fit statistic									
Log-likelihood	-4543.05			-4520.5			-4516.16		
AIC	9168.091			9150.996			9150.317		
BIC	9453.37			9533.688			9560.841		

AOR: Adjusted Odds Ratios, ICC: Intraclass Correlation Coefficient, VPC: Variance Partition Coefficient, AIC: Akaike Information Criterion (Given a set of candidate models for the data, the preferred model is the one with the minimum AIC value)

A.5 Multilevel mixed effect ordinal logistic regression models of predictors of MAMM adjusted odds ratios (AOR) among children 6-59 months in Nigeria

	Model 1			Model 2			Model 3			Model 4		
	AOR	p-value	95% CI	AOR	p-value	95% CI	AOR	p-value	95% CI	AOR	p-value	95% CI
Child's sex												
Male												
Female	0.73	<0.001	(0.67-0.81)									
Child's age in group												
6-11 months												
12-23 months	1.51	<0.001	(1.28-1.79)									
24-35 months	1.44	0.002	(1.15-1.81)									
36-47 months	1.3	0.024	(1.04-1.64)									
48-59 months	1.03	0.804	(0.82-1.3)									
Child's birth size												
Large												
Average	1.04	0.651	(0.88-1.23)									
Small	1.43	0.001	(1.15-1.78)									
Preceding birth interval												

None												
8-24 months	1.42	<0.001	(1.22-1.65)									
25-35 months	1.2	0.013	(1.04-1.39)									
36-59 months	1.11	0.157	(0.96-1.29)									
60+ months	0.99	0.925	(0.81-1.21)									
Child took Iron supplements												
No												
Yes	0.96	0.549	(0.84-1.1)									
Duration of breastfeeding												
Ever breastfed, not currently breastfeeding	*											
Never breastfed	1.28	0.223	(0.86-1.9)									
Still breastfeeding	1.1	0.301	(0.92-1.31)									
Child was dewormed in last 6 months before the survey	^											
No												
Yes	0.72	<0.001	(0.63-0.82)									
Child had fever in last 2 weeks before the survey	*											
No												
Yes	1.62	<0.001	(1.44-1.83)									
Place of child’s delivery												
Home												
Public facility	0.58	<0.001	(0.51-0.67)									
Private facility	0.53	<0.001	(0.45-0.63)									
Elsewhere	0.78	0.166	(0.54-1.11)									

Maternal/caregiver highest educational level	*											
No education												
Primary				0.74	<0.001	(0.62-0.87)						
Secondary				0.51	<0.001	(0.43-0.6)						
Higher				0.28	<0.001	(0.22-0.35)						
Mother staying with a partner												
Staying with partner												
staying elsewhere				0.96	0.573	(0.81-1.12)						
Mother's religious status												
Catholic												
Other Christian				1.07	0.468	(0.89-1.29)						
Islam				1.25	0.059	(0.99-1.56)						
Traditionalist & others				0.93	0.801	(0.52-1.65)						
Mother's Anaemia status												
Not Anaemic												
Anaemic				1.66	<0.001	(1.5-1.83)						
Maternal body weight status												
Normal												
Underweight				1.25	0.013	(1.05-1.49)						
Overweight				0.69	<0.001	(0.61-0.78)						
Obese				0.6	<0.001	(0.51-0.71)						
Paternal work status												
Not working												
Working				1.26	0.112	(0.95-1.68)						

Partner education status												
No education												
Primary education				0.87	0.129	(0.72-1.04)						
Secondary education				0.7	<0.001	(0.59-0.82)						
Tertiary education				0.56	<0.001	(0.46-0.68)						
Household wealth index												
Poorest												
Poorer							0.7	<0.001	(0.59-0.84)			
Middle							0.42	<0.001	(0.35-0.51)			
Richer							0.26	<0.001	(0.22-0.32)			
Richest							0.12	<0.001	(0.1-0.15)			
Under-5 slept under a bed net												
No child												
All children							0.97	0.666	(0.82-1.13)			
Some children							1.18	0.116	(0.96-1.46)			
No net in household							0.95	0.557	(0.81-1.12)			
Sex of household head												
Male												
Female							0.88	0.144	(0.75-1.04)			
Number of people in household	*											
2-3												
4-6							0.9	0.228	(0.75-1.07)			
7-9							1.06	0.565	(0.87-1.28)			
10+							1.33	0.009	(1.07-1.64)			
Community wealth level												
Low												
High										0.39	<0.001	(0.32-0.46)

Proportion of community distance to health facility is no big problem	*											
Low												
High										0.77	<0.001	(0.66-0.89)
Proportion of community maternal education level	*											
Low												
High										0.59	<0.001	(0.49-0.71)

Appendix A.5 continues

	Model 5			Model 6			Model 7		
	AOR	**p-value**	**95% CI**	**AOR**	**p-value**	**95% CI**	**AOR**	**p-value**	**95% CI**
Child's sex									
Male									
Female				0.74	<0.001	(0.67-0.81)	0.73	<0.001	(0.67-0.8)
Child's age in group									
6-11 months									
12-23 months				1.41	<0.001	(1.19-1.67)	1.45	<0.001	(1.22-1.71)
24-35 months				1.28	0.033	(1.02-1.6)	1.34	0.01	(1.07-1.68)
36-47 months				1.14	0.259	(0.91-1.43)	1.17	0.178	(0.93-1.47)
48-59 months				0.89	0.341	(0.71-1.13)	0.94	0.615	(0.75-1.19)
Child's birth size									
Large									
Average				1	0.996	(0.85-1.18)	1	0.994	(0.85-1.18)
Small				1.28	0.024	(1.03-1.58)	1.34	0.008	(1.08-1.66)
Preceding birth interval									

None									
8-24 months				1.35	<0.001	(1.16-1.58)	1.36	<0.001	(1.16-1.6)
25-35 months				1.09	0.223	(0.95-1.26)	1.12	0.157	(0.96-1.31)
36-59 months				1	0.986	(0.86-1.16)	1.04	0.662	(0.88-1.21)
60+ months				0.91	0.334	(0.74-1.11)	0.94	0.562	(0.77-1.15)
Child took Iron supplements									
No									
Yes				1.02	0.752	(0.89-1.17)	1	0.968	(0.87-1.14)
Duration of breastfeeding									
Ever breastfed, not currently breastfeeding	*			1					
Never breastfed				1.26	0.251	(0.85-1.87)	1.23	0.308	(0.83-1.81)
Still breastfeeding				1	0.968	(0.84-1.19)	1.01	0.895	(0.85-1.21)
Child was dewormed in last 6 months before the survey	*								
No									
Yes				0.79	<0.001	(0.7-0.9)	0.79	<0.001	(0.69-0.9)
Child had fever in last 2 weeks before the survey	*								
No									
Yes				1.61	<0.001	(1.44-1.81)	1.56	<0.001	(1.39-1.76)
Place of child's delivery									
Home									
Public facility				0.83	0.005	(0.73-0.94)	0.77	<0.001	(0.67-0.87)
Private facility				0.76	0.002	(0.64-0.9)	0.76	0.001	(0.64-0.9)
Elsewhere				0.96	0.804	(0.67-1.36)	0.91	0.622	(0.64-1.3)

Maternal/caregiver highest educational level	*								
No education									
Primary				0.76	0.001	(0.64-0.9)			
Secondary				0.54	<0.001	(0.46-0.64)			
Higher				0.31	<0.001	(0.24-0.39)			
Mother staying with a partner									
Staying with partner									
staying elsewhere				0.96	0.574	(0.81-1.12)			
Mother's religious status									
Catholic									
Other Christian				1.07	0.48	(0.89-1.29)			
Islam				1.19	0.134	(0.95-1.49)			
Traditionalist & others				0.95	0.864	(0.54-1.69)			
Mother's Anaemia status									
Not Anaemic									
Anaemic				1.67	<0.001	(1.51-1.84)			
Maternal body weight status									
Normal									
Underweight				1.19	0.059	(0.99-1.41)			
Overweight				0.7	<0.001	(0.62-0.8)			
Obese				0.63	<0.001	(0.53-0.74)			
Paternal work status									
Not working									
Working				1.28	0.089	(0.96-1.71)			

Partner education status									
No education									
Primary education				0.89	0.232	(0.74-1.07)			
Secondary education				0.73	<0.001	(0.62-0.86)			
Tertiary education				0.59	<0.001	(0.48-0.72)			
Household wealth index									
Poorest									
Poorer							0.75	0.002	(0.62-0.9)
Middle							0.47	<0.001	(0.39-0.56)
Richer							0.3	<0.001	(0.25-0.37)
Richest							0.15	<0.001	(0.12-0.19)
Under-5 slept under a bed net									
No child									
All children							0.94	0.467	(0.8-1.11)
Some children							1.16	0.168	(0.94-1.43)
No net in household							0.95	0.573	(0.81-1.12)
Sex of household head									
Male									
Female							0.89	0.163	(0.75-1.05)
Number of people in household	*								
2-3									
4-6							0.88	0.194	(0.73-1.07)
7-9							1.03	0.798	(0.83-1.27)
10+							1.25	0.057	(0.99-1.58)
Community wealth level									
Low									

High									
Proportion of community distance to health facility is no big problem	*								
Low									
High									
Proportion of community maternal education level	*								
Low									
High									
State multidimensional poverty index (SMPI)	*								
Highly deprived									
Above averagely deprived	1.02	0.909	(0.67-1.56)						
Averagely Deprived	0.5	0.015	(0.28-0.87)						
Mildly Deprived	0.38	0.001	(0.21-0.69)						
Lowest Deprived	0.31	0.001	(0.15-0.63)						
State human development index (HDI)	*								
Lowest HDI									
Low HDI	1.12	0.557	(0.76-1.66)						
Average HDI	0.86	0.54	(0.53-1.39)						
High HDI	0.97	0.91	(0.55-1.72)						
Highest HDI	0.56	0.072	(0.29-1.05)						
Gender inequality index by state (GII)	*								

Lowest GII									
Low GII	0.53	0.001	(0.37-0.77)						
Average GII	1.22	0.321	(0.82-1.82)						
High GII	1	0.99	(0.7-1.41)						
Highest GII	1.24	0.342	(0.8-1.94)						
Region of residence									
North-central									
North-east	0.77	0.286	(0.48-1.24)						
North-west	1.14	0.628	(0.67-1.94)						
South-east	1.43	0.088	(0.95-2.17)						
South-south	1.21	0.383	(0.78-1.88)						
South-west	1.51	0.078	(0.95-2.38)						
Type of place of residence									
Urban									
Rural	2.4	<0.001	(2.06-2.79)						

A.6: Multiple-imputation estimates mixed-effects ordered logit regression

	Model 10 (N=10,451): Level-1, 2 & 3 variables			
outc2	Coefficient	P-value	95% CI	AOR
Child's sex				
Male				1.000
Female	-0.269	0.000	(-0.35,-0.19)	0.764
Child's age in group				
6-11 months				1.000
12-23 months	0.356	0.000	(0.2,0.51)	1.427
24-35 months	0.285	0.006	(0.08,0.49)	1.330
36-47 months	0.111	0.285	(-0.09,0.31)	1.117
48-59 months	-0.115	0.273	(-0.32,0.09)	0.892
Child's birth size				
Large				1.000
Average	0.065	0.377	(-0.08,0.21)	1.067
Small	0.29	0.002	(0.1,0.48)	1.337
Preceding birth interval				
None				1.000
8-24 months	0.264	0.000	(0.12,0.41)	1.303
25-35 months	0.099	0.143	(-0.03,0.23)	1.104
36-59 months	0.014	0.841	(-0.12,0.15)	1.014
60+ months	-0.123	0.175	(-0.3,0.05)	0.884
Child took Iron supplements				
No				1.00
Yes	0.059	0.324	(-0.06,0.18)	1.061
Duration of breastfeeding				
Ever breastfed, not currently breastfeeding				1.000
Never breastfed	0.215	0.200	(-0.11,0.54)	1.240
Still breastfeeding	-0.046	0.556	(-0.2,0.11)	0.955
Child was dewormed in last 6 months before the survey				
No				1.000
Yes	-0.207	0.000	(-0.32,-0.09)	0.813
Child had fever in last 2 weeks before the survey				
No				1.000
Yes	0.465	0.000	(0.36,0.57)	1.592
Place of child's delivery				
Home				1.000
Public facility	-0.098	0.094	(-0.21,0.02)	0.907
Private facility	-0.173	0.025	(-0.32,-0.02)	0.841
Elsewhere	0.024	0.881	(-0.29,0.33)	1.024

Maternal/caregiver highest educational level				
No education				1.000
Primary	-0.157	0.041	(-0.31,-0.01)	0.854
Secondary	-0.389	0.000	(-0.55,-0.23)	0.678
Higher	-0.79	0.000	(-1.01,-0.56)	0.454
Mother staying with a partner				
Staying with partner				1.000
staying elsewhere	-0.062	0.485	(-0.24,0.11)	0.940
Mother's religious status				
Catholic				1.000
Other Christian	0.031	0.711	(-0.13,0.2)	1.032
Islam	0.239	0.027	(0.03,0.45)	1.270
Traditionalist & others	-0.026	0.917	(-0.51,0.46)	0.975
Mother's Anaemia status				
Not Anaemic				1.000
Anaemic	0.453	0.000	(0.37,0.54)	1.573
Maternal body mass index				
Normal				1.000
Underweight	0.218	0.016	(0.04,0.4)	1.244
Overweight	-0.215	0.000	(-0.33,-0.1)	0.807
Obese	-0.388	0.000	(-0.55,-0.23)	0.678
Paternal work status				
Not working				1.000
Working	0.164	0.226	(-0.1,0.43)	1.178
Partner education status				
No education				1.000
Primary education	-0.116	0.175	(-0.28,0.05)	0.891
Secondary education	-0.17	0.031	(-0.32,-0.02)	0.844
Tertiary education	-0.304	0.002	(-0.49,-0.12)	0.738
Household wealth index				
Poorest				1.000
Poorer	-0.119	0.147	(-0.28,0.04)	0.887
Middle	-0.307	0.001	(-0.49,-0.12)	0.736
Richer	-0.459	0.000	(-0.67,-0.25)	0.632
Richest	-0.813	0.000	(-1.06,-0.57)	0.444
Under-5 slept under a bed net				
No child				1.000
All children	-0.104	0.147	(-0.24,0.04)	0.902
Some children	0.141	0.142	(-0.05,0.33)	1.151
No net in household	-0.104	0.151	(-0.25,0.04)	0.901
Sex of household head				
Male				1.000
Female	-0.059	0.455	(-0.22,0.1)	0.942
Number of people in household				

2-3				1.000
4-6	-0.078	0.339	(-0.24,0.08)	0.925
7-9	-0.022	0.807	(-0.2,0.16)	0.978
10+	0.14	0.167	(-0.06,0.34)	1.151
Community wealth level				
Low				1.000
High	-0.238	0.006	(-0.41,-0.07)	0.788
Proportion of community distance to health facility is no big problem				
Low				1.000
High	-0.157	0.011	(-0.28,-0.04)	0.855
Proportion of community maternal education level				1.000
Low				1.000
High	0.063	0.481	(-0.11,0.24)	1.065
State multidimensional poverty index (SMPI)				1.000
Highly deprived				1.000
Above averagely deprived	0.314	0.036	(0.02,0.61)	1.369
Averagely Deprived	-0.27	0.182	(-0.67,0.13)	0.764
Mildly Deprived	-0.302	0.159	(-0.72,0.12)	0.739
Lowest Deprived	-0.295	0.246	(-0.79,0.2)	0.745
State human development index (HDI)				
Lowest HDI				1.000
Low HDI	0.268	0.057	(-0.01,0.54)	1.308
Average HDI	0.271	0.122	(-0.07,0.61)	1.311
High HDI	0.383	0.065	(-0.02,0.79)	1.466
Highest HDI	0.152	0.514	(-0.3,0.61)	1.164
Gender inequality index by state (GII)				
Lowest GII				1.000
Low GII	-0.237	0.079	(-0.5,0.03)	0.789
Average GII	0.281	0.054	(0,0.57)	1.325
High GII	0.009	0.943	(-0.24,0.25)	1.009
Highest GII	0.241	0.138	(-0.08,0.56)	1.272
Region of residence				
North-central				1.000
North-east	-0.394	0.021	(-0.73,-0.06)	0.675
North-west	0.153	0.418	(-0.22,0.52)	1.165
South-east	0.466	0.003	(0.16,0.77)	1.593
South-south	0.471	0.004	(0.15,0.79)	1.602
South-west	0.493	0.003	(0.17,0.82)	1.638
Type of place of residence				
Urban				1.000
Rural	0.239	0.000	(0.11,0.37)	1.269
Intercept	0.239	0.000	(0.11,0.37)	

A.7: Risk factors from updated scoping reviews of anaemia, malaria, and malnutrition

Child-related variables					
S/N	Variables	Significance Levels	Anaemia	Malaria	Malnutrition
1	Sex of the child (Male as reference)	**Harmful effects** Increased Significant Factors (ISF)		(Nzabakiriraho and Gayawan, 2021)	(Amoako Johnson, 2022)
		Protective effects Decreased Significant Factors (DSF)	(Amadu *et al.*, 2021; Aregbeshola, Onifade _ _ _ _ _ and Awuviry-Newton, 2021; Tesema *et al.*, 2021)		(Hailu, Bogale and Beyene, 2020; Kassie and Workie, 2020; Khamis *et al.*, 2020; Masibo, Humwa and Macharia, 2020; Simelane, Chemhaka and Zwane, 2020; Aboagye *et al.*, 2021; Adam Birhan and Bitew Belay, 2021; Adedokun and Yaya, 2021; Fenta, Zewotir and Muluneh, 2021; Muche and Dewau, 2021; Muche *et al.*, 2021; Musuka *et al.*, 2021; Seboka *et al.*, 2021; Sserwanja *et al.*, 2021; Tesema *et al.*, 2021; Tesfaw and Fenta, 2021; Uwiringiyimana *et al.*, 2022)
2	Age of the child (Younger children as reference)	(ISF)		(Aheto *et al.*, 2021; Emina, Doctor and Yé, 2021)	(Kassie and Workie, 2020; Khamis *et al.*, 2020; Masibo, Humwa and Macharia, 2020; Rutayisire *et al.*, 2020; Simelane, Chemhaka and Zwane, 2020; Aboagye *et al.*, 2021; Adam Birhan and Bitew Belay, 2021; Bekele and Fetene, 2021; Kebede and Aynalem, 2021; Muche and Dewau, 2021; Sserwanja *et al.*, 2021; Tesema *et al.*, 2021; Uwiringiyimana *et al.*, 2022)
		(DSF)	(Elmardi *et al.*, 2020; Gebremeskel *et al.*, 2020; Ag *et al.*, 2021; Amadu *et al.*, 2021; Anjorin and Yaya, 2021; Anteneh and Van Geertruyden, 2021; Aregbeshola, Onifade and Awuviry-Newton, 2021; Barry *et al.*, 2021; Heinrichs *et al.*, 2021; Jember *et al.*, 2021; Tesema, Tessema, *et al.*, 2021; Tesema, Worku, *et al.*, 2021; Eshete *et al.*, 2022)		(Seboka *et al.*, 2021; Wondimu and Dejene, 2022)
4	Birth size (Small as reference)	ISF			(Khamis *et al.*, 2020)
		DSF	(Amadu *et al.*, 2021)		(Amegbor *et al.*, 2020; Rutayisire *et al.*, 2020; Aboagye *et al.*, 2021; Adam Birhan and Bitew Belay, 2021; Adedokun and Yaya, 2021; Fenta, Zewotir and Muluneh, 2021; Kebede and Aynalem, 2021; Tesema *et al.*, 2021; Uwiringiyimana *et al.*, 2022)

6	Product of multiple birth (No as reference)	ISF	(Tesema *et al.*, 2021)		(Hailu, Bogale and Beyene, 2020; Adam Birhan and Bitew Belay, 2021; Fenta, Zewotir and Muluneh, 2021; Kebede and Aynalem, 2021; Muche *et al.*, 2021; Tesema *et al.*, 2021; Tesfaw and Fenta, 2021; Amoako Johnson, 2022)
		DSF			
7	Preceding birth interval (60 months+ as reference)	ISF:	(Ag *et al.*, 2021)		(Bekele and Fetene, 2021; Muche *et al.*, 2021; Amoako Johnson, 2022)
		DSF:			
8	Birth order (1st order as reference)	ISF:	(Gebremeskel *et al.*, 2020; Ag *et al.*, 2021; Amadu *et al.*, 2021; Anteneh and Van Geertruyden, 2021; Aregbeshola, Onifade and Awuviry-Newton, 2021; Tesema *et al.*, 2021)		(Adam Birhan and Bitew Belay, 2021; Chikako *et al.*, 2021; Tesema *et al.*, 2021)
		DSF:			
9	Breastfeeding status (Ever & Currently as Ref)	ISF:			(Tesfaw and Fenta, 2021; Uwiringiyimana *et al.*, 2022)
		DSF:			
10	Had diarrhoeal 2 weeks before survey (No)	ISF	(Aregbeshola, Onifade and Awuviry-Newton, 2021; Tesema *et al.*, 2021)		(Adam Birhan and Bitew Belay, 2021; Chikako *et al.*, 2021; Muche *et al.*, 2021; Tesfaw and Fenta, 2021; Uwiringiyimana *et al.*, 2022)
		DSF			(Bekele and Fetene, 2021)
11	Fever in the last 2 weeks (No)	ISF:	(Gebreegziabher *et al.*, 2020; Gebremeskel *et al.*, 2020; Anteneh and Van Geertruyden, 2021; Aregbeshola, Onifade and Awuviry-Newton, 2021; Jember *et al.*, 2021)		(Kassie and Workie, 2020; Adam Birhan and Bitew Belay, 2021; Chikako *et al.*, 2021; Muche *et al.*, 2021)
		DSF:			(Bekele and Fetene, 2021)
14	Minimum dietary Diversity (No)	ISF			
		DSF			(Aboagye *et al.*, 2021)
16	Deworming in last 6 months before survey (No)	ISF	(Heinrichs *et al.*, 2021; Tesema *et al.*, 2021)		(Uwiringiyimana *et al.*, 2022)
		DSF	(Tesema *et al.*, 2021)		
17	Anaemia status (No as reference)	ISF:		(Aheto *et al.*, 2021)	
		DSF:			
19	Stunting (No as reference)	ISF	(Gebremeskel *et al.*, 2020; Anteneh and Van Geertruyden, 2021; Jember *et al.*,		

			2021; Tesema, Tessema, *et al.*, 2021; Tesema, Worku, *et al.*, 2021)		
		DSF			
20	Wasting (No versus Yes)	ISF	(Anteneh and Van Geertruyden, 2021; Aregbeshola, Onifade and Awuviry-Newton, 2021; Jember *et al.*, 2021; Tesema *et al.*, 2021)		
		DSF			
21	Underweight	ISF	(Anteneh and Van Geertruyden, 2021; Tesema, Tessema, *et al.*, 2021; Tesema, Worku, *et al.*, 2021)		
		DSF			
23	Place of delivery (Home)	ISF:			
		DSF:			(Amaha and Woldeamanuel, 2021; Tesema *et al.*, 2021)
24	Had malaria fever	ISF:	(Elmardi *et al.*, 2020)		
		DSF:			

Parental-related variables					
			Anaemia	Malaria	Malnutrition
S/N	**Variables**	**Significance Levels**			
1	Maternal age (Younger age as reference)	Increased Significant Factors (ISF)			
		Decreased Significant Factors (DSF)	(Ag *et al.*, 2021; Amadu *et al.*, 2021; Anteneh and Van Geertruyden, 2021; Aregbeshola, Onifade and Awuviry-Newton, 2021; Tesema, Tessema, *et al.*, 2021; Tesema, Worku, *et al.*, 2021)		(Aboagye *et al.*, 2021; Adedokun and Yaya, 2021; Muche and Dewau, 2021; Tesema *et al.*, 2021)
	Maternal age at first birth (Younger age as reference)	(ISF)			
		(DSF)			(Kassie and Workie, 2020; Tesfaw and Fenta, 2021)
2	Maternal education status (None as reference)	(ISF)			
		(DSF)	(Amadu *et al.*, 2021; Anjorin and Yaya, 2021; Aregbeshola, Onifade and Awuviry-Newton, 2021; Barry *et al.*, 2021; Tesema, Tessema, *et al.*, 2021; Tesema, Worku, *et al.*, 2021; Eshete *et al.*, 2022)	(Emina, Doctor and Yé, 2021; Nzabakiriraho and Gayawan, 2021; Oguoma *et al.*, 2021)	(Hailu, Bogale and Beyene, 2020; Kassie and Workie, 2020; Khamis *et al.*, 2020; Simelane, Chemhaka and Zwane, 2020; Aboagye *et al.*, 2021; Adam Birhan and Bitew Belay, 2021; Adedokun and Yaya, 2021; Amaha and Woldeamanuel, 2021; Bekele and Fetene, 2021; Chikako *et al.*, 2021; Fenta, Zewotir and Muluneh, 2021; Muche and Dewau, 2021; Muche *et al.*, 2021; Tesema *et al.*, 2021; Tesfaw and Fenta, 2021; Amoako Johnson, 2022)
3	Paternal education status (None as reference)	(ISF)			
		(DSF)			(Rutayisire *et al.*, 2020; Bekele and Fetene, 2021; Fenta, Zewotir and Muluneh, 2021)
4	Maternal work status (Not working)	(ISF)	(Eshete *et al.*, 2022)		(Aboagye *et al.*, 2021; Amaha and Woldeamanuel, 2021; Chikako *et al.*, 2021; Fenta, Zewotir and Muluneh, 2021)
		(DSF)	(Amadu *et al.*, 2021; Anjorin and Yaya, 2021; Jember *et al.*, 2021)		(Amegbor, Yankey and Sabel, 2020)

5	Mother living with partner (Yes, as reference)	(ISF)	(Ag *et al*., 2021)		
		(DSF)			
6	Maternal body mass index (<18.5, as reference)	ISF			(Muche and Dewau, 2021; Sserwanja *et al.*, 2021)
		DSF	(Amadu *et al.*, 2021; Aregbeshola, Onifade and Awuviry-Newton, 2021)		(Kassie and Workie, 2020; Khamis *et al*., 2020; Adam Birhan and Bitew Belay, 2021; Amaha and Woldeamanuel, 2021; Chikako *et al.*, 2021; Kebede and Aynalem, 2021; Muche *et al*., 2021; Musuka *et al*., 2021; Tesfaw and Fenta, 2021; Uwiringiyimana *et al*., 2022)
7	Maternal anaemia status (Normal as reference)	ISF	(Elmardi *et al.*, 2020; Gebremeskel *et al*., 2020; Aregbeshola, Onifade and Awuviry-Newton, 2021; Heinrichs *et al*., 2021; Jember *et al*., 2021; Tesema, Tessema, *et al*., 2021; Tesema, Worku, *et al.*, 2021)		(Kassie and Workie, 2020)
		DSF	(Anjorin and Yaya, 2021)		
	ANC Attendance (<4 as Ref)	ISF			
		DSF			(Aboagye *et al*., 2021; Adedokun and Yaya, 2021; Tesema *et al*., 2021; Amoako Johnson, 2022)
8	Maternal religious status (Protestant vs Muslim)	ISF	(Jember *et al*., 2021)		(Adam Birhan and Bitew Belay, 2021; Tesfaw and Fenta, 2021; Amoako Johnson, 2022)
		DSF			
9	Maternal ante-natal care (<4, as reference)	ISF			
		DSF	(Ag *et al*., 2021; Amadu *et al.*, 2021)		
11	Maternal knowledge of malaria fever	ISF			
		DSF			
12	Number of children ever born (> 2 as reference)	ISF:	(Heinrichs *et al.*, 2021)		
		DSF:			
14	Mother current marital status Married as reference	ISF:	(Amadu *et al*., 2021)		
		DSF:			
15	Family structure (Single vs Poly union)	ISF:	(Anjorin and Yaya, 2021)		
		DSF:			

Household-related variables					
			Anaemia	Malaria	Malnutrition
1	Household wealth status (Poorest as reference	ISF:			(Wondimu and Dejene, 2022)
		DSF:	(Gebremeskel *et al.*, 2020; Ag *et al*., 2021; Amadu *et al*., 2021; Anjorin and Yaya, 2021; Anteneh and Van Geertruyden, 2021; Aregbeshola, Onifade and Awuviry-Newton, 2021; Heinrichs *et al.*, 2021; Jember *et al*., 2021; Tesema, Tessema, *et al.*, 2021; Tesema, Worku, *et al*., 2021; Eshete *et al*., 2022)	(Aheto *et al.*, 2021; Emina, Doctor and Yé, 2021; Nzabakiriraho and Gayawan, 2021; Oguoma *et al.*, 2021)	(Amegbor *et al.*, 2020; Hailu, Bogale and Beyene, 2020; Kassie and Workie, 2020; Khamis *et al*., 2020; Masibo, Humwa and Macharia, 2020; Simelane, Chemhaka and Zwane, 2020; Aboagye *et al*., 2021; Adam Birhan and Bitew Belay, 2021; Adedokun and Yaya, 2021; Bekele and Fetene, 2021; Chikako *et al*., 2021; Fenta, Zewotir and Muluneh, 2021; Muche and Dewau, 2021; Muche *et al*., 2021; Musuka *et al*., 2021; Tesema *et al*., 2021; Tesfaw and Fenta, 2021; Amoako Johnson, 2022; Uwiringiyimana *et al*., 2022)
2	Household had bed net (No as reference)	ISF:			
		DSF:		(Nzabakiriraho and Gayawan, 2021)	
3	Age of household head (Youngest as ref)	ISF			
		DSF			(Khamis *et al*., 2020)
5	Household size (Lower, as reference)	ISF	(Amadu *et al*., 2021; Tesema *et al*., 2021)	(Oguoma *et al*., 2021)	(Aboagye *et al*., 2021; Tesfaw and Fenta, 2021)
		DSF			(Muche *et al*., 2021)

6	Number of under-5 in household (<3, as reference)	ISF	(Anteneh and Van Geertruyden, 2021; Jember *et al.*, 2021)	(Aheto *et al.*, 2021)	(Kassie and Workie, 2020; Simelane, Chemhaka and Zwane, 2020; Tesfaw and Fenta, 2021)
		DSF			(Fenta, Zewotir and Muluneh, 2021)1
8	Improved water source (No as reference)	ISF:			(Adedokun and Yaya, 2021)
		DSF:			(Kassie and Workie, 2020; Bekele and Fetene, 2021; Seboka *et al.*, 2021; Uwiringiyimana *et al.*, 2022)
11	Use biomass for cooking	ISF	(Letuka and Frade, 2020)		
		DSF			
12	Under 5 years child slept under bed net	ISF			
		DSF		(Emina, Doctor and Yé, 2021; Nzabakiriraho and Gayawan, 2021; Oguoma *et al.*, 2021)	
16	Household connected electricity (No as reference)	ISF:			
		DSF:		(Aheto *et al.*, 2021)	
17	Improved floor material (No as reference)	ISF			
		DSF			(Uwiringiyimana *et al.*, 2022)

Community-related variables					
1	Community wealth status (Low, as reference)	ISF			
		DSF	(Gebremeskel *et al.*, 2020; Eshete *et al.*, 2022)		
2	Place of residence (Rural as reference)	ISF			
		DSF	(Elmardi *et al.*, 2020; Heinrichs *et al.*, 2021)	(Nzabakiriraho and Gayawan, 2021; Oguoma *et al.*, 2021)	(Khamis *et al.*, 2020; Adedokun and Yaya, 2021; Chikako *et al.*, 2021; Fenta, Zewotir and Muluneh, 2021; Muche and Dewau, 2021; Tesema *et al.*, 2021; Tesfaw and Fenta, 2021; Amoako Johnson, 2022)

Appendix B: Copies of ethical approval(s)

B.1: Ethical Approval by the ScHARR Research Ethics Committee

School Of

The University Of Sheffield.

Health And Related Research.

ScHARR

Charlotte Claxton
Ethics Committee Administrator
Regent Court
30 Regent Street
Sheffield S1 4DA

Telephone: +44 (0) 114 222 5446
Email: c.claxton@sheffield.ac.uk

17 March 2020

Project title: Investigating the Multiple overlaps of Socioeconomic, Demographic and Contextual determinants of
Malaria, Anaemia and Malnutrition among Under-5 Children in Nigeria: Multinomial Multilevel Structural Equation Model Approach.

Reference Number: 031534

Dear Phillips,

Thank you for submitting the above amended research project for approval by the ScHARR Research Ethics Committee. On behalf of the University, I am pleased to inform you that the project with changes was approved.

If during the course of the project you need to deviate significantly from the documents you submitted for review, please inform me since written approval will be required.

Yours sincerely

Charlotte Claxton
On behalf of the ScHARR Research Ethics Committee

ScHARR Research Ethics Committee

NOTICE OF AMENDMENT

For use in the case of all research where an amendment is made.
To be completed as a word document by the Chief Investigator in language comprehensible to a lay person and submitted to the Ethics Administrator.

Further guidance is available at http://www.shef.ac.uk/scharr/research/ethicsgovernance

Details of Chief Investigator:

Name: Phillips Edomwonyi Obasohan *Type of ethics application:*

PGR Student (Approved Self Declaration)

Telephone: 07933252050

Email: peobasohan1@sheffield.ac.uk

Full title of study:	Investigating Multiple Overlaps of Socioeconomic, Demographic and Contextual Determinants of Malaria, Anaemia and Malnutrition among Under-5years Children in Nigeria: Multinomial Multilevel Structural Equation Model Approach
REC reference number (if known):	031534
Date study commenced:	01-10-2019
Amendment number and date (for office use):	

Type of amendment (indicate all that apply in bold)

(a) Amendment to information previously given on the REC Application Form: **Yes**

Yes *No*

If yes, please refer to relevant sections of the REC application in the "summary of changes" below.

(b) Amendment to the protocol **No**

Yes *No*

If yes, please submit <u>either</u> the revised protocol with a new version number and date, highlighting changes in bold, <u>or</u> a document listing the changes and giving both the previous and revised text.

(c) Amendment to the information sheet(s) and consent form(s) for participants, or to any other supporting documentation for the study ***No***

Yes *No*

If yes, please submit all revised documents with new version numbers and dates, highlighting new text in bold.

Is this a modified version of an amendment previously notified to the REC? No

Yes *No*

Summary of changes

Briefly summarise the main changes proposed in this amendment using language comprehensible to a lay person. Explain the purpose of the changes and their significance for the study.

1. **Amendment to the title of the project, which the new title has now included the new variables of interest in the project**
2. **Two separate surveys (NMIS 2015 and NDHS 2013) were previously carried out by the same organization (DHS) in Nigeria addressing separate variables. However, the most recent survey conducted by this organization (DHS) has combined the two surveys to one (NDHS 2018). The initial REC approval was given on account of using only one of the survey data sets (NMIS, 2015). I have now got the permission from DHS to use the new combined data set, NDHS 2018.**
3. **In addition, other variables of interest in my project at the area level that were not captured by NDHS 2018 data set are held by United Nation Development Programme (UNDP Nigeria), the National Human Development Report (NHDR) 2018 survey. The UNDP (Nigeria) has also granted permission to me to use the data set for my project.**
4. **Both data sets do not carry any mark of identifier of any of their participants**.

If the amendment significantly alters the research design or methodology, or could otherwise affect the scientific value of the study, supporting scientific information should be given (or enclosed separately). Indicate whether or not additional scientific critique has been obtained.

The amendment will neither alter the research design nor methodology, nor could affect the scientific value of the study

Any other relevant information

Applicants may indicate any specific ethical issues relating to the amendment, on which the opinion of the REC is sought.

There is no any ethical issues relating to this amendment

List of enclosed documents		
Document	*Version*	*Date*
Permission Notification from DHS to use data set of NDHS 2018 (Nigeria)	**2nd**	**24th January 2020**
Permission notification from UNDP (Nigeria) to use data set of NHDR 2018 (Nigeria)	**1st**	**3rd March 2020**

Declaration by Chief Investigator

• I confirm that the information in this form is accurate to the best of my knowledge and I take full responsibility for it.

Signature of Chief Investigator: ……

Print name: ……

Date of submission: …….

Declaration by the supervisor (if appropriate)

• I confirm the supervisors support for this amendment.

Print name: Professor Stephen Walters…….……

Post: Professor of Medical Statistics and Clinical Trials

Date:23 March 2020 ……..

B.2: Approval to use NDHS & NHDR 2918 data set

Jan 24, 2020

Phillips Obasohan
Niger State Polytechnic
Nigeria
Phone: +2348036368497
Email: philiobas@yahoo.com

Request Date: 01/24/2020

Dear Phillips Obasohan:

This is to confirm that you are approved to use the following Survey Datasets for your registered research paper titled: "PhD in School Health and Related Research (ScHARR)":

Nigeria

To access the datasets, please login at: https://www.dhsprogram.com/data/dataset_admin/login_main.cfm. The user name is the registered email address, and the password is the one selected during registration.

The IRB-approved procedures for DHS public-use datasets do not in any way allow respondents, households, or sample communities to be identified. There are no names of individuals or household addresses in the data files. The geographic identifiers only go down to the regional level (where regions are typically very large geographical areas encompassing several states/provinces). Each enumeration area (Primary Sampling Unit) has a PSU number in the data file, but the PSU numbers do not have any labels to indicate their names or locations. In surveys that collect GIS coordinates in the field, the coordinates are only for the enumeration area (EA) as a whole, and not for individual households, and the measured coordinates are randomly displaced within a large geographic area so that specific enumeration areas cannot be identified.

The DHS Data may be used only for the purpose of statistical reporting and analysis, and only for your registered research. To use the data for another purpose, a new research project must be registered. All DHS data should be treated as confidential, and no effort should be made to identify any household or individual respondent interviewed in the survey. Please reference the complete terms of use at: https://dhsprogram.com/Data/terms-of-use.cfm.

The data must not be passed on to other researchers without the written consent of DHS. However, if you have coresearchers registered in your account for this research paper, you are authorized to share the data with them. All data users are required to submit an electronic copy (pdf) of any reports/publications resulting from using the DHS data files to: references@dhsprogram.com. Sincerely,

Bridgette Wellington

Bridgette Wellington
Data Archivist
The Demographic and Health Surveys (DHS) Program

United Nations Development Programme

Empowered lives.
Resilient nations.

PRG/3335/03/03/2020

3 March 2020

Dear Mr. Obasohan,

Re: Permission to Use Data Set from National Human Development Report 2018

This is to acknowledge your letter dated 2nd March 2020 requesting for approval to use Data from 2018 National Human Development Report (NHDR) for your Ph. D. research work in University of Sheffield.

We are pleased to grant your request and give you approval to go ahead and use the data from the report for your research work as requested. We wish you all the best in your research.

Yours sincerely,

Amarakoon Bandara
Economic Advisor

Mr. Philips Obasohan
The University of Sheffield
School of Health and Related Research
West Court Office Room 114, Regent Court
30 Regent Street
Sheffield Sl 4DA, UK

Appendix C: Scoping reviews and other publications

C.1: A Scoping Review of the Risk Factors Associated with Anaemia among Children Under Five Years in Sub-Saharan African Countries

International Journal of
Environmental Research and Public Health

MDPI

Review

A Scoping Review of the Risk Factors Associated with Anaemia among Children Under Five Years in Sub-Saharan African Countries

Phillips Edomwonyi Obasohan [1,2,*], Stephen J. Walters [1], Richard Jacques [1] and Khaled Khatab [3]

1 School of Health and Related Research (ScHARR), University of Sheffield, Sheffield S1 4DA, UK; s.j.walters@sheffield.ac.uk (S.J.W.); r.jacques@sheffield.ac.uk (R.J.)

2 Department of Liberal Studies, College of Administrative and Business Studies, Niger State Polytechnic, Bida Campus, Bida 912231, Nigeria

3 Faculty of Health and Wellbeing, Sheffield Hallam University, Sheffield S10 2BP, UK; K.Khatab@shu.ac.uk * Correspondence: peobasohan1@sheffield.ac.uk

Received: 29 October 2020; Accepted: 25 November 2020; Published: 27 November 2020

Abstract: *Background/Purpose:* Globally, anaemia is a severe public health condition affecting over 24% of the world's population. Children under five years old and pregnant women are the most vulnerable to this disease. This scoping review aimed to evaluate studies that used classical statistical regression methods on nationally representative health survey data to identify the individual socioeconomic, demographic and contextual risk factors associated with developing anaemia among children under five years of age in sub-Saharan Africa (SSA). *Methods/Design:* The reporting pattern followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines. The following databases were searched: MEDLINE, EMBASE (OVID platform), Web of Science, PUBMED, Cumulative Index to Nursing and Allied Health Literature (CINAHL), PsycINFO, Scopus, Cochrane library, African Journal of online (AJOL), Google Scholar and Measure DHS. *Results:* The review identified 20 relevant studies and the risk factors for anaemia
were classified as child-related, parental/household-related and community- or area-related factors. The risk factors for anaemia identified included age, birth order, sex, comorbidities (such as fever, diarrhoea and acute respiratory infection), malnutrition or stunting, maternal education, maternal age, mother's anaemia status, household wealth and place of residence. *Conclusion:* The outcome of this review is of significant value for health policy and planners to enable them to make informed decision that will correct any imbalances in anaemia across socioeconomic, demographic and contextual characteristics, with the view of making efficient distributions of health interventions. **Keywords:** anaemia; iron-deficiency; under five; sub-Saharan Africa; risk factors; scoping review

Introduction

Globally, anaemia is a severe public health condition affecting over 24% of the world's population [1]. People across different regions, ages and sexes are affected by this health burden [2]. It indicates that the prevalence of anaemia cuts across developed and developing countries, males and females, children and adults. Nevertheless, children under five years of age and pregnant women are the ones who are most likely to be affected by this disease condition. Developing countries have a four times higher burden of anaemia than in developed countries [3]. Between 1990 and 2014, during the global Millennium Development Goals (MDG) watch, under-five anaemia witnessed a global decline from a prevalence of 51.4% to 41.4%, but in 2016 it gradually increased to 41.7% [4]. In Nigeria, the post MDG prevalence of under-5 anaemia has risen from 60% in 2015 to 68.1% in 2018 [5,6]. Belachew and Tewabe classified anaemia as a widespread hematologic disorder in children [7]. Diagnosis of anaemia is through blood examination for the haemoglobin or haematocrit concentration of a standard threshold by age and sex [8]. At the population level, a survey reported that using a haemoglobin (Hb) concentration test is more reliable for detecting anaemia than clinical measurement [8]. However, the same study cautioned that the mean Hb concentration level could be found to be lower in a population with high rates of inherited haemoglobinopathies [8].

The causes of anaemia, especially in developing countries, are primarily attributed to iron deficiency [9] in conjunction with other predisposing factors, such as acute and chronic infections like malaria, tuberculosis, cancer and HIV. Other causes are malnutrition and haemoglobinopathies [8]. Globally, more than 50% of cases of anaemia are caused by iron deficiency [3], and specifically over 42% of all under-5 anaemia is attributable to iron deficiency [10]. The harmful effects of under-five anaemia include long-term cognitive disorder, impaired educational performance [3,11], retardation in physical growth, poor motor skills, impaired language development [3] and an increased risk of child mortality as a result of severe anaemia [8]. Furthermore, of the relevant literature identified, other risk factors associated with under-five anaemia categorised as child-related are age, birth order, sex, nutritional status and the use of insecticide-treated nets for children [10–13]; others include household-related characteristics: wealth status, parental or caregiver's educational attainment, employment status, age at first marriage and place of residence [10,12].

To effectively tackle the harm caused by anaemia through careful health interventions, knowing the estimates of its prevalence, associated causes and risk factors are very crucial [3]. This scoping review study is an integral part of a more extensive doctoral research work focusing on multi-morbidities among children of under five years of age in Nigeria. The relative lack of studies on anaemia among children of under five years (otherwise referred to as "under-five anaemia") in Nigeria using nationally representative surveys has necessitated expanding the review to cover sub-Saharan Africa (SSA). Given the rising trend of under-five anaemia, identification, and description of various risk factors, as well as using classical statistical regression methods and an array of different survey types, will be useful tools to enhance future health science investigations [14]. In Nigeria and perhaps in SSA, studies on scoping reviews to evaluate the risk factors that are associated with under-five anaemia are urgently needed to help programme planners and policymakers in the efficient distribution of scarce health interventions. The methodological approach of a qualitative review of many studies' contents has made this study lean towards a scoping rather than systematic review [14]. The overall research question for this scoping review is what are the risk factors associated with the development of anaemia in children under five years of age in sub-Saharan Africa?

The Aim of the Scoping Review

This scoping review aimed to identify and evaluate studies that performed classical regression analysis—a regression analysis that is based on Frequentist statistical methods on nationally representative health survey data to identify the individual socioeconomic, demographic and contextual risk factors associated with developing anaemia among children under five years of age in sub-Saharan Africa (SSA).

2. Materials and Methods

The pattern of reporting this scoping review followed the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines" [15,16]. The scoping study also adopted the steps described in the four-phase flow chart recommended by the PRISMA statement (see Figure 1).

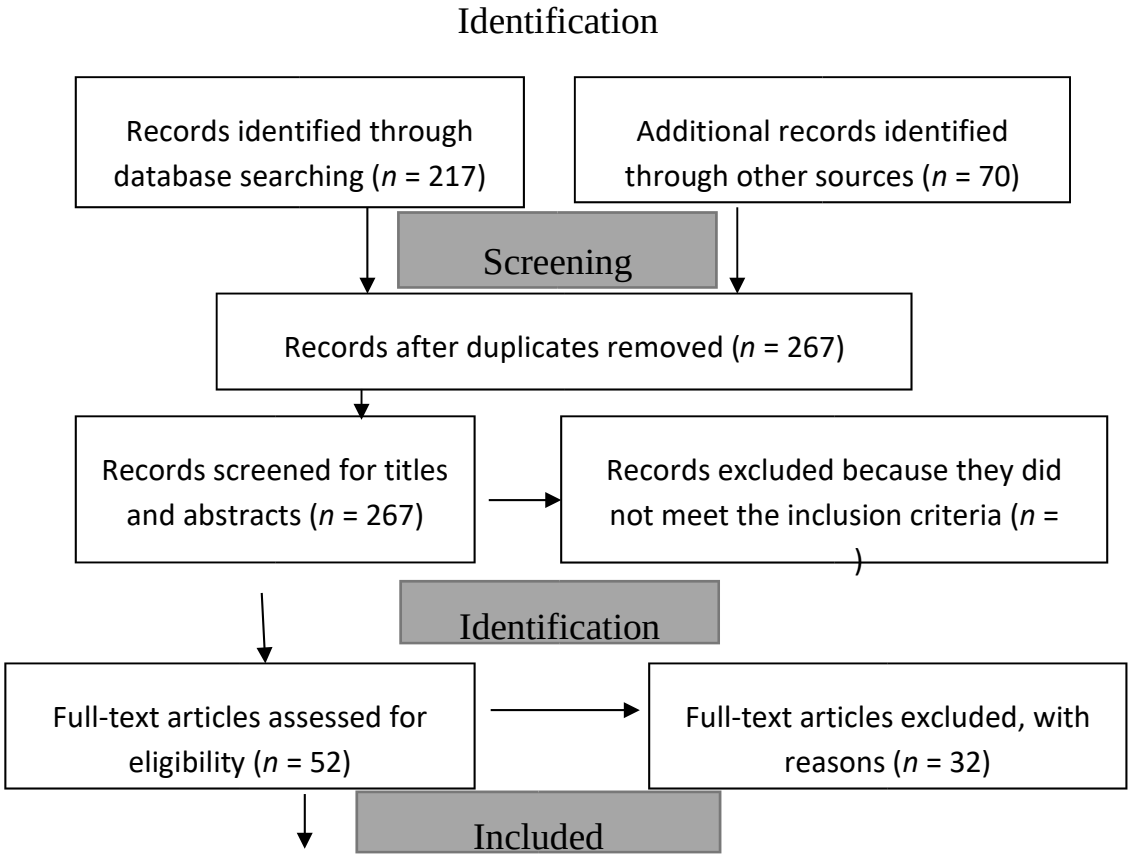


Figure 1. Flowchart showing the inclusion process.

2.1. Protocol and Registration Declaration

There was a protocol study prepared for this review but it was neither registered nor published.

2.2. Eligibility Criteria

Studies included in the review followed the PICOTS (Population, Interventions, Comparators, Outcomes, Timing and Setting/Study Design) principles enumerated below:

2.2.1. Population

Participating studies were searched for those that were conducted in countries in SSA, which addressed the individual socioeconomic, demographic and community risk factors that are related to anaemia among children under five years of age, using national health representative surveys. The studies also included both male and female children less than five years of age and who resided in any of the sub-Saharan Africa countries. We also considered for inclusion studies that involved both adults (and/or children above five years) and children under 5 years of age, taking into consideration that the data for the under-fives were reported differently from others [8].

2.2.2. Interventions

Eligible for inclusion were studies that focused on predictors or risk factors or determinants of anaemia among under-five or pre-school children in SSA. In view of this, the following were considered: (i) child-related variables; (ii) parental/caregiver-related variables; (iii) household-related variables and socioeconomic status; (iv) demographic status; and (v) area characteristics. This scoping review spanned both individual and contextual exposures.

2.2.3. Comparators

Given the broad dimension of the exposures of interest, we included studies involving some perspectives of comparisons. These studies suggested two mutually exclusive groups: those that are "anaemic" and those that are "not anaemic", for which we compared the exposures. However, studies that classified anaemia status into severe, moderate and mild were included and considered as anaemic. However, we excluded studies that reported determinants of anaemia status in children by specific characteristics, such as age, maternal education and status, etc., rather than by their anaemia status.

2.2.4. Outcomes

The outcome of interest for inclusion was the under-five anaemia status and was determined by the haemoglobin (Hb) level being less than 11.0 grams per decilitre. Anaemia status was, however, further classified as mild when Hb = 10–10.9 g/dL, moderate when Hb = 7.0–9.9 g/dL and severe anaemia when Hb < 7 g/dL [7]. Studies were also included that considered haemoglobin deficiency, malaria-induced anaemia, nutritional-deficiency anaemia and iron-deficiency anaemia (IDA) as the outcomes of interest. The most common contributory factor to the development of anaemia is iron deficiency and is responsible for more than 50% of anaemia cases worldwide. So, IDA and anaemia are often taken as the same [8].

2.2.5. Timing or Time Frames

The studies considered for inclusion were those published between 1 January 1990 and 26 June 2020.

2.2.6. Study Designs

This scoping review included observational studies, such as case-control and nested case-control studies, cross-sectional and cohort studies (prospective and retrospective) and randomised control trials, which controlled the risk factors under consideration. The search also included those studies that applied classical statistical regression methods for the analyses.

2.3. Information Sources

The strategy for this literature search was carried out by the candidate (P.E.O.) of the School of Health and Related Research (ScHARR), the University of Sheffield, United Kingdom. The selection of the literature for screening was based on keywords and subject headings. The following databases and grey literature, using the identified search terms, were used: MEDLINE, EMBASE (OVID platform), Web of Science, PUBMED, Cumulative Index to Nursing and Allied Health Literature (CINAHL), African Journal of online (AJOL), Google Scholar and Scopus. The search was supplemented by searching for relevant literature in the "Unishef" library, WhiteRose Research Online and Measure DHS. A hand search for potential papers from the reference list of identified documents was also conducted. Only articles written in the English language, and with a publication date between 1 January 1990 and 26 June 2020, were included.

2.4. Search Strategy

The literature search included searching for each key term or text words individually. The phrases were first searched in PubMed headings using the appropriate truncation and wildcard parameters [17]. The search terms applied in the PICOTS (Population, Intervention, Comparators, Outcomes, Timing and Settings) categories were as follows: demographic health survey, AIDS indicator survey, malaria indicator survey, multiple indicator cluster surveys, health survey, MIS, DHS, sub-Saharan Africa [14], logistic regression, multilevel regression, multinomial logistic, random effects, hierarchical, fixed effects, Anemi*, Anaemi*,

Anaemia, Haemoglobin, Iron deficiency anaemia. These were the various terms used with appropriate Boolean connectors, "AND/OR", in this order: (demographic health survey or AIDS indicator survey or malaria Indicator survey or multiple indicator cluster survey or health survey or MIS) and (sub-Saharan Africa) and (logistic regression OR multilevel regression OR multinomial logistic OR random-effects OR hierarchical OR fixed effects) AND (Anemi* OR Anaemi* OR Anaemia OR Haemoglobin OR Iron deficiency anaemia). We applied age-specific filters: 0–23 months and 24–59 months and year of publication from 1990 to 2020. The search was carried out between 22 to 26 June 2020

2.5. Selection Process

The reviewer, P.E.O., screened all the selected literature's titles and abstracts as a function of the inclusion and extraction criteria. The reviewer conducted a full-text report screening and showed the reasons for excluding any paper. Two overseers of the project vetted this process. In the event of any contrary opinions, the most senior member of the overseeing team brokered any discrepancies noticed at this point.

2.6. Data Charting Management

The data extracted from the studies was first transferred into a Microsoft Excel (Microsoft Corporation, Washington, DC, USA) spreadsheet designed by the reviewer for this review. Relevant information from each study was included, such as the study outcome (anaemia status), various predictor variables concerning the child-related variables, parental/household-related variables and contextual or community-related variables, as well as the magnitude of their significant effects. Other items extracted were the titles of the studies and their authors/year of publication, the survey types, the number of samples
or sample sizes (under five years) and the country in which the study was conducted.

3. Results

The results section reports the profile of the quantitative analysis of the risk factors associated with anaemia in under-five children in SSA. The results extracted are those reported from the studies that investigated the risk factors (both protective and harmful effects) that were evident from the Odds Ratios (OR), Relative Risk Ratios (RRR) or Risk Difference (RD) and Regression Estimates (RE).

3.1. The Study Profile Counts

A total of 217 studies (publications) were extracted from the electronic databases (Pubmed = 140, Scopus = 13 and Medline = 1) and another 63 studies from Google Scholar (using adjusted search terms to accommodate the length required for search terms in Google Scholar). Other sources searched include MeasureDHS journal publications, while using broad conditions such as "Anaemia" filtered for African countries and publication years between 1990 and 2020. The search yielded 43 studies.

Twenty-six (26) other reviews were added from checking the references of the included studies and

AJOL = 1. After the removal of 20 duplicate studies, the first scoping glance at the titles and abstracts eliminated a further 215 studies (publications). Fifty-two (52) studies were subjected to full-text examination, which resulted in retaining 20 publications for this review, after excluding 32 other studies (see Figure 1). The reasons for the exclusion of most of the studies were as follows:

Using other analytical methods rather than classical regression analysis.

Studies did not report separate results for children 0–59 months.

Studies that considered anaemia outcomes based on the maternal or child's specifics.

Studies not from SSA countries.

Papers without the full text available.

The 20 publications that met the inclusion criteria were further subjected to full-text scrutiny to answer the scoping review question. However, in this scoping review, the unit of analysis was the country for which a unique analysis of a unique data set was done. What this means is that a single study of two nations, in which the two countries were analysed separately

according to their nationally representative surveys from each country, was counted as two studies. On the other hand, studies in several countries with pooled data as single analysis were counted as one study. Overall, a total of 24 countries' studies were included in this review.

3.2. Characteristics of the Included Studies

Table 1 describes the profiles of the studies included in this scoping review. It shows the authors' names and year of publication, the country of research, the title of the studies, survey type (i.e., the nationally representative survey type), the number of children of under five years used in each research and the classical statistical regression methods applied to determine the predictors of under-five anaemia in SSA countries. There is no preference in the order in which the authors are presented in Table 1.

The number of participants in each of the studies ranged from 933 under-five children captured in the study of Cape Verde by Semedo et al. [35] and published in 2014, to 96,804 under-five children from a pooled sample surveys of 27 SSA countries conducted by Moschovis et al. [23] and published in 2018. The statistical methods used to identify the potential risk factors for anaemia used in the selected studies include multivariate linear regression (two studies), multivariate binary logistic regression (nine studies), proportional regression (two studies), multilevel regression analysis (five studies), generalized linear mixed regression (5 studies), ordered logistic regression (1 study) and multinomial regression analysis (1 study). The earliest surveys considered in this scoping review were conducted in Ethiopia (EDHS), Malawi (MNCS) and Tanzania (TDHS) in 2016, while the oldest studies were BDHS (2001) and MDHS (2001), conducted in Benin and Mali, respectively.

Table 1. Characteristics of the selected studies on anaemia (*n* = 24).

Author(s) (Year)	Country	Title of Study	Survey Type	Prevalence of Anaemia	Participation	Methods
Dwumoh et al. (2014) [18]	Ghana	Determinant of factors associated with child health outcomes and service utilization in Ghana: Multiple indicator cluster survey conducted in 2011	MICS	There was no % prevalence reported	7550	Binary logistic regression models and multiple linear regression
Hershey et al. (2017) [19]	Malawi	Malaria Control Interventions Contributed to Declines in Malaria Parasitaemia, Severe Anaemia, and All-Cause Mortality in Children Less Than 5 Years of Age in Malawi, 2000–2010	DHS, MICS and MIS	Prevalence of severe anaemia in 2010 was 8.7%	Proportion	Multivariable, random effects logistic regression models
Jones et al. (2018) [20]	Ghana	Livestock ownership is associated with higher odds of anaemia among preschool-aged children, but not women of reproductive age in Ghana	DHS	Moderate anaemia was 56.4%, mild anaemia was 40.2%	2735	Multiple binary logistic regression models
Machisa et al. (2013) [21]	Swaziland	Biomass fuel use for household cooking in Swaziland: is there an association with anaemia and stunting in children aged 6–36 months?	DHS	51.8% in children 6–36 months	1150	Multinomial logistic regression analyses
Mohammed et al. (2019) [22]	Ethiopia	Household, maternal, and child-related determinants of haemoglobin levels of Ethiopian children: hierarchical regression analysis	DHS 2016	71.92% in the study population (6–23 months)	2902	Hierarchical linear regression analysis
Moschovis et al. (2018) [23]	27 SSA countries	Individual, maternal and household risk factors for anaemia among young children in sub-Saharan Africa: a cross-sectional study	DHS 2008–2014	59.9% among children 6–59 months	96,804	Multiple linear regression or multiple binary logistic regression
Nambiema et al. (2019) [24]	Togo	Prevalence and risk factors of anaemia in children aged from 6 to 59 months in Togo: analysis from Togo demographic and health survey data	DHS 2013–2014	70.9% among children 6–59 months	2890	Logistic regression models

Ngnie-Teta et al. (2007)[25]	Benin	Risk factors for moderate to severe anaemia among children in Benin and Mali: insights from a multilevel analysis	DHS 2001	82%	2284	Multilevel binary logistic model

Table 1. *Cont.*

Author(s) (Year)	Country	Title of Study	Survey Type	Prevalence of Anaemia	Participation	Methods
	Mali	Risk factors for moderate to severe anaemia among children in Benin and Mali: insights from a multilevel analysis	DHS 2001	83%	2826	Multilevel binary logistic model
Ntenda et al. (2019) [26]	Malawi	Clinical malaria and the potential risk of anaemia among preschool-aged children: a population-based study of the 2015–2016 Malawi micronutrient survey	2015–2016 MNS	29%	1051	Multivariate binary logistic regression models
Ntenda et al. (2018) [27]	Malawi	Multilevel Analysis of the Effects of Individual- and Community-Level Factors on Childhood Anaemia, Severe Anaemia, and Haemoglobin Concentration in Malawi	2010 DHS	63%	2597	Multilevel linear regression models
Kawo et al. (2018) [2]	Ethiopia	Multilevel Analysis of Determinants of Anaemia Prevalence among Children Aged 6–59 Months in Ethiopia: Classical and Bayesian Approaches	2010 DHS	42.8%	5507	Multilevel binary logistic regression analysis
Immurana and Arabi (2017) [28]	Ghana	Socioeconomic factors and child health status in Ghana	2014 DHS	71.11% male and 67.95% female children	2220	Binary probit model
Candia (2017) [29]	Uganda	Influence of malaria on anaemia levels among children less than 60 months of age	MIS	53.22%	4940	Ordered logistic regression model
Menon and Yoon (2015) [30]	Uganda	Prevalence and Factors Associated with Anaemia among Children Under 5 Years of Age—Uganda, 2009	2009 MIS	60% of children under five years	4065	Multivariate binary logistic regression model

Nikol and Anthamatten (2013) [31]	Ghana	Childhood anaemia in Ghana: an examination of associated socioeconomic and health factors	2008 DHS	79.8%	2055	Generalized linear mixed regression model
Ojoniyi et al. (2019) [32]	Tanzania	Does education offset the effect of maternal disadvantage on childhood anaemia in Tanzania? Evidence from a nationally representative cross-sectional study	2015–2016 DHS/MIS	58.6%	7916	Proportional odds model

Table 1. *Cont.*

Author(s) (Year)	Country	Title of Study	Survey Type	Prevalence of Anaemia	Participation	Methods
Muchie (2016) [33]	Ethiopia	Determinants of severity levels of anaemia among children aged 6–59 months in Ethiopia: further analysis of the 2011 Ethiopian demographic and health survey	2011 DHS	28.6% were severely/moderately anaemic and 21.7% were mildly anaemic	7636	Proportional odds model of ordinal logistic regression
Asresie et al. (2020) [34]	Ethiopia	Determinants of Anaemia among Children Aged 6–59 Months in Ethiopia: Further Analysis of the 2016 Ethiopian Demographic Health Survey	2016 DHS	58% of children 6–59 months	8462	Binary Logistic regression analyses
Semedo et al. (2014) [35]	Cape Verde	Prevalence of anaemia and associated factors among children below five years of age in Cape Verde, West Africa	NHS	51.8%	933	Hierarchical model for multiple analysis
Ntenda et al. (2018) [36]	Malawi	Maternal anaemia is a potential risk factor for anaemia in children aged 6–59 months in Southern Africa: a multilevel analysis	2010 DHS	63.8%	2507	Generalized linear mixed models (GLMMs)
	Mozambique	Maternal anaemia is a potential risk factor for anaemia in children aged 6–59 months in Southern Africa: a multilevel analysis	2013 DHS	70%	1933	Generalized linear mixed models (GLMMs)

	Namibia	Maternal anaemia is a potential risk factor for anaemia in children aged 6–59 months in Southern Africa: a multilevel analysis	2013 DHS	49%	1116	Generalized linear mixed models (GLMMs)
	Zimbabwe	Maternal anaemia is a potential risk factor for anaemia in children aged 6–59 months in Southern Africa: a multilevel analysis	2010–2011 DHS	58.6%	2578	Generalized linear mixed models (GLMMs)

Note: Multiple Indicators Cluster Survey (MICS); Demographic and Health Survey (DHS); Malaria Indicator Survey (MIS); National Household Survey (NHS); Micronutrient Survey (MNS).

3.3. The Study Profiles by Countries

The country of study is the unit of our review. Table 2 gives a breakdown of the study profiles by country—a total of twenty-four (24) unique country-based studies where examined from 20 extracted publications. A study conducted by Ngnie-Teta et al. [25] focused on two separate countries,

Benin and Mali, and Ntenda et al. [36] focused on four different countries, Malawi, Mozambique, Namibia and Zimbabwe. Each of these countries used the country's national representative survey, and their findings were also reported separately; hence, in this review, we also counted each as a separate study. However, the highest number of publications came from Ghana, Malawi and Ethiopia,

with four studies each (representing 16% each). Uganda closely followed these with two studies (representing 8%).

Table 2. Study profiles by country.

Country Specific Articles	Number	%	References
Ghana	4	16.8	[18,20,28,31]
Ethiopia	4	16.8	[2,22,33,34]
Mali	1	4.2	[25]
Benin	1	4.2	[25]
Uganda	2	8.4	[29,30]
Tanzania	1	4.2	[32]
Malawi	4	16.8	[19,26,27,36]
Swaziland	1	4.2	[21]
Multi-country	1	4.2	[23]
Togo	1	4.2	[24]
Cape Verde	1	4.2	[35]
Mozambique	1	4.2	[36]
Namibia	1	4.2	[36]
Zimbabwe	1	4.2	[36]
	24 *	100	

* A total of twenty-four (24) unique country-based studies were examined from 20 extracted studies (publications).

The remaining countries had one study each. It is worth noting that one of the studies was classified as a multi-country study because it comprised 27 SSA countries, with the data pooled together and analysed as one study [23]. For Nigeria, there was no study that used classical regression analysis to determine the risk factors associated with under-five anaemia. The same was true for some other SSA countries.

3.4. Classification by Survey Types

Table 3 describes the various survey types captured in the review. A total of 27 nationally representative surveys were used in the 24 countries' unique studies. Five different types of national representative sampled surveys were extracted, DHS, NHS, MIS, MNS and MICS. The most frequently used survey is the Demographic and Health Survey (DHS), with 19 studies (representing 70%), followed by the Malaria Indicator Survey (MIS) with four studies, and then the Multiple Indicator and Cluster Survey (MICS) with two studies (7%).

Table 3. Description of the survey types in this anaemia review.

Survey Type Specific	N	%
Demographic and Health Survey (DHS)	19	70
Multiple Indicator Survey (MIS)	4	15
Micronutrient Survey (MNS)	1	4
Multiple Indicator Cluster Survey (MICS)	2	7
National Health Survey (NHS)	1	4
Total	27 *	100

* Some studies used more than one survey (see Table 1).

Other surveys captured in the review were the Micro-Nutrient Survey (MNS) and the National Health Survey (NHS), having one study each. One unique feature about these surveys is that they were conducted under the same technical assistance from ICF International through the MeasureDHS program, with the exemption of the NHS held in Cape Verde [35]. Some of these studies used a combination of two or more of these survey types.

3.5. Classification by Analytical Methods

Another essential feature of this scoping review is the identification of the varied analytical methods used to establish the risk factors associated with the anaemia status of children under five years of age in SSA. This is represented in Table 4.

Table 4. Classification of the analytical methods.

Analytical Methods	N	%	References
Multivariate Linear Regression	2	8	[18,23]
Multivariate Logistic Regression	9	36	[18–20,23,24,26,28,30,34]
Proportional Ordinal Logistic Regression	3	12	[29,32,33]
Multilevel Regression	5	20	[2,22,25,27]
Generalised Linear Mixed Regression Model	5	20	[31,36]
Multinomial Regression	1	4	[21]
Total	25 *	100	

* Some studies used more than one analysis technique.

Only studies that applied classical regression analysis tools were included. Nine (9) studies out of the 25 unique methods in the studies (36%) used multivariate binary logistic regression. Multilevel (which provides for hierarchical, random and fixed effects) and generalized linear mixed regression models were each applied in five studies. There was only one study that used multinomial regression analysis [21]. There were a couple of studies that used a combination of two or more of these analytical tools [18,23].

3.6. Classification of the Risk Factors

This section reports the distributions of the studies according to the variable groups, namely, the child-related, parental/caregiver-related, household-related and community-related variables.

3.6.1. Child-Related Variables

Table 5 describes the distribution of the child-related variables in the included studies. Out of the twenty-four (24) unique, country-based studies, only one study [20] did not consider the age of the child as part of the child-related variables that were investigated. This implies that 96% of the studies evaluated considered the age of the child (0–59 months) as a risk factor, either as classified into different degrees of age groups or used as an interval variable. These

studies found that the age of the child is a significant predictor of the development of anaemia among children under five years of age in SSA. The chances of having anaemia are much higher for children at a lower age (below 24 months) than at an older age [18,24,25,36]. For instance, Nambiema et al. [24] found a reduced effect of a child's age with the Odds Ratio (OR) (OR = 0.22, 95% CI = 0.17–0.29); Ngnie-Teta et al. (Benin Republic study) [25] found an increased risk of developing anaemia for children aged 6–11 months (OR = 4.05, 95% CI = 2.40–7.09) and 12–35 months (OR = 2.81 95% CI = 1.99–4.52) when compared with children aged above 35 months. In another Malian study, Ngnie-Teta et al. [25] found that a child aged 6–11 months (OR = 1.73, 95% CI = 1.32–2.92) or 12–35 months (OR = 2.90, 95% CI = 2.24–3.92) is more likely to be anaemic when compared with a child older than 35 months.

Table 5. Distribution of the child-related variables for anaemia from the 24 country-specific results.

Risk Factor: Child-Related Variables	Number of Studies Which Investigated the Risk Factor (%)	References
Age of the child	23/24 (96%)	[2,18,19,21–25,27–30,32–36]
Sex of the child	17/24 (71%)	[2,18–32,35,36]
Has health insurance	4/24 (17%)	[18,28,31,32]
Perceived birth size	3/24 (12%)	[2,22,33]
Ever had vaccination status	1/24 (4%)	[35]
Product of multiple births	2/24 (8%)	[23,32]
Preceding birth interval	1/24 (4%)	[23]
Birth order	6/24 (25%)	[23,25,26,28,33]
Iron supplement	4/24 (17%)	[2,20,21]
Duration of breastfeeding	4/24 (17%)	[20–22,35]
Breastfeeding	2/24 (8%)	[22,23]
Had diarrhoea in last 2 weeks	12/24 (50%)	[20,21,23,25,26,34–36]
Had fever in last 2 weeks	11/24 46%)	[20,21,23,26,31,35,36]
Vitamin A consumption	4/24 (16.6%)	[20–22,27]
Min Dietary Diversity (MDD)	1/24 (4%)	[22]
Min Meal Frequency (MMF)	1/24 (4%)	[22]
Treatment for intestinal worms in the last 6 months	3/24 (12%)	[20,23,36]
Nutrition status	1/24 (4%)	[24]
Stunting	9/24 (37%)	[2,23,25,27,36]
Wasting	3/24 (12%)	[2,27]
Underweight	5/24 (20%)	[36]
Overweight	1/24 (4%)	[32]
Malaria status (blood smear)	3/24 (12%)	[19,24,26]
Malaria status (rapid test)	1/24 (4%)	[30]

Furthermore, the sex of the child as a risk factor predicting the chance of developing anaemia among children of under five years in SSA was reported in 17 studies (representing 71%). Almost all of these 17 studies reported significant variations in the status of anaemia by sex. In almost all the studies that reported sex as a risk factor, it was found that a male child was more prone to having anaemia than a female child [18,22,23,26,29,32].

Comorbidities of anaemia with having diarrhoea and fever (in the last two weeks before the survey) were reported in 12 (50%) and 11 (46%) studies, respectively. Moschovis et al. [23] reported a slight harmful effect of anaemia for a child who had non-bloody diarrhoea (OR = 1.11, 95% CI = 1.04–1.18) or bloody diarrhoea (OR = 1.21, 95% CI = 1.07–1.36) when compared with a child without diarrhoea in the last two week before the survey [23]. However, Jones et al. [20] found no significant effect (OR = 1.1, 95% CI = 0.77–1.6). Significantly higher odds of developing anaemia among children of under five years in SSA was also reported for children that had a fever in the last two weeks before the survey than those that had not (OR = 1.42, 95% CI = 1.36–1.49, [23]; and OR = 1.46, 95% CI = 1.04–2.32) in Mali [25]. Besides the strong relationship between the anaemia and nutrition indicators, stunting as a risk factor was examined in nine (36%) of the included studies. In comparison, "wasting" was examined in three (12%) of the included studies. Moreover, nutrition status (a composite of all the nutrition indicators) was only reported in one (4%) of the 24 studies [24]. The odds of having under-five anaemia was 1.82 times higher for a malnourished child than a child who is well nourished [24].

Treatment for intestinal worms in the last 6 months was reported as a significant factor in Moschovis et al. (OR = 1.06, 95% CI = 1.02–1.11) [23], but not significant in Jones et al. (OR = 0.98, 95% CI = 0.76–1.3) [20]. Birth order as a risk factor for anaemia in children of under five years of age was reported in six (6) countries studies. Two studies reported significant harmful effects, but contrary to one another. Mischovis et al. [23] found that having a lower birth order is significantly harmful in developing under-five anaemia compared with having more than three birth orders,

while Ngnie-Teta et al. (Benin Republic study) [25] concluded that being born as the sixth birth order or

later is significantly two-folds more harmful than a single birth order (OR = 2.05, 95% CI = 1.02–3.97).

3.6.2. Distributions of Parental/Caregivers-Related Variables

Mother's age, work status, educational status and anaemia status was frequently reported in the included studies. Table 6 indicates that the mother's educational status was reported in 21 (84%) of the studies, followed by mother's age (13 studies) and mother's anaemia status (12 studies). Therefore, among the parental/caregiver related variables, 84% of the studies placed the mother's educational status as one of the most frequently considered risk factors of anaemia in under-five children in SSA. The results from most of these 21 studies showed that, as the level of educational status of the mother increases, the chance that the child will develop anaemia decreases. For instance, Nambiema et al. [24] found that a child whose mother has a secondary level of education and above has a lower adjusted odds of developing anaemia than a child whose mother has no education (OR = 0.67, 95% CI = 0.52–0.86). There was also a clear-cut pattern of how the variation in the mother's age affected the chances a child developing anaemia. For instance, Moschovis et al. [23], Asresie et al. [34] and Ojoniyi et al. [32] reported a drop in the odds of having anaemia among children of under five years as the mothers' age increases.

The mother's anaemia status was reported in 12 (50%) of the studies included in this scoping review. Moschovis et al. [23] found that a child whose mother was anaemic had an 85% greater odds of having anaemia than another child whose mother was not anaemic (OR = 1.85, 95%

CI=1.76–1.95). Iron supplementation during pregnancy was reported in only one study [21] and was not a significant risk factor (RRR = 1.00, 95% CI = 0.7–1.6).

Table 6. Distribution of the study characteristics of the parental/caregiver-related variables for anaemia.

Parental/Caregiver-Related Variables	Number of Studies That Investigated the Risk Factors	References
Mother's age in years (grouped)	13/24 (54%)	[18,22,23,25–28,32–34,36]
Mother's age at child's birth	1/24 (4%)	[21]
Mother working Status	6/24 (25%)	[2,24,28,32–34]
Mother's educational status	20/24 (83%)	[2,18,20–22,24,25,27–34,36]
Father's educational status	4/24 (17%)	[25,28,33]
Father is alive at the date of the survey	1/24 (4%)	[24]
Mother's marital status	3/24 (12%)	[2,28,32]
Mother's body mass index (kg/m^2)	4/24 (17%)	[21–23,31]
Mother's anaemia status	12/24 (50%)	[21–24,26,27,31,33,34,36]
ANC attendance	1/24 (4%)	[22]
Religion status	2/24 (8%)	[28,33]
Mother's iron supplementation during pregnancy	$\frac{1}{4}$ (4%)	[21]

3.6.3. Distributions of Household-Related Variables

Another critical component of the risk factors associated with anaemia among children under five years in SSA was the household-related variables. Table 7 shows the details of the distribution of various household-related risk factors. Wealth status, a proxy of household socioeconomic status, was one among many factors that drew more attention in this category of risk factors. Twenty-one (21) studies, representing 87%, considered for this scoping review were examined for wealth status. Most of the studies that reported significant effects of household wealth status on under-five anaemia in SSA countries established that the higher the wealth quintiles, the lower the risk of developing anaemia among under-fives [19,23,29,32]. The Hershey et al. [19], Mohammed et al. [22] and Moschovis et al. [23] studies found, respectively, that being in the richest category (OR = 0.55, 95% CI = 0.44–0.70; OR = 0.48, 95% CI = 0.33–0.63; and OR = 0.417, 95% CI = 0.287–0.547, respectively) had a significant protective effect against under-five anaemia. On the contrary, Ntenda et al. [27] found in their Malawi study (OR = 0.81 95% CI = 0.60–1.08), Mozambique study (OR = 0.48, 95% CI = 0.38–1.24) and Namibia study (OR = 0.76, 95% CI = 0.53–1.11) that being in higher quintiles of wealth status is a protective but not a significant factor.

Table 7. Distribution of study characteristics by household-related variables.

Household-Related Variables	Number of Studies Which Investigated the Risk Factor	References
Wealth status	21/24 (87%)	[2,18–25,27–32,34,36]
Place of residence	18/24 (75%)	[2,18,20,22–27,29,30,36]
Household had bed net	2/24 (8%)	[20,30]
Age of household head	1/24 (4%)	[28]
Recent anti-malaria indoor residual spraying of household	1/24 (4%)	[20]
Household size	4/24 (17%)	[21,23,25,34]
Number of children under 5 in the household	3/24 (12%)	[2,32–34]
Water source outside the premises	1/24 (4%)	[23]
Improved source of drinking water	8/24 (33%)	[2,20,22,23,25,29,33]
Improved type of toilet facilities	2/24 (8%)	[20,23]
Unsafe stool disposal	1/24 (4%)	[23]

Improved floor material type	1/24 (4%)	[23]
Sex of household head	2/24 (8%)	[20]
Shared toilet facilities with other household members	1/24 (4%)	[23]
Use biomass for cooking	3/24 (12%)	[23,36]
Under-fives slept under mosquito nets last night	4/24 (17%)	[19,21,25]
Household ownership of livestock	1/24 (4%)	[20]

Closely following the effect of wealth status in this category of household-related risk factors was the place of residence (that is, whether the household under study is in a rural or urban area). With 18 (75%) studies, the place of residence was the second most examined household-related variable as a risk factor associated with anaemia among children of under five years in SSA countries. Among the studies that reported a significant association of place of residence, there was no clear-cut conclusions relating to the comparison of rural and urban dwellers. For instance, Menon and Yoon (OR = 0.768, 95% CI = 0.592–0.996) [30], Mohammed et al. [22] and Moschovis et al. [23] reported a protective effect for rural compared to urban areas, while Ngnie-Teta et al. [25], in their Malian study (OR = 2.04, 95% CI = 1.38–3.44), as well as Nambiema et al. (OR = 0.66, 95% CI = 0.53–0.82) [24] and Dwumoh et al. (OR = 0.53, 95% CI = 0.46–0.65) [18] found that it was more likely for a child in the rural area to develop anaemia than in the urban area of SSA. In turn, Ntenda et al. [26] discovered it was more harmful being in a rural than urban area, but it was not a significant factor (OR = 1.27, 95% CI = 0.53–3.01).

Other risk factors that were of utmost importance in many of the studies included in this scoping review include the following:

Household size, in four (17%) studies.

The number of children that were under-five years living in the same household (17%).

Having an improved source of drinking water, reported in eight (33%) studies.

The child slept under a mosquito net the previous night before the survey (17%).

Two studies reported findings on the use of biomass for cooking in three country-related studies. Contrary to the expectation from other studies not included in this review [37,38], in that exposure to biofuel for cooking and heating may result in harmful effects, with likely developing anaemia compared to those children exposed to cleaner cooking and heating fuel, the studies [23,36] included in this scoping review found the opposite conclusion. Moschovis et al. (OR = 0.99, 95% CI = 0.90–1.10) [23], Ntenda et al. [27], in Mozambique study (OR = 0.93, 95% CI = 0.50–1.73) and in a Namibia study

(OR = 0.92, 95% CI = 0.58–1.45), reported a protective association regarding the use of biofuel for cooking, but it was not significant.

3.6.4. Distribution of Study Characteristics by Community-Related Variables

Community-based risk factors (Table 8) were not very popular in all the studies added to this review. The few that are of general importance are the community poverty and wealth statuses (these were computed as the mean per cent of the community wealthiest households), and community female educational status (computed as the mean percent of women in the community that has primary education and above). There were four studies in this category. Other variables included the distance to the nearest health facility and level of access to safe drinking water for the community.

Table 8. Distribution of the study characteristics by community-related variables.

Community Variables	Number of Studies Which Investigated the Risk Factor	References
Community wealth	4/24 (17%)	[20,36]

Community female education	4/24 (17%)	[27,36]
Community distance to health facility	3/24 (12%)	[36]
Community safe water access	3/24 (12%)	[36]

Some of the studies generally included their countries' regions or place of residence as community risk factors. Since the regions were not unique for all studies, we dropped them from the list of risk factors at the community levels.

4. Discussion

The aim of this scoping review was to identify and evaluate the studies that performed classical regression analysis on nationally representative health survey data to identify the individual socioeconomic, demographic and contextual risk factors associated with developing anaemia among children under five years of age in sub-Sahara Africa (SSA). The review identified 20 studies and the risk factors for anaemia were classified as child-related, parental/household-related and community or area-related factors. The risk factors for anaemia identified included age, birth order, sex, comorbidities (such as fever and diarrhoea), malnutrition or stunting, maternal education, maternal age, mother's anaemia status, household wealth and place of residence.

This review describes the existing pieces of evidence about results obtained in different studies using nationally representative samples in sub-Saharan Africa countries. The broad scope elicited information from studies using a range of classical regression methods, study designs and risk factors associated with anaemia among children of under five years in SSA. We have provided from the onset a broad research question that guided the review. We screened some electronic databases, search engines and grey literature-bases to draw out some substantial scholarly works that have been formally published. The comprehensive search, which lasted for a week, yielded a reasonable number of pieces of literature after applying some inclusion and exclusion criteria. The data charting form designed for this study extracted the relevant information, ranging from the authors' name and year of publication, the study design, the topics, the analytical techniques, the numbers in the sample and the identified risk factors (classified under child-related, parental/caregiver-related, household-related and community-related) associated with under-five anaemia in SSA. Out of a total of forty-six (46) SSA countries [39], this scoping review could extract publications involving only fifteen (15) countries
(representing 32%), but there were twenty-four (24) unique country studies, which means some countries recorded more than one study.

The results from this study showed that the overall prevalence of under-five anaemia from SSA countries is very high, ranging from 29% in Malawi from a study by Ntenda et al. [36] to 83% in Mali from a study conducted by Ngnie-Teta et al. [25]. Going by the WHO's classification of anaemia status,
wherein severe anaemia is a prevalence of more than 40%, then most SSA countries could be classified as highly burdened with severe under-five anaemia. These findings agree with the results found among children in India (which was found to be higher than 50%) [40], Nepal (46.4%) and Pakistan (62.5%) [41]. The findings from almost all the studies that considered gender as a risk factor also concluded that male under-five children are more prone to anaemia than their female counterparts. These findings do not agree with the study conducted among children in Kuwait [42], which found that female children between the age of 6 months and 3 years have a higher prevalence rate of anaemia than the male children in the same age bracket. Although in SSA, anaemia in under-fives has become one of the severe public health burdens for most countries' health sectors, little has been done in conducting large-scale research for informed decision-making. Nigeria is one of the countries in SSA that has increasingly a very

high prevalence of under-five anaemia, from 60% in 2015 to 68% in 2018 [5,6]. Though there are already three different nationally representative surveys [5,43,44] conducted with data on anaemia status, surprisingly from our search strategies (both inclusion and exclusion criteria) there was no single study on risk factors for anaemia among children aged under five years that used classical regression analysis methods to analyse the nationally representative data set found. This is a gap in knowledge that this is yearning to be addressed.

Most of the studies in this scoping review applied classical regression methods (multivariate linear regression and logistics) that only evaluate the risk factors at the individual and household levels, without accounting for the area or contextual risk factors. This lack of consideration for area variables often leads to random effect errors (heterogeneity). With less than 20% of the included studies using multilevel analysis techniques, most of the studies have neglected these critical components of determinants of anaemia status among children under five years in SSA.

One of the challenges in addressing anaemia among children using the best nutritional intervention is the utmost attention given to IDA as a proxy for nutritional anaemia at the expense of other micronutrient deficiencies. Most of the studies considered in this review used IDA to determine the anaemia status from the measure of haemoglobin level. Though most of the nationally representative survey collected data on some other micronutrient deficiencies, such as folate, vitamin A and B12, these are seldom considered as proxies for anaemia status in children.

Moreover, the alarming prevalence of anaemia among children under five years in most SSA countries calls for possible interventions through making iron-fortified food available to infants beyond the period of breastfeeding. Cultivation of iron-fortified crops or organic and healthy food production by these SSA countries is a way to address these deficiencies. Pregnant women as a matter of policy practice will require a substantial number of recommended doses of iron-enriched foods and supplements so that their infants are born endowed with enough iron reserves to sustain them through the nursing period.

Finally, the findings in most of the studies in this review showed that anaemia in children under five years in SSA is associated with other common but fatal childhood illnesses (diarrhoea, fever and malnutrition). Comorbidities and multi-morbidity are typical health issues that in the past years have been associated with adults over 60 years [45]. However, in the last few decades, it has increasingly becoming associated with children [46,47]. How this can affect a health system, particularly in SSA countries, is an emerging area for study [48]. Determinants of co-existence of illness are better examined with multinomial analysis while using classical regression methods. In this scoping review, only one study used multinomial regression analysis [21]. Results from any research that investigate the overlapping associations in comorbidities and multi-morbidity would be exciting although it may require some methodological rigours. However, they are worth investigating.

5. Strengths and Limitations

In our view, this is likely to be the first scoping review to provide information concerning the risk factors associated with anaemia in children under five years of age using nationally representative surveys from sub-Saharan Africa countries. The strength of the evaluation is the rigorous checks from the teams involved from different institutions and the outcomes that can be a pointer to a grey area of gaps in the study that needs urgent attention. For instance, the study has revealed some SSA countries where under-five anaemia studies that use classical regression analysis on nationally representative surveys are lacking. Most of these countries have a very high prevalence of under-five anaemia

It is acknowledged that there are a several limitations in this study. The numbers of studies meeting the inclusion criteria were very few, perhaps because of the inclusion/exclusion criteria. It is also possible not to have identified all the papers in this area of research in view

that we only included studies written in English [14]. However, researchers from developing countries have not shown much zeal in areas that needed more statistical rigour to analyse nationally representative surveys, such as the ones considered in this review. We are confident that we may have identified significant relevant texts meeting the inclusion/exclusion criteria. However, it is possible that we have omitted some insignificant risk factors during the charting and extraction of the information. We also recognized that we neither carried out any publication bias assessment nor did we evaluate the quality of the studies included due to the scoping review design [48].

6. Conclusions

A considerable amount of resources are spent annually to conduct nationally representative surveys across over 90 countries, but studies conducted to take sufficient advantage of these data sets that will influence practice and policy are too few to justify the huge expenditures [14]. This may have been one of the reasons why little or no significant achievements have been made in curbing the harm caused by these diseases in SSA. Therefore, research is urgently needed to analyse the vast nationally representative datasets for informed decision-making, to tackle the numerous public health issues in SSA. This is, however, without prejudice of the need to conduct studies focusing on specific diseases. Interestingly, our review found no studies on the risk factors for children under five years in Nigeria that used classical regression analysis methods that met the inclusion and exclusion criteria.

Author Contributions: The conceptualization of this study was done by P.E.O. and K.K.; the formal literature searching, screening and drafting of manuscript were carried out by P.E.O.; while, S.J.W., R.J. and K.K. participated in supervising, revising and editing of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This study is an integral part of PEO's doctoral study at the School of Health and Related Research of the University of Sheffield, United Kingdom. The funding for the doctoral study was granted by TETFUND (Nigeria).

Acknowledgments: The authors acknowledged the contributions received from ScHARR community. Phillips would like to appreciate the Rector and the management staff of Niger State Polytechnic, Nigeria, for the nomination and the receipt of the TETFUND (Nigeria) sponsorship of his doctoral program.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Global Anaemia Prevalence and Number of Individuals Affected. Available online: https://www.who.int/vmnis/anaemia/prevalence/summary/anaemia_data_status_t2/en/ (accessed on 25 November 2020).
2. Kawo, K.N.; Asfaw, Z.G.; Yohannes, N. Multilevel Analysis of Determinants of Anemia Prevalence among Children Aged 6–59 Months in Ethiopia: Classical and Bayesian Approaches. *Anemia* **2018**, *2018*, 3087354. [CrossRef] [PubMed]
3. Osungbade, K.O.; Oladunjoye, A.O. Anaemia in Developing Countries: Burden and Prospects of Prevention and Control. In *Anaemia*; IntechOpen: London, UK, 2012.
4. Prevalence of Anaemia in Children under 5 Years. Available online: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/prevalence-of-anaemia-in-children-under-5-years-(-) (accessed on 25 November 2020).
5. Nigeria Demographic and Health Survey 2018. Available online: https://www.dhsprogram.com/pubs/pdf/FR359/FR359.pdf (accessed on 25 November 2020).
6. Tradingeconomics Nigeria—Prevalence of Anemia Among Children (% Of Children Under 5). Available online: https://tradingeconomics.com/nigeria/prevalence-of-anemia-among-children-percent-of-childrenunder-5-wb-data.html (accessed on 25 November 2020).
7. Belachew, A.; Tewabe, T. Under-five anemia and its associated factors with dietary diversity, food security, stunted, and deworming in Ethiopia: Systematic review and meta-analysis. *Syst. Rev.* **2020**, *9*, 31. [CrossRef] [PubMed]
8. De Benoist, B.; Cogswell, M.; Egli, I.; McLean, E. *Worldwide Prevalence of Anaemia 1993–2005 of: WHO Global Database of Anaemia*; World Health Organization: Geneva, Switzerland, 2008; ISBN 978-92-4-159665-7.
9. Austin, A.M.; Fawzi, W.; Hill, A.G. Anaemia among Egyptian Children between 2000 and 2005: Trends and predictors. *Matern. Child Nutr.* **2012**, *8*, 522–532. [CrossRef] [PubMed]
10. Kikafunda, J.K.; Lukwago, F.B.; Turyashemererwa, F.; Kikafunda, J.K.; Lukwago, F.B.; Turyashemererwa, F. Anaemia and associated factors among under-fives and their mothers in Bushenyi district, Western Uganda. *Public Health Nutr.* **2009**, *12*, 2302–2308. [CrossRef]

11. Mitchinson, C.; Strobel, N.; McAullay, D.; McAuley, K.; Bailie, R.; Edmond, K.M. Anemia in disadvantaged children aged under five years; quality of care in primary practice. *BMC Pediatrics* **2019**, *19*, 178. [CrossRef]
12. Bamidele, J.O.; Abodunrin, O.L.; Olajide, F.O.; Oke, Y.F. Prevalence and determinants of anemia among primary school pupils of a peri-urban community in Osun State, Nigeria. *Int. J. Adolesc. Med. Health* **2010**, *22*, 461–468. [CrossRef]
13. Demirchyan, A.; Petrosyan, V.; Sargsyan, V.; Hekimian, K. Prevalence and determinants of anaemia among children aged 0–59 months in a rural region of Armenia: A case-control study. *Public Health Nutr.* **2016**, *19*, 1260–1269. [CrossRef]
14. Manda, S.; Haushona, N.; Bergquist, R. A Scoping Review of Spatial Analysis Approaches Using Health Survey Data in Sub-Saharan Africa. *Int. J. Environ. Res. Public Health* **2020**, *17*, 70. [CrossRef]
15. Larissa Shamseer, D.M. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: Elaboration and explanation. *BMJ* **2015**, *349*, g7647. [CrossRef]
16. Tricco, A.C.; Lillie, E.; Zarin, W.; O'Brien, K.K.; Colquhoun, H.; Levac, D.; Moher, D.; Peters, M.D.J.; Horsley, T.; Weeks, L.; et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann. Intern. Med.* **2018**, *169*, 467–473. [CrossRef]
17. Creating a PRISMA Flow Diagram. Available online: https://guides.lib.unc.edu/prisma (accessed on 16 August 2020).
18. Dwumoh, D.; Essuman, E.E.; Afagbedzi, S.K. Determinant of factors associated with child health outcomes and service utilization in Ghana: Multiple indicator cluster survey conducted in 2011. *Arch. Public Health* **2014**, *72*, 42. [CrossRef] [PubMed]
19. Hershey, C.L.; Florey, L.S.; Ali, D.; Bennett, A.; Luhanga, M.; Mathanga, D.P.; Salgado, S.R.; Nielsen, C.F.; Troell, P.; Jenda, G.; et al. Malaria Control Interventions Contributed to Declines in Malaria Parasitemia, Severe Anemia, and All-Cause Mortality in Children Less Than 5 Years of Age in Malawi, 2000–2010. *Am. J. Trop. Med. Hyg.* **2017**, *97*, 76–88. [CrossRef] [PubMed]
20. Jones, A.D.; Colecraft, E.K.; Awuah, R.B.; Boatemaa, S.; Lambrecht, N.J.; Adjorlolo, L.K.; Wilson, M.L. Livestock ownership is associated with higher odds of anaemia among preschool-aged children, but not women of reproductive age in Ghana. *Matern. Child Nutr.* **2018**, *14*, e12604. [CrossRef] [PubMed]
21. Machisa, M.; Wichmann, J.; Nyasulu, P.S. Biomass fuel use for household cooking in Swaziland: Is there an association with anaemia and stunting in children aged 6–36 months? *Trans. R. Soc. Trop. Med. Hyg.* **2013**, *107*, 535–544. [CrossRef] [PubMed]
22. Mohammed, S.H.; Habtewold, T.D.; Esmaillzadeh, A. Household, maternal, and child related determinants of hemoglobin levels of Ethiopian children: Hierarchical regression analysis. *BMC Pediatrics* **2019**, *19*, 113. [CrossRef]
23. Moschovis, P.P.; Wiens, M.O.; Arlington, L.; Antsygina, O.; Hayden, D.; Dzik, W.; Kiwanuka, J.P.; Christiani, D.C.; Hibberd, P.L. Individual, maternal and household risk factors for anaemia among young children in sub-Saharan Africa: A cross-sectional study. *BMJ Open* **2018**, *8*, e019654. [CrossRef]
24. Nambiema, A.; Robert, A.; Yaya, I. Prevalence and risk factors of anemia in children aged from 6 to 59 months in Togo: Analysis from Togo demographic and health survey data, 2013–2014. *BMC Public Health* **2019**, *19*, 215. [CrossRef]
25. Ntenda, P.A.M.; Chilumpha, S.; Mwenyenkulu, E.T.; Kazambwe, J.F.; El-Meidany, W. Clinical malaria and the potential risk of anaemia among preschool-aged children: A population-based study of the 2015-2016 Malawi micronutrient survey. *Infect. Dis. Poverty* **2019**, *8*, 95. [CrossRef]
26. Ntenda, P.A.M.; Chuang, K.Y.; Tiruneh, F.N.; Chuang, Y.C. Multilevel Analysis of the Effects of Individualand Community-Level Factors on Childhood Anemia, Severe Anemia, and Hemoglobin Concentration in Malawi. *J. Trop. Pediatr.* **2018**, *64*, 267–278. [CrossRef]
27. Immurana, M.; Urmi, A. Socio-economic factors and child health status in Ghana. *Int. J. Health* **2017**, *5*. [CrossRef]
28. Candia, D.A. Douglas Andabati Candia Influence of malaria on anemia levels among children less than 60 months of age. *Int. J. Adv. Res. Dev.* **2017**, *2*, 5.
29. Menon, M.P.; Yoon, S.S.; Uganda Malaria Indicator Survey Technical Working, G. Prevalence and Factors Associated with Anemia among Children under 5 Years of Age—Uganda, 2009. *Am. J. Trop. Med. Hyg.* **2015**, *93*, 521–526. [CrossRef] [PubMed]
30. Nikoi, E.; Anthamatten, P. Childhood anaemia in Ghana: An examination of associated socioeconomic and health factors. *Afr. Geogr. Rev.* **2013**, *33*, 19–35. [CrossRef]
31. Ojoniyi, O.O.; Odimegwu, C.O.; Olamijuwon, E.O.; Akinyemi, J.O. Does education offset the effect of maternal disadvantage on childhood anaemia in Tanzania? Evidence from a nationally representative cross-sectional study. *BMC Pediatrics* **2019**, *19*, 89. [CrossRef] [PubMed]

32. Muchie, K.F. Determinants of severity levels of anemia among children aged 6–59 months in Ethiopia: Further analysis of the 2011 Ethiopian demographic and health survey. *BMC Nutr.* **2016**, *2*, 51. [CrossRef]
33. Asresie, M.B.; Fekadu, G.A.; Dagnew, G.W. Determinants of Anemia among Children Aged 6–59 Months in Ethiopia: Further Analysis of the 2016 Ethiopian Demographic Health Survey. *Adv. Public Health* **2020**, *2020*, 3634591. [CrossRef]
34. Semedo, R.M.; Santos, M.M.; Baião, M.R.; Luiz, R.R.; da Veiga, G.V. Prevalence of anaemia and associated factors among children below five years of age in Cape Verde, West Africa. *J. Health Popul. Nutr.* **2014**, *32*, 646–657.
35. Ntenda, P.A.M.; Nkoka, O.; Bass, P.; Senghore, T. Maternal anemia is a potential risk factor for anemia in children aged 6–59 months in Southern Africa: A multilevel analysis. *BMC Public Health* **2018**, *18*, 650. [CrossRef]
36. Ngnie-Teta, I.; Receveur, O.; Kuate-Defo, B. Risk factors for moderate to severe anemia among children in Benin and Mali: Insights from a multilevel analysis. *Food Nutr. Bull.* **2007**, *28*, 76–89. [CrossRef]
37. Mishra, V.; Retherford, R.D. Does biofuel smoke contribute to anaemia and stunting in early childhood? *Int. J. Epidemiol.* **2007**, *36*, 117–129. [CrossRef]
38. Page, C.M.; Patel, A.; Hibberd, P.L. Does smoke from biomass fuel contribute to anemia in pregnant women in Nagpur, India? A cross-sectional study. *PLoS ONE* **2015**, *10*, e0127890. [CrossRef] [PubMed]
39. Sub-Saharan Africa. Available online: https://en.wikipedia.org/wiki/Sub-Saharan_Africa (accessed on 25 November 2020).
40. Nguyen, P.H.; Scott, S.; Avula, R.; Tran, L.M.; Menon, P. Trends and drivers of change in the prevalence of anaemia among 1 million women and children in India, 2006 to 2016. *BMJ Glob. Health* **2018**, *3*, e001010. [CrossRef] [PubMed]
41. Harding, K.L.; Aguayo, V.M.; Namirembe, G.; Webb, P. Determinants of anemia among women and children in Nepal and Pakistan: An analysis of recent national survey data. *Matern. Child Nutr.* **2018**, *14*, e12478. [CrossRef] [PubMed]
42. Jackson, R.T.; Hamad, N.A.; AL-Somaie, M.; Guoad, N.A.; Prakash, P. Gender and Age Differences in Anemia Prevalence during the Lifecycle in Kuwait. *Ecol. Food Nutr.* **2004**, *43*, 61–75. [CrossRef]
43. National Malaria Elimination Program (NMEP); National Population Commission (NPopC); National Bureau. *ICF International Nigeria Malaria Indicator Survey [MIS8] 2015*; NMEP, NPopC, and ICF International: Abuja, Nigeria; Rockville, ML, USA, 2016; p. 190.
44. National Population Commission (NPC); National Malaria Control Program (NMCP). ICF Macro Nigeria Malaria Indicator Survey [MIS8] 2010. NPC, NMCP, ICF International: Abuja, Nigeria; Rockville, ML, USA, 2012; p. 137.
45. Navickas, R.; Petric, V.K.; Feigl, A.B.; Seychell, M. Multimorbidity: What do we know? What should we do? *J. Comorb.* **2016**, *6*, 4–11. [CrossRef]
46. Ferro, M.A.; Lipman, E.L.; Van Lieshout, R.J.; Gorter, J.W.; Shanahan, L.; Boyle, M.; Georgiades, K.; Timmons, B. Multimorbidity in Children and Youth Across the Life-course (MY LIFE): Protocol of a Canadian prospective study. *BMJ Open* **2019**, *9*, e034544. [CrossRef]
47. Russell, J.; Grant, C.C.; Morton, S.M.B. Multimorbidity in Early Childhood and Socioeconomic Disadvantage: Findings from a Large New Zealand Child Cohort. *Acad. Pediatr.* **2020**, *20*, 619–627. [CrossRef]
48. Green, B.N.; Johnson, C.D.; Haldeman, S.; Griffith, E.; Clay, M.B.; Kane, E.J.; Castellote, J.M.; Rajasekaran, S.; Smuck, M.; Hurwitz, E.L.; et al. A scoping review of biopsychosocial risk factors and co-morbidities for common spinal disorders. *PLoS ONE* **2018**, *13*, e0197987. [CrossRef]

International Journal of Environmental Research and Public Health

MDPI

Review

A Scoping Review of Selected Studies on Predictor Variables Associated with the Malaria Status among Children under Five Years in Sub-Saharan Africa

Phillips Edomwonyi Obasohan [1,2,*], Stephen J. Walters [1], Richard Jacques [1] and Khaled Khatab [3]

[1] School of Health and Related Research (ScHARR), University of Sheffield, Sheffield S1 4AD, UK; s.j.walters@sheffield.ac.uk (S.J.W.); r.jacques@sheffield.ac.uk (R.J.)
[2] Department of Liberal Studies, College of Business and Administrative Studies, Niger State Polytechnic, Bida Campus, Bida 912231, Nigeria
[3] Faculty of Health and Wellbeing, Sheffield Hallam University, Sheffield S10 2BP, UK; k.khatab@shu.ac.uk
* Correspondence: peobasohan1@sheffield.ac.uk

Citation: Obasohan, P.E.; Walters, S.J.; Jacques, R.; Khatab, K. A Scoping Review of Selected Studies on Predictor Variables Associated with the Malaria Status among Children under Five Years in Sub-Saharan Africa. *Int. J. Environ. Res. Public Health* **2021**, *18*, 2119. https://doi.org/10.3390/ijerph18042119

Academic Editor: Paul B. Tchounwou

Received: 21 January 2021
Accepted: 18 February 2021
Published: 22 February 2021

Abstract: Background/Purpose: In recent times, Sub-Saharan Africa (SSA) had been rated by the World Health Organization (WHO) as the most malaria-endemic region in the world. Evidence synthesis of the factors associated with malaria among children aged under-five in SSA is urgently needed. This would help to inform decisions that policymakers and executors in the region need to make for the effective distribution of scarce palliative resources to curb the spread of the illness. This scoping review is aimed at identifying studies that have used multivariate classical regression analysis to determine the predictors associated with malaria among children under five years old in SSA. Methods/Design: The search terms followed population, intervention, comparator, outcome, timing, setting (PICOTS), and were used in searching through the following databases: PubMed, MEDLINE, Web of Science, Cumulative Index of Nursing and Allied Health Literature (CINAHL), Scopus, and Measure DHS. The databases were searched for published articles from January 1990 to December 2020. Results: Among the 1154 studies identified, only thirteen (13) studies met the study's inclusion criteria. Narrative syntheses were performed on the selected papers to synchronize the various predictors identified. Factors ranging from child-related (age, birth order and use of a bed net), parental/household-related (maternal age and education status, household wealth index) and community-related variables (community wealth status, free bed net distribution) were some of the identified significant predictors. Conclusions: It is timely to have a synthesis of predictors that influence the malaria status of children under-five in SSA. The outcome of the review will increase the knowledge of the epidemiology of morbidity that will form the basis for designing efficient and cost-effective distribution of palliatives and control of malaria in SSA.

Keywords: malaria; fever; *Plasmodium falciparum*; *Falciparum vivax*; under-five; determinants; risk factors; review

1. Introduction

Malaria has remained one of the major global public health challenges of the last two decades, especially in low and medium-income countries, putting almost half of the world population at risk of infection [1]. In 2015, over 214 million estimated cases of malaria were reported, with over 450,000 deaths worldwide [2,3]. Surprisingly, in 2018, the number of malaria cases had risen to over 300 million worldwide [4], and in 2019 the estimated malaria cases from 87 endemic nations were approximately 230 million [3]. It is on record that the world experienced a steady decline in the estimated number of deaths from malaria cases from over 730,000 in 2000 to over 400,000 in 2019 [3,5]. In 2017, there were an estimated 430,000 deaths; Sub-Saharan Africa (SSA) contributed over 90% of the global malaria deaths, with over 260,000 being children under five years of age,

translating into one child dying every two minutes [2,6]. By 2019, under five years, deaths from malaria were over 60% of the total estimated deaths [3]. It is worth noting that in the last two decades, many programs and strategies have been implemented to control malaria both at the global and country levels, which has resulted in the prevention of over 6 million deaths between 2000 and 2015 in SSA [4].

Deaths and the burden of malaria cases among children under five years old vary across the various countries in SSA. Malaria alone contributes to more than 30 percent of under-fives mortality in Nigeria [5]. With over 51 million cases and 200,000 deaths annually, Nigeria has become the most malaria burdened nation in the world, with more than 30% of child mortality as a result of malaria cases [2,5]. In Tanzania, malaria is responsible for more than 10% of under-five deaths and is the second largest contributor to childhood morbidity and mortality [7] and is the leading cause of death in Mozambique, accounting for over 30% of all deaths [8]. Ethiopia, on the other hand, is recorded amongst the countries with the highest under-five mortality in SSA [9], with almost a quarter of the country being malariaendemic, such that a greater proportion are exposed to malarial infection [4]. In 2016, Cameroon contributed about 3% of the total number of global deaths from malaria-related cases, and most of these deaths are among under-five-year-old children [10].

Apart from SSA, some other regions of the world contribute to the global burden of malaria. For instance, in 2019, out of the 107 malaria-endemic countries in the world, the Southeast Asia region had nine countries [3], making the area second only to Africa in terms of estimated malaria cases [11]. The South Asian region records between 90 and 167 million malaria cases, with over 125,000 deaths per annum [3,12]. Bangladesh is one of the four malaria-endemic countries in Southeast Asia [11], with over 17 million people at risk of malarial infection [13].

Plasmodium falciparum and *Plasmodium vivax* are the two most predominant malaria parasites causing malaria, with 60% and 40%, respectively, of cases in Ethiopia [14]. In India, this is estimated to be in the ratio 10:7 [12]. The reverse is the case for Brazil, where more than 60% of the 170 million people in the American region at risk of malaria cases reside, and over 70% of the cases are traceable to *Plasmodium vivax*, with *Plasmodium falciparum* contributing more than 25% [15]. However, *Plasmodium falciparum* alone accounts for more than 95% of malaria cases in Nigeria [5,16].

Researchers have attributed the prevalence of malaria in SSA to several factors, which include medical conditions, environmental factors/seasonal influences and human status (such as age, gender, pregnancy, blood group and rhesus factors, among others), socioeconomic, demographic and area-related characteristics [4,17]. Malaria infection is said to be more prevalent in rural areas than in urban centers [14]. Until recently, malaria was believed to be a rural area disease because the transmitting vectors are said to breed more in the rural areas [14]. On a contrary note, Baragatti *et al.*, 2009 [18] observed that malaria had remained a serious public health concern in urban areas. This is not unconnected with the general belief that developing urban centers will reduce the transmission of malaria infection [14]. Unfortunately, this is not the situation for most African countries with limited resources to provide adequate infrastructure amenities that cope with the rate of urbanization experienced, resulting in poor housing, sanitation and drainage systems, which could increase the vector breeding and human contacts [14]. Reports from studies on gender differences have also found mixed conclusions. For instance, a higher prevalence of malaria among boys than among girls has been reported in Oladeide et al. [19], while another study reported a higher prevalence among females than males [20]. The occurrence of mosquitoes, the vector for malaria, appears to be higher during the wet season than in the dry season [17]. However, the transmission rate of malaria is relatively higher in hotter regions, but with mountainous areas providing protection from transmission [8].

In Nigeria, for instance, as in most SSA, the need to measure the impact of the national malaria strategic plan (NMSP), 2014–2020, to reduce malaria-related mortality to zero by 2020 has resulted in a rise in the number of aged related studies on malaria [5]. As much as these studies are essential towards evidence-based healthcare decisions on malaria fever control in Nigeria and SSA, much more critical is the scoping of these studies. This has not been done, especially concerning determinants of the prevalence of malaria among children under five years in SSA. Therefore, this study aims to bridge this knowledge gap. The Purpose of the Scoping Review

This scoping review aimed to find and evaluate the studies that describe the association between the socioeconomic, demographic, and contextual factors and the prevalence of malaria fever among children under five years of age in Sub-Saharan Africa.

2. Materials and Methods

2.1. Criteria for Inclusion and Exclusion of Studies

The scoping review followed the preferred reporting items for systematic reviews and meta-analyses extension for scoping reviews (PRISMA-ScR) checklists [21,22]. The review question was in line with the population, interventions, comparators, outcomes, timing and study design (PICOTS).

The population of the study was any child under five years in SSA countries, irrespective of their gender.

The exposures include socioeconomic, demographic, and contextual predictors. These interventions were either classified as child-related, parental/household-related or communityrelated. Where the study reported both adjusted and crude effect sizes, the adjusted
was selected.

The comparator was between the children under five years in SSA that had malaria infection versus those that did not have malaria infection.

The outcome variable was the malaria status. This review considered studies on socioeconomic, demographic, and environmental determinants of malaria fever among children under five of both sexes that used standard testing procedures in identifying malaria fever status. The usual method of testing for the presence of *Plasmodium* parasites was by measuring the axillary temperature of 37.5 °C [23], and, carry out a microscopic examination of thick and thin blood smears that were positive with several asexual parasites per 200 white blood cells, while if white blood cells had a count of 8000 cells/μL [24]. In addition, studies, which identified malaria status through the rapid diagnostic test (RDT) and polymerase chain reaction (PCR) were included.

Studies and articles written in English and published between 1 January 1990 and 31 December 2020 were included.

The study design covers all observational studies (cross-sectional and cohort studies).

2.2. Search Strategy

The search strategy was first carried out in PubMed with the following terms as displayed in Table 1 and combined with appropriate Boolean connectors.

Table 1. Search terms combinations.

S/N	Search Terms
1	demographic health survey OR AIDS indicator survey OR malaria indicator survey OR multiple indicator cluster surveys OR health survey OR MIS OR DHS
2	sub-Sahara Africa OR SSA
3	logistic regression OR multilevel regression OR multinomial logistic OR random-effects OR hierarchical OR fixed effects OR Linear regression
4	Malaria OR fever OR *plasmodium falciparum* OR *P. malariae* OR *P. ovale* OR *P. vivax*)
5	1 AND 2 AND 3 AND 4

2.3. Sources of Information

The online databases for literature search using the search terms of PICOTS produced the following results as displayed in Figure 1. The results identified a total of 1157 publications. PubMed (867), Cumulative Index to Nursing and Allied Health Literature (CINAHL) (14), Scopus (0) MEDLINE (WOS) (122), Measure DHS (154). The databases were searched for published works from January 1990 to December 2020. The searches were done on 13 and 14 December 2020.

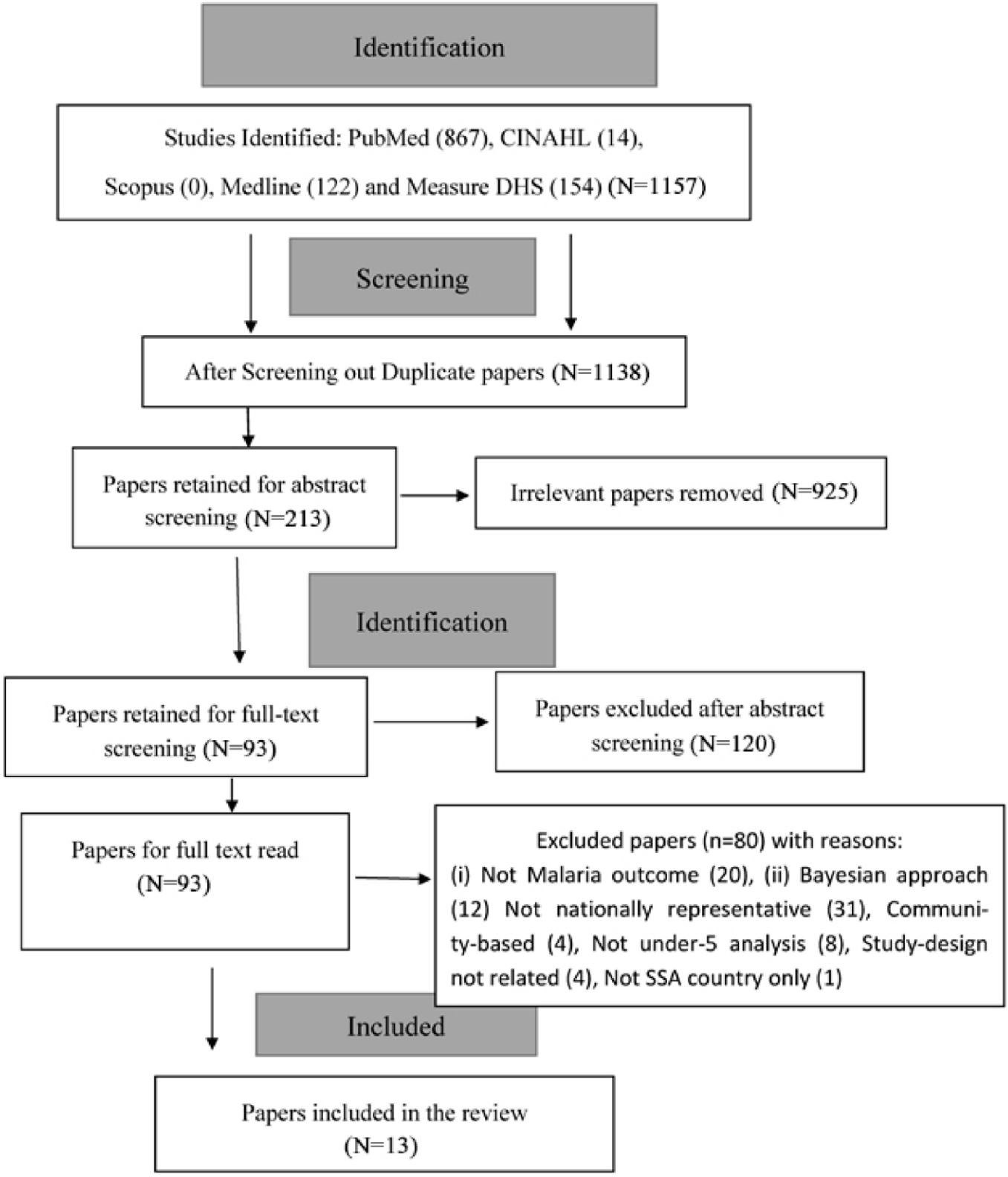


Figure 1. Flowchart of inclusion of studies for malaria review.

2.4. Study Selection

The selection processes followed the PRISMA-ScR recommendation [25]: identify all potential papers from databases and other sources; screen to remove duplicate publications; exclude those that did not meet up with inclusion criteria and inclusion for the review.

2.5. Data Selection Process

The reviewer PEO extracted relevant data from the selected studies into a Microsoft Excel spreadsheet (Microsoft Corporation, Washington, DC, USA); the design for this extraction was verified by the supervisory team.

3. The Results

3.1. Description of Study Records

This review aimed to synthesize evidence from published articles describing the determinants (socioeconomic, demographic and contextual) of the malaria status of children under five years in SSA between January 1990 and December 2020. The flowchart diagram in Figure 1 shows the selection of studies included for review. A total of 1157 records were identified from all the databases consulted. Ninety-three (93) were retained for full-text examination, and only thirteen (13) unique publications (with 18 country-specific studies) met the inclusion criteria and were examined for this review.

Study characteristics

Table 2 describes the characteristics of the 13 extracted papers considered for this review. The information includes the author's name and date of publication, the title of the paper, study location, survey type, target sample, the prevalence of the outcome, sample size, statistical methods, and software used for computation. The prevalence of malaria in children under five, as reported in the papers reviewed, ranged from 18% in Tanzania to 39% in Uganda, as reported in Njau et al. (2013) [26]. The mean sample size per study was 30,775 participants.

Table 2. Characteristics of the included studies.

Authors and Dates	Titles	Country	Survey *	Target Population	Prevalence n (%)	Participants (Sample Size)	Malaria Diagnostic Method **	Methods	Software	Funding Source
Berendsen *et al.*, 2019 [27]	BCG vaccination is associated with reduced malaria prevalence in children under the age of 5 years in Sub-Sahara Africa	Multi-country (13 SSA)	DHS	Under 5 years	12,325 (36)	34,205	RDT	Multilevel logistic regression (MLLR)	SPSS, STATA, MLWin	Multiple source
Chitunhu *et al.*, 2015 [28]	Direct and indirect determinants of childhood malaria morbidity in Malawi: a survey cross-sectional analysis based on malaria indicator survey data for 2012	Malawi	MIS	Under 5 years	367 (27.7)	1375	MT	Logistic regression (LR)	STATA	Institutionbased
Levitz *et al.*, 2018 [29]	Effect of individual and community-level bed net usage on malaria prevalence among under-fives in the Democratic Republic of Congo	Democratic Republic of Congo (DRC)	DHS	Under 5 years	2191 (37.4)	5857	Others (PCR)	Multilevel logistic regression (MLLR)	SAS	Multiple sources
Morakinyo *et al.*, 2018 [30]	Housing type and risk of malaria among under-five children in Nigeria: evidence from the malaria indicator survey	Nigeria	MIS	6–59 months		6991	RDT and MT	Logistic regression (LR)	STATA	No funding
Njau *et al.*, 2013 [26]	Exploring the impact of targeted distribution of free bed nets on households bed net ownership, socioeconomic disparities and childhood malaria infection rates: analysis of national malaria survey data from three sub-Saharan Africa countries	Angola, Tanzania and Uganda	MIS	Under 5 years	214 (20) 895 (39) 782 (18)	1125 3109 1954	RDT and MT	Multilevel logistic regression (MLLR)	STATA	Multiple source
Njau *et al.*, 2014 [31]	Investigating the Important Correlates of Maternal Education and Childhood Malaria Infections	Angola, Tanzania and Uganda (Pooled)	MIS	Under 5 years	-	1390 5975 2997	RDT	Multivariate logistic regression (MvLR)	STATA	Not reported
Semakula *et al.*, 2015 [32]	Potential of household environmental resources and practices in eliminating residual malaria transmission: a case study of Tanzania, Burundi, Malawi and Liberia	Tanzania, Burundi, Malawi and Liberia	MIS	Under 5 years	-	7695 3750 2115 3187	RDT	Multivariate logistic regression (MvLR)	JMP 10	Multiple source

Siri 2014 [33]	Independent Associations of Maternal Education and Household Wealth with Malaria Risk in Children	Multi-country (pooled)		Under 5 years	-	24,043	-	Multivariate logistic regression (MvLR)	SAS	Institutionbased

Table 2. *Cont.*

Authors and Dates	Titles	Country	Survey *	Target Population	Prevalence n (%)	Participants (Sample Size)	Malaria Diagnostic Method **	Methods	Software	Funding Source
Tusting *et al.*, 2020 [34]	Housing and child health in sub-Saharan Africa: A cross-sectional analysis	Multi-country (pooled)	Multiple surveys	Under 5 years	40,178 (21)	188,651	RDT and MT	Conditional logistic regression (LR)	STATA and R	Multiple source
Ugwu and Zewotir, 2018 [35]	Using mixed effects logistic regression models for complex survey data on malaria rapid diagnostic test results	Nigeria	MIS	6–59 months	-	5236	RDT	Generalized linear mixed model (GLMM)	SAS	No funding
Wanzira *et al.*, 2017 [24]	Factors associated with malaria parasitaemia among children under 5 years in Uganda: a secondary data analysis of the 2014 Malaria Indicator Survey dataset	Uganda	MIS	Under 5 years	938 (19.04)	4930	MT	Multivariate logistic regression (MvLR)	STATA	no funding
Yang *et al.*, 2020 [36]	Drinking water and sanitation conditions are associated with the risk of malaria among children under five-year-old in sub-Saharan Africa: A logistic regression model analysis of national survey data	Multi-country (pooled)	Multiple surveys	Under 5 years	40,217 (18.8)	213,920	RDT and MT	Multivariate logistic regression (MvLR)	SPSS	not reported
Zgambo *et al.*, 2017 [37]	Prevalence and factors associated with malaria parasitaemia in children under the age of five years in Malawi: A comparison study of the 2012 and 2014 Malaria Indicator Surveys (MISs)	Malawi	MIS	Under 5 years	636 (33)	1928	MT	Multivariate logistic regression (MvLR)	SPSS	no funding

* Surveys: MIS = malaria indicator survey, DHS = demographic and health survey; ** RDT = rapid diagnostic test, MT = microscopic test.

Figure 2 displays charts A–G and describes the various study characteristics of the included papers. Chart A describes that the publication years for the included studies were between 2013 and 2020. In 2016 there were no publications extracted. The 2018 period had the highest number of publications (23%), while 2013 and 2019 had one publication each (representing 7.7%), and the remaining years had 15% each. In terms of the study setting (chart B), the number of studies from multi-countries (33%) was more than every other country-specific study. Nigeria, Malawi, Tanzania and Uganda had two studies each (11%), and the remaining countries had one study each.

With more than 70% of the number of country-specific studies, the malaria indicator survey (MIS) was the most used survey among the included studies (chart C), followed by multi surveys (16%) and demographic and health surveys (11%). Likewise, chart (D) indicates that multivariate logistic regression methods (46%) were the most used statistical method. Furthermore, with 38%, STATA was the most preferred statistical software used in the selected publications. This was followed by SAS, SPSS and combined software applications. The least popular was JMP (7.6%). Funding sources (chart F) show that multiple sources of funding were the highest at (38%), while no funding was reported in 30% of the studies, and two of the studies did not disclose any funding source. Three diagnostic methods were reported to detect malaria infection status in children under five years. Among the studies included were rapid diagnostic test (RDT), microscopic test (of thin and thick blood smear), and polymerase chain reaction (PCR). Chart (G) shows that RDT and the combination of RDT and MT were the most popular, and one study reported using PCR.

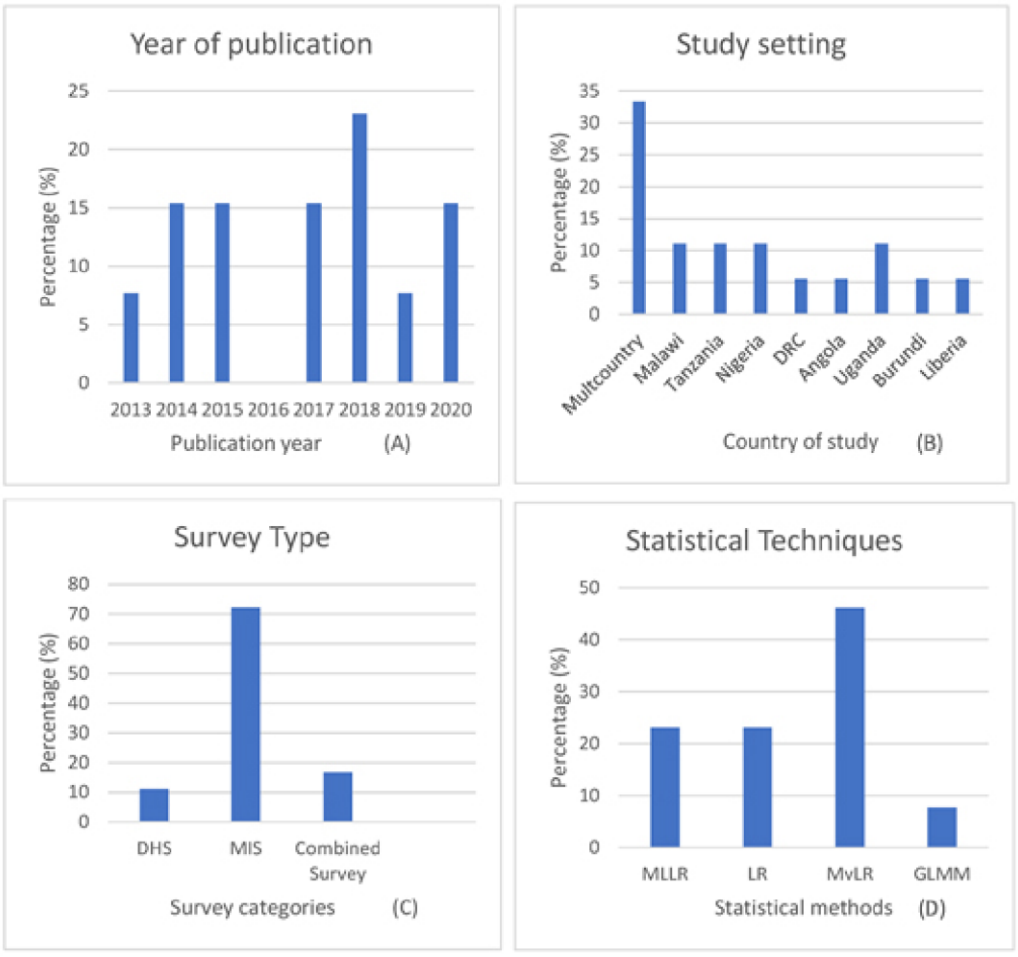


Figure 2. *Cont*.

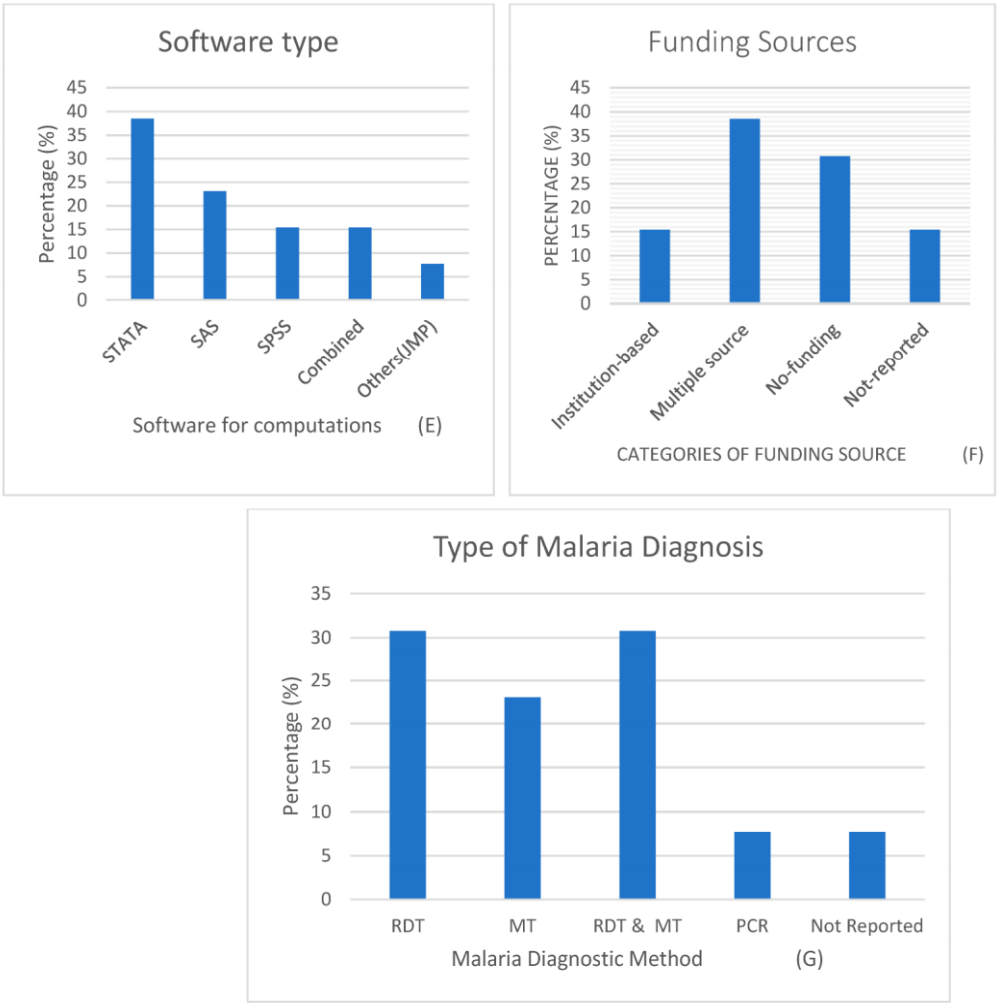


Figure 2. Charts (**A**–**G**) represent the distributions of the characteristics of included studies.

3.2. Data Synthesis Method

The narrative/tabulation syntheses of the outcomes/findings from multiple reports for this review following the narrative guidelines given in Popay et al. [38] were used. The objective of the review was to collate pieces of evidence on the association between the socioeconomic, demographic, and contextual indicators on malaria fever among children under five in SSA from 1990 to 2020. The results were appraised using the narration of the descriptive statistics and odds of the likelihood of the risk factors and the outcome variable (malaria status).

Predictors associated with Malaria Status

The socioeconomic, demographic, and contextual determinants of malaria status among children under five in SSA were grouped into child-related variables, mother or caregiver-related variables, household-related variables, and environmental or Area-related variables and interaction terms. These variables include age of the child, weight, anemia status, birth order status; maternal age and education status, parent's knowledge, attitude and practices of some basic facts about malaria fever; the type of material used to construct the building, distance from a health facility and cluster altitude as factors identified that are associated with malaria status among children under five years in SSA. A factor was considered statistically significant concerning what each paper considered as the *p*-value cut-off (0.01, or 0.05, or 0.001). In a situation where the factor was classified into different categories or dummies, the factor was labeled as statistically significant if at least one of the categories or dummies compared to the reference category was statistically significant.

Child-Related Variables

Table 3 shows the evidence found on child-related variables. This study revealed the role that the age of the child plays in the tendency for the child to be infected with malaria parasites. Eleven (11) of the country-specific studies investigated a child's age being under five years as a predictor of their potential malaria status. Nine of the studies found that the child's age in at least one of the age groups was significantly associated with the prevalence of malaria among under five years in SSA. In most of the studies, it was found that as the child's age increases, the odds of contracting malaria fever also increase [24,33,35,37,39]. However, Semakula et al. [32] in their multi-country study found no statistical significance in Tanzania (OR: 1.26, CI: 0.94–1.70, $p = 0.128$) and Burundi (OR: 0.79 CI: 0.60–1.05, $p = 0.108$), but found significant effect in Malawi (OR: 1.85 CI: 1.33–2.56, $p < 0.001$] and Liberia (OR: 2.10 CI: 1.59–2.80, $p < 0.001$]. Three studies investigated the sex of a child as a predictor of the prevalence of malaria among under five years old children in SSA. Surprisingly, these three studies ((OR: 0.96 CI: 0.91–1.02, $p = 0.18$) [39], (OR: 0.927, $p = 0.2627$) [35], and (OR: 1.04 CI: 0.82–1.32, $p = 0.764$)) [24] found no statistically significant effect. Also, three studies that explored the effect of birth order found statistically significant effects (OR: 1.03 CI: 1.01–1.06, $p = 0.011$) [27], when the child was second-order compared to the 1st child born: (OR: 1.43 CI: 1.04–1.96, $p = 0.03$) [28] and [marginal effect: 0.045, $p < 0.01$) [31].

Table 3. Association between child-related variables and malaria status.

S/N	Variables	Significance Levels	Number of Studies	Association Effect (95% CI)
1	Age of the child	S:	9	Increased significant factors (ISF) OR: 1.05 (1.04–1.06) [27] OR: 1.03 (1.02, 1.04) [28] 7–23: OR: 2.29 (1.21–4.34), 24–59: OR: 5.67 (3.01–10.70) [30] OR: 1.85 (1.33–2.56) [32] OR: 2.10 (1.59–2.80) [32] 6–11: OR: 2.22 (1.88, 2.62); 12–23: OR: 3.70 (3.12, 4.37) 24–35: OR: 5.00 (4.25, 5.87) [33] 13–24: OR: 1.7039 (1.34–2.16); 25–36: OR: 2.624 (2.06–3.33); 37–48: OR: 3.591 (2.82–4.55); 49–59: OR: 4.97 (3.888–6.38) [35] 7–12: OR: 1.62 (1.04–2.52); 13–24: OR: 2.20 (1.47–3.29); 25–36: OR: 3.47 (2.32–5.20); 37–48: OR: 3.69 (2.47–5.50); 49–59: OR: 4.01 (2.57–6.45) [24] 24–35: OR: 1.5 (1.0–2.5) ≥48: OR: 2.2 (1.4–3.5) [37] decreased significant factors (DSF) 36 month+ OR: 0.80 (0.72, 0.88) [33]
		NS:	2 [32]	
2	Vaccination status	S:	1	DSF: OR: 0.88 (0.82 to 0.94) [27]
		NS:	-	
3	Preceding birth interval	S:	1	ISF: OR: 1.00 (1.00 to 1.00) [27]
		NS:	-	
4	Birth order	S:	3 [27,28,31]	ISF: OR: 1.03 (1.01–1.06) [27] Second: OR: 1.43 (1.04, 1.96) [28] β: 0.045 [31]
		NS:	-	
5	Breastfeeding status	S:	1	DSF: currently: 0.85 (0.73–0.99) [27]
		NS:	-	
6		S:	1	ISF: OR: 1.967 (1.71–2.26) [35]

	Fever in the last 2 weeks	NS:	-	
7	Anemic	S:	2	ISF: OR: 2.982 (2.54–3.49) [35] DSF: OR: 0.95 (0.94, 0.96) [28]
		NS:	-	

Table 3. *Cont.*

S/N	Variables	Significance Levels	Number of Studies	Association Effect (95% CI)
8	Place of delivery	S:	1	DSF: public: 0.85 (0.78 to 0.92); private: 0.78 (0.70 to 0.87) [27]
		NS:	-	
9	Child slept under a mosquito bed net	S:	4	ISF: OR: 1.21 (1.08–1.36) [30] OR: 1.47 (1.16–1.89) [32] DSF: OR: 0.77 (0.60, 0.99) [28] OR:0.65 (0.56–0.77) [32]
		NS:	5 [27,32,33,37]	

OR: odds ratio, ME: marginal effect, β: coefficient estimate, S: significant, NS: not significant, ISF: increased significant factors, DSF: decreased significant factors.

Contrary to expectation, whether or not a child slept under a long-lasting insecticidetreated net was reported in five out of nine studies (OR: 0.93 CI: 0.84–1.02, p = 0.13) [27]; ((in Malawi study), OR: 0.88 CI: 0.73–1.07, p = 0.202) [32]; ((in Liberia study), OR: 0.99 CI: 0.85–1.17, p = 0.945) [32]; OR: 0.93 CI: 0.81–1.07] [33]; (OR: 1.5 CI: 0.9–2.4 p = 0.146) [37], not to be a significant predictor of malaria infection among children under five years in SSA.

Maternal-Related Variables

Table 4 describes the various factors predicting the likelihood that a child would contract malaria fever at the maternal-related-variable level. Out of three studies that analyzed maternal age as a predictor of contracting malaria fever among children underfives in SSA, two studies (Njau *et al.*, 2014 and Siri *et al.*, 2014) [31,33] found no statistically significant effect. While, Berendsen *et al.*, 2019 [27] found a statistically significant effect (OR: 0.99 CI: 0.98–0.99, p = 0.00047) of maternal age [27]. However, Zgambo *et al.*, 2017 [37] did not find any statistically significant effect of maternal education on the likelihood of malaria infection among children under five years in SSA.

Table 4. Association between maternal-related variables and malaria status.

Table 4. *Cont.*

S/N	Variables	Significance Levels	Number of Country Studies	Association Effect (95% CI)
4	Maternal	S:	1	DSF: β: −0.029 [31]
		S:	ante-nat 27]	
			5 Numb births in	
			1	
6	Maternal knowledge of	S:	2	ISF β: 0.013 [31] DSF: yes: OR: 0.78 (0.62–0.99) [36]
		S:	1	β: 0.003 [31]

S:		malaria	β: −0.030 [31]	
	7	Numb children bor		
	8	Mothe access to		
1				

OR: odds ratio, ME: marginal effect, β: coefficient estimate, S: significant, NS: not significant, ISF: increased significant factors, DSF: decreased significant factors.

In addition, maternal knowledge of malaria fever was found to be a statistically significant predictor of under-five malaria cases in SSA. Children whose mothers showed having knowledge of malaria fever were less likely to be infested with malaria *parasitemia* (β: −0.013, $p < 0.01$) [31] and (OR: 0.78 CI: 0.62–0.99, $p = 0.037$) [24].

Household-Related Variables

Table 5 describes the distribution of significant effects of household-related variables on the likelihood of developing malaria infections among children under five years in SSA. The most widely assessed household-related predictors are household socioeconomic status (designated as household wealth), place of residence (whether urban or rural area), Household size, improved water source and improved toilet facilities. All eleven countryspecific studies that investigated household wealth as a predictor found at least one of the categories being a statistically significant predictor of malaria status. The higher the household wealth quintile, the less likely it that the child in the household would contract malaria fever. The thirteen country-specific studies that found a statistically significant effect of the place of residence all reported that it was more harmful to a child under five years in rural SSA than in urban areas in contracting malaria fever. Though Wanzira *et al.*, 2017 [24] and Zgambo et al. *2017* [37] found no statistically significant effect of place of residence, yet they reported a more protective effect for urban children than rural children (OR: 1.74 CI: 0.92–3.29, $p = 0.089$) [24], (OR: 2.3 CI: 0.9–6.0, $p = 0.075$) [37].

It is worthy of note that access to mass media, number of rooms in the household and type of wall material were found not to be statistically significant predictors of malaria fever among children under-five in SSA [26,35]. The variations in household ownership of livestock were a statistically significant predictor of malaria status in children under five years in SSA. Semakula *et al.*, 2015 [32] reported consistent findings in their four country-specific studies that a child from a household that owns cattle has a lower odd of contracting malaria parasitemia than a child from a household without livestock (Tanzania (OR: 0.55 CI: 0.45–0.67, $p < 0.001$); Burundi (OR: 0.51 CI: 0.40–0.65, $p < 0.001$); Malawi (OR: 0.54 CI: 0.35–0.83, $p < 0.001$); Liberia (OR: 0.74 CI: 0.55–1.00, $p < 0.05$)).

Authors and Dates	Titles	Country	Survey *	Target Population	Prevalence n (%)	Participants (Sample Size)	Malaria Diagnostic Method **	Methods	Software	Funding Source
Berendsen *et al.,* 2019 [27]	BCG vaccination is associated with reduced malaria prevalence in children under the age of 5 years in Sub-Sahara Africa	Multi-country (13 SSA)	DHS	Under 5 years	12,325 (36)	34,205	RDT	Multilevel logistic regression (MLLR)	SPSS, STATA, MLWin	Multiple source
Chitunhu *et al.,* 2015 [28]	Direct and indirect determinants of childhood malaria morbidity in Malawi: a survey cross-sectional analysis based on malaria indicator survey data for 2012	Malawi	MIS	Under 5 years	367 (27.7)	1375	MT	Logistic regression (LR)	STATA	Institutionbased
Levitz *et al.,* 2018 [29]	Effect of individual and community-level bed net usage on malaria prevalence among under-fives in the Democratic Republic of Congo	Democratic Republic of Congo (DRC)	DHS	Under 5 years	2191 (37.4)	5857	Others (PCR)	Multilevel logistic regression (MLLR)	SAS	Multiple sources
Morakinyo *et al.,* 2018 [30]	Housing type and risk of malaria among under-five children in Nigeria: evidence from the malaria indicator survey	Nigeria	MIS	6–59 months		6991	RDT and MT	Logistic regression (LR)	STATA	No funding
Njau *et al.,* 2013 [26]	Exploring the impact of targeted distribution of free bed nets on households bed net ownership, socioeconomic disparities and childhood malaria infection rates: analysis of national malaria survey data from three sub-Saharan Africa countries	Angola, Tanzania and Uganda	MIS	Under 5 years	214 (20) 895 (39) 782 (18)	1125 3109 1954	RDT and MT	Multilevel logistic regression (MLLR)	STATA	Multiple source
Njau *et al.,* 2014 [31]	Investigating the Important Correlates of Maternal Education and Childhood Malaria Infections	Angola, Tanzania and Uganda (Pooled)	MIS	Under 5 years	-	1390 5975 2997	RDT	Multivariate logistic regression (MvLR)	STATA	Not reported
Semakula *et al.,* 2015 [32]	Potential of household environmental resources and practices in eliminating residual malaria transmission: a case study of Tanzania, Burundi, Malawi and Liberia	Tanzania, Burundi, Malawi and Liberia	MIS	Under 5 years	-	7695 3750 2115 3187	RDT	Multivariate logistic regression (MvLR)	JMP 10	Multiple source

Siri 2014 [33]	Independent Associations of Maternal Education and Household Wealth with Malaria Risk in Children	Multi-country (pooled)	Under 5 years	-	24,043	-	Multivariate logistic regression (MvLR)	SAS	Institutionbased

	Titles	Country	Survey *	Target Population	Prevalence n (%)	Participants (Sample Size)	Malaria Diagnostic Method **	Methods	Software	Funding Source
4]	Housing and child health in sub-Saharan Africa: A cross-sectional analysis	Multi-country (pooled)	Multiple surveys	Under 5 years	40,178 (21)	188,651	RDT and MT	Conditional logistic regression (LR)	STATA and R	Multiple source
	Using mixed effects logistic regression models for complex survey data on malaria rapid diagnostic test results	Nigeria	MIS	6–59 months	-	5236	RDT	Generalized linear mixed model (GLMM)	SAS	No funding
24]	Factors associated with malaria parasitaemia among children under 5 years in Uganda: a secondary data analysis of the 2014 Malaria Indicator Survey dataset	Uganda	MIS	Under 5 years	938 (19.04)	4930	MT	Multivariate logistic regression (MvLR)	STATA	no funding
	Drinking water and sanitation conditions are associated with the risk of malaria among children under five-year-old in sub-Saharan Africa: A logistic regression model analysis of national survey data	Multi-country (pooled)	Multiple surveys	Under 5 years	40,217 (18.8)	213,920	RDT and MT	Multivariate logistic regression (MvLR)	SPSS	not reported
37]	Prevalence and factors associated with malaria parasitaemia in children under the age of five years in Malawi: A comparison study of the 2012 and 2014 Malaria Indicator Surveys (MISs)	Malawi	MIS	Under 5 years	636 (33)	1928	MT	Multivariate logistic regression (MvLR)	SPSS	no funding

* Surveys: MIS = malaria indicator survey, DHS = demographic and health survey; ** RDT = rapid diagnostic test, MT = microscopic test.

Environmental/Area-related Variables

In consideration of environmental-related predictors, three variables (regional variations, malaria endemicity, and community free bed net distribution) were attractive for investigation among the included studies. Table 6 reports that Njau *et al.*, 2013 [26] found that the predicted marginal effects (ME) of malaria-endemic areas for malaria fever in Angola, Tanzania and Uganda were significantly ME: 0.01 ($p < 0.10$), ME: 0.095 ($p < 0.05$) and ME: 0.288 ($p < 0.01$) points, respectively. Additionally, the same authors [26] reported an insignificant increase in the predicted marginal effects of 25.1% points for free bed net in the community among malaria positive children in Angola, but a significant reduction of 1.5% ($p < 0.1$) and 8.2% ($p < 0.05$) in Tanzania and Uganda, respectively.

Table 6. Association between environmental-related variables and malaria status.

S/N	Variables	Significance Levels	Number of Country Studies	Association Effect (95% CI)
		S:	1	ISF: cluster level: OR: 0.984 (0.979,
		S:	2	
		S:	1 Community wealth status — NS: - 2 Community distance to health facilities — NS: - 3 Cluster altitude — S: 1; NS: 1 [28] 4 Community insecticide net use — NS: - 5 Regional variations — S: 3 [24,28]; NS: 1 [37] 1	29]
6 7	Malaria endemicity Free bed net in community	S:	4	ISF: ME: 0.010 (−0.0778–0.0572) [26] ME: 0.095 (0.0357–0.1561) [26] ME: 0.288 (−0.5526–−0.0247) [26] high: β: 0.093 [31]
		S:	NS: - 3	DSF: ME: −0.015 (−0.0134–0.0405) [26] ME: −0.082 (0.1479–0.0494) [26]
		NS:	-	
	Country-specific	S:	1	ISF: Liberia: OR: 1.09 (0.95–1.24); Uganda: OR: 40.15 (29.74–54.20); Malawi: OR: 16.68 (12.38, 22.48); Senegal: OR: 1.01 (0.77, 1.32); Nigeria: OR: 31.91 (23.86, 42.67) [33] DSF: Rwanda: OR: 0.15 (0.10, 0.21); Tanzania: OR: 0.82 (0.63, 1.07); Madagascar: OR:0.73 (0.57, 0.94) [33]
		NS:	-	

OR: odds ratio, ME: marginal effect, β: coefficient estimate, S: significant, NS: not significant, ISF: increased significant factors, DSF: decreased significant factors.

Also, significant regional variations were reported across the six geopolitical zones of Nigeria. Morakinyo *et al.*, 2018 [30], which found reduced odds of malaria infections among children 6–59 months in North Central (OR: 0.61 CI: 0.47–0.79, $p < 0.01$); North East (OR: 0.35 CI: 0.27–0.46, $p < 0.01$); North West (OR: 0.49 CI: 0.37–0.64, $p < 0.01$); South East (OR: 0.59 CI: 0.44–0.79, $p < 0.01$); South-South (OR: 0.42 CI: 0.31–0.55, $p < 0.01$), when compared with children from South West. Contrary to Morakinyo *et al.*, 2018 [30] report on Nigeria study, Ugwu *et al.*, 2018 [35] found insignificant effects on regional variations in South East, South-South, South West, and North Central when compared with North West, but found significant odd of malaria-positive cases among 6–59 months in North East (OR: 0.3059, $p = 0.015$) when compared with north West.

Interactions-related Variables

Interaction-related predictors were reported by two papers in four country-specific studies (Table 7). Njau *et al.*, 2013 [26] reported a significant decrease of 4.6% ($p < 0.05$) points in the predicted marginal effects among malaria-positive children in Angola with respect to interaction terms of free bed net and wealth status, but found an insignificant reduction of 0.9% and 6.4% in Tanzania and Uganda, respectively.

Table 7. Association between interaction-related variables and malaria status. household head

S/N	Variables	Significance Levels	Number of Country Studies	Association Effect (95% CI)
1	Free bed net/wealth status	S:	1	DSF: ME: −0.046 (0.0668–0.1772) [26]
		NS:	2 [26]	–
2	Wealth/place of residence	S:	1	DSF: poorest/rural: OR: 0.3567 (0.13–0.96); poorer/rural: OR: 0.2770 (0.11–0.66); middle/rural OR: 0.4477 (0.22–0.91); richer/rural: OR: 0.4174 (0.22–0.78) [35]
		NS:	-	
3	Number in household/age of	S:	1	DSF: OR: 0.9984 (0.997–0.999) [35]
		NS:	-	

OR: odds ratio, ME: marginal effect, β: coefficient estimate, S: significant, NS: not significant, ISF: increased significant factors, DSF: decreased significant factors.

Ugwu *et al.*, 2018 [35] found significant interaction effects of wealth index (poorest, poorer, middle, richer and richest) and place of residence (rural or urban). In consideration of the report, the middle and richer household group in the rural area (OR: 0.448 CI: 0.2197–0.9124, $p = 0.027$ and OR: 0.417 CI: 0.2213–0.7871, $p = 0.007$) displayed a higher odd of malaria-positive than the poorest and poorer household group in the rural area (OR: 0.3567 CI: 0.1319–0.0429, $p = 0.0429$ and OR: 0.2770 CI: 0.1149–0.6677, $p = 0.004$) using richest and urban as a reference category. There were no significant interaction effects of region and place of residence on the odds of contracting malaria parasitemia among children 6–59 months in Nigeria.

4. Discussion

This study aimed to conduct a scoping review of the predictors that affect the malaria status of children under five years in SSA. The review found thirteen studies that identified factors associated with malaria fever among children under five in SSA. Though the search strategies covered the period from 1990 to 2020, the distribution of the publication years shows that papers conducted on predictors affecting the occurrence of malaria among children under-five in SSA were carried out in the last decade. All the publications (meeting the inclusion criteria) were from 2013 to 2020, and no publications in 2016 or 2012 and earlier were found.

This may relate to the fact that the data set from nationally representative individual and household surveys in SSA, such as from malaria indicator surveys (MIS) designed a stand-alone survey [40] for use in areas where DHS and MCIS have not been used [41] were not often available until around 2012 and beyond [42]. Most of the MIS datasets collected from 2005 to 2012 remained unavailable within the period [42]. Furthermore, this review shows that the countries of the study were more concentrated in Southern and Central Africa, with just two recorded in West Africa. The reasons for this disparity are not clear. However, from a UNICEF report, the reduction in changes in the percentage of under-five mortality resulting from malaria between 2000 and 2017 was more drastic among the countries in Southern and Central Africa [6]. In addition, the regional disparity in the number of studies may be related to the fact that it is much easier for researchers to secure funding for their studies in Southern and Central Africa than in West African countries. There were more studies from the malaria indicator surveys (MIS) data set than from the Demographic and health surveys (DHS) data set. These differences are likely related to the fact that the timing of MIS is usually in the season where malaria infections are high [43,44], and it includes the use of biomarkers on the field and laboratory [44]. These reasons notwithstanding, technical assistance for both DHSs and MISs was provided for by DHS. In recent times, some country's surveys combined both surveys into one. For instance, Nigeria conducted Nigeria's malaria indicator survey (NMIS) in 2010 and 2015, conducted Nigeria demographic and health survey (NDHS) in 2008 and 2013 separately, but NDHS 2018 was a combination of both NDHS and NMIS [45].

From this review, the most vulnerable, in children under five in terms of age, are those between 2 to 5 years [24,30,33,35,37]. This finding agrees with report from another study [46]. The reasons may not be unconnected with the fact that most families, when they have new-born, intra-family attention and use of resources are shifted to the new-born. As revealed by this review, another factor of importance is the significance of the increase in the maternal/caregiver educational status has on protecting the child from having malaria parasitemia [24,27,28,31,33,35,37]. This is also in line with the findings in Mehretie et al. [47]. One of the pathways in which this can affect the malaria status of under-5 is through adequate knowledge of malaria symptoms, prompt response to seek healthcare attention [24,31].

5. Strengths and Limitations

There are several strengths identified in this scoping review. (i) This is the first scoping review that was carried out on predictors affecting the malaria status of under five years in SSA that used classical statistical regression methods on data from a secondary analysis of nationally representative surveys. (ii) The review was rigorous with intense supervision from the team that cuts across two institutions.

It is acknowledged that this review has some limitations. (i) All the studies considered in this review are the secondary analysis of nationally representative cross-sectional surveys. Causal effects are not established in the studies, and cross-sectional studies, which are carried out for a time point, cannot determine trends [48]. (ii) Very few studies reviewed in this project considered the contextual factors that may be associated with the malaria status of under-fives with appropriate statistical technique; this may have reduced the reliability of the results attained. Studies that can investigate the contextual factors related to malaria fever among children under five in SSA countries are urgently needed. (ii) Only thirteen studies were identified that met the inclusion criteria. The study may not have successfully identified all the papers as the only considered studies were those that were written in the English language [49]. (iii) In view of the scoping review study design applied [50], we also acknowledged that there was no publication bias and quality of study assessment done. (iv) Only studies that applied frequentist statistical methods were included. Therefore, the exclusion of studies that applied Bayesian statistical methods could have resulted in limitations in the findings. (v) The intervention terms were omitted in the search; this may have excluded some potential studies.

6. Future Work

There are a few areas not covered in the papers included in this review that require future investigations. Considering the limitations stated above, a scoping review that will take care of them should be the basis for future study. Malaria infection in children is comorbid and, as such, may have overlapping associative predictors. Studies that could explore this area are a potential study area for the future.

7. Conclusions

SSA is one of the high endemic malaria regions in the world, with a high mortality rate resulting from malaria morbidity. There is a more significant commitment on the part of government and partners to ensure that morbidity and mortality resulting from malaria fever in some countries is reduced to zero by the end of 2020 [5]. The target year is now passed, but it does not seem to have been achieved. The knowledge derived from a careful analysis of these many factors contributing to the rising burden could be used to fast track appropriate intervention mix as they become available [51]. For instance, children delivered in health facilities have a reduced risk of malaria infections when compared with those, who are delivered at home, so a child's place of delivery, child's anemia status, vaccination status, access to insecticide-treated bed net, maternal education status, number of births within five years, duration of breastfeeding, improved water source, availability of electricity, a constant residual spray of houses and environment, and community distance to healthcare facilities are areas that need government attention through policymaking and implementations to reduce malaria infection rates among children under five years. Generally, some population settings, especially the children under five, are more at risk than others, where over 70% of mortality from malaria occurs [52], and measures are needed to protect these vulnerable groups [53]. However, vector control (such as insecticide-treated mosquito nets, drug treatments and indoor residual spraying) is one of the main approaches most SSA governments have adopted to prevent and reduce the spread of malaria [52–54] caused through mosquito bites [55]. Inadequate knowledge of how the individual and contextual factors are associated with malaria contraction may jeopardize governments' ability to eliminate the malaria parasite [54].

Author Contributions: The conceptualization of this study was done by P.E.O. and K.K.; the formal literature searching, screening and drafting of the manuscript were carried out by P.E.O., while S.J.W., R.J. and K.K. participated in supervising, revising and editing of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This study is an integral part of P.E.O.'s doctoral study at the School of Health and Related Research of the University of Sheffield, United Kingdom. The funding for the doctoral study was granted by TETFUND (Nigeria).

Institutional Review Board Statement: This study is an integral part of a larger doctoral study. The ethical approval to carry out the doctoral research study was granted by the School of Health and Related Research (ScHARR) Ethics Committee of the University of Sheffield (Reference Number: 031534).

Informed Consent Statement: Not applicable.

Acknowledgments: The authors acknowledged the contributions received from the ScHARR community (especially Joanna Leaviss, Anthea Sutton and Mark Clowes). PEO would like to appreciate the Rector and the management staff of Niger State Polytechnic, Nigeria, for the nomination and the receipt of the TETFUND (Nigeria) sponsorship of his doctoral program.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Bennett, A.; Bisanzio, D.; Yukich, J.O.; Mappin, B.; Fergus, C.A.; Lynch, M.; Cibulskis, R.E.; Bhatt, S.; Weiss, D.J.; Cameron, E.; et al. Population Coverage of Artemisinin-Based Combination Treatment in Children Younger than 5 years with Fever and Plasmodium Falciparum Infection in Africa, 2003–2015: A Modelling Study Using Data from National Surveys. *Lancet Glob. Health* **2017**, *5*, e418–e427. [CrossRef]
2. Dawaki, S.; Al-Mekhlafi, H.M.; Ithoi, I.; Ibrahim, J.; Atroosh, W.M.; Abdulsalam, A.M.; Sady, H.; Elyana, F.N.; Adamu, A.U.;
   Yelwa, S.I.; et al. Is Nigeria Winning the Battle against Malaria? Prevalence, Risk Factors and KAP Assessment among Hausa Communities in Kano State. *Malar. J.* **2016**, *15*, 351. [CrossRef] [PubMed]
3. World Health Organization. World Malaria Report 2020: 20 Years of Global Progress & Challenges. Available online: https: //www.who.int/publications-detail-redirect/9789240015791 (accessed on 3 January 2021).
4. Aychiluhm, S.B.; Gelaye, K.A.; Angaw, D.A.; Dagne, G.A.; Tadesse, A.W.; Abera, A.; Dillu, D. Determinants of Malaria among Under-Five Children in Ethiopia: Bayesian Multilevel Analysis. *BMC Public Health* **2020**, *20*, 1468. [CrossRef] [PubMed]
5. World Health Organisation. World Malaria Report 2014. Available online: https://www.who.int/malaria/publications/world_ malaria_report_2014/en/ (accessed on 21 February 2019).
6. Unicef Malaria in Africa. Available online: https://data.unicef.org/topic/child-health/malaria/ (accessed on 3 January 2021).

7. Adinan, J.; Damian, D.J.; Mosha, N.R.; Mboya, I.B.; Mamseri, R.; Msuya, S.E. Individual and Contextual Factors Associated with Appropriate Healthcare Seeking Behavior among Febrile Children in Tanzania. *PLoS ONE* **2017**, *12*, e0175446. [CrossRef] [PubMed]
8. Carlucci, J.G.; Peratikos, M.B.; Cherry, C.B.; Lopez, M.L.; Green, A.F.; Gonzalez-Calvo, L.; Moon, T.D.; Ogumaniha, S.Z. Prevalence and Determinants of Malaria among Children in Zambezia Province, Mozambique. *Malar. J.* **2017**, *16*, 108. [CrossRef]
9. Alene, M.; Yismaw, L.; Berelie, Y.; Kassie, B. Health Care Utilization for Common Childhood Illnesses in Rural Parts of Ethiopia: Evidence from the 2016 Ethiopian Demographic and Health Survey. *BMC Public Health* **2019**, *19*, 57. [CrossRef]
10. Asoba, G.N.; Sumbele, I.U.; Anchang-Kimbi, J.K.; Metuge, S.; Teh, R.N. Influence of Infant Feeding Practices on the Occurrence of Malnutrition, Malaria and Anaemia in Children ≤5 years in the Mount Cameroon Area: A Cross Sectional Study. *PLoS ONE* **2019**, *14*, e0219386. [CrossRef] [PubMed]
11. Islam, N.; Bonovas, S.; Nikolopoulos, G.K. An Epidemiological Overview of Malaria in Bangladesh. *Travel Med. Infect. Dis.* **2013**, *11*, 29–36. [CrossRef]
12. Kumar, A.; Chery, L.; Biswas, C.; Dubhashi, N.; Dutta, P.; Dua, V.K.; Kacchap, M.; Kakati, S.; Khandeparkar, A.; Kour, D.; et al. Malaria in South Asia: Prevalence and Control. *Acta Trop.* **2012**, *121*, 246–255. [CrossRef]
13. Asia Pacific Leaders Malaria Alliance Bangladesh: New Plan for Malaria Elimination (2017–2021). Available online: https: //www.aplma.org/blog/42/bangladesh-new-plan-for-malaria-elimination-2017-2021.html (accessed on 3 January 2021).
14. Alemu, A.; Tsegaye, W.; Golassa, L.; Abebe, G. Urban Malaria and Associated Risk Factors in Jimma Town, South-West Ethiopia. *Malar. J.* **2011**, *10*, 173. [CrossRef] [PubMed]
15. Arevalo-Herrera, M.; Quiñones, M.L.; Guerra, C.; Céspedes, N.; Giron, S.; Ahumada, M.; Piñeros, J.G.; Padilla, N.; Terrientes, Z.; Rosas, A.; et al. Malaria in Selected Non-Amazonian Countries of Latin America. *Acta Trop.* **2012**, *121*, 303–314. [CrossRef]
16. National Malaria Elimination Program (NMEP); National Population Commission (NPopC); National Bureau of Statistics (NBS); ICF International. *Nigeria Malaria Indicator Survey [MIS8]*; National Bureau of Statistics (NBS): Abuja, Nigeria; NMEP, NPopC, and ICF International: Rockville, MD, USA, 2015.
17. Bassey, S.E.; Izah, S.C. Some Determinant Factors of Malaria Prevalence in Nigeria. *J. Mosq. Res.* **2017**, *7*, 7. [CrossRef]
18. Baragatti, M.; Fournet, F.; Henry, M.C.; Assi, S.; Ouedraogo, H.; Rogier, C.; Salem, G. Social and Environmental Malaria Risk Factors in Urban Areas of Ouagadougou, Burkina Faso. *Malar. J.* **2009**, *8*, 1–14. [CrossRef]
19. Oladeide, B.H.; Omoregie, R.; Osakue, E.O.; Onaiwu, T.O. Asymptomatic Malaria among Blood Donors in Benin City Nigeria. *Iran. J. Parasitol.* **2014**, *9*, 415–422.
20. Tela, I.A.; Modibbo, M.H.; Adamu, L.H.; Taura, M.G. Prevalence of Malaria Infection among ABO Blood Groups in Jama'are, Nigeria. *RA J. Appl. Res.* **2015**, *1*, 255–262.
21. Shamseer, L.; Moher, D.; Clarke, M.; Ghersi, D.; Liberati, A.; Petticrew, M.; Shekelle, P.; Stewart, L.A. Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015: Elaboration and Explanation. *BMJ* **2015**, *349*, g7647. [CrossRef]
22. Tricco, A.C.; Lillie, E.; Zarin, W.; O'Brien, K.K.; Colquhoun, H.; Levac, D.; Moher, D.; Peters, M.D.; Horsley, T.; Weeks, L.; et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann. Intern. Med.* **2018**, *169*, 467–473. [CrossRef]
23. Teh, R.N.; Sumbele, I.U.; Meduke, D.N.; Ojong, S.T.; Kimbi, H.K. Malaria Parasitaemia, Anaemia and Malnutrition in Children Less than 15 years Residing in Different Altitudes along the Slope of Mount Cameroon: Prevalence, Intensity and Risk Factors. *Malar. J.* **2018**, *17*, 336. [CrossRef]
24. Wanzira, H.; Katamba, H.; Okullo, A.E.; Agaba, B.; Kasule, M.; Rubahika, D. Factors Associated with Malaria Parasitaemia among Children under 5 years in Uganda: A Secondary Data Analysis of the 2014 Malaria Indicator Survey Dataset. *Malar. J.* **2017**, *16*, 191. [CrossRef]
25. Akinlua, J.T.; Meakin, R.; Umar, A.M.; Freemantle, N. Current Prevalence Pattern of Hypertension in Nigeria: A Systematic Review. *PLoS ONE* **2015**, *10*, e0140021. [CrossRef]
26. Njau, J.D.; Stephenson, R.; Menon, M.; Kachur, S.P.; McFarland, D.A. Exploring the Impact of Targeted Distribution of Free Bed Nets on Households Bed Net Ownership, Socio-Economic Disparities and Childhood Malaria Infection Rates: Analysis of National Malaria Survey Data from Three Sub-Saharan Africa Countries. *Malar. J.* **2013**, *12*, 1–5. [CrossRef]
27. Berendsen, M.L.; van Gijzel, S.W.; Smits, J.; de Mast, Q.; Aaby, P.; Benn, C.S.; Netea, M.G.; van der Ven, A.J. BCG Vaccination Is Associated with Reduced Malaria Prevalence in Children under the Age of 5 years in Sub-Saharan Africa. *BMJ Glob. Health* **2019**, *4*, e001862. [CrossRef]
28. Chitunhu, S.; Musenge, E. Direct and Indirect Determinants of Childhood Malaria Morbidity in Malawi: A Survey Cross-Sectional Analysis Based on Malaria Indicator Survey Data for 2012. *Malar. J.* **2015**, *14*, 1–9. [CrossRef]

29. Levitz, L.; Janko, M.; Mwandagalirwa, K.; Thwai, K.L.; Likwela, J.L.; Tshefu, A.K.; Emch, M.; Meshnick, S.R. Effect of Individual and Community-Level Bed Net Usage on Malaria Prevalence among under-Fives in the Democratic Republic of Congo. *Malar. J.* **2018**, *17*, 39. [CrossRef] [PubMed]
30. Morakinyo, O.M.; Balogun, F.M.; Fagbamigbe, A.F. Housing Type and Risk of Malaria among Under-Five Children in Nigeria: Evidence from the Malaria Indicator Survey. *Malar. J.* **2018**, *17*, 311. [CrossRef] [PubMed]
31. Njau, J.D.; Stephenson, R.; Menon, M.P.; Kachur, S.P.; McFarland, D.A. Investigating the Important Correlates of Maternal Education and Childhood Malaria Infections. *Am. J. Trop. Med. Hyg.* **2014**, *91*, 509–519. [CrossRef] [PubMed]
32. Semakula, H.M.; Song, G.B.; Zhang, S.S.; Achuu, S.P. Potential of Household Environmental Resources and Practices in Eliminating Residual Malaria Transmission: A Case Study of Tanzania, Burundi, Malawi and Liberia. *Afr. Health Sci.* **2015**, *15*, 819–827. [CrossRef] [PubMed]
33. Siri, J.G. Independent Associations of Maternal Education and Household Wealth with Malaria Risk in Children. *Ecol. Soc.* **2014**, *19*, 33. [CrossRef]
34. Tusting, L.S.; Gething, P.W.; Gibson, H.S.; Greenwood, B.; Knudsen, J.; Lindsay, S.W.; Bhatt, S. Housing and Child Health in Sub-Saharan Africa: A Cross-Sectional Analysis. *PLoS Med.* **2020**, *17*, e1003055. [CrossRef]
35. Ugwu, C.L.; Zewotir, T.T. Using Mixed Effects Logistic Regression Models for Complex Survey Data on Malaria Rapid Diagnostic Test Results. *Malar. J.* **2018**, *17*, 1–10. [CrossRef]
36. Yang, D.; He, Y.; Wu, B.; Deng, Y.; Li, M.L.; Yang, Q.; Huang, L.T.; Cao, Y.M.; Liu, Y. Drinking Water and Sanitation Conditions Are Associated with the Risk of Malaria among Children under Five Years Old in Sub-Saharan Africa: A Logistic Regression Model Analysis of National Survey Data. *J. Adv. Res.* **2020**, *21*, 1–13. [CrossRef] [PubMed]
37. Zgambo, M.; Mbakaya, B.C.; Kalembo, F.W. Prevalence and Factors Associated with Malaria Parasitaemia in Children under the Age of Five Years in Malawi: A Comparison Study of the 2012 and 2014 Malaria Indicator Surveys (MISs). *PLoS ONE* **2017**, *12*, e0175537. [CrossRef] [PubMed]
38. Popay, J.; Roberts, H.; Sowden, A.; Petticrew, M.; Arai, L.; Rodgers, M.; Britten, N.; Roen, K.; Duffy, S. Guidance on the Conduct of Narrative Synthesis in Systematic Reviews: A Product from the ESRC Methods Programme, Version 1. 2006. Available online: https://www.lancaster.ac.uk/media/lancaster-university/content-assets/documents/fhm/dhr/chir/ NSsynthesisguidanceVersion1-April2006.pdf (accessed on 20 January 2021).
39. Berendsen, M.L.; Smits, J.; Netea, M.G.; van der Ven, A. Non-Specific Effects of Vaccines and Stunting: Timing May Be Essential. *EBioMedicine* **2016**, *8*, 341–348. [CrossRef]
40. Roll Back Malaria. Household Survey Indicators for Malaria Control 2018. Available online: https://endmalaria.org/sites/ default/files/Household%20Survey%20Indicators%20for%20Malaria%20Control_FINAL.pdf (accessed on 21 February 2021).
41. MEASURE Evaluation Malaria Indicator Survey Tool Implemented in 8 African Countries. Available online: https://www. measureevaluation.org/our-work/malaria/malaria-indicator-survey-tool-implemented-in-8-african-countries (accessed on 21 February 2021).
42. Roll Back Malaria Malaria Indicator Surveys—Access to Malaria Indicator Surveys, Datasets. Available online: https://www. malariasurveys.org/ (accessed on 3 January 2021).
43. Massoda Tonye, S.G.; Kouambeng, C.; Wounang, R.; Vounatsou, P. Challenges of DHS and MIS to Capture the Entire Pattern of Malaria Parasite Risk and Intervention Effects in Countries with Different Ecological Zones: The Case of Cameroon. *Malar. J.* **2018**, *17*, 156. [CrossRef] [PubMed]
44. The DHS Program Malaria Indicators Survey (MIS): Overview. Available online: https://dhsprogram.com/methodology/ survey-types/mis.cfm (accessed on 3 January 2021).
45. National Population Commission; ICF International. *Nigeria Demographic and Health Survey 2018*; NPC and ICF: Abuja, Nigeria; Rockville, MD, USA, 2019.
46. Jeremiah, Z.A.; Uko, E.K. Childhood Asymptomatic Malaria and Nutritional Status among Port Harcourt Children. *East Afr. J. Public Health* **2007**, *4*, 55–58.
47. Mehretie Adinew, Y.; Feleke, S.A.; Mengesha, Z.B.; Workie, S.B. Childhood Mortality: Trends and Determinants in Ethiopia from 1990 to 2015—A Systematic Review. *Adv. Public Health* **2017**, *2017*, 7479295. [CrossRef]
48. Mkhize, M.; Sibanda, M. A Review of Selected Studies on the Factors Associated with the Nutrition Status of Children Under the Age of Five Years in South Africa. *Int. J. Environ. Res. Public. Health* **2020**, *17*, 7973. [CrossRef]
49. Manda, S.; Haushona, N.; Bergquist, R. A Scoping Review of Spatial Analysis Approaches Using Health Survey Data in Sub-Saharan Africa. *Int. J. Environ. Res. Public Health* **2020**, *17*, 3070. [CrossRef] [PubMed]
50. Green, B.N.; Johnson, C.D.; Haldeman, S.; Griffith, E.; Clay, M.B.; Kane, E.J.; Castellote, J.M.; Rajasekaran, S.; Smuck, M.; Hurwitz, E.L.; et al. A Scoping Review of Biopsychosocial Risk Factors and Co-Morbidities for Common Spinal Disorders. *PLoS ONE* **2018**, *13*, e0197987. [CrossRef] [PubMed]
51. World Health Organization. *Global Technical Strategy for Malaria, 2016–2030*; WHO: Geneva, Switzerland, 2015; ISBN 978-92-4156499-1.

52. ShelterBox Mosquito Nets—Helping Families Protect Themselves. Available online: https://www.shelterbox.org/about/aid/ mosquito-nets/ (accessed on 25 July 2020).
53. World Health Organisation. Fact Sheet about Malaria. Available online: https://www.who.int/news-room/fact-sheets/detail/ malaria (accessed on 25 July 2020).
54. Dhiman, S. Are Malaria Elimination Efforts on Right Track? An Analysis of Gains Achieved and Challenges Ahead.
Infect. Dis. Poverty **2019**, *8*, 1–9. [CrossRef]
55. Sallah, K.; Giorgi, R.; Ba, E.-H.; Piarroux, M.; Piarroux, R.; Cisse, B.; Gaudart, J. Targeting Malaria Hotspots to Reduce Transmission Incidence in Senegal. *Int. J. Environ. Res. Public Health* **2021**, *18*, 76. [CrossRef] [PubMed]

C.3: Risk Factors Associated with Malnutrition among Children Under-Five Years in Sub-Saharan African Countries: A Scoping Review

Review

Risk Factors Associated with Malnutrition among Children Under-Five Years in Sub-Saharan African Countries: A Scoping Review

Phillips Edomwonyi Obasohan [1,2,*], Stephen J. Walters [1], Richard Jacques [1] and Khaled Khatab [3]

1 School of Health and Related Research (ScHARR), University of Sheffield, Sheffield S1 4DA, UK; s.j.walters@sheffield.ac.uk (S.J.W.); r.jacques@sheffield.ac.uk (R.J.)

2 Department of Liberal Studies, College of Administrative and Business Studies, Niger State Polytechnic, Bida Campus, Bida 912231, Nigeria

3 Faculty of Health and Wellbeing, Sheffield Hallam University, Sheffield S10 2BP, UK; K.Khatab@shu.ac.uk * Correspondence: peobasohan1@sheffield.ac.uk

Received: 30 October 2020; Accepted: 24 November 2020; Published: 26 November 2020

Abstract: *Background/Purpose*: Malnutrition is a significant global public health burden with greater concern among children under five years in Sub-Saharan Africa (SSA). To effectively address the problem of malnutrition, especially in resource-scarce communities, knowing the prevalence, causes and risk factors associated with it are essential steps. This scoping review aimed to identify the existing literature that uses classical regression analysis on nationally representative health survey data sets to find the individual socioeconomic, demographic, and contextual risk factors associated with malnutrition among children under five years of age in Sub-Sahara Africa (SSA). *Methods*: The electronic databases searched include EMBASE (OVID platform), PubMed (MEDLINE), Cumulative Index to Nursing and Allied Health Literature (CINAHL), Scopus, Web of Science (WoS) and Cochrane Library. Only papers written in the English language, and for which the publication date was between 1 January 1990 and 31 July 2020, were included. *Results*: A total of 229 papers were identified, of which 26 were studies that have been included in the review. The risk factors for malnutrition identified were classified as child-related, parental/household-related and community or area-related. *Conclusions*: Study-interest bias toward stunting over other anthropometric indicators of malnutrition could be addressed with a holistic research approach to equally address the various dimension of the anthropometric indicators of malnutrition in a population.

Keywords: malnutrition; stunting; underweight; wasting; overweight; anthropometric indices; undernutrition; overnutrition; under five; Sub-Saharan Africa

1. Introduction

Malnutrition is the intake of an insufficient, surplus or disproportionate amount of energy and/or nutrients [1]. Malnutrition is a significant global public health burden with greater concern among children under five years [2]. In an attempt to address this global challenge of malnutrition, the World Health Organization (WHO) member states recently signed into effect a commitment to nine global targets by 2025, including a 40% reduction in childhood stunting, a less than 5% prevalence of childhood wasting, to ensure no increase in the number of children who are overweight [3], and to end all forms of malnutrition by 2030 [3,4]. With less than five years to the target date, the progress has remained relatively slow, with no country working toward full actualization of the nine targets [5]. Though there has been considerable global decline that has been noticed in childhood stunting, there are over 150 million, 50 million and 38 million children remaining stunted, wasted and overweight,

respectively [5]. However, contrary to the expectation and in line with a global target on malnutrition to keep the rate of overweight in children constant, in 2018 there were over 40 million children under five who were overweight [6], indicating a gradual global increase in overweight children. There is the possibility that the number of overweight children will increase further in the aftermath of covid-19 global lockdown. Just as most countries are witnessing multiple forms of malnutrition indices, in the same way, individual children are found to suffer from two or more forms of malnutrition indicators globally [5].

In recent times, Sub-Saharan Africa (SSA) has had so much to grapple with in terms of the malnutrition burden. In 2015, SSA accounted for more than 30% of global underweight children [7]. Additionally, in 2018, despite a worldwide decline in childhood stunting, the African region witnessed a rise in the relative figure from 50.3 million to 58.8 million children [6]. Interestingly, the 7.1% prevalence of children under five wasting in Africa is lower than the global rate of 7.3% [8]. Within the SSA region, sub-regional variations in malnutrition are reported in the literature. Akombi et al. [9] concluded in their study that countries in East and West Africa bore the greatest burden of malnutrition in the SSA region. Malnutrition is expressed through either undernutrition (the most common in less developed countries), a situation of low protein-energy intake [10] (which usually manifests at different anthropometric indices in stunting, wasting and underweight), and/or overnutrition, which is commonly associated with too great an intake of protein-energy (a situation widely associated with developed society, but of less concern in the developing countries [11], perhaps a dangerous position to assume especially in Africa).

Beside the SSA region, malnutrition has posed some serious public health challenges in other regions of the world. For instance, in Asia, though considerable steps have made towards the global target, there are lapses in achieving the targets that still exist. The region has experienced a prevalence of overweight among children under five years, which is less than the global average, but it also experienced more than the global average in stunting and wasting, which stood at 22.7% and 9.4%, respectively [5]. Similarly, the Latin American region has in the last three decades been working to deal with the burden of malnutrition, and is yet to achieve significant progress in some parts of the region. UNICEF's 2019 report states that almost 20% of children under five in Latin America and the Caribbean were either suffering from any of the indices of malnutrition or overlapping in any two of them [12]. Galasco and Wagstaff stated that by 2030, and with the current space for an annual reduction rate in stunting, Brazil, Costa Rica, the Dominican Republic and Mexico are on course to reduce the stunting rate by 50% [13]. Overnutrition is a burden in most developed regions of the world. In 2017, more than a quarter of children in more than 80% of the states in America were either overweight or obese due to inconsistent access to good food. The public health outcomes of malnutrition, manifesting in stunting, wasting, underweight, marasmus, kwashiorkor, edema and perhaps death, are functions of macronutrients and micronutrients missing from the child's meal [14].

Generally, malnutrition can lead to cognitive and physical impairment in children, especially those under five years old, with a high rate of morbidity and mortality [15,16]. A child's fundamental right to a higher level of physical and mental health development worldwide is boosted with access to good nutrition [13]. Martinez and Fernandez identified three analytical areas of concerns in addressing the burden of malnutrition. First is the analyses of the capacity of any society to be self-sufficient in terms of food security for all. Secondly, they look at how variations in the demographic and epidemiological set-up have affected the nutrition status of the population, and thirdly, they look at how the life-style of the people has affected their nutrition status [13]. To effectively address the problem of malnutrition, especially in

resource-scarce communities, knowing the prevalence, causes and risk factors associated with it are essential steps. This review is part of a doctoral degree work on multi-morbidities in children of under five years in Nigeria. Studies that have addressed malnutrition in Nigeria with a nationally representative sample are few, and this has necessitated a broader coverage in this scoping review to other areas with similar socio-economic and demographic set-ups as in SSA. Additionally, the methodology involved in the scoping review includes qualitatively reviewing the content of study, with a view to identifying the study gaps in the outcomes of interest, the analytical methods and the
study population, which have all influenced the use of a scoping review in this study.

The Aim of the Scoping Review

This scoping review aimed to identify existing literature that used classical regression analysis, (analysis that is based on frequentist statistics), on nationally representative health survey data sets to find the individual socioeconomic, demographic and contextual risk factors associated with malnutrition among children under five years of age in Sub-Sahara Africa (SSA).

2. Methodology

2.1. Design

The methodological pattern used in this scoping review followed Arkey and O'Malley [17], Lecac et al. [18], and the Agency for Healthcare Research and Quality (AHRQ) [19]-enhanced framework, recommendations and guidelines, respectively. The steps include the following: (1) identify the research question, (2) identify the relevant study sources, (3) select sources of evidence and eligibility criteria, and (4) chart data [20]. However, the pattern of reporting the results in this scoping review follows the
Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines [21,22].

2.2. Protocol and Registration Declaration

There was no review protocol and registration done for this scoping review.

2.3. Identification of the Research Questions

The research question was stated having been guided by PICOTS (population, intervention, comparators, outcomes, timing and study design) framework of Agency for Healthcare Research and Quality (AHRQ) [19].

The primary research question for this scoping review is what risk factors are associated with the malnutrition status of children less than five years of age in Sub-Saharan Africa countries that used classical regression methods to analyze a nationally representative survey data set?

Other secondary research questions are:

What are the existing examples of evidence of individual and contextual risk factors associated with the malnutrition status of children under five years in Sub-Saharan Africa countries?

What evidence exists in the use of classical regression analysis methods to determine the risk factors related to the malnutrition of children under five years in Sub-Saharan African countries?

2.4. Eligibility Criteria

The studies included in the review followed the PICOTS (population, interventions, comparators, outcomes, timing and study design) criteria enumerated and defined in Table 1 below.

Table 1. Structure for eligibility criteria in malnutrition studies.

Criteria	Determinants	Inclusion Criteria	Exclusion Criteria
Population (P)	Children Under five years are those less than five years of age.	The studies included both male and female children less than five years of age and residing in any of the Sub-Saharan Africa (SSA) countries. We also include publications that involved both adults, children above five years and children under five years; the provided data for under five years were reported differently from others.	Studies involving older children, but no separate reporting for data involving under five years were taken
Intervention (I)	Risk factors associated with malnutrition classified as child-related variables, parental/care-givers-related variables, household-related socioeconomic status, demographic status and area characteristics.	Studies that focused on predictors or risk factors or determinants of malnutrition among under five or pre-school children in SSA that covered both individual and contextual exposures.	
Comparator (C)	These studies involved two mutually exclusive groups: those that are 'nourished' and 'malnourished' for which we compared the exposures.	However, we included studies which declassified malnutrition status into stunting, wasting, underweight, overweight and nutrition status.	
Outcomes (O)	The main outcome is the **malnutrition status (MNS)** of children under five years. The MNS is determined through the measurement of anthropometric indices expressed as either stunting (assessed through height-for-age), wasting (assessed through weight-for-height) underweight (assessed through weight-for-age) each with Z-score ≤ -2SD from the median of the reference population, and overweight (estimated via weight-for-height) with Z-score > +2SD from the median of the reference population.	Studies that used any of the indicators or composite index of stunting, wasting, underweight and/or overweight, were onsidered for inclusion, as well as studies that used severity level (such as acute, mild etc.) for the indicators to classify malnutrition or nutrition status, and as such only one aspect was chosen (mild, severe or acute).	
Timing (T)	The time articles were published.	The publication period for the article is between 1st January 1990 and 30th July 2020 to capture recent publications on the topic from when UNICEF's conceptual framework of causes of malnutrition was in effect, the MDG and SDGs	All papers published outside the period 1990–2020.
Settings/Design (S)	These studies must be a nationally representative health-related survey in one or more of the Sub-Saharan African countries. These include Demographic and Health Survey (DHS), Multiple Indicator and Cluster Survey (MICS), AIDS Indicator Survey (AIDSIS), and any other countries' specific survey with a national spread.	Observational studies such as cross-sectional studies that focused on risk factors as predictors. The search also included those studies that applied classical regression for the analyses.	Studies that used other methods such as Bayesian or spatial analyses techniques. Papers on nationally representative health surveys not conducted for SSA countries. Community-based, facility-based and non-nationally representative surveys. Systematic review studies.

2.5. Identify the Relevant Sources of Evidence

Information Sources

The first author (PEO) of the School of Health and Related Research (ScHARR), the University of Sheffield, United Kingdom, carried out the literature search. The process was done at least twice on each of the databases consulted and we compared the outcomes to ensure that relevant papers were not excluded. The selection of bibliographies for screening was done on the basis of keywords and subject headings. The electronic databases searched include EMBASE (OVID platform), PubMed (MEDLINE), Cumulative Index to Nursing and Allied Health Literature (CINAHL), Scopus, Web of Science (WoS) and Cochrane Library. Only papers written in the English language, and published between 1 January 1990 and 31 July 2020, were included.

2.6. Selection of Sources for Evidence and Eligibility Criteria

Search Strategy

In this scoping review the search strategy involved searching for key terms or text words individually. The phrases were first searched in EMBASE (OVID platform) using "map terms to subject heading". The search terms applied were derived from the PICOTS categories and they include the variants of Sub-Saharan Africa, under five years, the determinants or risk factors, malnutrition status, and (with/without) regression techniques. These various terms were used with appropriate Boolean connectors, 'AND/OR', and with publication dates and research designs applied as restrictions.

The sample of the search strategy in EMBASE is displayed in Table 2 below.

Table 2. Draft search strategy and terms for EMBASE (OVID).

S/N	Terms and Keywords	Results
1	Demographic and health survey OR DHS OR AIDS indicator survey OR malaria Indicator survey OR multiple indicator cluster survey OR health survey OR Nutrition Survey OR MIS OR MICS	258,604
2	Sub-Saharan Africa OR SSA	37,452
3	1 AND 2	1764
4	Socioeconomic OR demographic OR contextual OR environmental OR community OR determinants OR risk factor OR predictor	3,298,141
5	Malnutrition OR stunting OR wasting OR underweight OR under-weight OR overweight OR over-weight OR Nutrition Status OR Nutritional	451,419
6	4 AND 5	107,110
7	3 AND 6	134
8	Limit 7 to human and English language and infant < to one year > OR preschool child < 1 to 6 years >	40
9	Logistic regression OR multilevel regression OR multinomial logistic OR random-effects OR hierarchical OR fixed effects	55,708
10	8 AND 9	12
11	Limit to last 30 years (1990 to 2020)	12

In the EMBASE search strategy result (Table 2), the publication period was set as 'limit to last 30 years', (because the default search time was set at 1974 to July 2020). However, for other electronic databases, the publication period was restricted to between 1990 and 2020.

The timing was informed over the periods when (i) Demographics and Health Surveys had been conducted in Nigeria, (ii) the UNICEF conceptual framework on causes of malnutrition began, (iii) the Millennium Development Goals were in effect, (iv) the WHO nine targets for malnutrition were on course, and (v) the Sustainable Development Goals were in progress. The search was conducted in the last week of July 2020.

2.7. Selection Process

The reviewer, PEO, screened all the selected literature for titles and abstracts using the inclusion and extraction criteria as a benchmark (Table 1). This process was also done twice in two citation managers platforms (Endnote and Zotero). Any discrepancy observed was resolved by examining them more closely. A full-text reading was conducted for all the selected articles. Papers excluded
were noted with reasons. Three overseeing team members vetted this process.

2.8. Data Charting Management

Initially the data extracted from the included articles were deposited into a Microsoft Excel spreadsheet designed by the reviewer specifically for this review. The relevant information obtained includes authors/year of publication, the survey type, the sample size, classical regression type and country of study. Other information includes the study aim, the outcomes (malnutrition status), the prevalence, various predictor variables assessed (child-related variables, parental/household-related variables and contextual or community-related variables), significant risk factors found for each of the malnutrition-related indicators, the specific conclusion reached, and the statistical software used for computation.

3. Results

The results section reports the profile of the quantitative analysis of risk factors associated with malnutrition in under five children in SSA following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklists [21,22].

3.1. Selection of Sources of Evidence

Figure 1 represents the flowchart of the included studies. A total of 224 unique papers were identified from the various electronic databases (EMBASE = 12, PUBMED = 18, WOS = 74, Scopus = 103, Cochran Library = 0, CINAHL = 12). Additionally, five other studies were retrieved from others sources (the reviewer’s files).

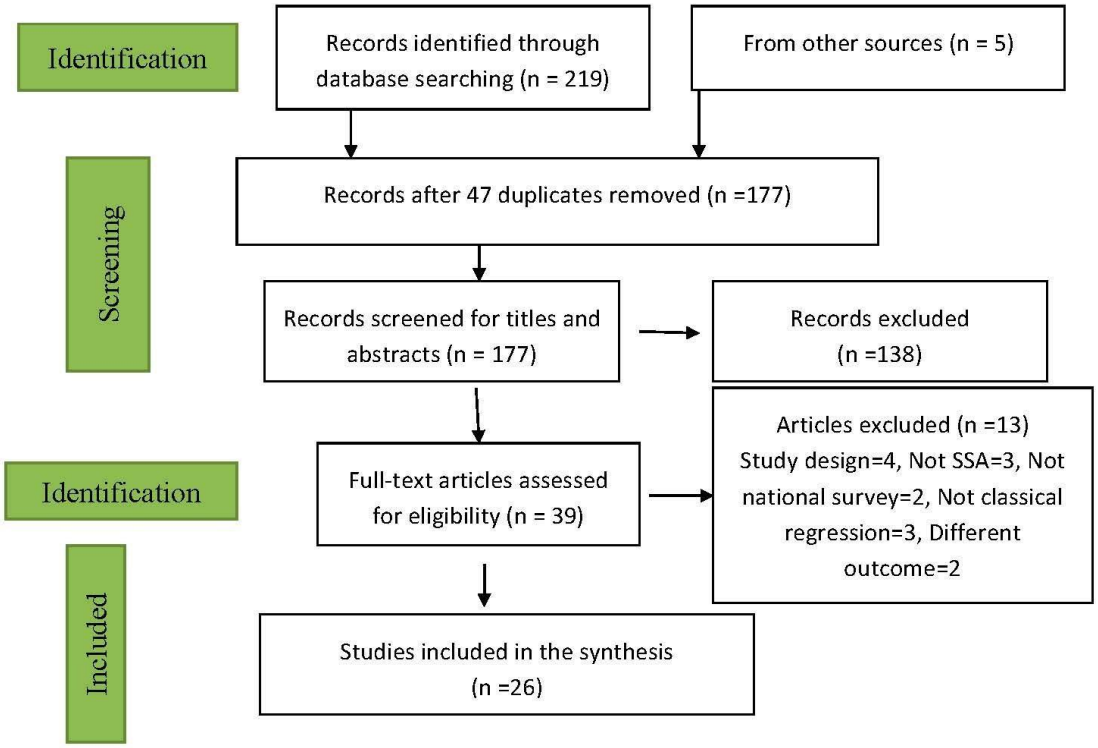


Figure 1. Flowchart of inclusion of studies for malnutrition review.

Twenty-five studies were duplicated in the search at different times (twice, thrice, four or five times). The duplication led to the removal of 47 titles. Out of a total of 177 studies screened for titles and abstract, 138 studies were removed for not meeting the inclusion criteria. A total of 26 studies were finally selected for this study after excluding 13 papers. The reasons for excluding these papers are listed in the chart above (Figure 1).

3.2. Characteristics of Sources of Evidence

To answer the questions raised in this scoping review, the relevant information was extracted from the selected papers and is presented in Tables 3 and 4. This section describes the characteristics of the sources of evidence.

3.2.1. Characteristics of Study Setting

Table 3 includes elements of the study setting. The unit of analysis in this scoping review is the country of study. Though there were 26 articles selected in this review, two studies (Kennedy *et al.*, 2006 and Ntoimo *et al.*, 2014) analyzed the data separately for three countries each, resulting in risk factor estimates for 30 country unique studies (and16 unique countries). The highest number of publications came from Nigeria, having five studies representing 16.7% [15,23–26], followed by Ethiopia [27–30], and articles with multi-countries [31–34] have four studies each. The multi-country articles are studies that focused on more than one country, with the countries' data sets pooled together and analyzed as one study. Ten countries (Swaziland, Senegal, Rwanda, Malawi, Kenya, Ghana, Equatorial Guinea, Democratic Republic of Congo (DRC), Cameroon, and Central Africa Republic (CAR)) had one study each.

Table 3. Characteristics of the 26 studies included in the review/synthesis.

Author and Data	Country	Study Design	Participants (N) and Study Population	Analysis Methods	Software Used
Adekanmbi et al. (2013) [23]	Nigeria	2008 Nigeria Demographic and Health Survey (NDHS)	28,647 0–59 months	Multilevel logistic regression	Stata
Acharya et al. (2020) [31]	Multi-countries	Demographic and Health Survey and Global Forest Change dataset	Women 15–49 years (25,285) and 12–59 months (73,941)	Logistic regression methods	Stata
Agadjanian et al. (2003) [35]	Angola	1996 Angola Multiple Indicator Cluster Survey (AMICS)	Number of participants not stated 6–59 months	Multivariate logistic regression	Stata
Aheto (2020) [36]	Ghana	2014 Ghana Demographic and Health Survey (GDHS)	2716 Under five years	Multivariate Simultaneous quantile regression	R-Package
Akombi et al. (2019) [24]	Nigeria	2003–2013 NDHS	22,217 0–59 months	Logistic regression	Stata
Akombi et al. (2017) [15]	Nigeria	2013 NDHS	24,529 0–59 months	Multilevel logistic regression	Stata
Amaral et al. (2017) [37]	Uganda	Uganda National Panel Survey (UNPS)	3427 under-5 years	Binary logistic regression	Stata
Amare et al. (2019) [27]	Ethiopia	2016 Ethiopia Demographic and Health Survey (EDHS)	9419 under-5 years	Multiple logistic regression	Stata
Custodio et al. (2008) [38]	Equatorial Guinea	2004 nationally survey	552 Under five years	Multivariate logistic regression	PEPI
Doctor & Nkhana-Salimu (2017) [7]	Malawi	1992–2016 Malawi Demographic and Health Survey (MDHS)	31,630 Under five years	Logistic regression	Nil
Gebru et al. (2019) [28]	Ethiopia	2016 Ethiopia Demographic and Health Survey (EDHS)	8855 Under five years	Multilevel logistic regression	Stata
Kennedy et al. (2006) [39] Multi-countries	Angola	2001 Angola Multiple Indicator Cluster Survey (AMICS)	5116 Under five years	Logistic regression	SPSS
	Central African Republic	2000 Multiple Indicator Cluster Survey (CARMICS)	12,499 Under five years	Logistic regression	SPSS

	Senegal	2000 Multiple Indicator Cluster Survey (SMICS)	8319 Under five years	Logistic regression	SPSS

Table 3. *Cont.*

Author and Data	Country	Study Design	Participants (N) and Study Population	Analysis Methods	Software Used
Kuche et al. (2020) [29]	Ethiopia	2016 Sustainable Undernutrition Reduction in Ethiopia (SURE)	1848 6–23 months	Ordinal logistic/linear regression model	Nil
Machisa et al. (2013) [40]	Swaziland	2008–2007 Swaziland Demographic and Health Survey (SDHS)	1155 6–36 months	Multinomial logistic regression	Stata
Magadi (2011) [32]	multi-countries	2003–2008 Demographic and Health Survey (DHS)	55,749 Under five years	Multilevel logistic regression	MlwiN
McKenna et al. (2019) [11]	Democratic Republic of Congo	2013–2014 Democratic Republic of Congo Demographic and Health Survey (CDHS)	3722 6–59 months	Logistic regression	SPSS
Miller et al. (2007) [41]	Botswana	2000 Botswana Multiple Indicator Cluster Survey (BMICS)	2723 Under five years	Multilevel logistic regression	MlwiN
Nankinga et al. (2019) [42]	Uganda	2016 Uganda Demographic and Health Survey (UDHS)	3531 under-5 years	Multivariate logistic regression	Stata
Nshimyiryo et al. (2019) [43]	Rwanda	2014–2015 Rwanda Demographic and Health Survey (RDHS)	3594 Under five years	Logistic regression	Stata
Ntoimo et al. (2014) [25] multi-countries	Cameroon	2011 Cameroon Demographic and Health Survey (CDHS)	5053 Under five years	Logistic regression	Nil
	Nigeria	2008 Nigeria Demographic and Health Survey (NDHS)	18,823 Under five years	Logistic regression	Nil
	Democratic Republic of Congo (DRC)	2007 Congo Demographic and Health Survey (CDHS)	3777 Under five years	Logistic regression	Nil
Ssentongo et al. (2019)	Uganda	2015–2016 Uganda Demographic and Health Survey (UDHS)	4765 0–5 years	Logistic regression	Nil
Takele et al. (2019) [30]	Ethiopia	2016 Ethiopia Demographic and Health Survey (EDHS)	8743 Under five years	Generalized Linear Mixed Model	Nil
Tusting et al. (2020) [33]	SSA countries	Demographic and Health Survey (DHS), Malaria Indicator Survey (MIS) and AIDS Indicator Survey (AIDSIS)	824,694 0–5 years	Conditional logistic regression	Nil

Mishra et al. (2007) [44]	Kenya	2003 Kenya Demographic and Health Survey (KDHS)	2756 0–4 years	Logistic regression	Nil
Ukwuani & Suchindran (2003) [26]	Nigeria	1990 NDHS	5331 0–59 months	Ordinal logistic analysis	
Yaya et al. (2019) [34]	SSA countries	Demographic and Health Survey (DHS)	299,065 Under five years	Multinomial and logistic regression	Stata

3.2.2. Characteristics of Study Analytical Methods

One of the inclusion criteria for this scoping review was that the statistical analytical techniques must be classical statistical regression methods. Table 3 contains the listing of various statistical analysis techniques used for each study. The most frequently used technique was logistic regression (LR). There were 21 studies (70%) out of the 30 selected country-based studies that used one form of LR or another (multivariate LR, multiple LR, ordinal LR or conditional LR). Five studies applied multilevel regression analysis, two studies used multinomial regression analysis and two other studies, including Aheto [36], used a relatively unpopular statistical approach, Simultaneous Quantile Regression (SQR), a technique used in modeling regression concerning quantiles (or percentiles) instead of the usual modeling about the mean (mean regression), while Takele et al. [30] used a Generalized Linear Mixed Model (GLMM).

3.2.3. Characteristics of Study Outcomes

In Table 4, it was observed that the most studied outcome was stunting. It was the focus of 28 (representing 93.3%) out of the 30 country-based articles (with stunting appearing in 16 publications as the only outcome variable and 12 studies paired with other malnutrition indicators). Wasting and underweight appeared in 13 reports, while overweight was only included in two papers. Furthermore, undernutrition (stunting, wasting and undernutrition) was the outcome of interest in six studies. However, there was only one study that focused on all the four indicators of malnutrition (stunting, wasting, underweight and overweight) [45].

3.2.4. Characteristics of Significant Risk Factors

Table 4 also contains the list of predictor variables considered for each study selected for this scoping review. It lists the significant risk factors concerning stunting, wasting, underweight and overweight of children less than five years old. The choice of predictor variables studied in some of the articles selected was guided by the UNICEF framework of causes of undernutrition in children [46]. These were classified as child-related (CR), parental/household-related (PHR) and community- or area-related factors (AR).

Among the child-related risk factors, gender and age (in months categories) were the most frequent significant predictors of stunting (13 studies), wasting (four reports), underweight (4 studies), overweight (no study) and stunting (12 articles), wasting (six reports), underweight (4 studies) and overweight (1 study), respectively. In the parental category, maternal education was the most active predictor in 14, 3, 5 and 1 studies for stunting, wasting, underweight and overweight, respectively. Out of the 28 studies that investigated stunting, 16 reported a significant association of household wealth status with stunting. Place of residence from the community-related category was significant in stunting (five studies), wasting (three studies) and underweight (one study). Significant comorbidity
was found for a child having diarrhea in the last two weeks before the survey with stunting (four studies) and underweight (two studies) captured in this review.

Table 4. Characteristics of outcomes of interest.

Author and Date	Aim of the Study	Outcome Variables Studied	Prevalence	Predictors Considered in the Study	Significant Risk Factors Identified (Stunting)	Significant Risk Factors Identified (Wasting)	Significant Risk Factors Identified (Underweight)	Significant Risk Factors Identified (Overweight)	Conclusion
Adekambi et al. (2013) [23]	To determine the predictor of childhood stunting	Stunting	25.6%	Child's age sex, birth weight, type of birth; mother's age, education, breastfeeding, immunization, BMI work status, birth interval, household under five size, ethnicity, mother health-seeking, type of family, wealth status; community place of residence, region, poverty rate, illiteracy rate proper sanitation and safe water	(CR): Child's age, sex, birth weight, type of birth; (PHR): mother's, education, breastfeeding, BMI, birth interval, mother health-seeking, wealth status; (AR): community region, illiteracy rate.	Nil	Nil	Nil	The study shows the importance of both individual and community-related risk factors in determining childhood stunting in Nigeria
Acharya et al. (2020) [31]	To establish the effect of deforestation on the individual- and household-level double burden of malnutrition in 15 SSA countries	Stunting and overweight	2.7%	Forest cover loss, child's age, sex, mother's education level, age, anaemia status, overweight status, household wealth, size, improve water, sanitation, own agriculture, own livestock, place of residence, a distance of cluster to the nearest road (Km)	(CR): child's age in months, and child's age square, (PHR): mother's education, age wealth status, improved sanitation, (AR): forest cover lost			Forest cover lost, mother's education, age wealth status, improved sanitation, child's age in months, and child's age square	
Agadjanian et al. (2003) [35]	To determine if regional or ethnic differences exist in malnutrition levels	Wasting and stunting	Nil	Place of residence, degree of war, region of residence, language spoken at home, age, full immunization for age	(CR): age, sex, immunization status, (PHR): sex of household head, mean of education of adults, ownership of radio, drinking water, language spoken	(PHR): age, mean years of schooling of adults, and language spoken	Nil	Nil	Malnutrition rates are higher than most SSA countries
Aheto (2020) [36]	To identify risk factors of under five severe stunting	Wevere stunting	5.30%	Type of birth, sex, age, had diarrhoea, had a fever, place of delivery, size at birth, number of children, health insurance, currently breastfeeding, wealth status, maternal education	(CR): birth type, age, sex, diarrhoeal, place delivered, birth size, (PHR): maternal age, and education. Numbers of children <5 years in the household, maternal health insurance, wealth status	Nil	Nil	Nil	Use of Simultaneous Quartile Regression (SQR) can benefit in addressing under 5 stunting
Akombi et al. (2019) [24]	To examine the trend and determinants of child undernutrition	Undernutrition (Stunting, wasting and underweight)		Child's age, mother's age sex of child, mother's education, father's education, wealth index, place of residence, region.	(CR): child's age, Sex of child; (AR): maternal, place of residence, zone.	(CR): child's age, sex of the child,	(CR): child's age, sex of the child; (PHR): father's education, wealth index,		
Akombi et al. (2017) [15]	To determine the associated risk factors of wasting and undernutrition	Wasting and underweight	18% and 29%	Place of residence, region, wealth index, mother work status, education, father's education, occupation, marital status, mother's literacy, source of drinking water, media factors newspaper, radio, television, Mother's age, age at birth, type, mode and place of delivery, ANC, the timing of postnatal check, breastfeeding, child's birth order, birth interval, sex, birth size, age, had diarrhoea, had a fever		(CR): child's birth interval, sex, had a fever (PHR): place of residence, region, education, father's education, television	(CR): duration breastfeeding, child's sex, birth size, had diarrhoea, had a fever (PHR): the region, mother's education, father's education, current		

Author and Date	Aim of the Study	Outcome Variables Studied	Prevalence	Predictors Considered in the Study	Significant Risk Factors Identified (Stunting)	Significant Risk Factors Identified (Wasting)	Significant Risk Factors Identified (Underweight)	Significant Risk Factors Identified (Overweight)	Conclusion
Amaral et al. (2017) [37]	to establish that greater staple food concentrations affect stunting and wasting	Stunting and wasting	Stunting (22.2%), wasting (3.1%)	Staple Budget Share, spending, place of residence, mother present, sex household head educated	(PHR): Staple Budget Share, spending, place of residence, mother present; (CR): sex of the child	(PHR): Staple Budget Share, household head educated; (CR): sex of the child	Nil	Nil	Nutritious staple food are strongly associated with higher odds of stunting and wasting
Amare et al. (2019) [27]	To establish the determinants of malnutrition among children under age 5 in Ethiopia	Stunting and wasting	Nil	Child's age, sex. Birth order, birth weight. Mother's marital status, age at child's birth, educational status, BMI, working status, maternal stature. Place of residence, region, wealth status, improve drinking water, toilet type, cooking fuel type	(CR): age, sex, birth weight; (PHR): mother above primary education, BMI, stature, household wealth above poorer, type of toilet facilities and cooking fuel	(CR): Child's age is 2years+, sex, birth weight > average; (PHR): mother's BMI, wealth status >middle quintile	Nil	Nil	A multi-sectoral and multidimensional approach is needed to curtail malnutrition in Ethiopia
Custodio et al. (2008) [38]	To determine the underlying factors affecting the malnutrition status of children in Equatorial Guinea	Stunting	35.20%	Socioeconomic status or wealth status, household social index, and community endowment index	(CR): child's age, (PHR): fishing by household, hospital as close at the health facility	Nil	Nil	Nil	An integrated strategy of combating poverty and improving maternal education to solve stunting problem in Equatorial Guinea
Doctor and Nkhana-Sali (2017) [7]	To understand the trend and effect of determinants of mu child nutrition among Malawian children under five	Stunting and underweight	32.60%	Place and region of residence, wealth index, source of drinking water, toilet facilities, mother's education status, age, number of under 5, child's sex, age, birth-order, size at birth, had diarrhoea, had a fever, had a cough	(PHR): region of residence, wealth index, mother's education status; (CR): child's sex, age, size at birth, had diarrhoea; (Others): survey rounds	Nil	(PHR): region of residence, wealth index, mother's education status (is Secondary+), age (is 20–30 years); (CR): child's sex, age, size at birth, had diarrhoea, had a fever, (Others) survey round	Nil	Decline experienced in underweight and stunting among children under 5, but remain a serious public health burden in Malawi
Gebru et al. (2019) [28]	to identify individual and community-related variables associated with stunting among children in Ethiopia under 5	Stunting	38.39%	Child's age, sex, mother's BMI, age, education, occupation, marital status, perceived child's birth size, the child had diarrhoea and/or fever in the last weeks, father's education, occupation, wealth index, place of delivery, number of children under 5 in the household, antenatal care visits, mother's age at 1st birth, birth type, birth interval and mass-media exposure.	(CR): Child's age, sex, perceived child's birth size, the child had diarrhoea and/or fever in the last weeks, birth type, and birth interval; (PHR): mother's BMI, education, occupation, marital status, father's occupation, wealth index, number of children under 5 in the household	Nil	Nil	Nil	That individual and community factors are important determinants of stunting in Ethiopia

Author Aim of the Study and Date	Outcome Variables Studied	Prevalence	Predictors Considered in the Study	Significant Risk Factors Identified (Stunting)	Significant Risk Factors Identified (Wasting)	Significant Risk Factors Identified (Underweight)	Significant Risk Factors Identified (Overweight)	Conclusion
To examine the relationship between wealth status and childhood undernutrition Kennedy et al. (2006) [39] Multi-countries undernutrition	Stunting and underweight	45.2% and 20.5%	Place of residence, women with formal education household with adequate sanitation, with access to safe water, had diarrhoea, had acute respiratory infection and wealth status	(PHR): wealth status (poorest poor and middle)	Nil	(PHR): wealth status	Nil	Prevalence of undernutrition is similar for the same socio-economic status across the place of residence in developing countries.
To examine the relationship between wealth status and childhood undernutrition	Stunting and underweight	38.9% and 24.3%	Place of residence, women with formal education, household with adequate sanitation, with access to safe water, had diarrhoea, had acute respiratory infection and wealth status	(PHR): wealth status (poorest, and middle)	Nil	(PHR): wealth status (poor and middle)	Nil	Prevalence of undernutrition is similar for the same socio-economic status across the place of residence.
To examine the relationship between wealth status and childhood undernutrition	stunting and underweight	25.4% and 22.7%	Place of residence, women with formal education, household with adequate sanitation, with access to safe water, had diarrhoea, had acute respiratory infection and wealth status	(PHR): wealth status (poorest and middle)	Nil	(PHR): wealth status (poorest)	Nil	Prevalence of undernutrition is similar for the same socio-economic status across the place of residence.
Kuche et al. (2020) [29]	To examine the impact of sociodemographic, agricultural diversity and women's employment variables on child's length-for-age z-score in children 6–23 months in Ethiopia	Length-for-age (Stunting)	Nil	Child's dietary diversity, age, sex, household wealth, maternal education, women decision-making power, paternal domestic chores, food insecurity, minimum women dietary diversity, animal source food types, fruit and vegetable types, land owned	(CR): child's dietary diversity, age (months), age squared, sex; (PHR): household wealth, maternal education, fruit and vegetable types, land owned	Nil	Nil	Nil	Household production of fruit and vegetables can improve a child's length-for-age
Machisa et al. (2013) [40]	To establish the association between the use of biomass fuels for household cooking and stunting in children	Stunting	27.60%	Child's age, sex, anaemia, birth order, preceding birth interval. Birthweight, recent episode of an acute respiratory infection, diarrhoea and fever; mother's age, BMI, highest education, iron supplement, anaemia status; household use of biomass fuel, place of residence, region, number of people in the household, wealth index	(CR): child's age, preceding birth interval, birthweight; (PHR): household wealth index and use of biomass fuel	Nil	Nil	Nil	The study shows that stunting in children needs to be given priority in health intervention

Author and Date	Aim of the Study	Outcome Variables Studied	Prevalence	Predictors Considered in the Study	Significant Risk Factors Identified (Stunting)	Significant Risk Factors Identified (Wasting)	Significant Risk Factors Identified (Underweight)	Significant Risk Factors Identified (Overweight)	Conclusion
Magadi (2011) [32]	To determine the effect of HIV/AIDS-affected household health outcomes on children under five years in SSA	Undernutrition (stunting, wasting underweight)	Nil	Household HIV status, paternal orphan, child's age sex, multiple births, birth order, birth interval, breastfed, birth size, place of residence, mother's age, education, single parenting, wealth status, community HIV prevalence, country HIV prevalence, GDP per capital	(CR): child's age sex, multiple births, birth order, birth interval, breastfed, birth size; (PHR): The place of residence, mother's age, education, single parenting, wealth status, household HIV status, paternal orphan; (AR): community HIV prevalence, GDP per capital	(CR): breastfed, birth size; (PHR): place of residence, mother's education, wealth status, country, household HIV status; (AR): community HIV prevalence	(CR): child's age sex, multiple births, birth order, birth interval, breastfed, birth size; (PHR): place of residence, mother's age, education, single parenting, wealth status, household HIV status, paternal orphan, GDP per capital	Nil	The study reveals the need for integration of HIV/AIDS improvement toward the management of child nutrition services in vulnerable communities
McKenna et al. (2019) [11]	To determine the relationship between women's decision-making power and stunting/wasting in children under five in DRC	Stunting/wastin3g5.2%/9.2%		Decide over their own income. Husband's income, own health, large household purchases, visits to family, child's sex, age, mother's education, age, birth interval, number of under-5 in HHs, Number people in HHs, province (region), place of residence, wealth status	(CR): child's sex, age; (PHR): mother's education, age, wealth status (richest), province (region), place of residence	(CR): child's, age; (PHR): mother's education (primary), place of residence, wealth status (richest)	Nil	Nil	Detailed studies with more relevant and contextual variables are needed to accurately determine the effects of women's decision-making power and undernutrition in children
Miller et al. (2007) [41]	To determine if orphan-based health inequalities measured with anthropometric data exist.	Underweight	Nil	Nil	Nil	Nil	(CR): the child being orphan, child's age; (PHR): number of dependent children, household head education, wealth index		More data and studies are needed to fully understand the processes that the orphan-based health disparities work on
Nankinga et al. (2019) [42]	To determine the association between maternal employment and the nutritional status of children under 5 in Uganda	Nutritional status (stunting, wasting, underweight)	Nil	Residence, region, wealth status, toilet type, source of drinking water, sex of household head, marital status, maternal occupation, mother's employer, decision-making power, the distance a problem to health services, child's sex, age, birth weight	(PHR): maternal age is 35–49 years, education level, maternal occupation; (CR): child's birth weight, dewormed,	(PHR): region, maternal employer, (CR); child's sex, age, birth weight	(PHR): mother's education, employer; (CR): child's birthweight	Nil	Flexible labor participation for women to enable them time to care for the child

Author and Date	Aim of the Study	Outcome Variables Studied	Prevalence	Predictors Considered in the Study	Significant Risk Factors Identified (Stunting)	Significant Risk Factors Identified (Wasting)	Significant Risk Factors Identified (Underweight)	Significant Risk Factors Identified (Overweight)	Conclusion
Nshimyiryo et al. (2019) [43]	To identify risk factors in stunting in Rwanda	Stunting	38%	Child's sex, age group, parity, birth weight, had diarrhoea in last two weeks; mother's height, educational level, took parasite-controlling drugs during pregnancy, number of days of daily intake of iron tablets, breastfed in the first hour after birth and household's wealth index, size, access to improved water, improved toilet facility, and household place of residence, region altitude	(CR): child's sex, age group, birth weight; (PHR): mother's height, educational level, took parasite-controlling drugs during pregnancy, and household's wealth	Nil	Nil	Nil	Family-related factors are the major determinants of stunting in Rwanda
Ntoimo et al. (2014) [25] multi-countrie	To determine the relationship between single motherhood and s stunting	Stunting	32.0%	The child died, marital status, maternal education, place of residence, occupation, wealth status, sibling size, prenatal care, breastfeeding, birth interval, BMI, widowhood, other single mothers	Nil	Nil	Nil	Nil	Single motherhood is a challenge to stunting in SSA countries which can be reduced considerably when the families of the single mother are economically empowered
	To determine the relationship between single motherhood and stunting	Stunting	41%	The child died, marital status, maternal education, place of residence, occupation, wealth status, sibling size, prenatal care, breastfeeding, birth interval, BMI, widowhood, other single mothers	Nil	Nil	Nil	Nil	
	To determine the relationship between single motherhood and stunting	Stunting	44.50%	The child died, marital status, maternal education, place of residence, occupation, wealth status, sibling size, prenatal care, breastfeeding, birth interval, BMI, widowhood, other single mothers	Nil	Nil	Nil	Nil	
Ssentongo et al. (2019)	To establish the relationship between vitamin A deficiency and deficit in linear and ponderal growth	Stunting, wasting and underweight	27%, 4% and 7%	Child age, sex, birth order, vitamin A supplementation, deworming, had diarrhea, anaemia level, wealth status, mother educated, father educated, mother working, father working, iodized salt, owns the land for agriculture, owns livestock, place of residence, region	(CR): vitamin A deficiency	Nil	Nil	Nil	VAD is associated with stunting and not with wasting and underweight

.

Author and Date	Aim of the Study	Outcome Variables Studied	Prevalence	Predictors Considered in the Study	Significant Risk Factors Identified (Stunting)	Significant Risk Factors Identified (Wasting)	Significant Risk Factors Identified (Underweight)	Significant Risk Factors Identified (Overweight)	Conclusion
Takele et al. (2019) [30]	To determine the risk factors associated with child stunting	Stunting	Nil	Child's sex, age, birth interval, mother's BMI, household wealth index, source of drinking water, type of toilet facility, breastfed, mother's education level and region	(CR): child's sex, age, age and birthweight; (PHR): mother's BMI, household wealth index, use of internet facility, type of toilet facility, breastfed, mother's education level and interaction terms, source of drinking water and mother's BMI	Nil	Nil	Nil	Children whose mothers are uneducated are at higher risk of being stunted
Tusting et al. (2020) [33]	To establish that improved housing is associated with improved child health in SSA	stunting, wasting and underweight	30%, 8% and 22%	improved drinking water, improved sanitation, house built with finished materials, improved house, the household head had secondary education+; children mean age, child sex	Finished building materials, improved housing	(PHR): improved housing	(PHR): finished building materials, improved housing	Nil	Poor housing is a predictor of health outcomes related to child survival in SSA
Mishra et al. (2007) [44]	To determine the effect of the child being orphaned or fostered, and of HIV-infected parents, on nutrition status	Stunting, wasting and underweight	Nil	The child is orphaned, fostered, HIV+ parents, the mother is HIV– but no spouse, HIV status is unknown, HIV– parents	(PHR): child's parent HIV status is unknown	(PHR): child whose parent is HIV+	(CR): child is fostered	Nil	Welfare programs should include children that are orphans, fosters, single mothers, HIV-infected parents
Ukwuani and Suchindran (2003) [26]	To establish the relationship between women's work and child nutritional status (stunting and wasting)	Stunting and wasting	42.6% and 8.9%	Women economic activity, maternal education, paternal education, occupation, wealth index, type of marriage, religion, duration of breastfeeding, sex of the child, birth order, prenatal care, place of delivery, birth size, food supplement, immunization, had fever, had cough, had diarrhoea, source of drinking water, types of toilet, place of residence, region	(PHR): maternal education, wealth index, religion, age at 1st birth; (CR): duration of breastfeeding, sex of the child, birth order, birth size, immunization, had diarrhoea, place of residence, age	(CR): birth size, vaccination, had a fever, toilet, age of child; (PHR): religion	Nil	Nil	
Yaya et al. (2019) [34]	To establish the effect of birth spacing interval on child health outcomes	Stunting, wasting, underweight and overweight	Nil	Inter-pregnancy interval (<24 months, 24–36 months, 37–59 months and ≥60 months)	(PHR): inter-pregnancy interval (<24 months, 24–36 months (ref), 37–59 months and ≥60 months)	(PHR): inter-pregnancy interval (24–36 months (ref), ≥60 months)	(PHR): inter-pregnancy interval (<24 months, 24–36 months (ref), 37–59 months and ≥60 months)	(PHR): inter-pregnancy interval (24–36 months (ref), ≥60 months)	The study stressed the importance of promoting an inter-pregnancy interval of between 24 and 36 months to enhance child health outcomes

4. Discussion

This scoping review aimed to identify the existing literature that used classical regression analysis on nationally representative health survey data sets to find the individual socioeconomic, demographic and contextual risk factors associated with malnutrition among children under five years of age in Sub-Sahara Africa (SSA). The review identified 26 studies and the risk factors for malnutrition, which were classified as child-related, parental/household-related and community or area-related factors. The risk factors for malnutrition identified included age, gender, comorbidities (such as diarrhoea), maternal education, household wealth and place of residence.

This scoping review has demonstrated the importance researchers have attached to studying malnutrition (especially in children under five years) in order to provide a basis for evidence-based decision-making toward meeting the WHO's nine targets on malnutrition by 2025. Some of the most common determinants of malnutrition indicators include child's age, sex, birth size, breastfeeding status, and whether the child had a fever in the last two weeks before the survey. Other indicators are the mother's age, education level, Body Mass Index, and father's education level. In the household category, wealth status, number of children under five years in the household, source of information, and improved building materials, and from the community-related category, place and region of residence, and Gross Domestic Product (GDP). However, there are a few issues from these studies that need to be discussed here.

Firstly, malnutrition in children is a situation where children are either undernourished (less necessary energy and nutrient intake) or 'over-nourished' (too much necessary energy and nutrient intake) [1]. The authors believed that 'malnutrition' and 'malnourished' are two different things. Malnourishment (or undernourished or undernutrition) is a component of malnutrition. However, most studies often show some inconsistencies in the classification of malnutrition in this direction. The anthropometric indices generally used by the World Health Organization to measure nutritional status stipulate height-for-age, weight-for-height and weight-for-age for measuring stunting, wasting and underweight, respectively. These indices are computed as 'standard deviation units (Z-scores) from the median of the reference population' [47]. In the 2018 NDHS, for instance, malnutrition was classified into four areas, as follows: (i) stunting in a child too short for his/her age with a height-for-age Z-score less than minus two standard deviations (−2SD) from the median; (ii) wasting in a child is acute undernutrition status, which describes a child's status whose weight-for-height Z-score is less than minus two standard deviations (−2SD) from the median; (iii) underweight is a composite extraction of both stunting and wasting, giving a weight-for-age Z-score of below minus two standard deviations (−2SD) from the median; and (iv) overweight, in this case, refers to a child whose weight-for-height Z-score is above two standard deviations (+2SD) from the median of the reference population [47]. So, most studies that focused on malnutrition have always considered stunting, wasting and underweight as only proxies for nutritional status without including overweight [48]. Some of these studies that have excluded overweight in their nutritional status often used the word 'undernutrition', while others used 'malnutrition', and some used the terms interchangeably [48,49]. The argument here surrounds the exclusion of overweight when determining the nutritional or malnutrition status of children in a population. Magadi et al. [32] reported that overweight was excluded from among the malnutrition indicators because it is not of greater importance in the least developed countries. This measure of excluding overweight in effect can lead to underestimating the nutrition status of the population under study. In a recent paper, WHO grouped malnutrition into three essential areas, as follows: undernutrition, micronutrient deficiency and overweight related malnutrition [1]. Undernutrition involves not getting the adequate nutrients necessary for daily activities, while overnutrition is getting more nutrients than you can utilize daily [50]. So, malnutrition is a

composite of undernutrition and overnutrition [49]; as such, we submit that overweight should always be included when determining the malnutrition status. In our opinion, the reasons why researchers often exclude overweight in nutritional (or malnutrition) status is that the analysis involves some statistical manipulations, and the fact that overweight's anthropometric measures obviously connect with those of wasting. Resolving the problem in computation is done by including overweight into the application of 'Composite Index of Anthropometric Failure (CIAF)' [51], or by simple use of 'composite index' computation [52].

The second issue of concern from some of the studies in the scoping review is in the attention given to stunting over other anthropometric indices of malnutrition. This scoping review identified that for every ten studies on malnutrition, at least nine studies are investigating stunting. This trend in studying stunting may be related to the need to meet the WHO target of 40% reduction in stunting prevalence by 2025 [5], and stunting's obvious association with poverty and hunger, which are major characteristics of the least developed and war/conflict-torn nations. These reasons, however, cannot justify the almost absence of equal attention being paid to other malnutrition indicators, especially overweight, which is seen to be increasing in some populations [53], and may increase further in the aftermath of covid-19 global lockdown.

The third issue of concern is the multiple overlaps in the malnutrition indicators. Though few studies have focused on two or more anthropometric indicators of malnutrition, they were analyzed individually using classical logistic regression methods. In some populations, there are tendencies for multipleformsofmalnutritionindicatorsinchildren[5,51,54]. Notmanyofthestudiesconsideredinthis review evaluated the multiple overlaps in these anthropometric indices. This observation is a gap in the study. However, with appropriate statistical techniques, it becomes easy to determine the prevalence of the simultaneous occurrence of anthropometric indices among children in a population [51], thereby determining their risk factors in a population. There are over 3.6% and 1.8% children under five globally who are both stunted and wasted, and stunted and overweight, respectively [5]. However, wasting and overweight are mutually exclusive; as such, we do not expect multiple overlaps in them.

Finally, the issue of inconsistencies found in some studies concerns the proper way of categorizing undernutrition indicators (stunting, wasting and underweight) into moderate and severe undernourishment [24,32,47].

For instance, a stunted child has height-for-age (HAZ < −2SD), on a scale, a severely stunted child has HAZ < −3SD. Since stunted is moderate plus severe, then the moderately stunted child is $^{-}$3SD $^{\leq}$ HAZ $^{\leq-}$2SD. The same classification holds for other anthropometric indicators for undernutrition as displayed in the chart above (Figure 2).

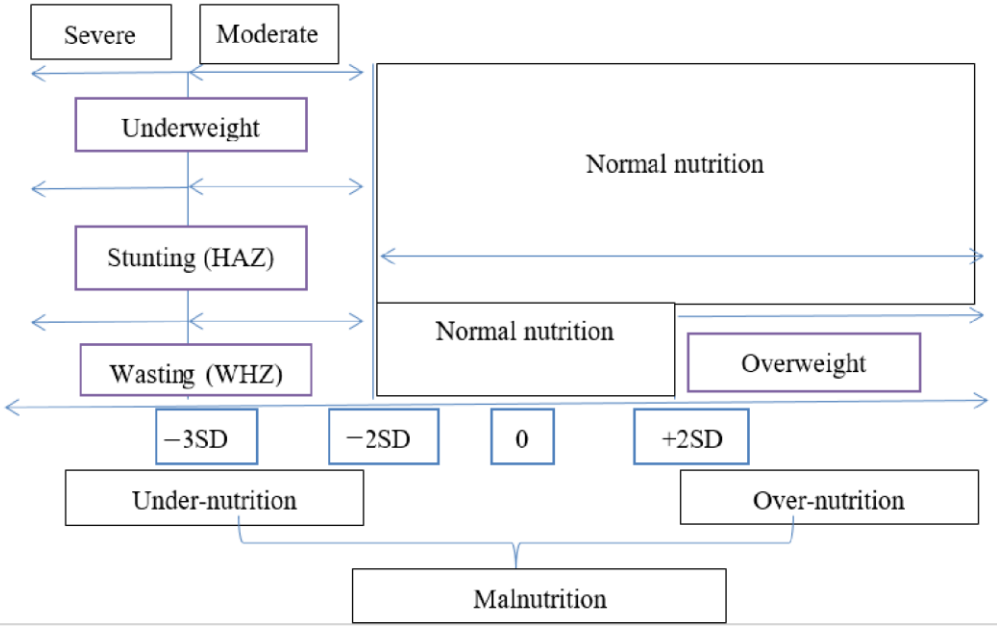


Figure 2. Showing the classifications of Anthropometric indicators of malnutrition.

5. Strengths and Limitations

This scoping review has some level of strengths. (i) This study is about the first scoping review on risk factors associated with malnutrition in children under five in SSA countries that used classical statistical regression modeling techniques on nationally representative survey samples. (ii) The identification of some grey areas that urgently need research cover, especially in the field of using appropriate statistical methods that will compositely determine the actual index of malnutrition in a population. However, there are some limitations, which include but are not restricted to the following: (i) Some potential studies may have been excluded due to the search strategies adopted. (ii) The grey literature search to seek for possible papers was not done. (iii) The references of the included publications were not searched through to ascertain more pieces of evidence. (iv) SSA countries include other countries that are not English-speaking, so some potential papers not written in English from these countries may have been lost to our search. (v) The studies included had analytical techniques restricted to classical statistics regression methods (analysis based on frequentist statistical methods); therefore, potential papers that used Bayesian statistical methods in their analyses were excluded. (vi) Linear regression as an analytic technique was omitted in the search and this may have excluded some potential papers. (vii) There was no assessment of the potential risk or publication bias conducted.

6. Future Work

Areas not covered in this review, especially to satisfy the limitations highlighted above, are potential work for future studies. More important is a review that will map out a piece of study evidence on malnutrition that used either classical regression analysis or Bayesian analysis methods, or both. In addition, studies that include overweight and/or micronutrient deficiencies as part of the indicators of malnutrition among children under five years are urgently needed. Furthermore, studies that will explore the interrelationship between malnutrition and other childhood diseases using appropriate statistical techniques while recognizing the interdependencies of these diseases are areas of future interest.

7. Conclusions

In this scoping review, we have identified several significant risk factors that predict the probability that a child under five years of age in an SSA country will develop malnutrition status. These factors

were classified as child-related (CR), parental/household-related (PHR) and area-related (AR) variables. The CR include child's age, sex, birth weight, type of birth, birth type, diarrhoeal, and place delivered. Factors related to parental/household include mother's education, breastfeeding, BMI, birth interval, mother's health-seeking status, mother's age, household wealth status, improved sanitation, number of children under 5 years in the household, maternal health insurance, type of toilet facilities and cooking fuel, while among the area-related (AR) variables were forest cover lost, community region, and community illiteracy rate. To prevent the wide spread of malnutrition in developing countries, these significant risk factors must be taken into consideration when developing practice and policy formulation. Central to these controls are the maternal education and health status. Pregnant and nursing mothers should have access to a balanced diet.

The review also discovered that there was a study-interest bias toward stunting as an index over other anthropometric indicators of malnutrition. Furthermore, the review also identified some limitations in the current studies reviewed when overweight and/or micronutrient deficiencies were excluded as indices of malnutrition. In the authors' opinion, the exclusion may be partly related to the methodological complications involved in determining the true status of malnutrition when these indices are included. Some of the nationally representative surveys used in the studies reviewed collected information regarding the overweight and/or micronutrient status of children under five years. Micronutrient deficiencies in children of under five years in developing countries are measured by the levels of iron, iodine and vitamin A intake [55]. Apart from iron, which was measured through a biomarker examination of blood samples to establish the anaemia status, iodine and vitamin A were determined subjectively through examining the nature of the foods the child consumed a day before the survey [47]. This cannot give an objective assessment of the status of the micronutrients present in a child. As such, researchers often find it difficult to include them while determining the true malnutrition status of children under five years old in developing countries. In addition, the review identified some inconsistences in the sub classifications of the malnutrition indicators into severe, moderate and mild, while applying the WHO anthropometric cut off points.

Finally, barely five years to the set date of achieving the WHO's nine targets of malnutrition in children, in this scoping review we conclude that a holistic research approach to equally address the various dimensions of anthropometric indicators of malnutrition in a population is needed. Evidence from such findings will be valuable documents in the hands of many planners/policymakers for informed decision making.

Author Contributions: The conceptualization of this study was carried out by P.E.O. and K.K.; the formal literature searching, screening and drafting of manuscript were done by P.E.O.; S.J.W., R.J. and K.K. supervised, revised and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This study is an integral part of Phillips' doctoral study at the School of Health and Related Research (ScHARR) of the University of Sheffield, United Kingdom. The funding for the doctoral study was granted by TETFUND (Nigeria). The publication received an APC waiver from MDPI.

Acknowledgments: The authors recognized the contributions of some members of the ScHARR community. Also, Phillips would like to appreciate the Rector and Management staff of Niger State Polytechnic, Nigeria for the nomination and receipt of TETFUND (Nigeria) sponsorship for the doctoral program.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. World Health Organisation Fact Sheets—Malnutrition. Available online: https://www.who.int/news-room/ fact-sheets/detail/malnutrition (accessed on 31 May 2020).
2. Simonyan, H.; Sargsyan, A.; Balalian, A.A.; Davtyan, K.; Gupte, H.A. Short-term nutrition and growth indicators in 6-month to 6-year-old children are improved following implementation of a multidisciplinary community-based programme in a chronic conflict setting. *Public Health Nutr.* **2020**, *23*, 134–145. [CrossRef] [PubMed]
3. World Health Organisation WHO|Global Targets 2025. Available online: http://www.who.int/nutrition/ global-target-2025/en/ (accessed on 11 August 2020).

4. Martin Goal 2: Zero Hunger. Available online: https://www.un.org/sustainabledevelopment/hunger/ (accessed on 6 August 2020).
5. Global Nutrition Report The Burden of Malnutrition. Available online: https://globalnutritionreport.org/ reports/global-nutrition-report-2018/burden-malnutrition/ (accessed on 25 June 2020).
6. UNICEF/WHO/World Bank Group Levels and Trends in Child Malnutrition: Key Findings of the 2019 Edition. Available online: https://www.who.int/nutgrowthdb/jme-2019-key-findings.pdf?ua=1 (accessed on 8 March 2020).
7. Doctor, H.V.; Nkhana-Salimu, S. Trends and Determinants of Child Growth Indicators in Malawi and Implications for the Sustainable Development Goals. *AIMS Public Health* **2017**, *4*, 590. [CrossRef] [PubMed]
8. Global Nutrition Report Africa Nutrition Profile. Available online: https://globalnutritionreport.org/ resources/nutrition-profiles/ (accessed on 6 August 2020).
9. Akombi, B.J.; Agho, K.E.; Hall, J.J.; Wali, N.; Renzaho, A.M.N.; Merom, D. Stunting, wasting and underweight in Sub-Saharan Africa: A systematic review. *Int. J. Environ. Res. Public Health* **2017**, *14*, 863. [CrossRef]
10. Akombi, B.J.; Agho, K.E.; Hall, J.J.; Merom, D.; Astell-Burt, T.; Renzaho, A.M. Stunting and severe stunting among children under-5 years in Nigeria: A multilevel analysis. *BMC Pediatrics* **2017**, *17*, 15. [CrossRef]
11. McKenna, C.G.; Bartels, S.A.; Pablo, L.A.; Walker, M. Women's decision-making power and undernutrition in their children under age five in the Democratic Republic of the Congo: A cross-sectional study. *PLoS ONE* **2019**, *14*, e0226041. [CrossRef]
12. UNICEF 1 in 5 Children under Five Are Not Growing Well Due to Malnutrition in Latin America and the Caribbean, Warns UNICEF. Available online: https://www.unicef.org/lac/en/press-releases/1-in-5-childrenunder-five-are-not-growing-well-due-to-malnutrition-in-LAC (accessed on 21 November 2020).
13. Amalia, P. Malnutrition among Children in Latin America and the Caribbean. Available online: https: //www.cepal.org/en/insights/malnutrition-among-children-latin-america-and-caribbean (accessed on 21 November 2020).
14. Institute of Child Health Micronutrient Malnutrition—Detection, Measurement and Intervention: A Training Package for Field Staff. Available online: https://www.unhcr.org/uk/45fa6dad2.pdf (accessed on 21 November 2020).
15. Akombi, B.J.; Agho, K.E.; Merom, D.; Hall, J.J.; Renzaho, A.M. Multilevel Analysis of Factors Associated with Wasting and Underweight among Children Under-Five Years in Nigeria. *Nutrients* **2017**, *9*, 44. [CrossRef]
16. World Health Organization. *Guideline: Updates on the Management of Severe Acute Malnutrition in infants and Children*; World Health Organization: Geneva, Switzerland, 2013; ISBN 978-92-4-150203-0.
17. Arksey, H.; O'Malley, L. Scoping studies: Towards a methodological framework. *Int. J. Soc. Res. Methodol.* **2005**, *8*, 19–32. [CrossRef]
18. Levac, D.; Colquhoun, H.; O'Brien, K.K. Scoping studies: Advancing the methodology. *Implement. Sci.* **2010**, *5*, 69. [CrossRef]
19. FDA Media Using the PICOTS Framework to Strengthen Evidence Gathered in Clinical Trials—Guidance from the AHRQ's Evidence-based Practice Centers Program. Available online: https://www.fda.gov/media/ 109448/download (accessed on 21 November 2020).
20. Maphosa, T.P.; Mulqueeny, D.M.; Osei, E.; Kuupiel, D.; Mashamba-Thompson, T.P. Mapping evidence on malnutrition screening tools for children under 5 years in sub-Saharan Africa: A scoping review protocol. *Syst. Rev.* **2020**, *9*, 52. [CrossRef] [PubMed]
21. Larissa Shamseer, D.M. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: Elaboration and explanation. *BMJ* **2015**, *349*. [CrossRef]
22. Tricco, A.C.; Lillie, E.; Zarin, W.; O'Brien, K.K.; Colquhoun, H.; Levac, D.; Moher, D.; Peters, M.D.J.; Horsley, T.; Weeks, L.; et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann. Intern Med.* **2018**, *169*, 467–473. [CrossRef] [PubMed]
23. Adekanmbi, V.T.; Kayode, G.A.; Uthman, O.A. Individual and contextual factors associated with childhood stunting in Nigeria: A multilevel analysis. *Matern. Child Nutr.* **2013**, *9*, 244–259. [CrossRef] [PubMed]
24. Akombi, B.J.; Agho, K.E.; Renzaho, A.M.; Hall, J.J.; Merom, D.R. Trends in socioeconomic inequalities in child undernutrition: Evidence from Nigeria Demographic and Health Survey (2003–2013). *PLoS ONE* **2019**, *14*, e0211883. [CrossRef] [PubMed]

25. Ntoimo, L.F.C.; Odimegwu, C.O. Health effects of single motherhood on children in sub-Saharan Africa: A cross-sectional study. *BMC Public Health* **2014**, *14*, 1145. [CrossRef] [PubMed]
26. Ukwuani, F.A.; Suchindran, C.M. Implications of women's work for child nutritional status in sub-Saharan Africa: A case study of Nigeria. *Soc. Sci. Med.* **2003**, *56*, 2109–2121. [CrossRef]
27. Amare, Z.Y.; Ahmed, M.E.; Mehari, A.B. Determinants of nutritional status among children under age 5 in Ethiopia: Further analysis of the 2016 Ethiopia demographic and health survey. *Glob. Health* **2019**, *15*, 62. [CrossRef]
28. Gebru, K.F.; Haileselassie, W.M.; Temesgen, A.H.; Seid, A.O.; Mulugeta, B.A. Determinants of stunting among under-five children in Ethiopia: A multilevel mixed-effects analysis of 2016 Ethiopian demographic and health survey data. *BMC Pediatrics* **2019**, *19*, 176.
29. Kuche, D.; Moss, C.; Eshetu, S.; Ayana, G.; Salasibew, M.; Dangour, A.D.; Allen, E. Factors associated with dietary diversity and length-for-age z-score in rural Ethiopian children aged 6–23 months: A novel approach to the analysis of baseline data from the Sustainable Undernutrition Reduction in Ethiopia evaluation. *Matern. Child Nutr.* **2020**, *16*. [CrossRef]
30. Takele, K.; Zewotir, T.; Ndanguza, D. Understanding correlates of child stunting in Ethiopia using generalized linear mixed models. *BMC Public Health* **2019**, *19*, 626. [CrossRef]
31. Acharya, Y.; Naz, S.; Galway, L.P.; Jones, A.D. Deforestation and Household- and Individual-Level Double Burden of Malnutrition in Sub-saharan Africa. *Front. Sustain. Food Syst.* **2020**, *4*. [CrossRef]
32. Magadi, M.A. Household and community HIV/AIDS status and child malnutrition in sub-Saharan Africa: Evidence from the demographic and health surveys. *Soc. Sci. Med.* **2011**, *73*, 436–446. [CrossRef] [PubMed]
33. Tusting, L.S.; Gething, P.W.; Gibson, H.S.; Greenwood, B.; Knudsen, J.; Lindsay, S.W.; Bhatt, S. Housing and child health in sub-Saharan Africa: A cross-sectional analysis. *PLoS Med.* **2020**, *17*, 1–18. [CrossRef] [PubMed]
34. Yaya, S.; Uthman, O.A.; Ekholuenetale, M.; Bishwajit, G.; Adjiwanou, V. Effects of birth spacing on adverse childhood health outcomes: Evidence from 34 countries in sub-Saharan Africa. *J. Matern. Fetal. Neonatal. Med.* **2019**, 1–8. [CrossRef] [PubMed]
35. Agadjanian, V.; Prata, N. Civil war and child health: Regional and ethnic dimensions of child immunization and malnutrition in Angola. *Soc. Sci. Med.* **2003**, *56*, 2515–2527. [CrossRef]
36. Aheto, J.M.K. Simultaneous quantile regression and determinants of under-five severe chronic malnutrition in Ghana. *BMC Public Health* **2020**, *20*. [CrossRef]
37. Amaral, M.M.; Herrin, W.E.; Gulere, G.B. Using the Uganda National Panel Survey to analyze the effect of staple food consumption on undernourishment in Ugandan children. *BMC Public Health* **2017**, *18*, 32. [CrossRef]
38. Custodio, E.; Descalzo, M.A.; Roche, J.; Sánchez, I.; Molina, L.; Lwanga, M.; Bernis, C.; Villamor, E.; Baylin, A. Nutritional status and its correlates in Equatorial Guinean preschool children: Results from a nationally representative survey. *Food Nutr. Bull.* **2008**, *29*, 49–58. [CrossRef]
39. Kennedy, G.; Nantel, G.; Brouwer, I.D.; Kok, F.J. Does living in an urban environment confer advantages for childhood nutritional status? Analysis of disparities in nutritional status by wealth and residence in Angola, Central African Republic and Senegal. *Public Health Nutr.* **2006**, *9*, 187–193. [CrossRef]
40. Machisa, M.; Wichmann, J.; Nyasulu, P.S. Biomass fuel use for household cooking in Swaziland: Is there an association with anaemia and stunting in children aged 6–36 months? *Trans. R. Soc. Trop. Med. Hyg.* **2013**, *107*, 535–544. [CrossRef]
41. Miller, C.M.; Gruskin, S.; Subramanian, S.V.; Heymann, J. Emerging health disparities in Botswana: Examining the situation of orphans during the AIDS epidemic. *Soc. Sci. Med.* **2007**, *64*, 2476–2486. [CrossRef]
42. Nankinga, O.; Kwagala, B.; Walakira, E. Maternal Employment and Child Nutritional Status in Uganda. Available online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6922416/ (accessed on 11 August 2020).
43. Nshimyiryo, A.; Hedt-Gauthier, B.; Mutaganzwa, C.; Kirk, C.M.; Beck, K.; Ndayisaba, A.; Mubiligi, J.; Kateera, F.; El-Khatib, Z. Risk factors for stunting among children under five years: A cross-sectional population-based study in Rwanda using the 2015 Demographic and Health Survey. *BMC Public Health* **2019**, *19*, 175. [CrossRef] [PubMed]
44. Mishra, V.; Retherford, R.D. Does biofuel smoke contribute to anaemia and stunting in early childhood? *Int. J. Epidemiol.* **2007**, *36*, 117–129. [CrossRef] [PubMed]
45. Yaya, S.; Uthman, O.A.; Amouzou, A.; Bishwajit, G. Mass media exposure and its impact on malaria prevention behaviour among adult women in sub-Saharan Africa: Results from malaria indicator surveys. *Glob. Health Res. Policy* **2018**, *3*, 20. [CrossRef] [PubMed]

46. *United Nations Children's Fund UNICEF's Approach to Scaling up Nutrition for Mothers and their Children*; Discussion Paper; Programme Division; UNICEF: New York, NY, USA, 2015.
47. National Population Commission (NPC); ICF International. *Nigeria Demographic and Health Survey 2018*; NPC: Abuja, Nigeria; ICF International: Rockville, MD, USA, 2019.
48. Hien, N.N.; Kam, S. Nutritional status and the characteristics related to malnutrition in children under five years of age in Nghean, Vietnam. *J. Prev. Med. Public Health* **2008**, *41*, 232–240. [CrossRef] [PubMed]
49. Seetharaman, N.; Chacko, T.V.; Shankar, S.L.R.; Mathew, A.C. Measuring malnutrition -The role of Z scores and the composite index of anthropometric failure (CIAF). *Indian J. Community Med.* **2007**, *32*, 35. [CrossRef]
50. Lehman, S. The Different Types of Malnutrition and Your Health: Overnutrition and Undernutrition of Nutrient. Available online: https://www.verywellfit.com/understanding-malnutrition-2507055 (accessed on 19 August 2020).
51. Nandy, S.; Jaime Miranda, J. Overlooking undernutrition? Using a composite index of anthropometric failure to assess how underweight misses and misleads the assessment of undernutrition in young children. *Soc. Sci. Med.* **2008**, *66*, 1963–1966. [CrossRef]
52. Bamiwuye, S.O.; Wet, N.D.; Adedini, S.A. Linkages between autonomy, poverty and contraceptive use in two sub-Saharan African countries. *Afr. Popul. Stud.* **2013**, *27*, 164–173. [CrossRef]
53. Sakwe, N.; Bigoga, J.; Ngondi, J.; Njeambosay, B.; Esemu, L.; Kouambeng, C.; Nyonglema, P.; Seumen, C.; Gouado, I.; Oben, J. Relationship between malaria, anaemia, nutritional and socio-economic status amongst under-ten children, in the North Region of Cameroon: A cross-sectional assessment. *PLoS ONE* **2019**, *14*, e0218442. [CrossRef]
54. Nandy, S.; Daoud, A.; Gordon, D. Examining the changing profile of undernutrition in the context of food price rises and greater inequality. *Soc. Sci. Med.* **2016**, *149*, 153–163. [CrossRef]
55. Gorstein, J.; Sullivan, K.M.; Parvanta, I.; Begin, F. *Indicators and Methods for Cross-Sectional Surveys of Vitamin and Mineral Status of Populations*; The Micronutrient Initiative: Ottawa, ON, Canada; The Centers for Disease Control and Prevention: Atlanta, GA, USA, 2007; p. 155.

.

International Journal of Environmental Research and Public Health

MDPI

Article

Individual and Contextual Factors Associated with Malaria among Children 6–59 Months in Nigeria: A Multilevel Mixed Effect Logistic Model Approach

Phillips Edomwonyi Obasohan [1,2,*], Stephen J. Walters [1], Richard Jacques [1] and Khaled Khatab [3]

Citation: Obasohan, P.E.; Walters, S.J.; Jacques, R.; Khatab, K. Individual and Contextual Factors Associated with Malaria among Children 6–59 Months in Nigeria: A Multilevel Mixed Effect Logistic Model Approach. *Int. J. Environ. Res. Public Health* **2021**, *18*, 11234. https://doi.org/10.3390/ijerph182111234

Academic Editor: Paul B. Tchounwou

Received: 5 August 2021
Accepted: 23 October 2021
Published: 26 October 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

[1] School of Health and Related Research (ScHARR), University of Sheffield, Sheffield S1 4DA, UK;
s.j.walters@sheffield.ac.uk (S.J.W.); r.jacques@sheffield.ac.uk (R.J.)
[2] Department of Liberal Studies, College of Administrative and Business Studies, Niger State Polytechnic, Bida Campus, Bida 912231, Nigeria
[3] Faculty of Health and Wellbeing, Sheffield Hallam University, Sheffield S10 2BP, UK; k.khatab@shu.ac.uk * Correspondence: peobasohan1@sheffield.ac.uk

Abstract: Background/Purpose: Over the last two decades, malaria has remained a major public health concern worldwide, especially in developing countries leading to high morbidity and mortality among children. Nigeria is the world most burdened malaria endemic nation, contributing more than a quarter of global malaria cases. This study determined the prevalence of malaria among children at 6–59 months in Nigeria, and the effects of individual and contextual factors. Methods: This study utilized data from 2018 Nigeria Demographic and Health Survey (NDHS) involving a weighted sample size of 10,185 children who were tested for malaria using rapid diagnostic test (RDT). Given the hierarchical structure of the data set, such that children at Level-1 were nested in communities at Level-2, and nested in states and Federal Capital Territory (FCT) at Level-3, multilevel mixed effect logistic regression models were used for the analysis. Results: The proportion of children 6–59 months of age in Nigeria that had malaria fever positive as assessed by RDTs was 35.5% (3418/10,185), (CI: 33.9–37.1). Kebbi State had 77.7%, (CI: 70.2–83.5), which was the highest proportion of 6–59 months who were malaria positive, next in line was Katsina State with 55.5%, (CI: 47.7–63.1). The Federal Capital Territory (FCT), Abuja had the proportion of 29.6%, (CI: 21.6– 39.0), malaria positive children of 6–59 months of age. Children between the age of 48 and 59 months were 2.68 times more likely to have malaria fever than children of ages 6–11 months (AOR = 2.68, 95% CI: 2.03–3.54). In addition, children from the rural area (AOR = 2.12, 95% CI: 1.75–2.57), were more likely to suffer from malaria infection compared to children from urban area. Conclusion: The study identified some individual and contextual predictors of malaria among children in Nigeria. These factors identified in this study are potential areas that need to be considered for policy designs and implementations toward

control and total elimination of malaria-related

morbidity and mortality among children in Nigeria.

Keywords: malaria; fever; *Plasmodium falciparum*; *Falciparum vivax*; under-five; determinants; risk factors

Int. J. Environ. Res. Public Health **2021**, *18*, 11234. https://doi.org/10.3390/ijerph182111234 www.mdpi.com/journal/ijerph

Introduction

The past twenty years and up till now, malaria has persisted as a major global public health concern [1,2], with over 300 million cases reported in 2018 [3] and has remained a leading cause of morbidity and mortality. Low and medium-income countries (LMIC), especially in Sub-Sharan Africa (SSA), contribute to more than 80% of the global malaria burden [4,5]. Nigeria, with a population of over 200 million people, is the world most burdened malaria endemic nation, contributing more than a quarter of global malaria cases. The risk of malaria infection cut across all age segments with women, (especially the pregnant), and children (especially under-five years), the most vulnerable. Malaria is a deadly disease that kills an estimated number of 30 children every hour worldwide. There were great commitments by governments and global partners to end malaria induced mortality and morbidity by 2020 [6]. In 1998 Roll Back Malaria (RBM) initiative was established by World Health Organization (WHO) in conjunction with United Nations Children Fund (UNICEF), inpartnership with some financial bodies and heads of governments across the United Nations (UN) to reduce malaria induced under-five mortality by 50% in 2010 through prompt diagnosis, treatment, and use of insecticides treated nets [7]. These efforts targeted primarily to improve the health-related quality of life of the child [7]. Furthermore, by 2018 there was a renewed commitment by some commonwealth nations to prevent more than 650,000 deaths arising from malaria infections by 2023 [8].

Between 2001 and 2014, Nigeria has implemented four National Malaria Strategic Plans (NMSPs), with the most recent, which ended in 2020 (2014–2020), was aimed at reducing malaria-related deaths to zero by 2020 [9]. Unfortunately, this was far from being achieved. However, to scale up the intervention strategies through evidence-based data, Nigeria has conducted three nationally representative surveys with the baseline survey conducted in 2010, followed up in 2015, and the third incorporated into 2018 Nigeria Demographic and Health Survey [9–11].

The transmission of malaria parasites has its root in the socio-cultural and economic statuses of the people [12]. Studies have showed that age of the child [13–16], birth order [13,14], breast feeding status [13], anaemia status [5,14], that the child slept under bed net [15,17], maternal education [5,16,18], body weight status [13], age of household head [5], improved source of drinking water [14], place of residence [13–15,19], household socioeconomic factors [13,16,20], and regional variations [14,15,21,22] are significant predictors of the risk of malaria infection in under-five years of age in SSA, and in Nigeria.

Effective control of malaria in Nigeria will require strategies that identify areas and characteristics of people that are highly vulnerable to malaria infections leading to the development of plans and the implementation of policies to reach them. This study complements the findings in previous studies to show potential effects of contextual variables at both cluster and state levels [2,11,18]. Therefore, this study is aimed at establishing the prevalence of malaria across the states and federal capital territory, and to examine the individual- and contextual-level predictors of malaria fever among children 6–59 months of age in Nigeria.

2. Materials and Methods

2.1. Study Area

Nigeria is a country located in West Africa sharing borders with Cameroon, Niger,

Benin Republic and the Atlantic Ocean with a total area of 923,768 square kilometres [9– 11]. The Nigeria population grew from over 140 million people as of 2006 population census [23,24] to more than 180 million people in 2016 and is expected to rise to over 260 million people by the year 2030 with an estimated annual national growth rate of 2.38% making her the most populous black nation in the world [24]. The population density for Nigeria was estimated to about 215 people per square kilometre in 2018 from approximately 194 people per square kilometre in 2015 [25]. The country has variety of ethnic groups of over 250 [23] with

different dialects and customs. The three major ethnic groups with a population of over 68% are the Fulani/Hausa, Yoruba, and Igbo, while the Edos, Ijaw, Kanuri, Ibibio, Ebira, Nupe, Tiv and other minority ethnic groups accounted for 32% [23,26]. Nigeria has 37 administrative divisions (36 states and the Federal Capital Territory (FCT) which are classified into six geopolitical zones [15]. The 37 political, administrative areas are sub-divided into 774 local government areas (LGAs), and each of the LGAs are divided into wards with each LGA having between 10 and 15 political wards [27].

2.2. Source of Data

This study is a secondary analysis of two independent nationally representative cross-sectional surveys data sets, such that the 2018 National Human Development Report (known as NHDR 2018) [28] data set is incorporated into the 2018 Nigeria Demographic and Health Survey (otherwise known as 2018 NDHS) [11]. The human development index (HDI) and multi-dimensional poverty index (MPI) from the NHDR 2018 were extracted to serve as the state variables.

2.3. Sampling Techniques

NDHS, being the primary data set for this study, samples were selected separately from each stratum using a two-stage stratified cluster design on each stratum derived from the 2006 census identified enumeration demarcation. At the first stage, 1400 enumeration areas (EAs) were selected as sampling units. At the second stage, 30 households were randomly selected from each EA using equal probability sampling, leading to a target total sample of 42,000 (30 × 1400) households used for the survey. In total, 11 EAs were excluded from being captured because of in-security. Therefore, a total of 41,668 households was earmarked for sampling, but only 40,427 households representing a response rate of 99.4% were finally captured in the survey [11].

The target groups for the survey were women aged 15–49 years from all the randomly picked households and men aged 15–59 years in one-third of all randomly selected households across Nigeria [11]. Besides, children 6–59 months in 14,000 households (i.e., in the households where men questionnaire was administered) had their blood sample taken for malaria (via rapid diagnostic test—RDT), anaemia, and genotype testing. In addition, 75% of the children tested for malaria using RDT, were randomly selected for confirmatory test for malaria using macroscopic blood smear in a laboratory. Only 97.2% of all eligible children for RDTs test were successfully captured, resulting to 2.8% missing values. In this study therefore, the unit of analysis was children 6–59 months of age in Nigeria. Further details of sampling procedures have been published elsewhere [11].

2.4. Outcome Variable

In 2018 NDHS diagnostic tests for malaria parasite were carried out for children 6– 59 months of age in approximately a third of the selected households. Children in this age bracket have not developed enough immunity as such and they are more prone to contracting malaria [29]. Two testing methods were adopted:

Rapid diagnostic tests (RDTs) were conducted on blood samples taken from pricking the finger or heal of the child using SD Bioline Ag *Pf* (HRP-II). The RDTs detect the Histidine-rich protein-II (HRT-II) human whole blood (antigen). The results were either classified as positive or negatives for *Pasmodium falciparum (Pf).*

Laboratory microscopy investigation on thick blood smears was performed for a three quarter of the households where RDTs was done. Malaria results were also classified as either positive or negative

There was a strong positive correlation 0.581 (95% CI: 0.57–0.60; $p < 0.0001$), between these two test results. However, the microscopy laboratory test was performed essentially as a confirmatory test for the RDT that was carried out on the field [9–11]. Therefore, in this study, the malaria status of children 6–59 months of age in Nigeria using RDTs was classified as "one" if the result was positive and "zero" when the result was negative.

2.5. Independent Variables

The predictor variables considered for this study were identified from previous scoping reviews [1,30,31], and categorized in line with previous studies, and as reported in NDHS 2018 final report [21]. Two files in 2018 NDHS, children under-five years (KR), and household members (PR), were merged using a common identifier to obtain variables that meet this analysis [32]. The health status (healthy or not) of a child in a population is a function of interrelated factors at both individual and environmental level [33]. These factors are called

determinants and are divided into three main groups: individual characteristics; physical and social; and health services [33]. As for individual determinants, these are on one hand, biological uncontrolled inherent traits from birth that distinguish the health status of one child from another, such as age, sex, parental affiliation. On the other hand, they could be behavioural factors that pertains to the child which are subject to modification through some control measures such as diet, immunization, or food supplements, etc. Other determinants of child's health outcomes relate to the household's physical and social environment [33]. In this study, the determinants of the risk of malaria infection among children 6–59 months of age in Nigeria were grouped into child-, parental- household- cluster-, and area-related variables. The definitions and classifications of these variables are given as follows:

2.5.1. Child-Related Variables

Age of the child was classified into quintiles of one year interval each, with the reference group (6–11 months) corresponds to the period the child had not begun to walk, 12– 23 months is another important landmark (completion of immunization), by 24–36 months, some children would have had another sibling following, 36 months and above connotes immediate preschool age. Further, sex of the child, maternal perceived birth size of the child classified into, large, average, and small categories. Birth order of the child defines a child's rank among other children of same mother. However, the effect of this on child's health outcome is not well established [34]; duration of breastfeeding, breast milk is very important to a child in the first few years of life [35]. It gives the child all the nutrients needed, and thus strengthens the child's natural immunity against diseases, this was classified as: (i) ever breastfed, not currently breast-feeding (ii) never breastfed (iii) still breastfeeding; whether the child had taken iron, vitamin A, and deworming treatment in the last 6 months before. In addition, also considered were if a child had diarrhoea, fever, or acute respiratory infection (ARI), 2 weeks before survey. Nutritional status was derived through a composite index computed from the four nutrition indicators (stunting, wasting, underweight, and overweight), using the composite index of anthropometric failure (CIAF) [36–38]. Children with no trace of anthropometric failure were classified as "well-nourished" and those that have at least one of the four indicators were classified as "poorly nourished"; anaemia status derived from the record of whether the child was mildly, moderately, or severely anaemic and were collapsed into one group, such that a child with haemoglobin level less than 11.0 g per decilitre was regarded as being "anaemic" and classified as "one", otherwise, for 11.0 g or more was "not anaemic" and classified as "zero".

2.5.2. Parental-Related Variables

Mother's age (year) at last birthday was classified as reported in similar studies to distinguish younger mothers (below 25 years), middle aged, and older mothers, above 34 years [39–41]. The mother's age when she had her first child was also important. Younger mothers lack baby-care experience, and their babies are very likely to have poor health outcomes. Age groups of mothers are often supported in 10 s of years brackets [42], age at first birth was classified as (i) 10–19 years, (ii) 20–29 years, and (iii) 30 years+. Mother working status, paternal working status, and mother's educational status is very important in maternal and child health. Maternal literacy can enhance the level of knowledge, altitude, and practice (KAP) of some common childhood diseases. Paternal education status is worthwhile investigating the role it plays in child's health outcome. This is likely going to be moderating the effect of maternal characteristics on child's health. Both maternal and paternal education statuses were classified as: (i) no education, (ii) primary, (iii) secondary and above; marital status (never in union, in union, widow/divorced/separated); mother slept under mosquito net; mother's body weight status (kg/m2), (i) underweight when BMI <18.5 (kg/m2), (ii) healthy when BMI is 18.5–25.0 (kg/m2), and (iii) overweight/obese when BMI >25.0 (kg/m2). Mother's anaemia status, and maternal anaemia statuses (whether mildly, moderately, or severely anaemic), were collapsed into one group, such that mild, moderate, or severe were regarded as "anaemic" and classified as "one", otherwise, it was "not anaemic" and classified as "zero". Number of antenatal care visit mother attended during the child's pregnancy was also provided. The WHO as at the time of the survey for this study recommended a minimum of four visits [11,43]. Maternal autonomy was derived using the composite index score from the mother's level of participation in decision concerning her own health, large purchases, and visits to family [36]. The score

ranged from three to six such that three and four represent "less" autonomy, and five and six represent "more" autonomy. Maternal ethnicity affiliation was classified into four groups; and maternal religion status, since it defines people's belief system and can affect several maternal and child's health-related outcomes [44].

2.5.3. Household-Related Variables

Household wealth status is the measure of household economic status derived as the composite score from some durable goods using IRR

(PCA). The wealth status was originally classified into quintiles. In this study, three categories were derived, such that poor and poorest groups were collapsed into poor, while rich and richest were collapsed into rich categories [41,45]; household had mosquito bed net; household number size measures the number of people that stay in a household, and was originally a scale variable, but for the purpose of this analysis, the variable was classified into four categories in line with average typical family sizes of four to five members in Nigeria [11]; number of bedrooms in household, though in the survey the number of rooms available for sleeping in a household were given in scale values with less than 10% indicated having five or more rooms for sleep. A typical building in Nigeria has either one-, two-, three-, or four-bedrooms, hence in this analysis, we categorized the variables into five groups; number of children under-5 year in household were also treated as categories as in previous studies [2,45]; improved source of drinking water, toilet facilities, floor materials, roofing materials, and wall materials. These materials are either natural, rudimentary, or finished. Unimproved are the natural and rudimentary, and the improved are the finished materials [46]; sex of household head; household head age (years) in groups. In some developing countries, the age status of the household head is very important as it relates to maturity with which final decision making are taken, particularly on the issue of health. This was also classified as, ((i) less than 34 years, (ii) 35–44 years, (iii) 45–55 years (iv) 56 years +); whether the household had electricity. The presence or absence of electricity in household can impact food storage, cooling at certain season can affect the health of children in particular; type of cooking fuel; under-five slept under a bed net last night, (i) no child, (ii) all children, (iii) some children, (iv) no net in the house [11].

2.5.4. Cluster-Related Variables

Proportion of cluster's household with no bed net; distance to a health facility is no big problem; and proportion of low cluster wealth status. These were derived from the household characteristics. The classification into low and high was based on the cut-off point of 50th percentile (median) score for each variable [47].

2.5.5. Area-Related Va31riables

Region of residence are the six geopolitical zones in Nigeria where the child resides in. There is seasonal variation across the zones, and this can impact differently on health outcome particularly on children under-five years; place of residence is the type of place where the child's household is located and is classified as either urban or rural; state human development index (SHDI). The human development index by each state defines the average on key indicators of human development of the communities. The higher the HDI, the more protective the children from these communities will be from diseases. These categorizations of HDI by states in this study as given in NHDR 2018 [28]; state multidimensional poverty index (SMPI), is the measure of the socioeconomic status of the state and is taken as proxies to the multidimensional poverty index of the communities. The highly deprived a community's MPI is, the more harmful the people are to diseases. This categorizations of HDI by states are also given in NHDR 2018 [28].

2.6. Statistical Analysis

Descriptive analysis using percentage frequencies was used to establish the prevalence, distribution, and association of the malaria status among children 6–59 months of age in Nigeria with the predictor variables considered in this study. "*Svyset"* command was used to adjust for under- and over-reporting in the survey using a weighting factor of (v005/1000000), where v005 is the sample weight [45,48]. Given the complex/hierarchical nature of the data sets, such that children/parental/household in individual units (at Level-1), since children from the same parent, and household tend to be more similar than children from other households because they share the same characteristics, are nested in communities/clusters (at Level-2), and

nested in states (at Level-3), multiple multilevel logistic regression models were fitted to determine the predictors of malaria status among 6–59 months of age in Nigeria. A likelihood ratio test was carried out to establish that the three-level model was more appropriate than the two-level model (the likelihood-ratio test is LR $\chi^2 = 30.21$, $p < 0.001$ for Level-2 nested in Level-3).

In handling the missing values, the listwise deletion technique was applied. In the first instance, all variables having more than 20% missingness were removed, furthermore, any variable with incomplete observations, and those with responses "I don't know" or refusal to answer the questions were deleted [45].

2.6.1. Multilevel Model Description for the Three-Level Survey on Malaria Status

The dependent variable of interest is binary and follows the Bernoulli π_{ijk} distribution with a logit link function:

$$\eta_{ijk} = \beta^*_{0,0} + \sum_{a=1}^{m} \beta^*_{a,0} W_{a,ijk} + \sum_{b=1}^{n} \beta^*_{b,0} X_{b,jk} + \sum_{c=1}^{p} \beta^*_{c,0} Z_k + \varepsilon_{0,jk} + \varepsilon_{0,k} \quad (1)$$

where $\eta\eta_{iiiiii}$ is the predicted log odds of individual child *i* (Level-1) in community (com) *j* (Level-2), and in state (sta) *k* (Level-3) having a positive RDT for malaria. $\beta\beta_{0^*,0}$ represents the overall intercept (the grand mean of Level-3), $\beta^*_{a,0}$, $\beta^*_{b,0}$, and $\beta^*_{c,0}$ is respectively the *m*th, the *n*th, and the *p*th coefficients associated with *W* (Level-1), *X* (Level-2), and *Z* (Level-3) predictors. Further, $\varepsilon_{0,jk}$ represents the random effect of *j*th community in *k*th state, while $\varepsilon_{0,k}$ denotes the state-level random effect, with the assumption that $\varepsilon_{0,jk} \sim N(0, \sigma^2_{com})$ and $\varepsilon_{0,jk} \sim N(0, \sigma^2_{sta})$ are identical and independently distributed [49,50].

Equation (1) has a logistic transformation, with

$$\eta_{ijk} = ln\left(\frac{\pi_{ijk}}{1-\pi_{ijk}}\right) \quad (2)$$

and it denotes the probability that an *i*th child in the *j*th community and the *k*th state will be RDT malaria fever positive.

2.6.2. Model Building

In this study, five multilevel logistic models were considered. Model 1, a null model (or empty model), without any predictors. The essence is to measure the variation across the communities and the states. Model 2 included only child-related variables; Model 3, adjusted for/parental-related variables, while for Model 4, household-related variables were added to Model 3; Model 5 (full model) was derived for all the selected variables including the area-related variables. Goodness of fit was determined using Akaike's information criteria (AIC), such that the model with the lowest AIC was chosen as the best fit [2].

2.6.3. Measure of Association

The measures of association (i.e., fixed effects) were described using adjusted odds ratio (AOR) with their corresponding *p*-values and 95% confidence intervals (CIs).

2.6.4. Measures of Variations

The measures of variation (i.e., random effects) were captured using intra-cluster correlation (ICC), and variance partition coefficient (VPC).

2.6.5. Intraclass Correlation Coefficient (ICC)

Intraclass correlation coefficient (ICC) represents the proportion of the total variation in the model that can be accounted for by variations across the different level of clusters. In our model (three-level model), we identified two intraclass correlation coefficients: the one pertaining to children/individuals nested in community-level, and community-level groups nested in the state-level group [50,51]. Therefore:

$$ICC_{com} = \frac{\sigma^2_{com} + \sigma^2_{sta}}{\sigma^2_{com} + \sigma^2_{sta} + \frac{\pi^2}{3}} \quad (3)$$

ICC_{com} is the correlation between two children/individuals (unit of analysis) within the same community and the same state [52,53].

However, Equation (3), in terms of the variance partition coefficient *(VPC*) differs, as it does not have corresponding interpretation, therefore:

$$VPC_{com} = \frac{\sigma^2_{com}}{\sigma^2_{com} + \sigma^2_{sta} + \frac{\pi^2}{3}} \quad (4)$$

refers to the proportion of the total variance in the same state, but different communities [52]

$$ICC_{sta} = \frac{\sigma^2_{sta}}{\sigma^2_{com} + \sigma^2_{sta} + \frac{\pi^2}{3}} \quad (5)$$

ICC_{sta} is the correlation between two children/individuals within the same state, but different in community clusters. In VPC, it refers to the proportion of the total variance that is attributable to between state-level [52]. From (3), (4), and (5), σ^2_{com} is across community variance, σ^2_{sta} is the across the state $_{\pi\pi 2}$ variance, and $\frac{\pi^2}{3} \simeq 3.29$ is between children/individuals' variance with scale factor one, and for logistic regression [49]. The values of ICCs help to establish the need for multilevel analysis as against the single-level analysis. The rule of thumb could be that when the ICC is less than 5% at the null model, hierarchical modelling may not be necessary [54].

All computations were performed in Stata 16 SE (StataCorp LP: College Station, TX, USA). In recognition of the complexity of the survey design, weight proportion as specified in Stata was used to account for over- and under-estimation. The listwise deletion, the default missing values handling technique in Stata was applied.

3. Results

3.1. Prevalence of Malaria Fever

There was a total of unweighted sample of 10,152 and weighted sample of 10,185 children 6–59 months of age in Nigeria considered in this analysis. In Figure 1, the proportion of children 6–59 months of age in Nigeria that had malaria fever positive as assessed by RDTs was 35.5% (3418/10,185), (CI: 33.9–37.1). The proportion of six states from the northern part of Nigeria, and one state from the southwest are in the highest quintile proportion group of malaria among children 6–59 months in Nigeria. Of these seven states (areas represented in deep green colour in the map), Kebbi State had the highest proportion of children 6–59 months who were malaria positive, 77.6%, (CI: 70.2–83.5), followed by Katsina State, 55.5%, (CI: 47.7–63.1). Besides, the Federal Capital Territory (FCT), Abuja had the proportion of 29.6%, (CI: 21.6–39.0), malaria positive children of 6–59 months of age. In addition, Borno, Imo, Edo, and Lagos states with proportions of 0.159 (CI: 0.11– 23), 0.15 (CI: 0.10–0.23), 14.0%, (CI: 7.5–24.6), and 3.4%, (CI: 1.8–6.0), respectively are among the seven states in the lowest quintile proportion of malaria positive children of 6– 59 months of age in Nigeria. Adamawa and Kaduna states have the same proportion (35%) of malaria positive children, but Adamawa state (CI: 0.26–0.45), had a wider confidence interval than Kaduna state (CI:0.28–0.43).

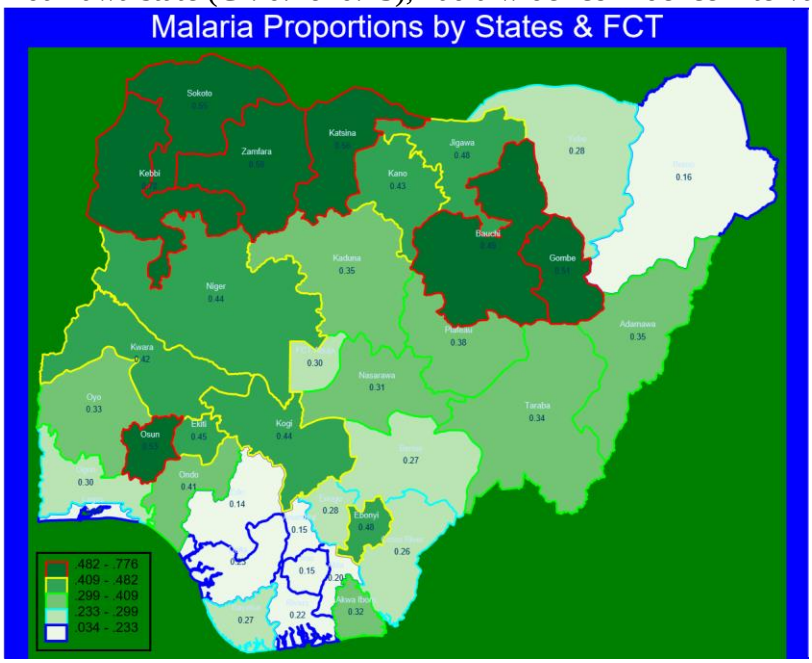


Figure 1. Spatial plot of the proportion of malaria positive children 6–59 months of age in Nigeria by states and FCT.

3.2. Bivariate Analysis of Proportion and Associations between Predictors and Malaria Status

Table 1 displays the descriptions of the background characteristics, the association with malaria fever status of children 6–59 months in Nigeria and presented under; child, parental-, household-, and area-related factors, respectively. In (a) part of the table, there were more children 12–23 months of age, 23.8% (2421/10,185) among the age groups, males. In total, there were 51.2% (5216/10,185) compared to females, and 1.7% (171/10,185), were never breastfed. The prevalence of malaria fever among children 24 months and above is more than the national prevalence of 35.5%. Furthermore, the result shows that malaria status was strongly associated with child's, age, birth order, vaccination, malaria status, nutritional status, fever, diarrhoea, duration of breastfeeding, deworming, iron pills/syrup, and vitamin A intake.

Table 1. (a) Crosstabulation of malaria status versus child-related predictors. (b) Crosstabulation of malaria status versus parental-related predictors. (c) Crosstabulation of malaria status versus household-related predictors. (d) Crosstabulation of malaria status versus community-related predictors. (e) Crosstabulation of malaria status versus area-related predictors.

(**a**)

Malaria Status (6–59 Months)			
Variables (Categories)	Total	No	Yes
	(*n*)	*n* (%)	*n* (%)
Age of the child	10,185	χ^2 = 148.15, *p*-value < 0.0001	
06–11 months	1232	925 (0.75)	307 (0.25)
12–23 months	2421	1686 (0.70)	736 (0.30)
24–35 months	2159	1379 (0.64)	780 (0.36)
36–47 months	2229	1332 (0.60)	896 (0.40)
48–59 months	2143	1245 (0.58)	898 (0.42)
Sex	10,185	χ^2 = 0.551, *p*-value = 0.516	
Male	5216	3346 (0.64)	1871 (0.36)
Female	4968	3221 (0.65)	1747 (0.35)
Perceived birth size	10,060	χ^2 = 8.006, *p*-value = 0.073	
Large	923	631 (0.68)	292 (0.32)
Average	7915	5094 (0.64)	2822 (0.36)
Small	1222	764 (0.63)	457 (0.37)
Birth order	10,185	χ^2 = 157.98, *p*-value < 0.0001	
1st order	1945	1373 (70)	582 (30)
2nd or 3rd order	3483	2388 (69)	1095 (31)
4th–6th order	3207	2007 (63)	1200 (37)
7th+ order	1549	809 (52)	740 (48)
Duration of breastfeeding	10,185	χ^2 = 47.86, *p*-value < 0.0001	
ever, but not currently	7441	4662 (63)	2780 (37)
never breastfed	171	102 (60)	69 (40)
still breastfeeding	2572	1803 (70)	769 (30)
Child had diarrheal in the last 2 weeks	10,182	χ^2 = 41.25, *p*-value < 0.0001	
No	8832	5801 (66)	3031 (34)
Yes	1350	765 (57)	585 (43)
Child had fever in the last 2 weeks	10,182	χ^2 = 304.96, *p*-value < 0.0001	
No	7487	5201 (69)	2285 (31)
Yes	2695	1366 (51)	1330 (49)
Child had acute respiratory infections in past 2 weeks	10,183	χ^2 = 0.340, *p*-value = 0.6332	
No	9575	6168	3407
Yes	608	398	209
Child took vitamin A supplements	10,141	χ^2 = 173.345, *p*-value < 0.0001	
No	5309	3106 (58)	2203 (42)
Yes	4832	3432 (71)	1399 (29)

Child had deworming treatment in the last 6 months	10,133	χ^2 = 235.73, *p*-value < 0.0001	
No	7235	4330 (60)	2905 (40)
Yes	2898	2203 (76)	695 (24)
Child took iron supplements	10,151	χ^2 = 42.173, *p*-value < 0.0001	
No	8224	5183 (63)	3040 (37)
Yes	1927	1367 (71)	561 (29)
Nutritional status	10,185	χ^2 = 267.41, *p*-value < 0.0001	
Well-nourished	5688	4060 (71)	1627 (29)
Poorly nourished	4497	2507 (56)	1990 (44)
Stunting	10,185	χ^2 = 297.16, *p*-value < 0.0001	
No	6285	4457 (71)	1827 (29)
Yes	3900	2109 (54)	1790 (46)
Wasting	10,185	χ^2 = 4.03, *p*-value =0.1169	
No	9481	6138 (65)	3343 (35)
Yes	703	429 (61)	274 (39)
underweight	10,185	χ^2 = 156.20, *p*-value < 0.0001	
No	7915	5355 (68)	2560 (32)
Yes	2269	1212 (53)	1058 (47)
Overweight	10,185	χ^2 = 6.20, *p*-value = 0.0337	
No	10,019	6445 (64)	3573 (36)
Yes	166	122 (74)	44 (26)
Anaemia status	10,183	χ^2 = 649.60, *p*-value < 0.0001	
No	3241	2664 (82)	577 (18)
Yes	6942	3902 (56)	3040 (44)

(b)

Variables (Categories) Categories	Malaria Status		
	Total	No	Yes
	(*n*)	*n* (%)	*n* (%)
Maternal age (years) group	10,185	χ^2 = 14.59, *p*-value = 0.0095	
15–24 years	2048	1265 (62)	784 (38)
25–34 years	5262	3481 (66)	1781 (34)
35 years+	2874	1821 (63)	1052 (37)
Maternal age at first birth	10,185	χ^2 = 385.04, *p*-value < 0.0001	
10–19 years	5406	3033 (56)	2373 (44)
20–29 years	4369	3177 (73)	1192 (27)
30+ years	409	357 (87)	53 (13)
Mother working Status	10,185	χ^2 = 8.83, *p*-value = 0.038	
Not working	2978	1855 (62)	1123 (38)
Working	7207	4712 (65)	2494 (35)

Mother's educational status	10,185	χ^2 = 864.57, *p*-value < 0.0001	
No education	3970	1951 (49)	2018 (51)
Primary education	1643	985 (60)	658 (40)
Secondary and above	4571	3631 (79)	940 (21)
Marital status	10,185	χ^2 = 1.756, *p*-value = 0.5012	
Never in union	171	110 (64)	61 (36)
In union	9733	6265 (64)	3468 (36)
Widow/divorced/separated	281	191 (68)	89 (32)
Paternal educational status	9604	χ^2 = 672.98, *p*-value < 0.0001	
No education	2872	1369 (48)	1503 (52)
Primary education	1423	817 (57)	606 (43)
Secondary education	5308	4018 (76)	1290 (24)
Paternal Occupation	10,185	χ^2 = 0.294, *p*-value = 0.7133	
Not working	304	191 (63)	112 (37)
Working	9881	6376 (65)	3505 (35)
Mother lives with a partner	9733	χ^2 = 7.433, *p*-value =0.0291	
Living with partner	8862	5668 (64)	3194 (36)
Living alone	871	598 (69)	273 (31)
Mother slept under mosquito net	10,185	χ^2 = 91.02, *p*-value < 0.0001	
No	4671	3242 (69)	1429 (31)
Yes	5514	3325 (60)	2188 (40)
Mother's body weight status	8690	χ^2 = 250.16, *p*-value < 0.0001	
Underweight	5310	3219 (61)	2092 (39)
Healthy	884	513 (58)	371 (42)
Overweight and obese	2537	1977 (78)	559 (22)
Preceding birth interval	8220	χ^2 = 15.683, *p*-value= 0.0155	
08–24 months	2190	1356 (62)	834 (38)
25–35 months	2884	1775 (62)	1109 (38)
36–59 months	2351	1515 (64)	836 (36)
60+ months	795	544 (68)	251 (32)
Mother's anaemia status	10,053	χ^2 = 120.013, *p*-value < 0.0001	
Normal	4206	2991 (71)	1214 (29)
Anaemic	5847	3519 (60)	2328 (40)
Number of ANC attendance	6375	χ^2 = 185.99, *p*-value < 0.0001	
None	1342	715 (53)	627 (47)
Less WHO number	954	624 (65)	329 (35)
Met WHO number	4079	2987 (73)	1092 (27)
Maternal autonomy	10,185	χ^2 = 178.05, *p*-value < 0.0001	
Less autonomy	5071	2947 (58)	2124 (42)
more autonomy	5114	3620 (71)	1494 (29)
Maternal ethnicity	10,185	χ^2 = 325.93, *p*-value < 0.0001	
Hausa/Fulani	4067	2226 (55)	1841 (45)

Ibos	1650	1273 (77)	377 (23)
Yoruba	1490	1068 (72)	421 (28)
Others	2978	2000 (67)	977 (33)
Religion status	10,185	χ^2 = 255.02, *p*-value < 0.0001	
Catholic	1027	754 (73)	273 (27)
Other Christian	3438	2509 (73)	929 (27)
Islam	5655	3266 (58)	2389 (42)
Others (traditional)	64	39 (60)	25 (40)
Place of delivery	10,184	χ^2 = 455.18, *p*-value < 0.0001	
Home	5348	2953 (55)	2394 (45)
Public health facility	2977	2137 (72)	840 (28)
Private health facility	1660	1334 (80)	326 (20)
Somewhere else	200	142 (71)	58 (29)

(c)

Variables (Categories)	Malaria Status (6–59 Months)		
	Total	No	Yes
	n	*n* (%)	*n* (%)
Household wealth status	10,185	χ^2 = 1102.49, *p*-value < 0.0001	
Poor	3882	1813 (47)	2069 (53)
Middle	2139	1335 (62)	804 (38)
Rich	4163	3419 (82)	744 (18)
Household had mosquito bed net	10,185	χ^2 = 65.709, *p*-value < 0.0001	
No	3111	2187 (70)	924 (30)
Yes	7074	4389 (62)	2693 (39)
Household member size	10,185	χ^2 = 159.22, *p*-value < 0.0001	
0–3 persons	980	678 (71)	282 (29)
4–6 persons	4835	3322 (69)	1513 (31)
7–9 persons	2461	1521 (62)	940 (38)
10+ persons	1908	1026 (54)	881 (46)
Number of bedrooms in household	10,185	χ^2 = 47.584, *p*-value < 0.0001	
One room	2807	1952 (70)	854 (30)
Two rooms	3489	2221 (64)	1268 (36)
Three rooms	2030	1239 (61)	791 (39)
Four rooms	981	604 (62)	377 (38)
Five+ rooms	877	550 (63)	326 (37)
Number of children under-five in household	10,185	χ^2 = 130.40, *p*-val	ue < 0.0001
No children or one child	2700	1880 (70)	819 (30)
Two children	4315	2848 (66)	1468 (34)
Three children	2054	1270 (62)	783 (38)
Four children+	1115	568(51)	547 (49)
Improved source of drinking water	10,185	χ^2 = 298.76, *p*-value < 0.0001	
Unimproved	3078	1601 (52)	1477 (48)
Improved	7106	4966 (70)	2140 (30)
Improved toilet facilities	10,185	χ^2 = 650.37, *p*-value < 0.0001	
Unimproved	4607	2357 (51)	2250 (49)
Improved	5577	4210 (75)	1367 (25)
Youngest child's stool disposal	6408	χ^2 = 0.102, *p*-value= 0.8208	

Proper	3606	2348 (65)	1257 (35)
improper	2803	1836 (66)	967 (34)
Improved floor material type	10,185	χ^2 = 329.83, *p*-value < 0.0001	
Unimproved	2877	1460 (51)	1418 (49)
Improved	7307	5107 (70)	2200 (30)
Improved roofing materials	10,185	χ^2 = 87.795, *p*-value < 0.0001	
Unimproved	1125	583 (52)	542 (48)
Improved	9060	5984 (66)	3076 (34)
Improved wall materials	10,184	χ^2 = 638.88, *p*-value < 0.0001	
Unimproved	3265	1535 (47)	1730 (53)
Improved	6919	5032 (73)	1887 (27)
Sex of household head	10,185	χ^2 = 7.815, *p*-value= 0.0283	
Male	9008	5824 (64)	3273 (36)
Female	1087	743 (68)	344 (32)
Household head age (years) group	10,185	χ^2 = 27.139, *p*-value= 0.0026	
less 34 years	2828	1825 (65)	1003 (35)
35–44 years	3946	2648 (67)	1298 (33)
45–55 years	2091	1300 (62)	792 (38)
56 years+	1318	794 (60)	524 (40)
Household had electricity	10,066	χ^2 = 590.89, *p*-value < 0.0001	
No	4296	2186 (51)	2109 (49)
Yes	5771	4296 (74)	1475 (26)
Type of cooking fuel	10,182	χ^2 = 384.85, *p*-value < 0.0001	
Electricity and Gas	1211	1088 (90)	123 (19)
Biofuel/mass	8971	5477 (61)	3494 (39)
Under-five slept under bed net	10,112	χ^2 = 104.81, *p*-value < 0.0001	
No child	1317	863 (66)	454 (34)
All children	4715	2965 (63)	1750 (37)
Some children	996	530 (53)	466 (47)
No net in the house	3083	2165 (70)	918 (30)

(d)

Variables (Categories)	Malaria Status (6–59 Months)		
	Total	No	Yes
	n	*n* (%)	*n* (%)
Proportion of low cluster wealth level	10,185	χ^2 = 842.35, *p*-value < 0.0001	
Low	5323	4133 (78)	1189 (22)
High	4861	2433 (50)	2428 (50)
Distance to health facility is no big problem	10,185	χ^2 = 233.12, *p*-value < 0.0001	
Low	4702	2664 (57)	2038 (43)
High	5483	3903 (71)	1579 (29)
Proportion of low cluster household with bed net	10,185	χ^2 = 210.75, *p*-value < 0.0001	
Low	4981	2861 (57)	2121 (43)
High	5202	3705 (71)	1497 (29)

(e)

Variables (Categories)	Malaria Status (6–59 Months)		
	Total	No	Yes
	n	*n* (%)	*n* (%)

Lowest HDI	2150	1219 (57)	839 (43)
Low HDI	2416	1297 (54)	1120 (46)
Average HDI	2223	1511 (68)	712 (32)
High HDI	2680	1886 (70)	793 (30)
Highest HDI	716	654 (91)	62 (9)
Region of residence	10,185	$\chi^2 = 428.79$, p-value < 0.0001	
North-central	1436	906 (63)	530 (37)
North-east	1573	1034 (66)	538 (34)
north-west	2967	1502 (51)	1465 (49)
South-east	1328	826 (76)	336 (25)
South-south	1086	826 (76)	260 (24)
South-west	1794	1307 (73)	487 (27)
State Multidimensional Poverty Index (SMPI)	10,185	$\chi^2 = 364.70$, p-value < 0.0001	
Highly Deprived	847	481 (57)	366 (43)
Above Averagely deprived	3093	1659 (54)	1434 (46)
Averagely Deprived	2318	1499 (65)	819 (35)
Mildly deprived	1939	1395 (72)	544 (28)
Lowest deprived	1987	1532 (77)	455 (23)
Place of residence	10,185	$\chi^2 = 724.32$, p-value < 0.0001	
Urban	4485	3538 (79)	946 (21)
Rural	5700	3029 (53)	2671 (47)
State Human Development Index (SHDI)	10,185	$\chi^2 = 456.50$, p-value < 0.0001	

However, malaria status was not statistically associated with child's sex, perceived birth size, wasting, and the presence of acute respiratory infection two weeks before the survey.

The results in (b) part show the relationship between parental characteristics and malaria status of children 6–59 months of age in Nigeria, only marital status and paternal occupational status were not strongly associated with the malaria status at 5% level of significance. Whereas child's place of delivery; preceding birth interval, maternal religious status, age group, age at first birth, educational status, working status, body mass index, anaemia status, autonomy level, ante-natal care visit, maternal ethnicity, religious status, maternal iron supplement during pregnancy, and paternal education status were all strongly associated with the child's

malaria fever status. The proportion of children with malaria fever (38%) was highest among mothers in the youngest age groups (15–24 years) compared to other age groups. More than 50% of children whose mother and father had no education reported RDT positive results.

Additionally, 38%, 38%, 36%, and 32% of children whose mother had a preceding birth interval of 12–24 months, 25–35 months, 36–59 months, and 60+ months were RDT positive, respectively. In addition, the prevalence of malaria fever among children aged 6–59 months was higher for those whose mothers were underweight compared to normal and overweight mothers.

On the household-related categories of predictors, (i.e. the (c) part of Table 1), indicates that household socioeconomic status (wealth index), household size, number of bedrooms available, number of under-five in the household, age and sex of household head, number of under-five who slept under bed net the night before the survey, the various household characteristics were statistically associated with RDT positive status among children 6–59 months of age in Nigeria at 5% level of significance, while disposal of youngest child's stool methods and household sharing toilet facilities were not statistically associated with malaria status. The proportion of malaria fever among children 6–59 months in Nigeria varied inversely with the level of household wealth index. The highest was recorded among the poor household (53%) followed by middle (38%) and rich (18%) household.

Accordingly, the household where only some under-five years slept under a bed net the night before the survey witnessed the highest prevalence of malaria fever among children 6–59 months of age in Nigeria when compared to the household where "no net in the house" (30%), "no child" (34%), "all children" (37%), slept under a bed net the night before the survey.

In addition, (d) of Table 1 displays the results of the univariate analysis and the association between the cluster-related factors and the malaria fever status of children 6–59 months of age in Nigeria. All the three variables were strongly associated with malaria fever status of children 6–59 months in Nigeria.

Furthermore, (e) of Table 1 displays the results of the univariate analysis and the association between the area-related factors and the malaria fever status of children 6–59 months of age in Nigeria. All the area variables (human development index, multidimensional poverty index, regions of residence, and place of residence) were strongly associated with malaria fever status of children 6–59 months in Nigeria.

3.3. Multilevel Multivariable Models of Predictors of Malaria Fever Status

In the first instance, all the variables that serves as proxies to nutritional status and household wealth were excluded from the multilevel analysis. Furthermore, a multicollinearity test was conducted to check for highly correlated predictors. Out of the variables included two factors: "under-five slept under a bed net the night before the survey" and "household had bed net" were perfectly correlated with variance inflation factors (VIF) of 7.08 and 11.18, respectively such that the mean VIF was 2.23. The variable "household had bed net" was dropped resulting in a mean VIF of 1.79. We used a forward stepwise variable selection procedure by entering all variables that were statistically associated with the malaria status of children 6–59 months of age in Nigeria at a 5% level of significance, and removal was by $p > 0.20$. Because of this, 25 variables (child's age, duration of breastfeeding, anaemia status, nutritional status, fever status, deworming, maternal age in group, age at first birth, maternal education status, paternal education status, maternal anaemia status, ethnic group, religious status, household wealth, number of under-five in household, household head age group, under-five slept under a bed net, number of bedrooms, low cluster wealth level, Cluster distance to health facility is no big problem, low cluster household with bed net, state multidimensional poverty index, state human development index, region of residence, and place of residence), were finally retained for the multilevel model building.

3.3.1. Multilevel Model Results

A Measure of Variation (Random Effects)

Model 1 is the null model (no predictors) with the fixed effect showing that the proportions of the total variations due to differences in the communities and the states were respectively, 1.266 and 0.614, while the variance due to individual level is 3.29 ($\pi^2/3$), which is fixed for logit.

Therefore, the variations in the prevalence of malaria status due to the three-level factors were assessed through intrastate correlation coefficient of 0.1188 (95% CI: 0.75– 0.183) and intracommunity correlation

coefficient of 0.3636 (95% CI: 0.318–0.412), indicating that 11.9% and 36.4% of the total variation in the odds of malaria positive were respectively due to state and community levels. The variance partition coefficient (VPC) at the state level corresponds with the ICC at the state level. However, the VPC at community level is 0.249, meaning that 24.9% of the total variance is collectively attributed to both the state and community levels. However, from the chosen model (Model 4) in Table 2, the ICC at the community-level has dropped from 36.4% in the null model to 21.0% (95% CI:17–25%), meaning the correlation between two children/individuals (unit of analysis) within the same community and the same state is 0.21, and the ICC at state-level dropped from 11.88% to 4.8% (95% CI: 3–8%), both had remained significant. The performance of models was established using AIC and likelihood ratio. Improvements in model fit was achieved at Model 4 (full model), with AIC = 9646, and log likelihood = −4763.47.

Measures of Association (Fixed Effects)

Table 2 shows the results of the adjusted odds ratios (AOR) for each of the variables considered in the analysis after adjusting for the rest variables. Model 2 represents the model fitting with child/individual-level variables only: age of the child, the child's duration of breast feeding, had fever two weeks before the survey, dewormed in the last six months before the survey, anaemic status of the child, maternal age at first birth, secondary education and above of maternal and paternal, mother's anaemia and ethnicgroup, household wealth, number of under-five in the house is more than four children, and the household head is between 35 and 44 years of age were statistically significant predictors of malaria status among children 6–59 months of age in Nigeria. The child's nutritional status, maternal age and religious status, number of under-five who slept under a bed net the night before the survey, and the number of bedrooms in the household were not statistically significant predictors. However, after including all the predictor variables (Model 4), the significant status of the child-specific factors remains.

The odds of a child having malaria increased as the child's age increased. The odds of children between the age of 48–59 months experiencing malaria fever were 2.68 times the odds of children 6–11 months of age (AOR = 2.68, 95% CI: 2.03–3.54). Children who were still breastfeeding (AOR = 0.61, 95% CI: 0.51–0.76), and dewormed (AOR = 0.75, 95% CI: 0.65–0.87), had 39% and 25% reduced odds of contracting malaria infection. Similarly, children whose mother had their first birth after the age of 20 years had reduced odds of experiencing malaria fever than their counterparts whose mothers had their first birth earlier than 20 years.

Variables	Model 2 (*n* = 9277) (Level-1 Factors Only)			Model 3 (*n* = 9277) (Added Level-2 Factors)			Model 4 (*n* = 9277) (Added Level-3 Factors)		
Individual Level	AOR	95% CI	*p*-Value	AOR	95% CI	*p*-Value	AOR	95% CI	*p*-Value
Child's age									
6–11 months	1.00			1.00			1.00		
12–23 months	1.26	1.02–1.56	0.031	1.26	1.02–1.56	0.029	1.28	1.04–1.58	0.021
24–35 months	1.65	1.26–2.16	<0.001	1.65	1.26–2.15	<0.001	1.65	1.26–2.16	<0.001
36–47 months	2.20	1.67–2.88	<0.001	2.20	1.67–2.89	<0.001	2.20	1.68–2.89	<0.001
48–59 months	2.69	2.04–3.55	<0.001	2.68	2.03–3.54	<0.001	2.66	2.02–3.51	<0.001
Duration of breastfeeding									
Ever breastfed	1.00			1.00			1.00		
Never breastfed	1.28	0.84–1.94	0.251	1.26	0.83–1.92	0.276	1.28	0.84–1.96	0.243
Still breastfeeding	0.63	0.51–0.76	<0.001	0.62	0.51–0.76	<0.001	0.61	0.50–0.75	<0.001
Anaemia status									
Not anaemic	1.00			1.00			1.00		
Anaemic	3.84	3.36–4.39	<0.001	3.82	3.34–4.37	<0.001	3.82	3.34–4.37	<0.001
Nutrition status									
Well-nourished	1.00			1.00			1.00		
Poorly nourished	1.07	0.95–1.2	0.284	1.06	0.94–1.19	0.378	1.05	0.94–1.19	0.386
Fever in last 2 weeks									
No	1.00			1.00			1.00		
Yes	1.95	1.72–2.2	<0.001	1.94	1.71–2.2	<0.001	1.96	1.73–2.22	<0.001
Dewormed in last 2 weeks									
No	1.00			1.00			1.00		
Yes	0.75	0.65–0.87	<0.001	0.75	0.65–0.87	<0.001	0.75	0.65–0.87	<0.001
Maternal age (years) in group									
15–24 years	1.00			1.00			1.00		
25–34 years	1.04	0.89–1.22	0.611	1.05	0.9–1.23	0.532	1.06	0.91–1.24	0.464
35 years+	1.16	0.95–1.4	0.143	1.17	0.96–1.42	0.111	1.19	0.98–1.44	0.085
Maternal age at first birth									

10–19 years	1.00	1.00	1.00

Table 2. Multilevel multivariate models of predictors of malaria with adjusted odds ratios (AOR) among children 6–59 months in Nigeria.

20–29 years	0.82	0.72–0.93	0.003	0.82	0.72–0.94	0.003	0.81	0.71–0.93	0.002
30 years+	0.52	0.35–0.77	0.001	0.52	0.36–0.77	0.001	0.51	0.35–0.75	0.001
Maternal education status									
No education	1.00			1.00			1.00		
Primary	0.82	0.68–0.99	0.038	0.85	0.7–1.03	0.093	0.86	0.71–1.04	0.128
Secondary+	0.61	0.5–0.75	<0.001	0.65	0.53–0.79	<0.001	0.67	0.55–0.82	<0.001
Paternal education status									
No education	1.00			1.00			1.00		
Primary	0.87	0.71–1.06	0.157	0.89	0.73–1.08	0.244	0.90	0.74–1.10	0.304
Secondary+	0.74	0.62–0.88	0.001	0.77	0.64–0.92	0.004	0.80	0.66–0.95	0.013
Maternal anaemia status									
Not anaemic	1.00			1.00			1.00		
Anaemic	1.24	1.11–1.39	<0.001	1.24	1.1–1.39	<0.001	1.23	1.1–1.38	<0.001
Maternal ethnic group									
Hausa/Fulani/Kanuri	1.00			1.00			1.00		
Ibo	0.83	0.54–1.28	0.401	0.86	0.56–1.32	0.489	0.81	0.49–1.31	0.387
Yoruba	1.57	1.08–2.26	0.017	1.61	1.11–2.34	0.012	1.45	0.98–2.15	0.064
Others	1.36	1.08–1.71	0.010	1.33	1.05–1.68	0.016	1.29	1.02–1.63	0.037
Maternal religion status									
Catholics	1.00			1.00			1.00		
Other Christian	0.89	0.7–1.14	0.359	0.91	0.72–1.16	0.460	0.92	0.72–1.17	0.491
Islam	0.82	0.6–1.11	0.199	0.85	0.62–1.15	0.288	0.90	0.66–1.23	0.499
Traditionalists	0.78	0.39–1.54	0.467	0.78	0.39–1.54	0.470	0.80	0.41–1.58	0.526
Household wealth									
Low	1.00			1.00			1.00		
Middle	0.71	0.6–0.84	<0.001	0.84	0.7–1.01	0.070	0.86	0.71–1.03	0.102
Rich	0.43	0.36–0.52	<0.001	0.55	0.44–0.69	<0.001	0.61	0.49–0.76	<0.001
Number of under-5 in household									
No children or one child	1.00			1.00			1.00		
Two children	1.03	0.9–1.19	0.667	1.04	0.90–1.20	0.584	1.04	0.91–1.20	0.556

Three children	1.12	0.94–1.33	0.222	1.12	0.94–1.34	0.201	1.11	0.93–1.32	0.249
Four children+	1.48	1.18–1.85	0.001	1.47	1.17–1.84	0.001	1.46	1.16–1.83	0.001
Household head age (years) group									
Less 35 years	1.00			1.00			1.00		
35–44 years	0.85	0.73–0.98	0.031	0.85	0.73–0.99	0.041	0.86	0.74–1.00	0.050
45–55 years	0.87	0.72–1.05	0.135	0.89	0.73–1.07	0.204	0.90	0.75–1.09	0.270
56 years+	1.07	0.86–1.32	0.549	1.10	0.89–1.36	0.386	1.12	0.90–1.38	0.304
Under-5 slept under a bed net									
No child	1.00			1.00			1.00		
All children	0.89	0.74–1.07	0.217	0.89	0.74–1.07	0.202	0.88	0.73–1.06	0.176
Some children	1.15	0.91–1.46	0.244	1.16	0.91–1.47	0.234	1.15	0.91–1.46	0.239
No net in household	0.96	0.8–1.17	0.701	0.99	0.81–1.2	0.887	0.98	0.8–1.19	0.802
Number of bedrooms in household									
One room	1.00			1.00			1.00		
Two rooms	1.03	0.88–1.20	0.705	1.01	0.87–1.18	0.894	1.00	0.86–1.17	0.989
Three rooms	1.07	0.89–1.28	0.477	1.04	0.86–1.25	0.692	1.02	0.84–1.22	0.869
Four rooms	0.91	0.72–1.14	0.392	0.87	0.69–1.1	0.240	0.84	0.67–1.06	0.148
Five+ rooms	0.82	0.64–1.05	0.122	0.78	0.61–1.01	0.062	0.76	0.59–0.98	0.037
Cluster level									
Proportion of cluster's household with no bed net									
Low				1.00			1.00		
High				0.92	0.76–1.12	0.410	0.97	0.80–1.17	0.718
Distance to a health facility is no big problem									
Low				1.00			1.00		
High				0.72	0.6–0.86	<0.001	0.76	0.64–0.90	0.002
Proportion of low cluster wealth status									
Low				1.00			1.00		
High				1.41	1.13–1.75	0.002	1.15	0.92–1.43	0.226
State-level									
Region of residence									

North central							1.00		
North-east							0.48	0.22–1.05	0.065
North-west							1.46	0.62–3.45	0.387
South-east							1.07	0.51–2.25	0.854
South-south							0.50	0.25–0.98	0.045
South-west							1.44	0.64–3.25	0.378
Type of place of residence									
Urban							1.00		
Rural							2.12	1.75–2.57	<0.001
State human development index (HDI)									
Lowest HDI							1.00		
Low HDI							1.32	0.71–2.45	0.374
Average HDI							1.50	0.68–3.33	0.314
High HDI							1.87	0.73–4.80	0.192
Highest HDI							1.03	0.35–2.98	0.961
State Multidimensional poverty index (SMPI)									
Highly deprived							1.00		
Above averagely deprived							1.75	0.90–3.43	0.101
Averagely deprived							1.51	0.62–3.68	0.362
Mildly deprived							1.20	0.44–3.26	0.721
Lowest deprived							1.29	0.41–4.03	0.665
Intercept	0.24	0.14–0.40	<0.001	0.20	0.11–0.35	<0.001	0.07	0.02–0.21	<0.001
Random effect									
Community-level variance	0.73	0.58–0.90		0.74	0.59–0.91		0.67	0.54–0.84	
State-level variance	0.38	0.22–0.65		0.39	0.23–0.68		0.20	0.11–0.36	
VPC: child-level	0.749			0.74			0.79		
VPC: community-level	0.165			0.167			0.161		
VPC: state-level	0.09			0.089			0.048		
ICC%: community-level	25.18	21–30		25.57	21–30		21.00	17–25	
ICC%: state-level	8.65	5–14		8.90	5–14		4.82	3–8	
Model fit statistics									

Log-likelihood	−4818.16	−4804.56	−4763.47
AIC	9722.32	9701.12	9646.94
BIC	10,029.14	10,029.35	10,075.06

AOR: adjusted odds ratios, ICC: intraclass correlation coefficient, VPC: variance partition coefficient, AIC: Akaike information criterion (given a set of candidate models for the data, the preferred model is the one with the minimum AIC value), BIC: Bayesian information criterion.

.

In addition, children whose mothers (AOR = 0.67, 95% CI: 0.55–0.82), or fathers (AOR = 0.79, 95% CI: 0.66–0.95) had secondary education and above had 33% and 21% significantly reduced odds, respectively, of being malaria fever positive. The wealthier the household (AOR = 0.61, 95% CI: 0.49–0.76), the less likely the child can be malaria positive. From among the clusters-related variables, children from a community with high proportion of mothers who said distance to the nearest health centre is "no big problem" had lower odds of malaria fever infested. The result from among the area-specific variables shows that children from south–south geopolitical zone (AOR = 0.50, 95% CI: 0.25–0.98), had 50% reduced odds to contract malaria fever when compared with children from the north central geopolitical zone. On the contrary, children from rural area (AOR = 2.12, 95% CI: 1.75–2.57), were more likely to suffer from malaria infection compared to children from urban area.

Finally, the result shows that the state-level multidimensional poverty index and state human development index were not statistically significant predictors of malaria status among children 6–59 months of age in Nigeria.

4. Discussion

This study assessed the prevalence of malaria across the states and the federal capital territory and examined its predictors among children 6–59 months of age in Nigeria. Some researchers use either rapid diagnostic test or microscopy thick blood smears result to classify the presence or absence of *Pf*. However, Azikiwe et al. (2012) found that RDTs and microscopy laboratory investigation of malaria *Pf* yield similar results with RDTs being more precise [55]. In addition, in a recent scoping review [1], RDT was found to be more frequently used in studies compared to microscopic smears. Additionally, in 2018 NDHS, RDTs account for more samples than microscopic blood smear laboratory test. RDT result was used in this study. The study compliments the findings in previous studies [15,22], to show impacts of some potential effects of contextual variables at both cluster and state levels. About one-third of children were found to be malaria positive. This result shows that substantial reduction in malaria prevalence among children 6–59 months of age in Nigeria have been achieved since 2010 when the first national representative survey was conducted, (52%), and 2015 recorded 45% prevalence [9,10]. Furthermore, the study established that malaria status among children 6–59 months of age in Nigeria is determined by both child-, parental/household-, community-, and state-related variables. The results revealed that children in the higher age group are more prone to malaria infection than their younger counterparts, this agrees with other studies [5,15,16,21]. The reason for this may be that the younger the child, the more attention he/she gets from caregivers, i.e., priority is often given to the younger ones in the use of bed net when available. However, children less than 12 months may not have started walking, and as the age increases and the likelihood to walk it becomes more difficult to protect them. The study also discovered that currently breastfeeding children had reduced odds of malaria infections of which this agrees with another study [13]. The possible reasons for these are that a breastfeeding child gets more antibodies from the mother to help fight infection, and a breastfeeding child often sleeps alongside the mother who normally ensures that the child is unexposed to mosquito bites and this could provide additional protection [5]. Furthermore, there are evidence that comorbidity in anaemia and non-malaria fever increased the chance of malaria infection [5] but had decreased influence with anaemia [13].

As the maternal age at first birth increases, the odd of child's RDT outcome decreases. The study also found that maternal and paternal education statuses are significantly associated with child's malaria status. The odds reduced with an increase in educational level [5,13,21]. However, it is not clear how these two factors interact to affect child's health outcomes, (this can be interesting for future analysis). This finding further demonstrates the important role parental education plays in a child's health [5]. In addition, the result shows that the anaemia status of the mother is significantly associated with the child's malaria prevalence.

Household wealth plays a significant role in child's health, children from rich household are less likely to be infected with the malaria parasite. Similar conclusions were reached in recent studies [5,13,15,56]. Furthermore, the study revealed that the higher the number of rooms available in the household for sleep, the less likely the child will be malaria RDT positive, this agrees with the result found in a similar study [19]. This may relate to the fact that when fewer people sleep in a room, the tendency for reduced cross-infection. Children from rural areas were found to be more vulnerable to malaria infection compared to their urban counterparts, this finding is consistent with similar studies [13– 17]. The study also shows that the higher the proportion of respondents whose distance getting to health centre "is no big problem", the less likely is the children would contract malaria infections. In other words, when immediate action for prompt medical attention becomes a big problem in a community, the children are highly exposed to be bitten by an infected mosquito and other childhood diseases.

4.1. Strengths and Limitations of the Study

A recent scoping review conducted has revealed that there are very few studies that analysed the influence of contextual factors on the risk of contracting malaria infection among children under-five years in SSA countries [1]. This study has contributed to bridging this knowledge gap. Moreover, the few studies available adopted a two-level multilevel analysis procedure, but in this study, we found that a three-level multilevel analysis was more appropriate, as such, this study is one among the few to carry out such analysis at a country level. The study involved large data sets, which might make it possible to draw inference over the country.

However, there were some limitations: (i) The data sets were cross-sectional and could not ascertain the remote causes of RDT malaria positive among children 6–59 months of age in Nigeria. Information regarding the causes is better obtained from a longitudinal study which requires periodic follow up of participants [41,48]. (ii) The accuracy of the information provided at the survey time were not ascertained to be correct because of high maternal illiteracy in Nigeria which could have resulted in recall errors while responding to some questions. (iii) some variables were dropped for missingness, and listwise deletion method was used to handle incomplete data in the remaining variables. Other methods such as multiple imputation could have been used for the incomplete observation. (iv) The classification of the determinants of RDT malaria prevalence among children 6–59 months of age were tailored through child-, parental- household, and contextual framework. However, it is argued that some variables may not directly increase or decrease the risk of contracting malaria (indirect), and some may do (direct), and the interactions effects may be interesting. This was not performed in this study and could be a subject of future study.

4.2. Policy Implications

Between 2010 when a national representative survey on malaria was first conducted to determine the prevalence of malaria among children 6–59 months of age in Nigeria, and 2018 when the current survey was conducted, the prevalence of malaria had dropped significantly by 15% from 50% in 2010 to 35% in 2018. This drop is commendable but was not enough to meet the expectations of total elimination of malaria-related death in Nigeria by the year 2020 [6,9]. Despite the achievement obtained so far, Nigeria remains the most malaria-endemic nation in the world. In view of this, the current efforts regarding the Government, need a boost to ensure that the scare resources are channelled to areas that will require more and urgent attention. The findings from this study will aid informed decisions that will help reduce the incidence of malaria among children 6–59 months of age in Nigeria.

In line with some findings in this study, we have proffered some suggestions for policy implementation.

The findings show that older children are often at risk compared to younger siblings. These children are allowed by their parents to walk about freely unattended to, perhaps to obtain more feeding opportunities elsewhere. These children have been weaned from breast feeding,

nutritious foods are often not provided at home because some households cannot afford it. Most of these children scavenge about to find food. It is recommended that the school feeding program of the Government should also be extended to what may be called "community feeding program" where children of pre-school age can access food and boost their immunity.
Parenting is a very serious matter in our society. The age at which most women first become a mother is often very low, thereby making them "baby-mothers". Some of these mothers are not even mature enough to take care of themselves, particularly becoming mothers at that tender age, and not even able to care of their babies. Policies and the political will should be in place to discourage early girl-child marriage that often result into early childbirth. Girl-child education often delay the age at which most females become married and give birth. Therefore, female education should be made free and compulsory for up to secondary education. Any parent who withdraws their girl child from school for early marriage or whose daughter gets pregnant while still in school should be liable for prosecution.
Most families sleep in over-crowded apartments. The governmental housing policies in some states see some buildings constructed but are never allotted to anyone until they are eventually vandalized. The Government's policies should encourage early allocation of these buildings to those that need them to ease off over-crowding households and communities. This will reduce cross-infections in communicable diseases such as malaria
Due to the problem of accessibility to most rural areas (especially during the raining season when malaria infection rates are usually very high), these communities are often neglected in the distribution of scare palliatives from the Government and agencies (such as medicals and bed nets), to addressing the issue of malaria. The Government can also invest in the use technologies available for logistics such as drone to transport these items to the hard-to-reach communities.
When community distance to health facility is not a "big problem" to the people, they become prompt in getting the much-needed timely medical attention for their children. Therefore, having identified areas of high malaria prevalence, the governments for these areas should among other suggestions ensure that increased proportion of the people do not travel long distances before they can access prompt medical attention. Therefore, more functional health centres are available in such localities.
Lastly, the results also indicates that children from a high category among low cluster wealth areas had significantly higher proportion of malaria positive status compared to the proportion among the low category ((d) in Table 1). Therefore, the Government can investigate and implement ways to bring many homes out of poverty lines. Many of the governmental programs in the past toward poverty alleviation have ended up without achieving their aims. These measures do not find their way into the hands of those that need them. Sometimes they are distributed as political campaign "juices" for political party supporters. There should be sincerity in the part of both the program implementers and the beneficiaries in driving the program to success.

5. Conclusions

Despite the huge resources committed to eliminating malaria induced morbidities and mortalities, Nigeria has remained the most burdened malaria-endemic nation in the world. This study has identified some important individual and contextual predictors of malaria among children 6–59 months of age in Nigeria. These predictors are areas that need to be considered for policy designs and implementations toward control and total elimination of malaria-related morbidity and mortality among children in Nigeria.

Author Contributions: The conceptualization of this study was performed by P.E.O. and K.K.; the formal drafting of manuscript was carried out by P.E.O.; while S.J.W., R.J. and K.K. supervised, revised, and edited the manuscript. All authors have read and agreed to the published version of the manuscript.
Funding: This study is an integral part of PEO's doctoral study at the School of Health and Related Research of the University of Sheffield, United Kingdom. The funding for the doctoral study was granted by TETFUND (Nigeria).

Institutional Review Board Statement: The ethical approval to carry out this research study had been granted by the School of Health and Related Research (ScHARR) Ethics Committee of the University of Sheffield (Reference Number: 031534). This study is a secondary analysis of two nationally representative samples. Permission to use the data sets (2018 Nigeria Demographic and Health Survey and 2018 National Human Development Report) had been obtained from two organizations: Inner City Fund (ICF)-International, and United Nations Development Programme (UNDP-Nigeria).
Informed Consent Statement: Informed consent had been obtained by the original owners of the data sets (MeasureDHS and UNDP-Nigeria).
Data Availability Statement: The data set used in this study is available in MeasureDHS https://dhsprogram.com (accessed on 28 January 2020) and UNDP-Nigeria http://hdr.undp.org/sites/default/files/hdr_2018_nigeria_finalfinalx3.pdf (accessed on 3 March 2020).
Acknowledgments: The authors acknowledged the contributions received from ScHARR community. Phillips appreciate the Rector and the management staff of Niger State Polytechnic, Nigeria, for nominating him for the TETFUND (Nigeria) sponsorship of his doctoral program.
Conflicts of Interest: The authors declare no conflict of interest.

References

1. Obasohan, P.E.; Walters, S.J.; Jacques, R.; Khatab, K. A Scoping Review of Selected Studies on Predictor Variables Associated with the Malaria Status among Children under Five Years in Sub-Saharan Africa. *Int. J. Environ. Res. Public Health* **2021**, *18*, 2119, doi:10.3390/ijerph18042119.
2. Oguoma, V.M.; Anyasodor, A.E.; Adeleye, A.O.; Eneanya, O.A.; Mbanefo, E.C. Multilevel Modelling of the Risk of Malaria among Children Aged under Five Years in Nigeria. *Trans. R. Soc. Trop. Med. Hyg.* **2021**, *115*, 482–494, doi:10.1093/trstmh/traa092.
3. Aychiluhm, S.B.; Gelaye, K.A.; Angaw, D.A.; Dagne, G.A.; Tadesse, A.W.; Abera, A.; Dillu, D. Determinants of Malaria among
Under-Five Children in Ethiopia: Bayesian Multilevel Analysis. *BMC Public Health* **2020**, *20*, 1468, doi:10.1186/s12889-020-09560-
1.
4. Bennett, A.; Bisanzio, D.; Yukich, J.O.; Mappin, B.; Fergus, C.A.; Lynch, M.; Cibulskis, R.E.; Bhatt, S.; Weiss, D.J.; Cameron, E.; et al. Population Coverage of Artemisinin-Based Combination Treatment in Children Younger than 5 Years with Fever and Plasmodium Falciparum Infection in Africa, 2003–2015: A Modelling Study Using Data from National Surveys. *Lancet Glob. Health* **2017**, *5*, e418–e427, doi:10.1016/s2214-109x(17)30076-1.
5. Ugwu, C.L.J.; Zewotir, T. Evaluating the Effects of Climate and Environmental Factors on Under-5 Children Malaria Spatial Distribution Using Generalized Additive Models (GAMs). *J. Epidemiol. Glob. Health* **2020**, *10*, 304, doi:10.2991/jegh.k.200814.001. 6. World Health Organisation. World Malaria Report. 2014 Available online: https://www.who.int/malaria/publications/world_malaria_report_2014/en/ (accessed on 21 February 2019).
7. Gup, I. Malaria Morbidity among Under-Five Nigerian Children: A Study of Its Prevalence and Health Practices of Primary Care Givers (Mothers) in a Resource-Poor Setting of a Rural Hospital in Eastern Nigeria. *Eur. J. Prev. Med.* **2013**, *1*, 50, doi:10.11648/j.ejpm.20130103.11.
8. Ready to Beat Malaria (RBM). Commonwealth Leaders Respond to a Global Call to Action and Commit to Halve Malaria across the Commonwealth by 2023. Available online: https://endmalaria.org/news/commonwealth-leaders-respond-global-callaction-and-commit-halve-malaria-across-commonwealth (accessed on 8 June 2021).
9. National Malaria Elimination Program (NMEP); National Population Commission (NPopC); National Bureau; ICF International. *Nigeria Malaria Indicator Survey 2015*. NMEP, NPopC, and ICF International: Abuja, Nigeria, and Rockville, MD, USA, **2016**.
10. National Population Commission (NPC) [Nigeria]; National Malaria Control Programme. (NMCP) [Nigeria]; ICF International. *Nigeria Malaria Indicator Survey 2010.* NMEP, NPopC, and ICF International: Abuja, Nigeria, and Rockville, MD, USA, 2012.
11. National Population Commission; ICF International. *Nigeria Demographic and Health Survey 2018*; NPC: Abuja, Nigeria; ICF: Rockville, MD, USA, 2019.
12. Anumudu, C.I.; Okafor, C.M.F.; Ngwumohaike, V.; Afolabi, K.A.; Nwuba, R.I.; Nwagwu, M. Epidemiological Factors That Promote the Development of Severe Malaria Anaemia in Children in Ibadan. *Afr. Health Sci*. **2007**, *7*, 80–85, doi:10.5555/afhs.2007.7.2.80.
13. Berendsen, M.L.; van Gijzel, S.W.; Smits, J.; de Mast, Q.; Aaby, P.; Benn, C.S.; Netea, M.G.; van der Ven, A.J. BCG Vaccination Is Associated with Reduced Malaria Prevalence in Children under the Age of 5 Years in Sub-Saharan Africa. *BMJ Glob. Health* **2019**, *4*, e001862, doi:10.1136/bmjgh-2019-001862.
14. Chitunhu, S.; Musenge, E. Direct and Indirect Determinants of Childhood Malaria Morbidity in Malawi: A Survey CrossSectional Analysis Based on Malaria Indicator Survey Data for 2012. *Malar. J.* **2015**, *14*, 265, doi:10.1186/s12936-015-0777-1.
15. Morakinyo, O.M.; Balogun, F.M.; Fagbamigbe, A.F. Housing Type and Risk of Malaria among Under-Five Children in Nigeria: Evidence from the Malaria Indicator Survey. *Malar. J.* **2018**, *17*, 311, doi:10.1186/s12936-018-2463-6.

16. Siri, J.G. Independent Associations of Maternal Education and Household Wealth with Malaria Risk in Children. *Ecol. Soc.* **2014**, *19*, 33, doi:10.5751/es-06134-190133.
17. Semakula, H.M.; Song, G.B.; Zhang, S.S.; Achuu, S.P. Potential of Household Environmental Resources and Practices in Eliminating Residual Malaria Transmission: A Case Study of Tanzania, Burundi, Malawi and Liberia. *Afr. Health Sci.* **2015**, *15*, 819–827, doi:10.4314/ahs.v15i3.16.
18. Njau, J.D.; Stephenson, R.; Menon, M.P.; Kachur, S.P.; McFarland, D.A. Investigating the Important Correlates of Maternal Education and Childhood Malaria Infections. *Am. J. Trop. Med. Hyg*. **2014**, *91*, 509–519, doi:10.4269/ajtmh.13-0713.
19. Njau, J.D.; Stephenson, R.; Menon, M.; Kachur, S.P.; McFarland, D.A. Exploring the Impact of Targeted Distribution of Free Bed Nets on Households Bed Net Ownership, Socio-Economic Disparities and Childhood Malaria Infection Rates: Analysis of National Malaria Survey Data from Three Sub-Saharan Africa Countries. *Malar. J.* **2013**, *12*, 245, doi:10.1186/1475-2875-12-245.
20. Asia Pacific Leaders Malaria Alliance Bangladesh: New Plan for Malaria Elimination (2017–2021). Available online: https://www.aplma.org/blog/42/bangladesh-new-plan-for-malaria-elimination-2017-2021.html (accessed on 3 January 2021).
21. Wanzira, H.; Katamba, H.; Okullo, A.E.; Agaba, B.; Kasule, M.; Rubahika, D. Factors Associated with Malaria Parasitaemia among Children under 5 Years in Uganda: A Secondary Data Analysis of the 2014 Malaria Indicator Survey Dataset. *Malar. J.* **2017**, *16*, 191, doi:10.1186/s12936-017-1847-3.
22. Adigun, A.B.; Gajere, E.N.; Oresanya, O.; Vounatsou, P. Malaria Risk in Nigeria: Bayesian Geostatistical Modelling of 2010 Malaria Indicator Survey Data. *Malar. J.* **2015**, *14*, 156, doi:10.1186/s12936-015-0683-6.
23. Kayode, G.A.; Adekanmbi, V.T.; Uthman, O.A. Risk Factors and a Predictive Model for Under-Five Mortality in Nigeria: Evidence from Nigeria Demographic and Health Survey. *BMC Pregnancy Childbirth* **2012**, *12*, 10, doi:10.1186/1471-2393-12-10.
24. Macrotrends. Nigeria Population Growth Rate 1950–2020. Available online: https://www.macrotrends.net/countries/NGA/nigeria/population-growth-rate (accessed on 27 July 2020).
25. Tradingeconomics. Nigeria—Population Density (People Per Sq. Km)—1961–2018 Data 2020 Forecast. Available online: https://tradingeconomics.com/nigeria/population-density-people-per-sq-km-wb-data.html (accessed on 27 July 2020).
26. Mustapha, A.R. *Ethnic Structure, Inequality and Governance of the Public Sector in Nigeria*; Centre for Research on Inequality, Human Security and Ethnicity (CRISE): University of Oxford, Oxford, UK, 2005; pp. 18.
27. OpenStreetMap Wiki Contributors. WikiProject Nigeria [Internet]. Open Street/Map. Available online: https://wiki.openstreetmap.org/wiki/WikiProject_Nigeria (accessed on 23 January 2020).
28. United Nations Development Programme (UNDP). *National Human Development Report 2018: Nigeria Human Development Reports*; United Nations Development Programme (UNDP): Garki, Abuja FCT, Nigeria, 2018.
29. Demographic and Health Surveys. *Understanding and Using the Demographic and Health Surveys DHS Curriculum Facilitator's Guide*; ICF International: Rockville, MD, USA, 2014.
30. Obasohan, P.E.; Walters, S.J.; Jacques, R.; Khatab, K. A Scoping Review of the Risk Factors Associated with Anaemia among Children Under Five Years in Sub-Saharan African Countries. *Int. J. Environ. Res. Public Health* **2020**, *17*, 8829, doi:10.3390/ijerph17238829.
31. Obasohan, P.E.; Walters, S.J.; Jacques, R.; Khatab, K. Risk Factors Associated with Malnutrition among Children Under-Five Years in Sub-Saharan African Countries: A Scoping Review. *Int. J. Environ. Res. Public Health* **2020**, *17*, 8782, doi:10.3390/ijerph17238782.
32. Demographic and Health Survey. The DHS Program—Analysis FAQs. Available online: https://dhsprogram.com/data/analysis-faqs.cfm (accessed on 14 October 2021).
33. What are Health Determinants?—Individuals & Society Study.Com. Available online: https://study.com/academy/lesson/whatare-health-determinants-individuals-society.html (accessed on 3 July 2021).
34. Black, S.E. New Evidence on the Impacts of Birth Order. Available online: https://www.nber.org/reporter/2017number4/newevidence-impacts-birth-order (accessed on 2 October 2021).
35. Northern Ireland Breastfeeding | Department of Health. Available online: https://www.health-ni.gov.uk/articles/breastfeeding (accessed on 2 October 2021).
36. Bamiwuye, S.O.; Wet, N.D.; Adedini, S.A. Linkages between Autonomy, Poverty and Contraceptive Use in Two Sub-Saharan African Countries. *Afr. Popul. Stud.* **2013**, *27*, 164–173, doi:10.11564/27-2-438.
37. Nandy, S.; Daoud, A.; Gordon, D. Examining the Changing Profile of Undernutrition in the Context of Food Price Rises and Greater Inequality. *Soc. Sci. Med.* **2016**, *149*, 153–163.
38. Nandy, S.; Jaime Miranda, J. Overlooking Undernutrition? Using a Composite Index of Anthropometric Failure to Assess How Underweight Misses and Misleads the Assessment of Undernutrition in Young Children. *Soc. Sci. Med.* **2008**, *66*, 1963–1966, doi:10.1016/j.socscimed.2008.01.021.

39. Myrskylä, M.; Fenelon, A. Maternal Age and Offspring Adult Health: Evidence From the Health and Retirement Study. *Demography* **2012**, *49*, 1231–1257, doi:10.1007/s13524-012-0132-x.
40. Duncan, G.J.; Lee, K.T.H.; Rosales-Rueda, M.; Kalil, A. Maternal Age and Child Development. *Demography* **2018**, *55*, 2229–2255, doi:10.1007/s13524-018-0730-3.
41. Adedokun, S.T.; Uthman, O.A. Individual and Contextual Correlates of Mosquito Net Use among Women in Nigeria. *Malar. J.* **2020**, *19*, 138, doi:10.1186/s12936-020-03219-3.
42. Jennings-Edquist, G. Does the Age You Become a Parent Really Matter? We Asked Three Mums—ABC Everyday. Available online: https://www.abc.net.au/everyday/does-the-age-you-become-a-parent-actually-matter/12742736 (accessed on 14 October 2021).
43. Obasohan, D.N.; Karo, H.A.; Obasohan, P. Socioeconomic and Demographic Barriers to Assessing Ante Natal Care Services among Women of Child Bearing Age in Wushishi Local Government Area, Niger State, Nigeria. *World J. Pharm. Res.* **2018**, *7*, 1264–1271.
44. Obasohan, P. Religion, Ethnicity and Contraceptive Use among Reproductive Age Women in Nigeria. *Int. J. MCH AIDS (IJMA)* **2014**, *3*, 63, doi:10.21106/ijma.39.
45. Kawo, K.N.; Asfaw, Z.G.; Yohannes, N. Multilevel Analysis of Determinants of Anemia Prevalence among Children Aged 6-59 Months in Ethiopia: Classical and Bayesian Approaches. *Anemia* **2018**, *2018*, 3087354, doi:10.1155/2018/3087354.
46. Lia, F.; Taylor, C. *Using Household Survey Data to Explore the Effects of Improved Housing Conditions on Malaria Infection in Children in Sub-Saharan Africa*; ICF International.: Rockville, MD, USA, 2016.
47. Dhewantara, P.W.; Ipa, M.; Widawati, M. Individual and Contextual Factors Predicting Self-Reported Malaria among Adults in Eastern Indonesia: Findings from Indonesian Community-Based Survey. *Malar. J.* **2019**, *18*, 118, doi:10.1186/s12936-019-2758-
2.
48. Adedokun, S.T. Correlates of Childhood Morbidity in Nigeria: Evidence from Ordinal Analysis of Cross-Sectional Data. *PLoS ONE* **2020**, *15*, e0233259, doi:10.1371/journal.pone.0233259.
49. Gabr, H.M.K.M. Investigating Poverty and Labour Force Participation among Older Population in Egypt: A Multilevel Simultaneous Equations Modeling Approach. Ph.D. Thesis, University of Birmingham, Birmingham, UK, 2016.
50. Rozi, S.; Mahmud, S.; Lancaster, G.; Hadden, W.; Pappas, G. Multilevel Modeling of Binary Outcomes with Three-Level Complex Health Survey Data. *Open J. Epidemiol.* **2016**, *7*, 27–43, doi:10.4236/ojepi.2017.71004.
51. Prestevez, R. How to Compute Intraclass Correlation (ICC) for THREE-Level Negative Binomial Hierarchical Model? Available online: https://stats.stackexchange.com/questions/174071/how-to-compute-intraclass-correlation-icc-for-three-Level-negativebinomial-hi (accessed on 11 May 2021).
52. Leckie, G.; Browne, W.J.; Goldstein, H.; Merlo, J.; Austin, P.C. Partitioning Variation in Multilevel Models for Count Data. *Psychol. Methods* **2020**, *25*, 787–801, doi:10.1037/met0000265.
53. MLwiN User Forum. VPC in Three and Four Levels Binary Response Models. Available online: https://www.cmm.bris.ac.uk/forum/viewtopic.php?t=60 (accessed on 9 June 2021).
54. Heck, R.H.; Thomas, S.; Tabata, L. *Multilevel Modeling of Categorical Outcomes Using IBM SPSS*, 2nd ed.; Routledge: New York, NY, USA, 2014; ISBN 978-1-84872-956-8.
55. Azikiwe, C.; Ifezulike, C.; Siminialayi, I.; Amazu, L.; Enye, J.; Nwakwunite, O. A Comparative Laboratory Diagnosis of Malaria: Microscopy versus Rapid Diagnostic Test Kits. *Asian Pac. J. Trop. Biomed.* **2012**, *2*, 307–310, doi:10.1016/S2221-1691(12)60029-X.
56. Zgambo, M.; Mbakaya, B.C.; Kalembo, F.W. Prevalence and Factors Associated with Malaria Parasitaemia in Children under the Age of Five Years in Malawi: A Comparison Study of the 2012 and 2014 Malaria Indicator Surveys (MISs). *PLoS ONE* **2017**, *12*, e0175537, doi:10.1371/journal.pone.0175537.

C.5 Individual, household, and area predictors of anaemia among children aged 6-59 months in Nigeria

Public Health in Practice 3 (2022) 100229

Contents lists ScienceDir

Public Health in Practice

journal www.sciencedirect.com/journal/public-health-in-

Individual, household, and area predictors of anaemia among children aged 6_59 months in Nigeria

Phillips Edomwonyi Obasohan [a,b,*], Stephen J. Walters [a], Richard Jacques [a], Khaled Khatab [c]

[a] School of Health and Related Research (ScHARR), University of Sheffield, Sheffield, UK

[b] Department of Liberal Studies, College of Administrative and Business Studies, Niger State Polytechnic, Bida Campus, Bida, 912231, Nigeria [c] Faculty of Health and Wellbeing, Sheffield Hallam University, Sheffield, UK

ARTICLEINFO

Keywords:
Iron deficiency anaemia
Under-five years
Determinants
Associations
Logistic regression
Predicted probabilities

ABSTRACT

Objectives: This study aims to determine the prevalence of anaemia among children aged 6–59 months in all states of Nigeria, including the Federal Capital Territory (FCT), and to quantify the predicted probabilities by individual, household and area factors.

Study design: This study is a secondary analysis of data sets from two national representative cross-sectional surveys in Nigeria: the Nigeria Demographic and Health Survey (2018 NDHS) and the National Human Development Index (2018 NHDR). The state human development index (HDI) and the state multidimensional poverty index (MPI) from the 2018 NHDR were incorporated into the 2018 NDHS.

Methods: The study included a weighted sample of 10,222 children aged 6–59 months. Both univariate and bivariate analyses were computed to determine the prevalence and factors associated with anaemia status, respectively. Multiple binary logistic regression analyses with adjusted predicted probabilities (APPs) were performed to quantify the predictors' probabilities.

Results: The prevalence of anaemia among children aged 6–59 months in Nigeria was 68.1% (6962/10,222). Zamfara state had the highest prevalence (84.0% [266/317]), while Kaduna state recorded the lowest (50.0% [283/572]). The APPs of being anaemic decreased from 82.9% (95% confidence interval [CI]: 80.0–85.8) for children aged 6–18 months to 60.6% (95% CI: 56.8–64.4) for children aged 43–59 months, when other predictors were held constant. The APP for a child of an anaemic mother is 10.2% points higher than the APP for a child whose mother is not anaemic. In addition, the APPs for children decreased as the age group of their mothers increased. A child from a state that is mildly deprived in the MPI has a lower APP (67.2% [95% CI: 62.2–72.2]) compared with a child from highly deprived MPI state (79.0% [95% CI: 73.4–84.5]).

Conclusions: Health strategies, including supplementation programmes, should be carried out at both ante-natal and post-natal clinics to reduce the prevalence of anaemia, especially in vulnerable population groups.

1. Introduction

Anaemia in children is a major global public health concern [1], especially in developing countries, and it is one of the major causes of childhood mortality [2–5]. The World Health Organisation (WHO) and the Centres for Disease Control and Prevention (CDC) [5] reported that about one-quarter of the world's population are anaemic, with expectant mothers and children under-five years of age being the most vulnerable [1,6]; however, since 2016, the global prevalence of anaemia has been increasing more than 40% annually [7]. The WHO recent classification indicated that any country with a prevalence of anaemia >40% can be classified as 'severe' [8]. The burden of anaemia in some developing countries is 400% times higher than in

* Corresponding author. School of Health and Related Research (ScHARR), University of Sheffield, Sheffield, UK.
E-mail addresses: peobasohan1@sheffield.ac.uk (P.E. Obasohan), s.j.walters@sheffield.ac.uk (S.J. Walters), r.jacques@sheffield.ac.uk (R. Jacques), K.Khatab@ shu.ac.uk (K. Khatab).
https://doi.org/10.1016/j.puhip.2022.100229
Received 18 June 2021; Received in revised form 11 December 2021; Accepted 13 January 2022
Available online 20 January 2022

most developed countries [9]. In a recent multi-country study of 27 Sub-Sahara Africa (SSA) countries,
Moschovis et al. [10] reported an average prevalence of anaemia of 60% among children aged 6–59 months. Almost all the Demographic and Health Surveys conducted in the post-millennium development goals era on SSA countries reported prevalence of under-five years anaemia of >50% [6]. In 2018, the prevalence of anaemia among children aged <60 months in Nigeria was 68% [11], in 2016 this was 72% in Ethiopia [12], and 58.6% in Tanzania [13].
Although the causes of anaemia in children are multi-factorial, the primary cause in developing countries is iron deficiency, which accounts >50% of all cases [8,9]. Other causes of anaemia that are common in Africa, which often result in blood reduction in the body system, include infectious/non-communicable diseases, such as malaria fever, schistosomiasis, HIV-AIDS, tuberculosis, cancer, malnutrition and micronutrient deficiencies [1,4,6]. Several studies have also reported some important socioeconomic, demographic and area-related factors that are associated with the risk of developing anaemia [6]. Studies investigating the determinants of anaemia in under-5 years children in Nigeria are limited. A recent study by Ogunsakin et al. [14] examined the determinants of anaemia among children aged 6–59 months in Nigeria using 2018 Nigeria Demographic and Health Survey (NDHS) data considering the individual and contextual factors as predictors. Although this current study used the same data set, the approaches differ in several ways: (i) two state-level predictors extracted from the 2018 National Human Development Report (NHDR) were incorporated into the 2018 NDHS data set; (ii) the cut-off value used for determining anaemia status among children aged 6–59 months in Nigeria differed; (iii) at the multivariate level of analysis, the current study computed and interpreted the predicted probabilities of a child being anaemic in Nigeria.
The aim of the current study is to determine the prevalence of anaemia among children aged 6–59 months in all states of Nigeria, including the Federal Capital Territory (FCT), and to quantify the predicted probabilities of being anaemic by individual, household and area variables.

2. Methods

2.1. Study design

This study is a secondary analysis of data sets from the following two nationally representative cross-sectional surveys in Nigeria: the NDHS (2018) and the NHDR (2018). The two contextual variables were the state human development index (HDI) and the state multidimensional poverty index (MPI) from the 2018 NHDR and these were incorporated into the 2018 NDHS (the main data set).
In the 2018 NDHS, each of the 36 states and FCT of Nigeria were separated into urban and rural areas. An urban locality was classified as a population of ≥20,000 [15], resulting in the identification of 74 strata (with each state and FCT having urban and rural localities). The survey used a stratified two-stage cluster design on each stratum in accordance with the 2006 census enumeration area demarcation. During the first stage, a representative 1400 enumeration areas (EAs) were selected as the sampling units with probability proportional to the EA size, allowing this survey (with the largest sample size) to be compared with five previous surveys [15]. The second stage involved a complete listing of households in each of the selected 1400 EAs. A fixed number of 30 households were randomly selected from each EA using equal probability sampling. Overall, 11 EAs were excluded from the survey because of insecurity. A total of 41,668 households were selected for sampling, but only 40,427 households (representing a response rate of 99.4%) completed the survey [15], (see Fig. 1).

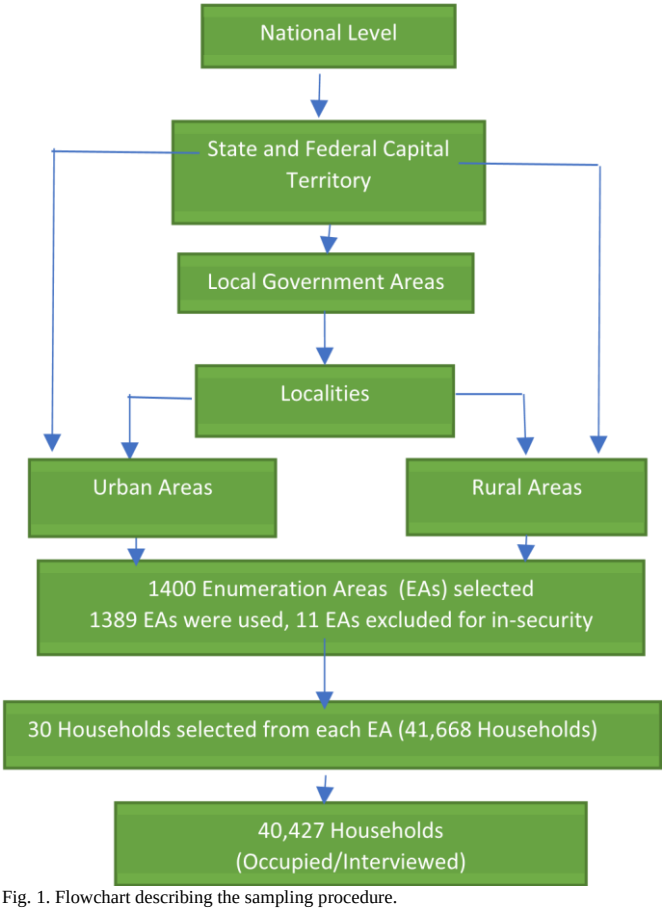


Fig. 1. Flowchart describing the sampling procedure.

2.2. Outcome or dependent variable

Anaemia Status: In Nigeria, the 2018 NDHS marked the first time that the DHS had collected data on haemoglobin (Hb) levels (anaemia) among women (15–49 years) and children (6–59 months), and the participants were taken from the subsample of households that were randomly selected for the male survey [15]. The anaemia status for children aged 6–59 months in Nigeria was determined by the altitude-adjusted Hb levels from a finger-prick test for children aged 12–59 months old or a heel-prick test for children aged 6–11 months. The blood samples were analysed with a Hb micro-cuvette using an on-site battery-powered portable HemoCue® analyzer, Hb 201+ device [14,15]. Children with Hb levels <11.0 g/dL (whether severe, moderate or mild anaemia) were classified as 'anaemic' and coded as '1', otherwise children were classified as 'not anaemic' and coded as '0' for the analysis. There were a total of 10,451 children aged 6–59 months in Nigeria who were included in survey; Hb levels were successfully computed for 10,188 children (representing a 97.4% response rate).

2.3. Predictor or independent variables

Several potential predictor variables arising from a scoping review of the predictors of anaemia among under-five years of age in SSA [6] were considered in the analysis. Table 1 defines and classifies these variables into the following categories: child-related variables, parental/caregiver-related variables and household/community-related variables.

Table 1
Description of the variables used in the analysis.

Variables	Definitions	Classifications
Child-related variables		
Age of the child	The age of the child (in months) on the day of the survey	6–18 months, 19–30 months, 32–42 months and 43–59 months
Sex of the child	The gender of the child at the birth	Male and female
Perceived Birth Size	This was the mother's percieved child's birth weight	Large, average and small
Birth Order	The child's rank among other children of the same mother	1st order, 2nd or 3rd order, 4th-6th order and 7th + order
Iron supplement	Whether the child has taken iron supplements in the last six months before the survey	No or Yes
Breastfeeding	Whether the child has been breastfed	Ever breastfed, not currently breastfed, never breastfed and still breastfeeding
Had Diarrhoea in the last 2 weeks before the survey	Whether the child been ill with diarrhoea	No or Yes
Had fever in last 2 weeks before the survey	Whether the child been ill with fever	No and Yes
The child had an acute respiratory illness (ARI) in the past 2 weeks before the survey	Whether the child has been ill with ARI	No or Yes
Vitamin A Consumption	Whether the child has ever taken vitamin A supplements in the last six months before the survey	No or Yes
Treatment for intestinal worms in the last 6 months	Whether the child took deworm tablets/syrup in the last 6 months before the survey took place	No or Yes
Nutritional Status	Whether the child is well nourished or poorly nourished (if the child had at least one of stunting, wasting, underweight, and overweight)	Well nourished and poorly nourished
Stunting	If a child is stunted	No or Yes
Wasting	If a child is wasted	No or Yes
Underweight	If a child is underweight	No or Yes
Overweight	If a child is overweight	No or Yes
Malaria status (RDT)	The child is confirmed to have malaria parasitaemia from results of rapid diagnostic test	No or Yes

Place of delivery	Type of facility where the child was delivered	Home, Public health facility, Private health facility and elsewhere
Parental/caregiver-related variables		
Mother's age group	Mother's age classified (in years)	15–24 years, 25–34 years and ≥35 years
Mother's age at first birth	The mother's age when she had her 1st child	10–19 years, 20–29 years and ≥30 years
Mother working Status	Whether the mother/caregiver of the child works	Not working and working
Mother's educational status	Mother/caregiver of the child's educational level of attainment	No education, Primary and Secondary & above
Father's educational status	Father of the child's educational level of attainment	No education, Primary and Secondary & above
Father's work status	Whether the child's father works	Not working and working
Mother's marital status	Mother's current marital status	Never in union, in union and divorced/ separated/widowed
Mother lives with a partner	Whether the mother resides with her partner	Living with partner and living alone
Mother slept under a mosquito net Mother's body mass index (kg/m^2)	If the mother slept under a mosquito net the night before the survey The body mass index classification of the mother	No or Yes Normal, underweight, overweight and obese
Preceding birth interval	Interval in months between the child's birth and the previous child's birth	8–24 months, 25–35 months, 36–59 months and ≥60 months
Mother's anaemia status	Anaemia status of the mother	Normal and anaemic
Antenatal care attendance/health seeking	Number of antenatal care visits the mother attended during the child's pregnancy	None, less WHO recommended number and met WHO recommendation
Maternal autonomy	The extent to which the mother participates in decision making concerning her health, large household purchases	Less autonomy and more autonomy
Maternal ethnicity	The ethnic background of the child's mother/caregiver	Hausa/Fulani, Ibos, Yoruba and others
Religious status	The religious denomination of the mother	Catholic, other Christians, Muslim and others (traditional)
Mother's iron supplementation during pregnancy	The mother took an iron supplement during the child's pregnancy	No or Yes
Household-related variables		
Wealth status	The measure of household economic status. This is a composite measure of the living standard of the household. This was computed using principal component analysis of durable assets and housing characteristics	Poorest, poor, middle, rich and richest
The household had a mosquito bed net	Whether the household had a bed net or not	No or Yes
Household size	The number of people that lived in the household	0-3, 4–6, 7–9 and ≥10
Number of rooms for sleeping	The number of rooms available for sleeping in the household	1 room, 2 rooms, 3rooms, 4 rooms and ≥5 rooms
Number of children Under-5 years in the household	Number of children who are aged <5 years in the household	None or 1, 2, 3 and ≥ 4
Source of drinking water	Whether there is improved source of drinking water in the household, such as piped, bottled or protected well, or not (unimproved)	Unimproved and improved
Type of toilet facilities	Whether the household uses improved toilet facilities, such as flush or ventilated pit, or not (unimproved)	Unimproved and improved
Youngest child's stool disposal	The mode of disposing of stool is safe or not	Proper and improper
Type of floor materials	Natural and rudimentary (unimproved), or finished floor (improved)	Unimproved and improved
Type of roofing materials	Natural and rudimentary (unimproved), or finished roof (improved)	Unimproved and improved
Type of wall materials	Natural and rudimentary (unimproved), or finished wall (improved)	Unimproved and improved
Household head age group in years	The age group of the household head	<34 years, 35–44 years, 45–55 years and ≥56 years

(*continued on next page*)

Table 1 (*continued*)

Variables	Definitions	Classifications
Sex of Household Head	The gender of the household head	Male and female
Shared toilet facilities with other households	Whether the household use the same toilet with other people	No or Yes
Type of cooking fuel	Electricity, natural gas or biogas	Electricity & gas, and biofuel/mass
Under-5 slept under a mosquito net last night	Children under-5 years slept inside mosquito net	No children, all children, some children and no net
State Human Development Index (SHDI)	The human development index indicates the level of deprivation in each state of residence	Lowest SHDI, low SHDI, average SHDI, high SHDI and highest SHDI
Region of residence	The geopolitical zone of the child's place of residence	North Central, North East, North West, South East, South-South and South West
Place of residence	The location of the household, whether in the rural or urban	Rural and urban
State Multidimensional Poverty Index (SMPI)	The multidimensional poverty index indicates the level of multidimensional poverty in each state	Highly deprived, above-average deprived, average deprived, mildly deprived, and lowest deprived

RDT, rapid diagnostic test.

2.4. Statistical analyses

Three levels of statistical analysis were considered in this study: namely, univariate, bivariate and multivariate methods.

At the univariate analysis level, percentage and frequencies were used to describe the baseline characteristics of all variables used in the analysis.

At the bivariate analysis level, the Pearson's chi-square test was applied to establish the association between the predictor variables and anaemia status of children aged 6–59 months in Nigeria. All variables that were found to be significantly associated with anaemia status at a 5% level of significance were further scrutinised to determine which were potential independent predictors (crude

odds ratios) of anaemia in children aged 6–59 months using a simple logistic regression technique. At the multivariate analysis level, backwards stepwise logistic regression at $p < 0.2$ was used to determine the predictor variables that would be considered for further analyses at this level. All the predictors that filtered through this test were used in the multiple logistic regression (adjusted odds ratios). Furthermore, for ease of interpretation [16], the margins were constructed to determine the predictive probability of being anaemic at each mean of the factor category, while holding other predictors constant at their respective mean value.

2.5. Logistic regression

The main aim of this study is to predict the probability of a child aged 6–59 months in Nigeria being anaemic, in any of the predictor variables of interest, while holding other variables constant. The regression analysis statistical method was used for prediction. Linear regression is a section of regression analysis that considers outcome variables (dependent variables) that are continuous (interval variables or scale). However, when the outcome variable is dichotomous (categorical or binary), logistic regression is the superior statistical method. For binary outcomes, such as the case in the current study, where 'no anaemia' is coded as '0' and 'anaemic' is coded as '1', the predicted values can only take the values of 0 or 1. On the other hand, linear regression for this type of outcome would provide results in the range of 0–1, unbounded [17] between $-\infty$ and $+\infty$, which would not be appropriate in these circumstances. The interpretations of the results differ when linear regression is used compared with when logistic regression is applied. For instance, in the case of a child being anaemic, linear regression will produce the predicted mean at any value of the independent variable. This is not the interest in the current study. This study wants to determine the probability that a child will suffer from anaemia if an independent variable is at a value of interest. Logistic regression can do this better.

$$P(Y_i=1)=\frac{exp(\beta_0+\beta_1 X_i)}{1+exp(\beta_0+\beta_1 X_i)} \quad (1)$$

Where: Y_i = the conditional probability that the outcome variable result into 1 (being anaemic as the condition of interest).

X_i = the predictor variable for a child *i*.

For meaningful interpretation, rather than just being interested in the prediction of the conditional probability that the outcome is present ('1'), the study may want to determine the conditional probability that the outcome is present over the probability that the outcome is not present ('0'). In this circumstance, a link function that can transform the conditional probability of S- Shape into a linear function type is required – logit transformation is favourable to make the function normal [3,18]. Now, consider the odds of having the outcome disease.

$$Odds=\frac{P(Y^i=1)}{1-P(Y_i=1)} \quad (2)$$

This is the ratio between the probability of being in the state of interest over the probability of not being in the state.

$$\varphi_i=logit(Odds)=log\left[\frac{P(Y^i=1)}{1-P(Y_i=1)}\right] \quad (3)$$

By substituting $P(Y_i = 1)$ in (1) into (3), it becomes

$$logit(Odds)=\beta_0+\beta_i X_i+\mu \quad (4)$$

The β_i, which is the coefficient estimate could be interpreted as the effect of the predictor variable on the log-odds of being anaemic. In other words, it could mean the amount an increase (or decrease) of one unit in the predictor variable will produce as an expected increase (or decrease) in the log-odds of developing anaemia among children aged 6–59 months in Nigeria after adjusting for other covariates (in the case of multivariate analysis). The exponentiation of β_i gives the odds ratio. This refers to the amount one can multiply the probability of the outcome of interest occurring rather than not occurring [17].

Alternatively, we can convert the log-odds of the outcome of interest to the predicted probability of the outcome of interest for ease of interpretation [16,19] using:

$$Predicted\ probability\ (PP)\ \rho_i=\frac{e^{\varphi_i}}{1+e^{\varphi_i}} \quad (5)$$

All computations were carried on Stata version 16 (College Station, TX: StataCorp LP) [20]. The units of analysis for this study are children (attached to the main individual respondent [i.e. mothers]), the weight proportion of v005/1,000,000 as formulated

for Stata was used to account for under- and over-sampling. The listwise deletion technique in Stata is the default method of handling missing data in regression. This could apply since the missing mechanism was that of missing completely at random (MCAR). Thus, the mechanising of missing is not associated with the variables [3]. Any variables with >30% missing values were excluded from the analysis.

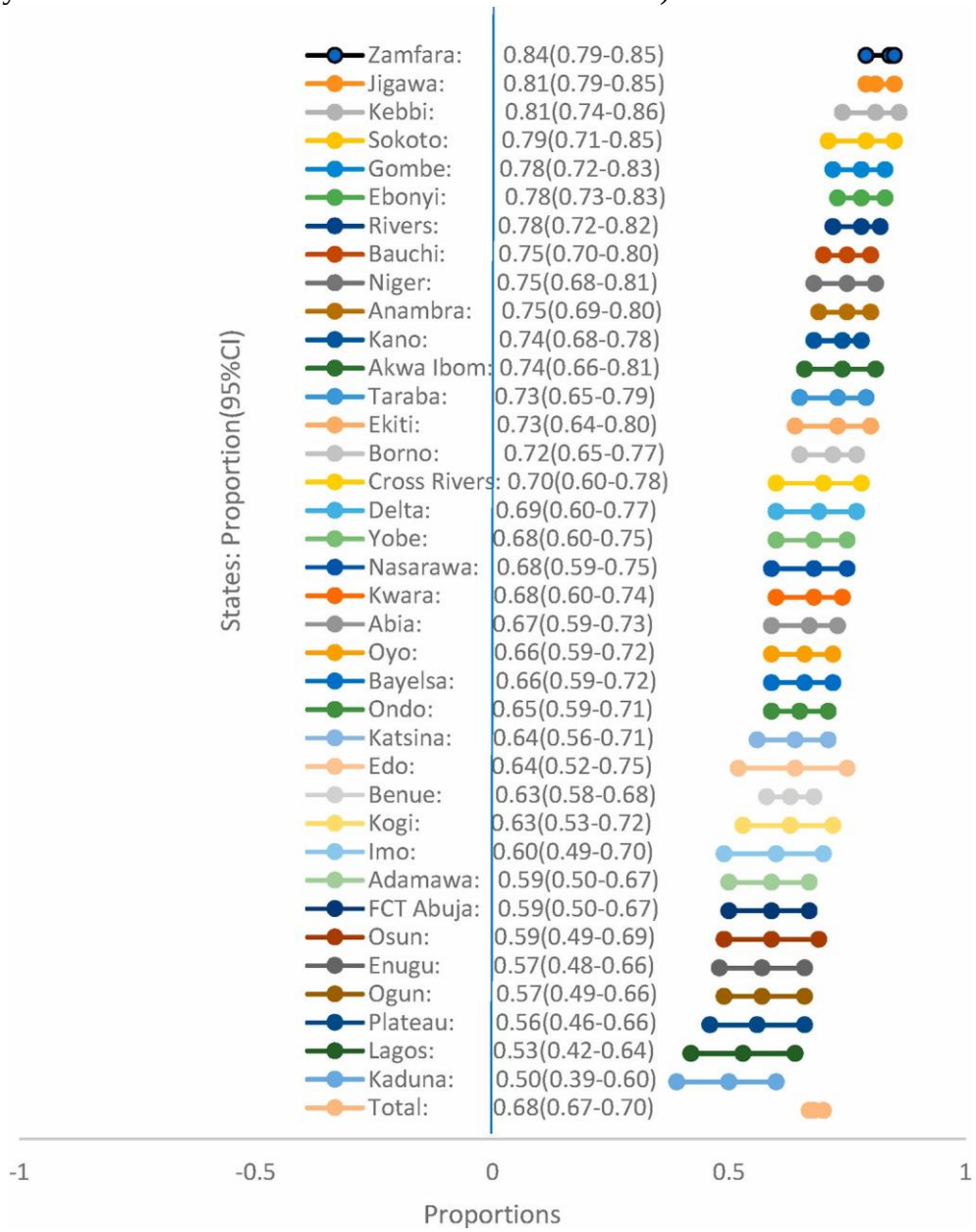


Fig. 2. Forest plot of the proportion of anaemic children aged 6–59 months in Nigeria by states. CI, confidence interval.

3. Results

3.1. Prevalence of anaemia

A total weighted sub-sample size of 10,222 children aged 6–59 months in Nigeria was reported in this study. The prevalence of anaemia in the sample was 68.1% (6962/10,222), while 31.9% (3260/10,222) were not anaemic. Fig. 2 shows the forest plot of the proportion of anaemic children of aged 6–59 months in Nigeria by states. Of the 36 states and FCT in Nigeria, Zamfara state had the highest proportion of anaemic children aged 6–59 months (84%; 95% confidence interval [CI]: 79–85), followed by Jigawa state (81%; 95% CI: 79–85). Lagos state (53%; 95% CI: 42–64) and Kaduna state (50%; 95% CI: 39–60) were the two states with the lowest proportion of anaemic children aged 6–59 months in Nigeria. In total, 59% (95% CI: 50–67) of children aged 6–59 months in the FCT were anaemic. So, by the WHO standard classification of anaemia prevalence, every state in Nigeria has severe

anaemia status among children aged 6–59 months [21].

3.2. Univariate and Bivariate Analyses of Associations between Predictors and Anaemia Status

Table 2, 3 and 4 report the descriptive and Pearson's chi-square analyses of the association between the response and the predictor variables. Among the child-related predictors (Table 2), Pearson's chi-square analysis shows that there are strong statistically significant associations between the anaemia status of children aged 6–59 months in Nigeria and the age of the child, the gender, the birth order, duration of breastfeeding, the various comorbidities (fever, diarrhoea, acute respiratory diseases, malnutrition status and malaria status) and place of delivery. However, the perceived birth size of the child and intake of iron supplement in the 2 weeks before the survey were not statistically significantly associated with the anaemia status of children aged 6–59 months in Nigeria.

There were more children in the 43–59 months age group (28.5%) than in any other age group. Each of the four age groups had a proportion of more than 20% each. As the age of the children increased, the

Table 2
Univariate and bivariate analysis of associations between child-related predictors and anaemia status.

Child-Related Variables	Total	Anaemic status	
		No	Yes
	N (%)	N (%)	N (%)
Prevalence of Anaemia	10,222 (100)	3260 (31.9)	6962 (68.1)
Age of the child		Chi-square = 363.987	
	10,222 (100)	p < 0.001	
06–18 months	2819 (27.6)	573 (20.3)	2246(79.3)
19–30 months	2269(22.2)	623 (27.5)	1646 (72.5)
31–42 months	2215 (21.7)	843 (38.1)	1372(61.9)
43–59 months	2917 (28.5)	1220 (41.8)	1697 (58.2)
Sex		Chi-square = 11.8822	
	10,222 (100)	p = 0.0040	
Male	5230 (51.2)	1587 (30.3)	3643 (69.7)
Female	4992 (48.8)	1673 (33.5)	3318 (66.5)
Perceived birth size		Chi-square =8.2058	
	10,096 (98.8)	p = 0.0580	
Large	924 (9.2)	295 (31.9)	629 (68.1)
Average	7984 (78.7)	2582 (32.5)	5366 (67.5)
Small	1223 (12.1)	347 (28.4)	876 (71.6)
Ever had vaccination status		Chi-square = 13.1023	
	3302 (32.3)	p = 0.0035	
No	839 (25.4)	172 (20.5)	667 (79.5)
Yes	2462 (74.6)	659 (26.8)	1803 (73.2)
Birth order		Chi-square =51.80	
	10,222 (100)	p < 0.001	
1st order	1951 (19.1)	728 (37.3)	1223 (62.7)
2nd or 3rd order	3494 (34.2)	1142 (2.7)	2352 (67.3)
4th – 6th order	3223 (31.5)	978 (30.4)	2244 (69.6)
≥7th order	1553 (15.2)	411 (26.5)	1141 (73.5)
Duration of breastfeeding		Chi-square = 238.00	
	10,222 (100)	p < 0.001	
ever, but not currently	7467 (73.1)	2692 (36.0)	4775 (64.0)
never breastfed	171 (1.7)	61 (35.6)	110 (64.4)
still breastfeeding	2583 (25.3)	507 (19.6)	2076 (80.4)
Had diarrhoea in last 2 weeks		Chi-square = 41.5120	
	10,219 (99.9)	p < 0.001	
No	8865 (86.7)	2931 (33.1)	5933 (66.9)

Yes	1355 (13.3)	329 (24.3)	1025 (75.7)
Had fever in last 2 weeks		Chi-square = 123.29	
	10,219 (99.9)	p < 0.001	
No	7519 (73.6)	2630 (35.0)	4889 (65.0)
Yes	2701 (26.4)	630 (23.3)	2070 (76.7)
Had acute respiratory illness in past 2 weeks		Chi-square = 22.018	
	10,220 (100)	p < 0.001	
No	9610 (94.0)	3118 (32.4)	6492 (67.6)
Yes	610 (6.0)	141 (23.3)	4368 (76.7)
Took vitamin A supplements		Chi-square = 11.274	
	10,177 (99.6)	p = 0.0114	
No	5323 (52.3)	1618 (30.4)	3704 (69.6)
Yes	4854 (47.7)	1627 (33.5)	3227 (66.5)
Deworming treatment in the last 6 months		Chi-square = 48.453	
	10,169 (99.5)	p < 0.001	
No	7265 (71.4)	2169 (29.9)	5095 (70.1)
Yes	2905 (28.6)	1075 (37.0)	1830 (63.0)
Child took iron supplements		Chi-square = 2.8553	
	10,188 (99.7)	p = 0.1861	
No	8255 (81.0)	2604 (31.5)	5651 (68.5)
Yes	1973 (19.0)	648 (33.5)	1285 (66.5)
Nutritional status		Chi-square = 126.2	
	10,222 (100)	p < 0.001	
Well nourished	5705 (55.8)	2083 (36.5)	3622 (63.5)
Poorly nourished	4517 (44.2)	1177 (26.1)	3339 (73.9)
Stunting		Chi-square = 130.34	
	10,222 (100)	p < 0.001	
No	6304 (61.7)	2281 (36.2)	4023 (63.8)
Yes	3918 (38.3)	979 (25.0)	2938 (75.0)
Wasting		Chi-square = 41.30	
	10,222 (100)	p < 0.001	
No	9515 (93.1)	3112 (32.7)	6403 (67.3)

(*continued on next page*)

Table 2 (*continued*)

Child-Related Variables	Total	Anaemic status	
		No	Yes
	N (%)	N (%)	N (%)
Yes	707 (6.9)	148 (21.0)	558 (79.0)
Underweight		Chi-square = 124.98	
	10,222 (100)	p < 0.001	
No	7943 (77.7)	2753 (34.7)	5190 (65.3)
Yes	2278 (22.3)	507 (22.3)	1771 (77.7)
Overweight		Chi-square = 9.7556	
	10,222 (100)	p = 0.0157	
No	10,056 (98.4)	3189 (31.7)	6867 (68.3)
Yes	166 (1.6)	71 (43.1)	94 (56.9)
Malaria status (RDT)		Chi-square = 649.6	
10,183 (99.6)		p < 0.001	
Negative	6566 (64.5)	2664 (40.6)	3902 (59.4)
Positive	3617 (35.5)	577 (16.0)	3040 (84.0)
Malaria status (blood smear)		Chi-square = 287.6	
7445 (72.8)		p < 0.001	
No	5794 (77.8)	2121 (36.6)	3673 (63.4)

Yes	1651 (22.2)	239 (14.5)	1411 (85.5)	
Place of delivery		Chi-square = 138.28		
10,222 (100)	p < 0.001			
Home	5365 (38.2)	1459 (27.2)	3905 (72.8)	
Public Health Facility		2987 (29.2)	1083 (36.2)	1906 (63.8)
Private Health Facility		1668 (16.3)	670 (40.2)	998 (59.8)
Somewhere else		200 (2.0)	48 (23.9)	152 (76.1)

Table 3

Univariate and bivariate analysis of associations between parental-related predictors and anaemia status.

Parental-related variables	Total	Anaemia status	
		No	Yes
	N (%)	N (%)	N (%)
Mother's age group		Chi-square = 34.615	
	10,222 (100)	p < 0.001	
15–24 years	2055 (20.1)	545 (26.5)	1509 (73.5)
25–34 years	5283 (51.7)	1737 (32.9)	3546 (67.1)
≥35 years	2884 (28.2)	977 (33.9)	1906 (66.1)
Mother's age at first birth		Chi-square = 116.26	
	10,222 (100)	p < 0.001	
10–19 years	5423 (53.1)	1492 (27.5)	3911 (72.5)
20–29 years	4386 (42.9)	1581 (36.0)	2805 (64.0)
≥30 years	411 (4.0)	186 (45.3)	225 (54.7)
Mother working status		Chi-square = 10.689	
	10,222 (100)	p = 0.0126	
Not working	2989 (29.2)	883 (29.5)	2106 (70.5)
Working	7232 (70.8)	2377 (32.9)	4855 (67.1)
Mother's educational status		Chi-square = 194.16	
	10,222 (100)	p < 0.001	
No education	3984 (39.0)	1000 (25.1)	2984 (74.9)
Primary education	1646 (16.10)	475 (28.9)	1171 (71.1)
Secondary & above	4592 (44.9)	1785 (38.9)	2806 (61.1)
		Chi-square = 0.9457	
Marital status	10,222 (100)	p = 0.6706	
never in union	171 (1.7)	51 (30.1)	119 (69.9)
in union	9767 (95.5)	3112 (31.9)	6655 (67.1)
widow/divorced/separated	284 (2.8)	97 (34.2)	187 (65.8)
Partner's educational status		Chi-square = 152.33	
	9637 (94.3)	p < 0.001	
No education	2884 (29.9)	686 (23.8)	2198 (76.2)
Primary education	1325 (14.8)	419 (29.4)	1006 (70.6)
Secondary education	5328 (55.3)	1967 (36.9)	3360 (63.1)
Father's occupation		Chi-square = 4.473	
	10,222 (100)	p = 0.1120	
Not working	305 (3.0)	80 (26.3)	225 (73.7)
Working	9916 (97.0)	3179 (32.1)	6736 (67.9)
Mother lives with a partner		Chi-square = 1.204	
	9767 (95.5)	p = 0.3892	
living with partner	8889 (91.0)	2817 (31.7)	6072 (68.3)
living alone	877 (9.0)	294 (33.5)	583 (66.5)

(*continued on next page*)

Table 3

Parental-related variables	Total	Anaemia status		
			No	Yes
	N (%)		N (%)	N (%)
Mother slept under a mosquito net		Chi-square = 29.19		
	10,222 (100)	p < 0.001		
No	4684 (45.8)	1621 (34.6)		3063 (65.4)
Yes	5537 (54.2)	1639 (29.6)		3098 (70.4)
Mother's body weight index (kg/m^2)		Chi-square = 106.63		
	8763 (85.7)	p < 0.001		
Normal	5331 (60.8)	1591 (29.9)		3739 (70.1)
Underweight	888 (10.1)	211 (23.8)		676 (76.2)
Overweight	1670 (19.1)	636 (38.1)		1034 (61.9)
Obese	873 (10.0)	367 (42.0)		506 (58.0)
Preceding birth interval		Chi-square = 24.30		
	8252 (80.7)	p = 0.0009		
8–24 months	2196 (26.6)	657 (29.9)		1539 (70.1)
25–35 months	2895 (35.1)	840 (29.0)		2055 (71.0)
36–59 months	2363 (28.6)	724 (30.6)		1639 (69.4)
≥60 months	798 (9.7)	303 (38.0)		495 (62.0)
Mother's anaemia status		Chi-square = 245.14		
	10,090 (98.7)	p < 0.001		
Normal	4215 (41.8)	1707 (40.5)		2508 (59.5)
Anaemic	5874 (58.2)	1512 (25.7)		4363 (74.3)
Number of antenatal care visits		Chi-square = 55.655		
	6398 (62.6)	p < 0.001		
None	1344 (21.0)	300 (22.3)		1044 (77.7)
Less WHO recommendation	961 (15.0)	226 (23.5)		735 (76.5)
Met WHO recommendation	4092 (64.0)	1293 (31.6)		2799 (68.4)
Maternal autonomy		Chi-square = 44.075		
	10,222 (100)	p < 0.001		
Less autonomy	5082 (49.7)	1464 (28.8)		3618 (71.2)
more autonomy	5140 (50.3)	1796 (34.9)		3344 (65.1)
Maternal ethnicity		Chi-square = 66.778		
	10,222 (100)	p < 0.001		
Hausa/Fulani	4077 (39.9)	1157 (28.4)		2920 (71.6)
Ibos	1656 (16.2)	529 (31.9)		1127 (68.1)
Yoruba	1497 (14.6)	596 (39.8)		902 (60.2)
Others	2991 (29.3)	979 (32.7)		2013 (67.3)
Religious status		Chi-square = 41.0977		
	10,222 (100)	p < 0.001		
Catholic	1028 (10.1)	360 (35.0)		668 (65.0)
Other Christians	3458 (33.8)	1220 (35.3)		2239 (64.7)
Islam	5671 (55.5)	1658 (29.2)		4013 (70.8)
Others (traditional)	64 (6.0)	22 (34.8)		42 (65.2)
Mother's iron tabs during pregnancy		Chi-square = 10.135		
	6493 (63.5)	p = 0.0188		
No	1784 (27.5)	459 (25.7)		1324 (74.3)
Yes	4709 (72.5)	1401 (29.8)		3308 (70.2)

prevalence of anaemia decreased. There were more male (5230/10,222) than female (4992/10,222) children aged 6–59 months. Also, the prevalence of anaemia was higher among male (69.7%) than female (66.5%) children. Results in Table 2 also reveal that the proportion of anaemic children differed by the child's birth order. Children in the ≥7th birth order group were more likely to have anaemia (73.5%) than children in the other birth order groups. In total, 25.3% of children aged 6–59 months were still being breastfed, and >80% of these children were anaemic compared with 64.4% of children who had never been breastfed. Children delivered in health centres (whether a private health facility or public health facility) had a lower prevalence of being anaemic (59.8% and 63.8%, respectively) than those delivered at home (72.8%).

Table 3 shows the proportion of children aged 6–59 months in Nigeria who are suffering from anaemia in each category of the parental- related predictor variables. The mother's age, age at first birth, work status, educational level, body mass index, anaemia status, ante-natal care attendance, autonomy status, ethnicity and religious status were significantly associated with anaemia in children aged 6–59 months in Nigeria. Other parental-related variables considered were paternal education and work statuses. Paternal work status, mother's marital status and mother living with a partner were not statistically significantly associated with the anaemia status of children aged 6–59 months in Nigeria.

The majority of children aged 6–59 months in Nigeria were born to mothers in the 25–34 years age group (51.7%). However, the prevalence of anaemia was highest among children of mothers aged 15–34 years (73.5%). In fact, as the age group of the mother increased, the prevalence of anaemia decreased. In total, 53.1% (5423/10,222) of children aged 6–59 months were born to mothers who had their first baby between 10 and 19 years of age. Of these children, 72.5% were anaemic; whereas, for mothers who had their first birth aged ≥30 years, only 54.7% of their children were anaemic. The prevalence of anaemia among children aged 6–59 months in Nigeria decreased significantly with an increase in the mother's educational level.

In total, 58.2% (5874/10,222) of children aged 6–59 months in Nigeria were born to anaemic mothers; of these children, 74.3% were anaemic. For mothers who were not anaemic (41.8%), 59.5% of their children were anaemic. In terms of maternal ethnicity, 40% of the children in this study were born to Hausa/Fulani mothers, 16% to Ibos mothers, 14.6% to Yoruba mothers and 29% to mothers from other minority ethnic groups. Among the children of Hausa/Fulani mothers, over 71% were anaemic, followed by children of Ibos mothers (68% of children were anaemic), other ethnic minorities mothers (67% of

Table 4

Univariate and bivariate analysis of associations between household and area-related predictors, and anaemia status.

Household and area-related variables					Total	Anaemia status	
						No	Yes
					N (%)	N (%)	N (%)
	Wealth status	Chi-square = 391.21					
	10,222 (100) p	0.001				<	
Poorest	1532 (80.7) Poor	1495 (75.0) Middle	1433 (66.6) Rich		1898 (18.6)	366 (19.3)	1423 (66.1)
	Richest 1078 (53.3)				1994 (19.5)	499(25.0)	
	The household has a mosquito bed net				2151 (21.0)	718 (33.4)	
	Chi-square = 18.217				2154 (21.1)	731 (33.9)	
	10,222 (100) p = 0.0015				2023 (19.8)	945 (46.7)	
	No 3123 (30.6)	1089 (34.9)					
			2034 (65.1)				
			Yes				
		7098 (69.4)			2171 (30.6)		4927 (69.4)
	Household size	Chi-square = 32.078					
	10,222 (100) p = 0.0006						
	0-3 persons 982 (9.6)	329 (33.5)	653 (66.5)				
	4-6 persons 3200 (66.0)				4851 (47.5)	1651 (34.0)	
	7-9 persons 1714 (69.3)				2472 (24.2)	758 (30.7)	
	≥10 persons 1394 (72.8)				1917 (18.8)	522 (27.2)	
			Number of rooms for sleeping		Chi-square = 1.2757		
	10,222 (100) p = 0.9405						
room	2813 (27.5) 894 (31.8)	1919 (68.2)					
rooms	2383 (68.1)				3498 (34.2)	1114 (31.9)	
rooms	1378 (67.4)				2043 (20.0)	666 (32.6)	
rooms					988 (9.7)	317(32.1)	671 (67.9)
≥5 rooms					878 (8.6)	267 (30.5)	610 (69.5)
			Number of children Under-5 years in the household		Chi-square = 73.199		
	10,222 (100) p	0.001				<	
None or 1 child	1766 (65.0)	Two children	2844 (65.7)	Three children	2716 (26.6)	950 (35.0)	1510 (73.4)
Four children+					4326 (42.3)	1402 (34.3)	
	Source of drinking water	Chi-square =			2056 (20.1)	547 (26.6)	
63.725					1123 (11.0)	282 (25.1)	842 (74.9)
	10,222 (100) p	0.001					
			Unimproved			<	
					3095 (30.3)	814 (26.3)	2281 (73.7)

			Improved			
		7127 (69.7)		2446 (34.3)		4680 (65.7)
Type of toilet facilities		Chi-square = 169.71				
10,222 (100)	p < 0.001					
Unimproved	4622 (45.2)	1168 (25.3)	3454 (74.7)			
			Improved			
		5600 (54.8)		2092 (37.4)		3508 (62.6)
Youngest child's stool disposal		Chi-square = 0.0153				
6436 (63.0)	p = 0.9200					
Proper	3621 (56.3)	1032 (28.5)	2590 (71.5)			
			Improper			
		2815 (43.7)		806 (28.6)		2009 (71.4)
Type of floor material		Chi-square = 152.06				
10,222 (100)	p	0.001			<	
Unimproved	2227 (77.2)			2885 (28.2)	658 (22.8)	
			Improved			
		7337 (71.8)		2602 (35.5)		4735 (64.5)
Type of roofing materials		Chi-square = 51.2785				
10,222 (100)	p	0.001			<	
Unimproved	877 (77.5)			1132 (11.1)	255 (22.5)	
			Improved			
		9090 (88.9)		3005 (33.1)		6084 (66.9)
Type of wall materials		Chi-square = 175.316				
10,222 (100)	p	0.001			<	
Unimproved	2527 (77.0)			3282 (32.1)	755 (23.0)	
			Improved			
		6940 (67.9)		2505 (36.1)		4434 (63.9)
Sex of household head		Chi-square = 0.7888				
10,222 (100)	p = 0.4591					
Male	9127 (89.3)	2898 (31.8)	6229 (68.2)			
			Female			
		1095 (10.7)		362 (33.1)	733 (66.9)	
Household head age group			Chi-square = 3.478			
10,222 (100)	p = 0.5367					
>34 years	2838 (27.8)	873 (30.8)				
1965 (69.2)				3959 (38.7)	1301 (32.9)	
35–44 years	2658 (67.1)			2100 (20.5)	664 (31.6)	
45–55 years	1436 (68.4)			1324 (13.0)	421 (31.8)	903 (68.2)
≥56 years						
			Shared toilet with other households		Chi-square = 0.1094	
	7756 (75.9)	p = 0.8216				

(*continued on next page*)

Table 4

Household and area-related variables	Total	Anaemia status		
			No	Yes
			N (%)	N (%)
N (%)				
No	4781 (61.6)	1624 (34.0)	3157 (66.0)	
Yes	2975 (38.4)	1000 (33.6)	1076 (66.4)	
Household had electricity			Chi-square = 217.23	
		10103 (98.8)	p < 0.001	
No		4310 (42.7)	1033 (24.0)	3277 (76.0)
Yes		5793 (57.3)	2193 (37.9)	3600 (62.1)
Type of cooking fuel			Chi-square = 205.47	
		10219 (99.9)	p < 0.001	
Electricity & Gas		1213 (11.9)	606 (49.9)	607 (50.1)
Biofuel/mass		9006 (88.1)	2653 (29.5)	6352 (70.5)
Under-5 slept under bed net			Chi-square = 48.145	
		10,149 (99.3)	p < 0.001	
No child		1320 (13.0)	426 (32.3)	894 (67.7)
All children		4734 (46.6)	1497 (31.6)	3236 (68.4)
Some children		999 (9.8)	229 (22.9)	771 (77.1)
No net in the house		3096 (30.5)	1073 (34.7)	2023 (65.3)
Region of residence			Chi-square = 74.7329	
		10,222 (100)	p < 0.001	
North central		1437 (14.1)	483 (33.6)	954 (66.4)
North east		1589 (15.5)	461(29.0)	1127 (71.0)
North west		2972 (29.1)	891 (30.0)	2081 (70.0)
South east		1334 (13.1)	406 (30.4)	928 (69.6)
South south		1886 (10.6)	301 (27.7)	786 (72.3)

South west	1802 (17.6)	718 (39.8)	1085 (60.2)
Type of Place of Residence		Chi-square = 126.24	
	10,222 (100)	p < 0.001	
Urban	4494 (44.0)	1697 (37.8)	2796 (62.2)
Rural	5727 (56.0)	1563 (27.3)	4164 (72.7)
State Human Development Index (SHDI)		Chi-square 79.553	
	10,222 (100)	p < 0.001	
Lowest SHDI	2157 (21.1)	601 (27.8)	1556 (72.2)
Low SHDI	2420 (23.7)	717 (29.6)	1702 (70.4)
Average SHDI	2239 (21.9)	719 (32.1)	1520 (68.9)
High SHDI	2690 (26.3)	903 (33.6)	1787 (66.4)
Highest SHDI	715 (7.0)	320 (44.8)	395 (55.2)
State Multidimensional Poverty Index (SMPI)		Chi-square 96.03	
	10222 (100)	p < 0.001	
Highly deprived SMPI	849 (8.3)	200 (23.6)	649 (76.4)
Above average deprived SMPI	3103 (30.4)	853 (27.5)	2250 (72.5)
Average deprived SMPI	2327 (22.8)	763 (32.8)	1563 (67.2)
Mildly deprived SMPI	1950 (19.1)	706 (36.2)	1244 (63.8)
Lowest deprived SMPI	1992 (19.5)	737 (37.0)	1254 (63.0)

children were anaemic) and Yoruba mothers had children with the lowest prevalence (60% of children were anaemic). Table 3 also reports that more children of Muslim mothers were anaemic than children from t other religious groups; 71% of children of Muslim mothers were anaemic compared with 65% of children of Catholic mothers, 64.7% of children of other Christian mothers and 65.2% of children of traditionalist mothers.

Household and area-related variables are other important factors for consideration. Table 4 reveals that household wealth status, whether the household had a mosquito bed net, the household size, the number of under-five years children in the household, under-five slept under a bed net, the region of residence, the place of residence, the state HDI and the state MPI were statistically significantly related to the anaemia status of children aged 6–59 months in Nigeria. However, the number of rooms for sleeping, the proper disposal of the youngest child's stool, the sex and age group of the household head, and the household sharing toilet facilities with other households were not statistically significantly associated with anaemia status of children aged 6–59 months in Nigeria.

Table 4 shows that the anaemia status of children aged 6–59 months in Nigeria varies by the household wealth. The household wealth is a proxy to the household socioeconomic status (SES). The anaemic status of children aged 6–59 months in Nigeria is inversely proportional to the level of the SES. The higher the SES, the lower the prevalence of anaemia. In total, 80.7%, 75%, 66.6%, 66.1% and 53.3% of children aged 6–59 months in Nigeria from the poorest, poor, middle, rich and richest households were anaemic, respectively. As the number of under- five children in the household increased, the prevalence of anaemia in children aged 6–59 months also increased.

An additional important factor to consider is the place of residence. There were more children from rural areas (56%) than urban areas (44%) considered in this analysis. The prevalence of anaemia among children aged 6–59 months from rural areas (73%) was higher than their counterparts in the urban areas (62%). In terms of state HDI, the prevalence of anaemia among children aged 6–59 months in Nigeria decreased as the level of state HDI increased. The prevalence of anaemia n the lowest, low, average, high and highest state HDIs was 72%, 70%, 69%, 66% and 55%, respectively. Also, the prevalence anaemia in children aged 6–59 months in Nigeria varied with the level of the state MPI. For example, children from a state with a highly deprived MPI had a prevalence of anaemia of 76%, followed by children from a state that is above average highly deprived in state MPI (72.5%) and the lowest prevalence was found among children from a state in the lowest deprived in state MPI (63%).

Table 5

Predictor Variables	AOR[a] (95% CI)		p-Value	APP (95% CI)	At sample means[b]
Child					
Sex of the child					
Male	1			0.745 (0.721–0.769)	0.515
Female	0.88 (0.670–1.153)		0.352	0.711 (0.685–0.736)	0.484
Age of the child					
6–18 months	1			0.829 (0.800–0.858)	0.310
19–30 months	0.68 (0.493–0.948)		0.022	0.767 (0.735–0.799)	0.207
31–42 months	0.43 (0.305–0.601)		<0.001	0.653 (0.615–0.692)	0.215
43–59 months	0.32 (0.229–0.438)		<0.001	0.606 (0.568–0.644)	0.268
Duration of breastfeeding					
ever breastfed, not currently breastfeeding		1		0.720 (0.694–0.745)	0.687
never breastfed	0.77 (0.460–1.302)		0.334	0.665 (0.550–0.781)	0.016
still breastfeeding	1.18 (0.913–1.514)		0.210	0.751 (0.713–0.790)	0.297
Had fever in last 2 weeks					
No	1			0.722 (0.699–0.745)	0.734
Yes	1.13 (0.954–1.348)		0.152	0.747 (0.716–0.777)	0.266
The child had an acute respiratory illness in the past 2 weeks					
No		1		0.725 (0.704–0.746)	0.941
Yes		1.35 (0.985–1.848)	0.062	0.781 (0.727–0.834)	0.059
Iron pill/syrup consumption					
No		1		0.723 (0.701–0.745)	0.812
Yes		1.17 (0.955–1.430)	0.130	0.753 (0.716–0.790)	0.188
Deworming in the last 6 months					
No		1		0.736 (0.714–0.758)	0.724
Yes		0.86 (0.723–1.060)	0.171	0.709 (0.673–0.745)	0.276
Nutritional Status					
Well nourished		1		0.707 (0.683–0.732)	0.556
Poorly nourished Malaria status (RDT)		1.27 (1.085–1.486)	0.003	0.754 (0.728–0.780)	0.443
Negative		1		0.633 (0.607–0.659)	0.646
Positive		3.51 (2.938–4.185)	<0.001	0.858 (0.838–0.878)	0.353
Interaction of sex & age					
Male*6–18 months				0.838 (0.804–0.871)	
Male*19–30 months				0.779 (0.741–0.818)	
Male*31–42 months				0.688 (0.641–0.736)	
Male*43–59 months				0.620 (0.572–0.669)	
Female*6–18 months				0.819 (0.782–0.856)	
Female*19–30 months		0.99 (0.666–1.460)	0.944	0.754 (0.709–0.798)	
Female*31–42 months		0.82 (0.556–1.208)	0.314	0.614 (0.564–0.665)	
Female*43–59 months		1.00 (0.703–1.433)	0.982	0.591 (0.542–0.639)	
Parental					
Mother's age group					
15–24 years		1		0.754 (0.705–0.804)	0.108
25–34 years		0.88 (0.665–1.159)	0.357	0.729 (0.705–0.753)	0.540
≥35 years		0.84 (0.619–1.134)	0.253	0.720 (0.690–0.750)	0.352
Mother's educational status					
No education		1		0.748 (0.719–0.777)	0.408
Primary education		1.03 (0.601–1.765)	0.914	0.753 (0.708–0.797)	0.174
Secondary & above Paternal's educational status		0.61 (0.360–1.017)	0.058	0.698 (0.659–0.737)	0.418
No education		1		0.733 (0.690–0.776)	0.311
Primary education		0.78 (0.513–1.180)	0.238	0.717 (0.676–0.759)	0.158
Secondary and above		0.85 (0.628–1.161)	0.313	0.730 (0.704–0.755)	0.531
Mother's body weight index (kg/m^2)					
Normal		1		0.730 (0.706–0.754)	0.604
Underweight		1.14 (0.902–1.451)	0.268	0.756 (0.714–0.798)	0.101
Overweight		0.88 (0.728–1.071)	0.206	0.705 (0.666–0.744)	0.192
Obese		1.03 (0.789–1.345)	0.826	0.736 (0.688–0.784)	0.103
Mother's anaemia status					
Normal		1		0.667 (0.638–0.696)	0.424
Anaemic		1.66 (1.440–1.912)	<0.001	0.769 (0.748–0.790)	0.576
Maternal Autonomy					

Less autonomy	1		0.737 (0.710–0.763)	0.517
More autonomy Religious status	0.92 (0.770–1.100)	0.357	0.720 (0.693–0.748)	0.483
Catholic	1		0.671 (0.609–0.734)	0.098
Other Christians	1.15 (0.866–1.516)	0.340	0.701 (0.664–0.738)	0.322
Islam	1.50 (1.056–2.133)	0.023	0.754 (0.724–0.784)	0.573
Others (traditional) Preceding Birth Interval	0.60 (0.274–1.307)	0.197	0.550 (0.365–0.735)	0.006
8–24 months	1		0.753 (0.724–0.783)	0.259
25–35 months	0.87 (0.724–1.048)	0.144	0.727 (0.699–0.755)	0.356
36–59 months	0.85 (0.701–1.031)	0.100	0.722 (0.694–0.751)	0.287

Risk factor and predicted probability of anaemia status of children aged 6–59 months in Nigeria form a multiple logistic regression model (N ¼ 6506).
(*continued on next page*)

Table 5

Predictor Variables	AOR[a] (95% CI)	p-Value	APP (95% CI)	At sample means[b]
≥60 months	0.71 (0.549–0.913)	0.008	0.684 (0.634–0.734)	0.098
Interactions of Maternal & Paternal Educational Levels				
no education & no education			0.771 (0.731–0.811)	
no education & primary			0.724 (0.656–0.792)	
no education & secondary+			0.742 (0.699–0.785)	
primary & no education			0.776 (0.695–0.857)	
primary & primary	0.91 (0.440–1.878)	0.797	0.711 (0.647–0.774)	
primary & secondary+	1.02 (0.538–1.914)	0.963	0.750 (0.692–0.809)	
secondary+ & no education			0.670 (0.569–0.772)	
secondary+ & primary	1.58 (0.792–3.137)	0.194	0.714 (0.644–0.784)	
secondary+ & secondary+	1.40 (0.799–2.442)	0.241	0.708 (0.675–0.741)	
Household and area Wealth status				
Poorest	1		0.775 (0.731–0.819)	0.192
Poor	0.92 (0.696–1.216)	0.559	0.760 (0.724–0.796)	0.193
Middle	0.72 (0.546–0.961)	0.026	0.714 (0.683–0.745)	0.209
Rich	0.75 (0.553–1.014)	0.062	0.721 (0.685–0.757)	0.217
Richest Household size	0.58 (0.415–0.816)	0.002	0.667 (0.622–0.713)	0.190
0–3 persons	1		0.642 (0.554–0.730)	0.036
4–6 persons	1.52 (1.026–2.260)	0.037	0.732 (0.706–0.758)	0.474
7–9 persons	1.41 (0.949–2.110)	0.089	0.717 (0.686–0.749)	0.277
≥10 persons	1.66 (1.089–2.541)	0.019	0.749 (0.712–0.786)	0.214
Under-five slept under a bed net				
No under-five	1		0.736 (0.695–0.777)	0.131
All children	0.97 (0.774–1.202)	0.748	0.729 (0.704–0.754)	0.454
Some children	1.32 (0.990–1.775)	0.059	0.787 (0.749–0.825)	0.115
No net in household Region of residence	0.84 (0.653–1.073)	0.160	0.700 (0.667–0.733)	0.300
North central	1		0.744 (0.701–0.787)	0.141
North east	0.64 (0.434–0.936)	0.022	0.649 (0.588–0.711)	0.161
North west	0.39 (0.258–0.574)	<0.001	0.528 (0.460–0.596)	0.295
South east	2.26 (1.623–3.147)	<0.001	0.868 (0.829–0.906)	0.128
South south	3.32 (2.336–4.707)	<0.001	0.906 (0.875–0.937)	0.100
South west	1.35 (0.967–1.874)	0.079	0.796 (0.746–0.846)	0.174
State Human Development Index (SHDI)				
Lowest SHDI	1		0.690 (0.631–0.749)	0.213
Low SHDI	1.53 (1.148–2.029)	0.004	0.773 (0.730–0.815)	0.247
Average SHDI	1.42 (0.975–2.054)	0.068	0.759 (0.722–0.796)	0.214
High SHDI	0.99 (0.656–1.497)	0.966	0.688 (0.641–0.736)	0.259
Highest SHDI	1.17 (0.625–1.199)	0.619	0.723 (0.622–0.825)	0.067
State Multidimensional Poverty Index (SMPI)				
Highly Deprived	1		0.790 (0.734–0.845)	0.085
Above average Deprived	0.90 (0.660–1.229)	0.510	0.772 (0.731–0.812)	0.309
Average Deprived	0.58 (0.387–0.863)	0.007	0.685 (0.643–0.726)	0.230
Mildly Deprived	0.55 (0.343–0.869)	0.011	0.672 (0.622–0.722)	0.188
Lowest deprived	0.72 (0.421–1.221)	0.221	0.729 (0.666–0.793)	0.188

AOR, Adjusted Odds Ratio; APP, Adjusted Predicted Probability; CI=Confidence Intervals; RDT, rapid diagnostic test.
[a] AOR – Adjusted odds ratio estimate for variables from multiple logistic regression adjusted for all the other 24 variables (these include 23 unique predictors, and two other interaction variables) in the model. [b] The 'at sample means' column contains the proportion of the sample with that variable characteristic.

3.3. Predictors of anaemia status

This section presents the results of the predicted probabilities of a child aged 6–59 months in Nigeria having anaemia. Variables that were found to be associated with anaemia in children aged 6–59 months in Nigeria with chi-square ($p < 0.05$) were subjected to variable selection method. The backward stepwise selection method was then used at $p < 0.20$ [3,22,23] to select potential variables that are predictors of anaemia. In total, 24 variables were included in the multiple logistic regression model. The child-related factors included child's age, sex, malaria status, nutritional status, fever, acute respiratory infection status, duration of breastfeeding, deworming and child took iron pills/syrup. The paternal-related factors were preceding birth interval, maternal religious status, age group, educational status, body mass index, anaemia status, autonomy level and paternal education status. Also included were household socioeconomic status (wealth quintile index), household size, if the household had a bed net, under-five slept under the bed net the night before the survey, household region of residence, the state MPI and the state HDI.

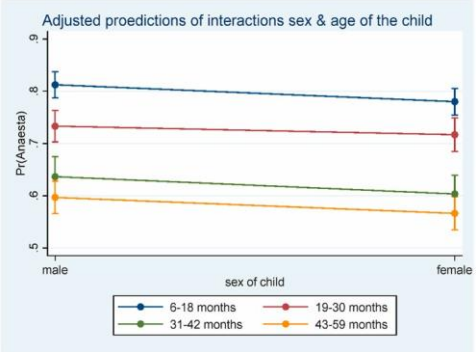
3.4. Test of multicollinearity and goodness of fit

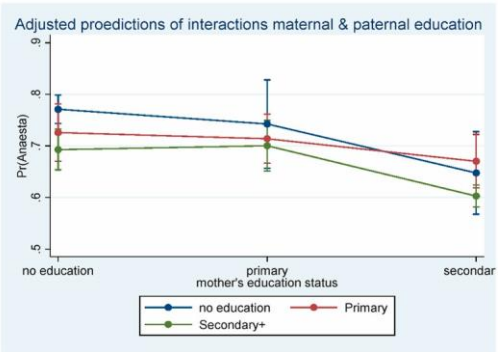
A multicollinearity test was performed to check for the existence of a high correlation among the predictor variables. Two variables, 'household had bed net' and 'under-five years slept under bed net last night', were perfectly correlated ($r = 1.00$) and had a variance inflation factor (VIF) of 11.13 and 7.04, respectively. The mean VIF was 2.17. The variable 'household had bed net' was dropped and the new VIF ranged from 1.02 to 3.35, with a mean VIF of 1.17. Another variable, 'frequency of mother watching television', which was a significant predictor of anaemia in children aged 6–59 months in Nigeria was dropped from the model because one of the responses provided on the questionnaire appears not to be properly worded (watching television 'less than once a week') and could have resulted in participants selecting the incorrect response. The model was therefore fitted, while including the remaining potential predictors, using survey logistic regression design to account for both under- and over-sampling [24]. A test statistic for the goodness of fit was carried out using a method that takes into consideration the survey design estimate as proposed by Archer and Lemeshow [25], to compute F-adjusted mean residual goodness of fit of 1.285 and Prob > F = 0.240, suggesting that there is no statistically significant evidence to conclude no good fit. The final model was adjusted for 23 variables, including: child's sex, age, malaria status, nutritional status, fever, acute respiratory infection status, duration of breastfeeding, deworming, child's intake of iron pills/syrup; preceding birth interval, maternal religious status, age group, educational status, body mass index, anaemia status, autonomy level, paternal education status; household socioeconomic status (wealth quintile index), household size, under-five slept under bed net last, household region of residence, the state MPI and the state HDI.

Table 5 presents the results of the multiple logistic regression model to predict anaemia status in the study sample. In total, 23 risk factors or predictor variables were included in the model and Table 5 reports the adjusted odds ratios (AORs) and the adjusted predicted probabilities (APPs) of the included variables (the odds ratios and predicted probabilities for each risk factor are adjusted for the other 22 variables in the model). The 'at sample means' column is simply the proportion in the sample with that attribute or characteristic [26]. For example, for the sex of the child variables, 0.516 or 51.6% of the sample were male and 0.484 or 48.4% were female.

However, for interpretation, the APPs were used because they were potentially simpler to understand than coefficient estimates or AORs [16]. The APP represents the probability of an 'average' or 'typical' child in the sample having anaemia given they have the 'average' sample values of the risk factors or predictor variables. Strictly speaking, there is no such thing as an 'average' child in the study sample as you cannot be 51.6% male, this helps with the interpretation of results (a common practice, but not general [16]). The APPs tell us that if we have two otherwise-average children, one

Fig. 3. Margin plots for interactions terms and anaemia status from unadjusted predicted probability: (a) child's age and sex and (b) paternal & maternal educational levels.





male and one female, that an 'average' female child has a lower predicted probability of being anaemic compared with their male counterpart (0.711 vs 0.745), with over 3% points lower holding other predictors constant at their means. What do we mean by 'average'? The average is defined as having the mean value of the other independent variables in the model, that is 31% aged 6–18 months, 20.7% aged 19–30 months, 21.5% aged 31–42 months, 26.8% aged 43–59 months, 68.7% had been breastfed, but were not currently breastfeeding, 1.6% had never breastfed, and 29.7% were still being breastfed at the time of the survey. Thus, the predicted probabilities show us how the average female child compares with the average male child, where the average is defined as having the mean values (or proportions with the characteristic) on all the other variables in the model.

The predicted probabilities for an average child who reported having fever 2 weeks before the survey (72.2%), had an acute respiratory illness in the past 2 weeks (72.5%), was poorly nourished (70.9%), diagnosed with *malaria parasitaemia* (75.3%), of having anaemia were higher than an average child who did not have any of these morbidities with over 3.0%, 2.2%, 2.7% and − 3.0%, respectively, while other predictors were respectively held constant at their means. Concerning the interaction terms of child's gender and age groups, the predicted probability of an average male child (0.515) varied decreasingly as the age group increased. The same can be said of an average female child whose mean is set at 0.484, the predicted probability varied decreasingly from 83.8% points to 62.9% points. However, the average female's variations compared with that of an average male child were correspondingly lower across the age groups.

Another group of predictors reported in Table 5 are parental-related factors. The predicted probabilities of being anaemic for child of an average mother who is aged 15–24 years, 25–34 years and ≥35 years is 75.4%, 72.9% and 72.0%, respectively, and whose other covariates are held constant at their means. Also, a child of an average mother who has no education (74.8%) has a slight increase in the predicted probability than a child of an average mother who holds a primary education (75.3%) while holding other variables constant at their respective mean. Furthermore, a child of an average father who had primary education has a predicted probability of anaemia with 1.6% points lower than a child of an average father who had no education, and 1.3% points higher for a child of an average father who had secondary education and above. A child of an average anaemic mother has a predicted probability of 76.9% of being anaemic compared with a child of an average mother who has a normal Hb level, with a predicted probability of 66.7% when the values of other covariates are constant at their respective means. Table 5 further reveals that a child of an average mother who has more autonomy is less likely to be anaemic, with a predicted probability of 72.0%, compared with 73.7% for a child of an average mother who is less autonomous holding other predictors constant at their means. The predicted probability of being anaemic is higher for a child of an average mother whose religious affiliation is Islam compared to other religious groups. The higher an average mother's preceding birth interval, the lower the predicted probability of the child being anaemic at constant means of other predictors.

Wealth index, which is a proxy for household SES, is an important predictor considered in this analysis. A child aged 6–59 months in Nigeria from an average poorest household has the predicted

probability of 1.16 times more likely of being anaemic compared with a child from an average richest quintile household wealth. Children aged 6–59 months in Nigeria have varied degrees of predicted probability of being anaemic from as low as 52.8% in the North-West geopolitical zone to as high as 90.6% in South-South geopolitical zone, with other predictors held constant at their means. Also, the findings in Table 5 shows that an average child aged 6–59 months from a state in Nigeria with the lowest, low, average, high and highest HDI has a predicted probability of being anaemic of 69.0%, 77.3%, 75.9%, 68.8% and 72.3%, respectively, when other predictors are held constant at their means. Lastly, the results show that an average child from a state that is mildly deprived in the

MPI has the lowest predicted probability of 67.2% of being anaemic compared with an average child from a state that is highly deprived in the MPI, with a predicted probability of being anaemic of 79.0%, when other independent variables are constant at their means. Concerning the interaction terms of a child's gender and age groups, the predicted probability of a male child being anaemic decreases varyingly as age group increases. The same can be said that the predicted probability of a female child decreases varyingly across the age groups. However, the variations in females compared with males are correspondingly lower across the age groups (Fig. 3a). Children of parents whose father has secondary education and above, and the mother is at any level of educational status have correspondingly lower predicted probabilities of being anaemic compared with children whose father either has 'no' or 'primary' education, and the mother is at any level of educational status. In addition, the predicted probability of a child aged 6–59 months in Nigeria whose father has no education and whose mother has secondary education and above is lower than that of the child whose father has primary education and whose mother has a secondary education and above (Fig. 3b).

4. Discussion

This study aimed to determine the prevalence of anaemia in children aged 6–59 months in Nigeria. In addition, the predicted probability of anaemia in children aged 6–59 months in Nigeria was calculated based on child-, parental- household and area-related factors.

The prevalence of anaemia is very high in all states of Nigeria, including the FCT, resulting in the country being a severe anaemic nation [21]. This is comparable to most other countries in SSA [6]. After adjustment for all covariates having significant goodness of fit from a backward stepwise logistic regression, the child-related variables that are significant predictors of anaemia status among children aged 6–59 months in Nigeria include age, sex, duration of breastfeeding, deworming status, intake of iron pills/syrup, comorbidities of malaria, malnutrition, fever and acute respiratory infection.

The distribution of the predicted probabilities of being anaemic among children aged 6–59 months in Nigeria across all included predictors were lowest and highest among the geographical variables, with 0.528 and 0.906 for the North-West and South-South regions, respectively.

The predicted probability of anaemia was found to be inversely proportional to age group; the older the age group, the lower the predicted probability. This result is consistent with a similar finding by Reithinger et al. [27]. A possible reason for this finding is that in the developing countries where foods are served and eaten in a communal form, as the child gets older they have more scavenging power to get more food than younger siblings who often depend on breast milk, which lacks adequate nutrients.

Female children are less likely to be anaemic than male children, which corroborates with findings by Reithinger et al. [27] and Nkulikiyinka et al. [28]. A possible reason for this result is that in Africa, female children are often closer to their mothers in the kitchen than their male counterparts and, therefore, often have increased access to food when it is being cooked.

Children who have never been breastfed have a lower predicted probability of being anaemic than those who were breastfed and those who are still being breastfed. This result is similar to findings in Mohammed et al. [12]. This may relate to the fact that, in this study, there is a high prevalence of anaemic mothers, so most breast milk lacks the adequate nutrients for the breast-feeding child [29,30].

Children who have comorbidities (e.g. malnutrition, fever, malaria fever and acute respiratory infection) were found to be more likely to be anaemic than those who did not have any comorbidities. These findings are consistent with studies of malnutrition [31], malaria [32,33], fever [10,34] and diarrhoea [10,34–36]. As expected, taking iron supplements

reduced the predicted probability of anaemia; however, this is contrary to the conclusions reached by Mohammed et al. [12].

Deworming children did not result in the child being less likely to have anaemia, which is similar to findings from previous studies [12, 35].

Additionally, the current study found a significant interaction between the sex and age of the child. Across the nexus of child's age, female children were found to be corresponding less likely to be anaemic than male children. This may be connected with the fact that, at an early age, male children grow faster than female children, and therefore depletes Hb more rapidly [23].

In terms of parental-related predictors, children of older mothers were less likely to be anaemic in Nigeria, which is similar to results from previous studies [10,13,37]. Also, as the maternal education level increases, the predicted probability of the children being anaemic decreases. The significance of the interaction effects of both parent's educational level signified the relevance of educational level as a predictor of anaemia status of children aged 6–59 months [3], which agrees with the findings by Nambiema et al. [31].

A child from the richest household wealth quintile has the lowest predicted probability of being anaemic compared with children from other household wealth quintiles. The current study also established that the wealthier a household is, the less anaemic the children will be; this finding agrees with previous studies [10,12,38]. Wealthier households can afford basic healthcare services, good food and other household amenities that were the proxies for the construction of the wealth index for good living conditions [3]. Contrary to expectations, the current study revealed that children from homes without a bed net have a lower predicted probability of anaemia compared with homes where some children under-five years slept under a bed net. Furthermore, regional differences in the predicted probabilities of anaemia among children aged 6–59 months were reported to be higher in southern Nigeria (mostly agricultural) than in northern Nigeria (mostly pastoral). This finding is contrary to Mohammed et al. [12], who reported that children from the pastoral region have lower Hb levels than children in the agricultural region due to the high prevalence of malaria in the pastoral region [12,39]. Of the six geo-political regions, South-South has the highest predicted probability of anaemia, while North-West has the lowest. This finding is consistent with that of a previous study [40], but inconsistent with another recent study [14], probably because the recent study used a slightly different classification for anaemia among children aged 6–59 months in Nigeria. 5. Strength and limitations

The 2018 NDHS was the main data set for this study and was the first of the past six surveys in Nigeria to capture data for blood Hb concentration in children and mothers. The current study is among limited research that has used the classical regression analysis approach. This study used predicted probabilities to provide an easier approach to interpret the results of the relationships between the predictors and the outcome variable, instead of the seemingly difficult to understand log- odds and odd ratios.

There are several limitations in the current study that are worth noting. Firstly, as this study uses a cross-sectional data set, causal effects of the independent variables on the dependent variables could not be determined. Secondly, a single-level regression model was used. The initial check for random effect variations across the clusters (states of origin) in a two-level model showed that intraclass correlation was negligible (3.8%) compared with the standard threshold of 5% [41], so this study could not use multilevel logistic regression. Sensitivity analysis was not performed to justify the use of the single-level regression model. It is possible that the hierarchical effect could have been ignored in this study when the states and FCT were used as clusters.

6. Conclusions

This study has revealed the enormous severity of anaemia among children aged 6–59 months in Nigeria. The status of under-five years anaemia in Nigeria continues to increase. This is an indication of a serious public health problem in the country. The consequences of this could be daunting, putting the lives of this young generation at risk of mental, reduced cognitive development, poor social, academic and working inability as they grow older [21,40]. There has been a paucity of studies on anaemia in Nigeria; however, these are essential to provide data for informed decision making in public health strategies. The lack of research may relate to the fact that data on micronutrient deficiencies and blood Hb concentrations have only recently been captured in a nationally representative survey [21,42]. In addition, political commitment to address the problems of anaemia in children has been limited. For example, the National Policy on Food and Nutrition in Nigeria includes a target to reduce maternal anaemia during pregnancy by 27% between 2013 and 2025; however, there is no mention of any specific target for childhood anaemia in Nigeria [42].

To address anaemia among children under-five years of age in Nigeria, a multidimensional approach is required, including research to establish how the contributing factors are distributed across the population and identify the at-risk population groups. The current study contributes to this area of knowledge and public health policies should target the identified areas of concern. Iron deficiency anaemia has been identified in developing countries to be responsible for >50% of anaemia cases. This low blood Hb concentration has predisposing causes, indicating the co-existence of anaemia with other diseases in children. In this study, malaria and nutritional status were strong child- related determinants of anaemia. The government of Nigeria has made concerted efforts to address malaria infections among children and pregnant women through the distribution of free insecticide-treated nets. Unfortunately, the result of this strategy has not been optimal because the distribution of nets was not targeted the most vulnerable groups in the population. Most people who collected the bed nets did not need them, so they are kept at home unused. In addition, to address nutritional imbalances, micronutrient-fortified foods and bio-available iron-rich food should be made available to high-risk population groups [43,44]. Antenatal care attendance has increased in recent times among reproductive-aged women in Nigeria. Health strategies, including supplementation programmes, should be carried out at both ante-natal and post-natal clinics to reduce the prevalence of anaemia, especially in vulnerable population groups.

Ethical approval

The ethical approval to carry out this research study had been granted by the School of Health and Related Research (ScHARR) Ethics Committee of the University of Sheffield (Reference Number: 031534). This study is a secondary analysis of two nationally representative samples. Permission to use the data sets (2018 Nigeria Demographic and Health Survey and 2018 National Human Development Report) had been obtained from two organisations: the Inner City Fund (ICF)-International and the United Nations Development Programme (UNDP-
Nigeria).

Funding

This study is an integral part of PEO’s doctoral study at the School of Health and Related Research of the University of Sheffield, United Kingdom. The funding for the doctoral study was granted by TETFUND (Nigeria).

Author contributions

The conceptualisation of this study was done by PEO and KK; the formal drafting of manuscript was carried out by PEO; while, SJW, RJ and KK supervised, revised and edited the manuscript. All authors read and agreed to the published version of the paper.

Declaration of competing interest

The authors declare no conflict of interest.

Acknowledgements

The authors acknowledge the contributions received from the ScHARR community. PEO appreciates the Rector and the management staff of Niger State Polytechnic, Nigeria, for nominating him for the TETFUND (Nigeria) sponsorship of his doctoral programme.

References

[1] E. Nikoi, P. Anthamatten, Childhood anaemia in Ghana: an examination of associated socioeconomic and health factors, Afr. Geogr. Rev. 33 (1) (2013) 19–35.

[2] B.J. Brabin, M. Hakimi, D. Pelletier, An analysis of anemia and pregnancy-related maternal mortality, J. Nutr. 131 (2) (2001) 604S–615S.

[3] K.N. Kawo, Z.G. Asfaw, N. Yohannes, Multilevel analysis of determinants of anemia prevalence among children aged 6-59 Months in Ethiopia: classical and Bayesian approaches, Anemia 2018 (2018) 3087354.

[4] P.J. Hotez, D.H. Molyneux, Tropical anemia: one of Africa's great Killers and a rationale for linking malaria and neglected tropical disease control to achieve a common goal, PLoS Neglected Trop. Dis. 2 (7) (2008), e270.

[5] B. De Benoist, World Health O, Centers for Disease C, Prevention. Worldwide Prevalence of Anaemia 1993-2005 of: WHO Global Database of Anaemia, World Health Organization, Geneva, 2008.

[6] P.E. Obasohan, S.J. Walters, R. Jacques, K. Khatab, A scoping review of the risk factors associated with anaemia among children under five years in sub-Saharan African countries, Int. J. Environ. Res. Publ. Health 17 (23) (2020) 8829.

[7] World Health Organisation, Prevalence of anaemia in children under 5 years [cited 2020 Jul 23];Available from: https://www.who.int/data/maternal-newborn-child -adolescent/monitor, 2017.

[8] World Health Organization, Centers for Disease Control and Prevention, Assessing the iron status of populations; report of a Joint World Health Organization/centers for disease control and prevention technical consultation on the assessment of iron status at the population level, Geneva, Switzerland, 6-8 April 2004 [Internet], [cited 2021 Apr 8];Available from: https://stacks.cdc.gov/view/cdc/6681, 2004.

[9] Kayode O. Osungbade, Adeolu O. Oladunjoye, Anaemia in developing countries: burden and prospects of prevention and control, Anaemia 3 (2012) 116–129.

[10] P.P. Moschovis, M.O. Wiens, L. Arlington, O. Antsygina, D. Hayden, W. Dzik, *et al.,* Individual, maternal and household risk factors for anaemia among young children in sub-Saharan Africa: a cross-sectional study, BMJ Open 8 (5) (2018), e019654.

[11] Tradingeconomics. Nigeria - prevalence of anemia among children (% of children under 5) [Internet]. Available from: https://tradingeconomics.com/nigeria/pre valence-of-anemia-among-children-percent-of-children-under-5-wb-data.html.

[12] S.H. Mohammed, T.D. Habtewold, A. Esmaillzadeh, Household, maternal, and child related determinants of hemoglobin levels of Ethiopian children: hierarchical regression analysis, BMC Pediatr. 19 (1) (2019) 113.

[13] O.O. Ojoniyi, C.O. Odimegwu, E.O. Olamijuwon, J.O. Akinyemi, Does education offset the effect of maternal disadvantage on childhood anaemia in Tanzania? Evidence from a nationally representative cross-sectional study, BMC Pediatr. 19 (1) (2019) 89.

[14] R.E. Ogunsakin, B.T. Babalola, O. Akinyemi, Statistical modeling of determinants of anemia prevalence among children aged 6–59 Months in Nigeria: a cross-sectional study, Anemia (2020), e4891965, 2020.

[15] National Population C, I. C. F. International. Nigeria Demographic and Health Survey 2018. Abuja, Nigeria, NPC and ICF, Rockville, Maryland, USA, 2019.

[16] R. Williams, Using the margins command to estimate and interpret adjusted predictions and marginal effects, STATA J. 12 (2) (2012) 308–331.

[17] N. Sommet, D. Morselli, Keep calm and learn multilevel logistic modeling: a simplified three-step procedure using Stata, R, Mplus, and SPSS, Int. Rev. Soc. Psychol. 30 (1) (2017) 203–218.

[18] H.M.K.M. Gabr, Investigating poverty and labour force participation among older population in Egypt: a multilevel simultaneous equations modeling approach [Internet], [cited 2020 Jul 28];Available from: https://etheses.bham.ac.uk/id/epr int/6551/, 2016.

[19] S. Dey, E. Raheem, Multilevel multinomial logistic regression model for identifying factors associated with anemia in children 6–59 months in northeastern states of India [Internet], Cogent Math. (2016) [cited 2019 Feb 21];3(1). Available from: htt ps://www.cogentoa.com/article/10.1080/23311835.2016.1159798.

[20] Stata Corporation SE. Stata Statistical Software, College Station, TX, 2016.

[21] WHO, The Global Prevalence of Anaemia in 2011, World Health Organization, Geneva, 2015.

[22] G. Maldonado, S. Greenland, Simulation study of confounder-selection strategies, Am. J. Epidemiol. 138 (11) (1993) 923–936.

[23] S. Keokenchanh, S. Kounnavong, K. Midorikawa, W. Ikeda, A. Morita, T. Kitajima, *et al.,* Prevalence of anemia and its associated factors among children aged 6–59 months in the Lao People's Democratic Republic: a multilevel analysis, PLoS One 16 (3) (2021), e0248969.

[24] B.O. Ahinkorah, E.K. Ameyaw, A.-A. Seidu, S. Yaya, Predictors of female genital mutilation/cutting among daughters of women aged 15-49 in Guinea: a multilevel analysis of the 2018 demographic and health survey data, Int. J. Transl. Med. Res. Public Health 5 (1) (2021) 4–13.

[25] K.J. Archer, S. Lemeshow, Goodness-of-fit test for a logistic regression model fitted using survey sample data, STATA J. 6 (1) (2006) 97–105.

[26] W.M.K. Trochim, Dummy variables [Internet], [cited 2021 May 17]; Available from: https://conjointly.com/kb/dummy-variables/, 2021.

[27] R. Reithinger, J.M. Ngondi, P.M. Graves, J. Hwang, A. Getachew, D. Jima, *et al.,* Risk factors for anemia in children under 6 years of age in Ethiopia: analysis of the data from the cross-sectional Malaria Indicator Survey, 2007, Trans. R. Soc. Trop. Med. Hyg. 107 (12) (2013) 769–776.

[28] R. Nkulikiyinka, A. Binagwaho, K. Palmer, The changing importance of key factors associated with anaemia in 6- to 59-month-old children in a sub-Saharan African setting where malaria is on the decline: analysis of the Rwanda Demographic and Health Survey 2010, Trop. Med. Int. Health 20 (12) (2015) 1722–1732.

[29] G. Gebreegziabiher, B. Etana, D. Niggusie, Determinants of anemia among children aged 6–59 Months living in Kilte Awulaelo Woreda, Northern Ethiopia, Anemia (2014), e245870, 2014.

[30] J.R. Khan, N. Awan, F. Misu, Determinants of anemia among 6–59 months aged children in Bangladesh: evidence from nationally representative data, BMC Pediatr. 16 (1) (2016) 3.

[31] A. Nambiema, A. Robert, I. Yaya, Prevalence and risk factors of anemia in children aged from 6 to 59 months in Togo: analysis from Togo demographic and health survey data, 2013-2014, BMC Publ. Health 19 (1) (2019) 215.

[32] M.P. Menon, S.S. Yoon, Uganda malaria indicator survey technical working G. Prevalence and factors associated with anemia among children under 5 Years of age–Uganda, 2009, Am. J. Trop. Med. Hyg. 93 (3) (2015) 521–526.

[33] E.L. Korenromp, J.R.M. Armstrong-Schellenberg, B.G. Williams, B.L. Nahlen, R. W. Snow, Impact of malaria control on childhood anaemia in Africa – a quantitative review, Trop. Med. Int. Health 9 (10) (2004) 1050–1065.

[34] P.A.M. Ntenda, Association of low birth weight with undernutrition in preschool- aged children in Malawi, Nutr. J. 18 (1) (2019) 51.

[35] A.D. Jones, E.K. Colecraft, R.B. Awuah, S. Boatemaa, N.J. Lambrecht, L. K. Adjorlolo, *et al.,* Livestock ownership is associated with higher odds of anaemia among preschool-aged children, but not women of reproductive age in Ghana, Matern. Child Nutr. 14 (3) (2018), e12604.

[36] M. Machisa, J. Wichmann, P.S. Nyasulu, Biomass fuel use for household cooking in Swaziland: is there an association with anaemia and stunting in children aged 6-36 months? Trans. R. Soc. Trop. Med. Hyg. 107 (9) (2013) 535–544.

[37] M.B. Asresie, G.A. Fekadu, G.W. Dagnew, Determinants of anemia among children aged 6–59 Months in Ethiopia: further analysis of the 2016 Ethiopian Demographic Health Survey, Adv. Public Health (2020) 1–6, 2020.

[38] C.L. Hershey, L.S. Florey, D. Ali, A. Bennett, M. Luhanga, D.P. Mathanga, *et al.,* Malaria control interventions contributed to declines in malaria parasitemia, severe anemia, and all-cause mortality in children less than 5 Years of age in Malawi, 2000-2010, Am. J. Trop. Med. Hyg. 97 (3_Suppl) (2017) 76–88.

[39] O.M. Morakinyo, A.F. Fagbamigbe, Neonatal, infant and under-five mortalities in Nigeria: an examination of trends and drivers (2003-2013), PLoS One 12 (8) (2017), e0182990.

[40] E. Gayawan, E.D. Arogundade, S.B. Adebayo, Possible determinants and spatial patterns of anaemia among young children in Nigeria: a Bayesian semi-parametric modelling, Int. Health 6 (1) (2014) 35–45.

[41] R.H. Heck, S. Thomas, L. Tabata, Multilevel Modeling of Categorical Outcomes Using IBM SPSS [Internet], second ed., Routledge, New York, 2014 [cited 2021 Apr 14]. Available from: https://www.routledge.com/Multilevel-Modeling-of-Catego rical-Outcomes-Using-IBM-SPSS/Heck-Thomas-Tabata/p/book/9781848729568.

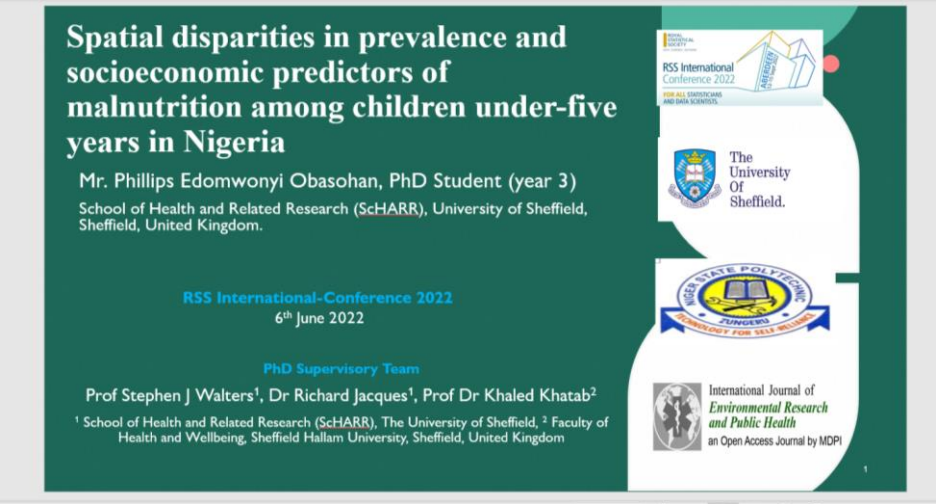
[42] Ministry of budget and national Planning. National policy on food and Nutrition in Nigeria [Internet], Available from: https://nigeria.savethechildren.net/sites/ni geria.savethechildren.net/files/library/NPFN%20manual%20design%20%20v13. pdf, 2016.

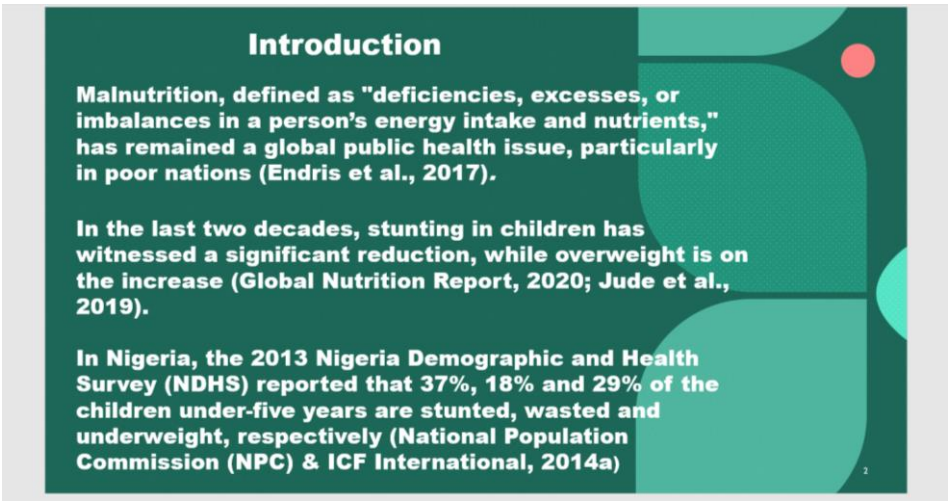
[43] United Nations Children's Fund, United Nations University, World Health Organization, Iron deficiency anaemia assessment, prevention, and control: a guide for programme managers [Internet], Available from: https://www.who.int/nutr ition/publications/en/ida_assessment_prevention_control.pdf, 2001.

[44] P.E. Obasohan, S.J. Walters, R. Jacques, K. Khatab, Risk factors associated with malnutrition among children under-five years in sub-Saharan African countries: a scoping review, Int. J. Environ. Res. Publ. Health 17 (23) (2020) 8782.

Appendix D: About conferences and workshops attendance

D.1: PowerPoint slides for paper presentation at RSS International conference 2022





The Objectives

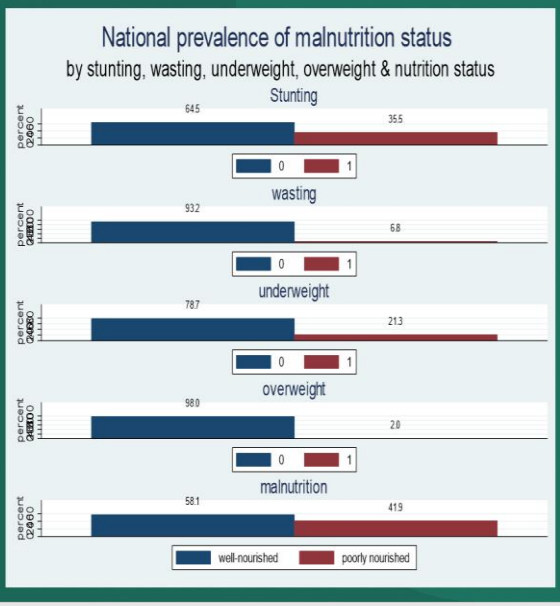
1. Derive the malnutrition status for children under under-five years in Nigeria using the composite index of anthropometric failure approach (CIAF)
2. Determine the spatial disparities of malnutrition at the state and geopolitical regional levels
3. Establish the socioeconomic determinants of malnutrition status among children under-five in Nigeria, relative to some covariates
4. Establish the spatial map disparities in socioeconomically poor and poorly-nourished (SEPPN) children across the States and FCT
5. Determine whether the effect of child's age on SEPPN varies by sex of the child

Data and methods

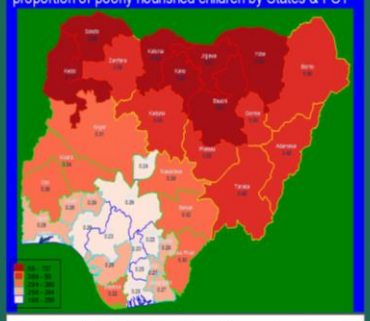
This study is a secondary analysis of a nationally representative cross-sectional survey of 2018 Nigeria Demographic and Health Survey (NDHS) data.

Four indicators (stunting, wasting, underweight and overweight, with each dichotomized as 0/1) were combined using the adjusted composite index of anthropometric failure (aCIAF).

The scores range from 0 to 4, such that '0' represent 'well-nourished', having none of the malnutrition indicators, and 1-4 represents 'poorly-nourished', having at least one of the malnutrition indicators.



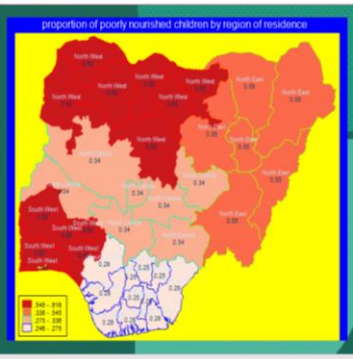
proportion of poorly nourished children by States & FCT



Sokoto, Kebbi, Katsina, Kano, Jigawa, Bauchi, and Yobe states are in the top quintiles of poorly nourished children under five years in Nigeria, while Edo, Lagos, Anambra, Ebonyi, and Rivers are in the lowest quintile.

On regional bases, North west and South west occupied the top quartile in the proportion of poorly nourished children, while South east and South South occupy the least 25th percentile.

proportion of poorly nourished children by region of residence



6

Table 1: Adjusted odds ratio of household socioeconomic status and nutrition status among children under five years in Nigeria (N=8551)

Household socioeconomic status	AOR	P-value
Poorest	1	
Poorer	0.890	0.160
Middle	0.893	0.226
Richer	0.741	0.007
Richest	0.639	0.001

Subject to other covariates: child's age (S), sex (S), birth size (S), duration of breastfeeding (NS), anaemia status (S), maternal education status (S), maternal anaemia (NS), Body Mass Index (S), region of residence, and community wealth status (S), interactions of child's age and sex

- From table 1, two SES classes are distinguished: The rich and the poor in the determinants of malnutrition status.
- Further investigation was carried out to find out how the distribution of the intersections between the nutrition status and wealth status varied across the states and differed concerning the demographic variables of the child (age and sex)

Table 2: Distribution of SES and Nutrition status among under-five years n Nigeria (N=11704)

Socioeconomic and wealth status	N	%
Socioeconomic rich and well nourished	2240	19
Socioeconomic poor and poorly nourished	9464	81

7

Results SES and nutrition status across the states

The highest proportion of children living in poor SES and poorly nourished are from Niger, Zamfara, Jigawa, Yobe, Gombe, and Adamawa states, while those from Kaduna, Delta and Bayelsa states had the lowest proportion quintile

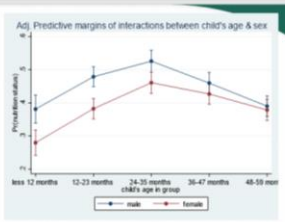
proportion of the poor & poorly nourished children by States & FCT

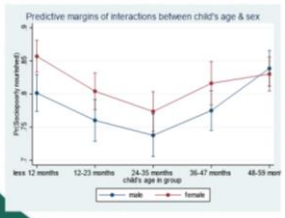
8

Interaction effects of child's age and sex

In the first graph, the non-parallel lines after 24 months indicate that poorly nourished status was highest for males but decreased more sharply than for female children.

Also, the probability of children being socioeconomically poor and poorly nourished was lowest for males till the age of 5 years





9

Summary

- The prevalence of malnutrition among children under-five years is 42%
- The northern part of Nigeria had the highest proportion of under-five malnutrition in Nigeria.
- Two SE classes were identified: the rich and the poor
- The highest quintile of children that are SE poor and poorly nourished was highest among states in the Northern part of Nigeria
- The probability of a male child being in SE poor and poorly nourished is more than that of a female at the age of 5 years.
- In conclusion, identification of a child's location and appropriate confrontation of specific socioeconomic factors that may reduce childhood malnutrition are necessary for controlling the incidence of poor nutrition in Nigeria.

10

Thank you for listening. Questions

The University Of Sheffield.

RSS International Conference 2022

International Journal of Environmental Research and Public Health an Open Access Journal by MDPI

NIGER STATE POLYTECHNIC ZUNGERU TECHNOLOGY FOR SELF-RELIANCE

11

D.2: Abstract Submitted for International Journal of Environmental Research and Public Health (IJERPH) 2022 Travel award

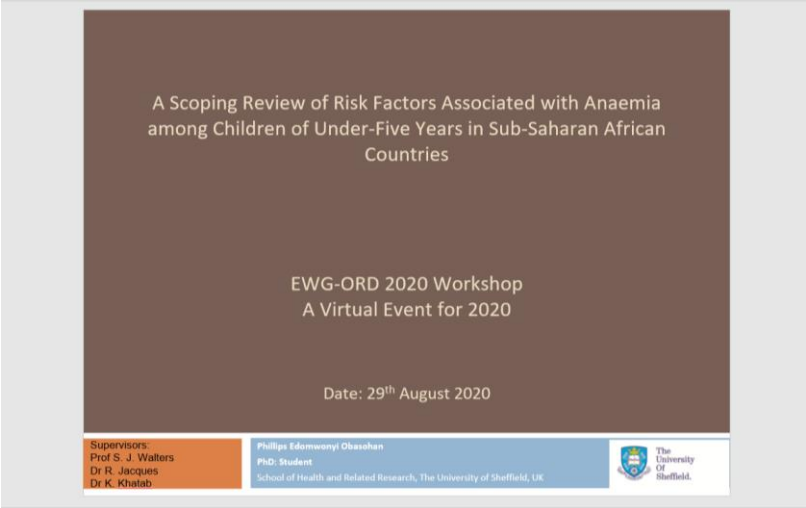
Spatial disparities in prevalence, and socioeconomic predictors of malnutrition among children under-five years in Nigeria

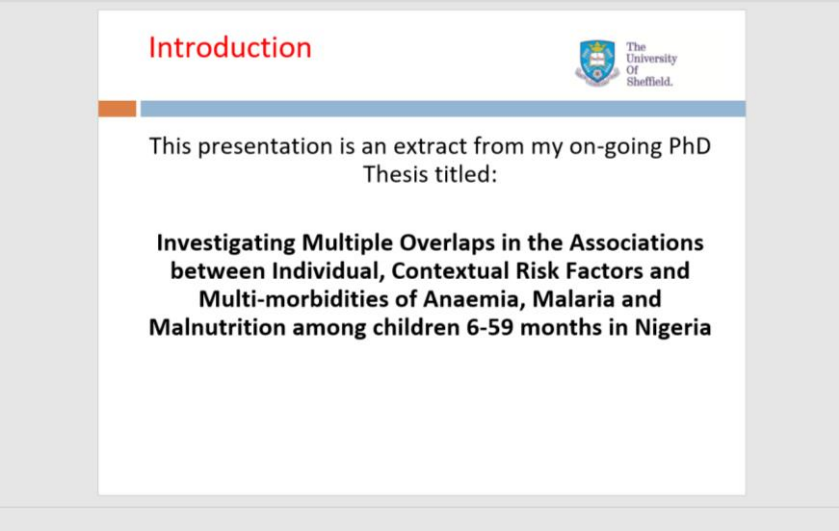
Phillips Edomwonyi Obasohan

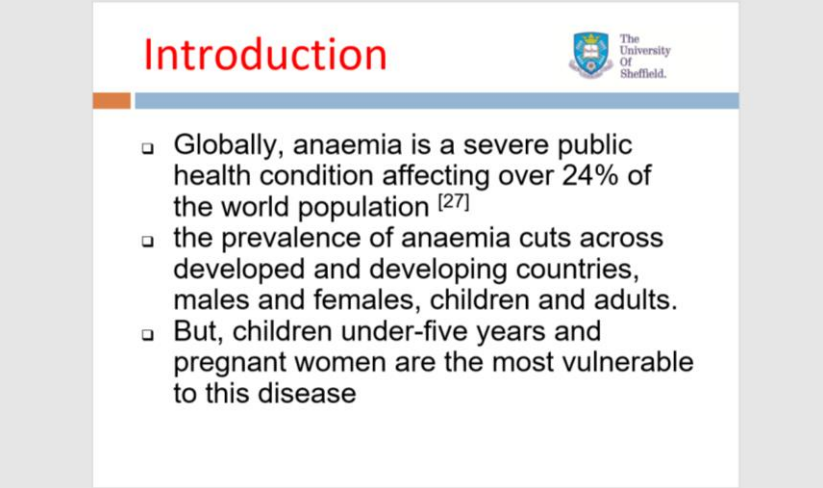
Background: Malnutrition has continued to be a public health concern world over and especially in developing countries. Over 200 million children under-five are either undernourished or overweight. However, in the last two decades, stunting in children has witnessed significant reduction, while overweight is on the increase. In Nigeria, more than 37%, 18% and 29% of the children under-five years are stunted, wasted and underweight, respectively. Understanding the spatial distribution of malnutrition and how different socio-economic, demographic, and contextual factors determine child malnutrition is a great way to improve the distribution of scare resources for the desired interventions. **Objectives:** This study aims to describe the spatial distributions of malnutrition among children under-five years in Nigeria across the state, and geopolitical regions and establish the socioeconomic predictors of malnutrition status. **Methods:** This study is secondary analysis of a nationally representative cross-sectional surveys of 2018 Nigeria Demographic and Health survey data set. Four indicators (stunting, wasting, underweight and overweight with each dichotomized as 0/1) were combined using the adjusted composite index of anthropometric failure (aCIAF), to compute the malnutrition index. The resulting scores were dichotomized as '0' (well nourished), and '1' (poorly nourished). Spatial maps were used to describe the distributions of prevalence of malnutrition across the states and geopolitical zones in Nigeria. A 2-level mixed effect logistic regression to explain the socioeconomic determinants of malnutrition among children under-five in Nigeria. Children/parents/household at level-1 are nested in communities at level-2. Furthermore, marginal effects were computed to properly explain the effects of socioeconomic status on malnutrition status. **Results:** A weighted sample of 11,732 children under-five years of age in Nigeria were included in this study, with the mean age of 28 months (standard error=0.16 months). About 42% (95%CI: 40.68,43.20) of the children were poorly nourished. The variance partition component for the null model (no covariates added), is 0.1937 (95%CI:0.171,0.218), meaning 19.37% of the total variations in prevalence malnutrition status is due to the community effects. Of the five quintiles of household wealth status (proxy for socioeconomic status), the result shows that children in a richer and richest household have significantly reduced odds of 0.24 and 0.39, respectively, less likely to be poorly nourished compared with children from poorest households when other covariates are held constant.

Further analysis shows that the marginal effects of children being in a richer and richest household are 6% (95%CI:1.00,11.5) and11% (95%CI:5.35,16.95), respectively less likely to change from being well nourished to being poorly nourished when compared with children from poorest household. Similarly, a female child is 7% (95%CI:4.82,9.33) less likely to become poorly nourished than a male child, while a child aged 24-35 months is 19% (95%CI: 13.9524.22) more likely to become poorly nourished than a in the first year of age. **Conclusion:** This study found the existence of two distinct socioeconomic classes (the rich and the poor), where the children of the rich class are well nourished, and the poor class are poorly nourished

D.3: PowerPoint slides for paper presentation at EWD-RD workshop 2020







Introduction cont'd

- Between 1990 and 2014, under-five anaemia witnessed a global decline from a prevalence of 51.4% to 41.4%, but in 2016 it gradually increased to 41.7% [28].
- Developing countries have a four times higher burden than in developed countries [40].
- In Nigeria for instance, in the post MDG, prevalence of under-5 anaemia has risen from 60% in 2015 to 68% in 2018 [41,42]

The causes of Anaemia

- The causes of anaemia, especially in developing countries, are primarily attributed to iron deficiency [43]
- in conjunction with other predisposing factors such as acute and chronic infections like malaria, tuberculosis, cancer, HIV.
- Others are malnutrition and haemoglobinopathies [26]

The consequences of Anaemia

- The harmful effects of under-five anaemia include long term cognitive disorder, impaired educational performance [40,45], retardation in physical growth, poor motor skill and language development [40], and increased risk of child mortality as a result of severe anaemia [26].
- Iron deficiency anaemia can lead to disability resulting in lost several years of healthy life [40].
- 89% of all cases of anaemia-related disabilities are associated with developing countries.

Rationale

- To effectively tackle the menace of anaemia a careful health intervention is needed
- Knowing the estimates of its prevalence, associated causes and risk factors are very crucial[40]
- Many pieces of literature have identified several risk factors associated with under-five anaemia cutting across child-, parental- household and community-related
- Given the rising trend of under-five anaemia, study to Identify and describe the various risk factors, analytical methods used, and an array of different survey types will be a useful tool to enhance future health science investigation [47] and intervention

The Aim

- The aim of this scoping review was to identify and evaluate studies that performed:
- Classical regression analysis on nationally representative health survey data
- To identify the individual socioeconomic, demographic and contextual risk factors
- Associated with developing anaemia among children under-five years of age in Sub-Sahara Africa (SSA)

Review Question

- The research question for this scoping review is:
- What are the risk factors determined using regression analysis methods that are associated with the development of/and/or presence of anaemia in children of under five years from secondary analysis of nationally representative health-related surveys in Sub-Sahara Africa countries

Methods and Design

- The pattern of reporting this scoping review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines [48,49]
- Studies included in the review followed the PICOTS (Participants, Interventions, Comparators, Outcomes, Timing, and Setting/Study Design) principles enumerated below
- These define the eligibility criteria for inclusion

Search strategies

- Databases and grey literature searched include: MEDLINE, EMBASE (OVID platform), Web of Science, PUBMED, Cumulative Index to Nursing and Allied Health Literature (CINAHL), African Journal of online (AJOL), Google Scholar, and Scopus. We supplemented the search with searching for relevant literature search's terms in 'Unishef' library, WhiteRose Research Online and MeasureDHS
- The search terms first carried out in PUBMED are: (demographic health survey OR AIDS indicator survey OR malaria Indicator survey OR multiple indicator cluster survey OR health survey OR MIS) AND (sub-Saharan Africa) AND (logistic regression OR multilevel regression OR multinomial logistic OR random-effects OR hierarchical OR fixed effects) AND (Anemi* OR Anaemi* OR Anaemia OR Haemoglobin OR Iron deficiency anaemia)

Results

- A total of 144 studies (publications) extracted from the electronic databases to include: Pubmed=140, Scopus=13, Medline=1,
- Another 43 studies from MeasureDHS, Google Scholar = 63 studies, Twenty-six (26) from the references of the included studies and AJOL =1.
- Grand total of 287 studies was captured. Duplicate studies (20) removed, then first scoping glance at the titles and abstracts eliminated further 215 studies (publications).
- Fifty-two (52) studies were subjected to full-text examination, 32 excluded with 20 publications retained for this review,

Results Profile by country of study

Country specific Articles	Number	%	References
Ghana	4	16.8	[51,53,61,64]
Ethiopia	4	16.8	[39,55,66,67]
Mali	1	4.2	[58]
Benin	1	4.2	[58]
Uganda	2	8.4	[62,63]
Tanzania	1	4.2	[65]
Malawi	4	16.8	[52,59,60,69]
Swaziland	1	4.2	[54]
Multi-countries	1	4.2	[56]
Togo	1	4.2	[57]
Cape Verde	1	4.2	[68]
Mozambique	1	4.2	[69]
Namibia	1	4.2	[69]
Zimbabwe	1	4.2	[69]
	24*	100	

Result Profile by Analytic Methods

Analytical Methods	N	%	References
Multivariate Linear Regression	2	8	[51,56]
Multivariate Logistic Regression	9	36	[49–51,54,55,57,59,61,65,]
Proportional Logistic Regression	2	8	[65,66]
Multilevel Regression	5	20	[39,55,58,60]
Generalised Linear Mixed Regression Model	5	20	[64,69]
Ordinal Logistic Regression	1	4	[62]
Multinomial Regression	1	4	[54]
Total	25*	100	

National Representative Survey Profile

Survey Type Specific	N	%
DHS	19	70
MIS	4	15
MNCS	1	4
MICS	2	7
NHS	1	4
Total	27*	100

Result Profile by Risk Factors

- The risk factors as captured from the pieces of literature are classified/reported as:
- Child-related
- Parental-related
- Household-related and
- Community-related factors.
- The tables for these are massive, so will only give the summary here

Summary of Risk Factors Profile: Childhood Factors

- Out of the twenty-four (24) unique country-based studies, only one study[53] did not consider the age of the child as part of child-related variables investigated.
- These studies found that the age of the child is a significant predictor of the development of anaemia among children of under-five years in SSA.
- The chances of having anaemia are much higher for children at lower age (below 24 months) than at the upper age [51,57,58,69,69]
- Almost all the studies in this scoping review reported significant variations in the status of anaemia by sex of the child
- Comorbidities of anaemia with having diarrhoea and fever (in the last two weeks before the survey) were reported in 12 (50%) and 11 (46%) studies respectively

Summary of Risk Factors Profile: Parental Factors

- Mother's educational status was reported in 21 (84%) of the studies, followed by mother's age (13 studies) and mother's anaemia status (12 studies).
- The results from most of these 21 studies (mother's educational status) showed that as the level of educational status of the mother increases, the chances that the child will develop anaemia drop.
- There was also a clear-cut pattern of how the variations in the mother's age affect the chance the child developing anaemia: the odds of having anaemia among children of under-five years as the mothers' age increase.

Summary of Risk Factors Profile: Household Factors

- Wealth status, a proxy of household socioeconomic status (with 21 studies) is one among many factors that drew more attention in this category of risk factors
- Most of the studies reported that the higher the wealth quintiles, the lower the risk of developing anaemia among under-five year anaemia [52,56,62,65].
- There was no clear cut of imbalance between rural and urban dwellers.
- For instance, Menon and Yoon [63], Mohammed et al [55] and Moschovis et al [56] reported protective effect for rural than for urban, while Ngnie-Teta et al [58]. Nambiema et al [57] and Dwumoh et al [70] found that it is more harmful to a child to develop anaemia in the rural area than in the urban area of SSA

Summary of Risk Factors Profile: Community Factors

- Community-based risk factors were not very popular in all the studies added to this review.
- The few factors that were of general importance include:
- The community poverty/wealth status (was computed as the mean per cent of the community wealthiest households), and
- Community female educational status (The mean per cent of women in the community that has primary education and above). There were only four studies that reported effects for these factors

Discussion

- Out of a total of forty-six (46) SSA countries [73], this scoping review could extract publications involving only fifteen (15) countries (representing 32%).
- In Nigeria, there are three nationally representative surveys [12,41,74] conducted with data on anaemia status
- Most studies included applied classical regression methods (Multivariate linear regression and logistics) that only evaluate risk factors at individual and household levels, without accounting for the area or contextual risk factors
- most of the studies have neglected these critical components of determinants of anaemia status among children of under-five years in SSA. This lack of consideration for area variables often leads to random effect errors (heterogeneity)

Discussion cont'd

- Comorbidities and multi-morbidity are typical health issues which in the past years are related to adults over 60 years [75].
- However, in the last few decades, it has increasingly becoming associated with children [35,76].
- How this can affect health system, particularly in SSA countries, is an emerging area for study[77].
- Determinants of co-existence of illness are better examined with multinomial analysis while using classical regression methods.
- In this scoping review, only one study used multinomial regression analysis [54]
- Results from any research that would investigate the overlapping associations in comorbidities and multi-morbidity could be exciting, and though it may require some methodological rigours, but urgently needed

Strength and weaknesses in the review

- In our view, this is likely to be the first scoping review to provide information concerning risk factors associated with anaemia in children of under-five using nationally representative surveys from Sub-Sahara Africa countries
- The rigorous checks from the teams involved from different institutions is a strength
- However, It is possible not to have identified all the papers in this area of research in view that we only included studies written in English [47].
- It is also possible that we omitted some insignificant risk factors during the charting of the extracted information
- We also did not evaluate the quality of the studies included due to the scoping review design [77]

Thank you for listening

D.4: PowerPoint slides of Rapid-Fire talk at RSS 2021 International conference

A Multilevel Mixed-Effect Ordinal Logistic Regression Analysis of Multimorbidity among Children 6-59 months of Age in Nigeria

Mr. Phillips Edomwonyi Obasohan (PhD Student)

School of Health and Related Research (ScHARR), University of Sheffield, Sheffield, United Kingdom.

Department of Liberal Studies, Niger State Polytechnics, Zungeru, Nigeria

PhD Supervisory Team

Prof Stephen J Walters[1], Dr Richard Jacques[1], Prof Dr Khaled Khatab[2]

[1] School of Health and Related Research (ScHARR), The University of Sheffield, [2] Faculty of Health and Wellbeing, Sheffield Hallam University, Sheffield, United Kingdom

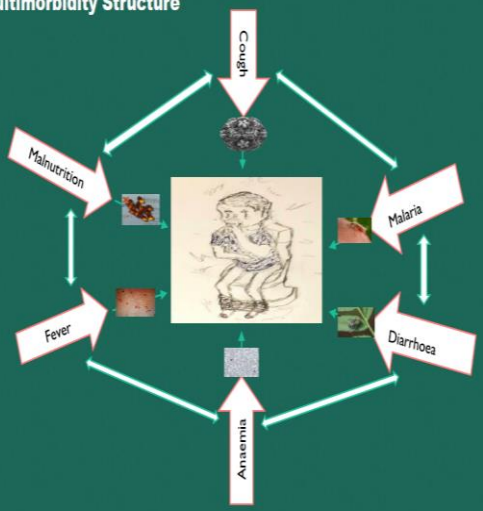
The University Of Sheffield.

NIGER STATE POLYTECHNIC ZUNGERU TECHNOLOGY FOR SELF-RELIANCE

1

1 Introduction

Multimorbidity Structure



- **Multimorbidity is the co-occurrence of two or more diseases in an individual without reference to an index disease (Abebe *et al*, 2020).**
- **Is an emerging public health concern in Low and Medium Income Countries (LMIC), especially among children under-5 years.**
- **The diseases interact, and therefore co-exist in the same epidemiological system and share common predictors (Khatab *et al*, 2016).**
- **Individual characterizations of the diseases using logistic regression are well established, but they do not recognize the interdependencies among the diseases and across the clusters. The focus of this study**

2

2 The Aims

The aims of this study are:

- **To investigate**
- **the prevalence, contextual variations and multiple overlaps in the determinants of order of occurrence of multimorbidity of diseases among children 6-59 months in Nigeria, using two national representative surveys: Nigeria Demographic and Health Survey (2018 NDHS), and National Human Development Report (2018 NHDR).**
- **Also, examine how much of the household socioeconomic status mediates the effect of area poverty index on multimorbidity.**

3

3 Statistical Analysis

- We adopted a four level analysis plan
- …..Third level: Multilevel mixed-effect ordered logistic regression of the occurrences of multimorbidity of the six overlapping disease conditions ….

- A three-**state multilevel model, such that individuals (level-1) are nested in communities (at level-2), and nested in states (at level-3), to properly account for the overlapping relationships in the interplay between six disease outcomes, categorized as 'no disease', 'one-disease', 'two-diseases', and 'three or more diseases', and coded as {0, 1, 2, 3}.**
- **Proportional odds assumption was naively tested, and upheld, using mean difference of predicted values for each individual in full and partial models, resulting to no significance at 5%.**
- **Alternative methods: (i) Multilevel multinomial logistic, (ii) Poison logistics regression, (iii) Multivariate joint model, but these methods have limitations for this research design.**

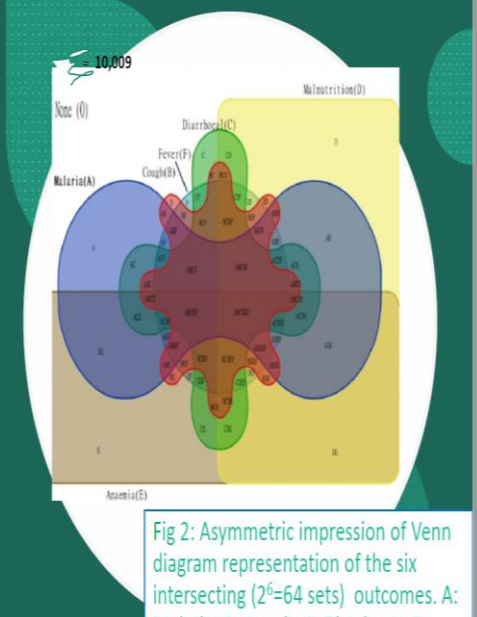
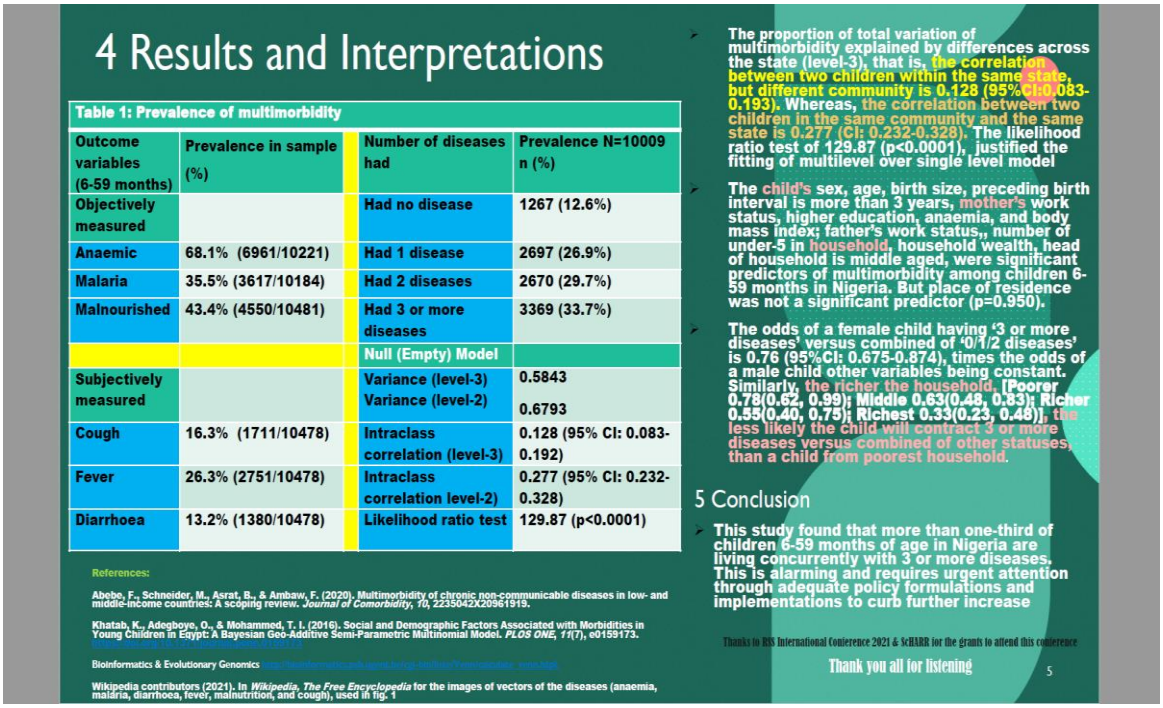


Fig 2: Asymmetric impression of Venn diagram representation of the six intersecting (2^6=64 sets) outcomes. A: Malaria, B: Cough, C: Diarrhoea, D: Malnutrition, E: Anaemia, F: Fever

4



4 Results and Interpretations

Table 1: Prevalence of multimorbidity

Outcome variables (6-59 months)	Prevalence in sample (%)	Number of diseases had	Prevalence N=10009 n (%)
Objectively measured		Had no disease	1267 (12.6%)
Anaemic	68.1% (6961/10221)	Had 1 disease	2697 (26.9%)
Malaria	35.5% (3617/10184)	Had 2 diseases	2670 (29.7%)
Malnourished	43.4% (4550/10481)	Had 3 or more diseases	3369 (33.7%)
		Null (Empty) Model	
Subjectively measured		Variance (level-3) Variance (level-2)	0.5843 0.6793
Cough	16.3% (1711/10478)	Intraclass correlation (level-3)	0.128 (95% CI: 0.083-0.192)
Fever	26.3% (2751/10478)	Intraclass correlation level-2)	0.277 (95% CI: 0.232-0.328)
Diarrhoea	13.2% (1380/10478)	Likelihood ratio test	129.87 (p<0.0001)

- The proportion of total variation of multimorbidity explained by differences across the state (level-3), that is, the correlation between two children within the same state, but different community is 0.128 (95%CI:0.083-0.193), Whereas, the correlation between two children in the same community and the same state is 0.277 (CI: 0.232-0.328). The likelihood ratio test of 129.87 (p<0.0001), justified the fitting of multilevel over single level model
- The child's sex, age, birth size, preceding birth interval is more than 3 years, mother's work status, higher education, anaemia, and body mass index; father's work status,, number of under-5 in household, household wealth, head of household is middle aged, were significant predictors of multimorbidity among children 6-59 months in Nigeria. But place of residence was not a significant predictor (p=0.950).
- The odds of a female child having '3 or more diseases' versus combined of '0/1/2 diseases' is 0.76 (95%CI: 0.675-0.874), times the odds of a male child other variables being constant. Similarly, the richer the household, [Poorer 0.78(0.62, 0.99); Middle 0.63(0.48, 0.83); Richer 0.55(0.40, 0.75); Richest 0.33(0.23, 0.48)], the less likely the child will contract 3 or more diseases versus combined of other statuses, than a child from poorest household.

5 Conclusion

- This study found that more than one-third of children 6-59 months of age in Nigeria are living concurrently with 3 or more diseases. This is alarming and requires urgent attention through adequate policy formulations and implementations to curb further increase

Thanks to RSS International Conference 2021 & ScHARR for the grants to attend this conference

Thank you all for listening

5

References:

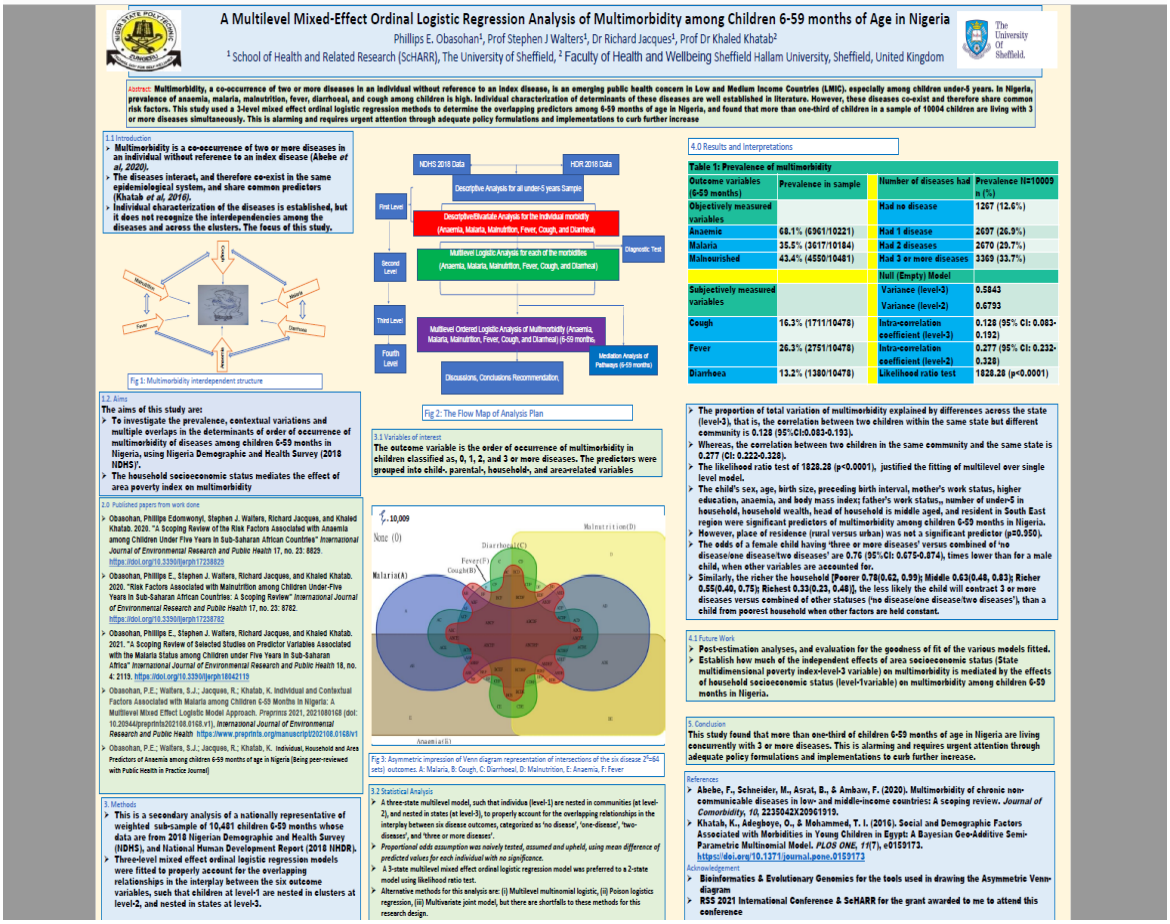
Abebe, F., Schneider, M., Asrat, B., & Ambaw, F. (2020). Multimorbidity of chronic non-communicable diseases in low- and middle-income countries: A scoping review. *Journal of Comorbidity, 10*, 2235042X20961919.

Khatab, K., Adegboye, O., & Mohammed, T. I. (2016). Social and Demographic Factors Associated with Morbidities in Young Children in Egypt: A Bayesian Geo-Additive Semi-Parametric Multinomial Model. *PLOS ONE, 11*(7), e0159173.

Bioinformatics & Evolutionary Genomics

Wikipedia contributors (2021). In *Wikipedia, The Free Encyclopedia* for the images of vectors of the diseases (anaemia, malaria, diarrhoea, fever, malnutrition, and cough), used in fig. 1

D.5: Poster presented at RSS (Manchester 2021) international conference



A Multilevel Mixed-Effect Ordinal Logistic Regression Analysis of Multimorbidity among Children 6-59 months of Age in Nigeria

Phillips E. Obasohan[1], Prof Stephen J Walters[1], Dr Richard Jacques[1], Prof Dr Khaled Khatab[2]

[1] School of Health and Related Research (ScHARR), The University of Sheffield, [2] Faculty of Health and Wellbeing Sheffield Hallam University, Sheffield, United Kingdom

Abstract: **Multimorbidity, a co-occurrence of two or more diseases in an individual without reference to an index disease, is an emerging public health concern in Low and Medium Income Countries (LMIC), especially among children under-5 years. In Nigeria, prevalence of anaemia, malaria, malnutrition, fever, diarrhoeal, and cough among children is high. Individual characterization of determinants of these diseases are well established in literature. However, these diseases co-exist and therefore share common risk factors. This study used a 3-level mixed effect ordinal logistic regression methods to determine the overlapping predictors among 6-59 months of age in Nigeria, and found that more than one-third of children in a sample of 10004 children are living with 3 or more diseases simultaneously. This is alarming and requires urgent attention through adequate policy formulations and implementations to curb further increase**

1.1 Introduction

- **Multimorbidity is a co-occurrence of two or more diseases in an individual without reference to an index disease (Abebe *et al, 2020*).**
- **The diseases interact, and therefore co-exist in the same epidemiological system, and share common predictors (Khatab *et al, 2016*).**
- **Individual characterization of the diseases is established, but it does not recognize the interdependencies among the diseases and across the clusters. The focus of this study.**

Fig 1: Multimorbidity interdependent structure

1.2. Aims

The aims of this study are:

- **To investigate the prevalence, contextual variations and multiple overlaps in the determinants of order of occurrence of multimorbidity of diseases among children 6-59 months in Nigeria, using Nigeria Demographic and Health Survey (2018 NDHS)'.**
- **The household socioeconomic status mediates the effect of area poverty index on multimorbidity**

2.0 Published papers from work done

- Obasohan, Phillipa Edomwonyi, Stephen J. Walters, Richard Jacques, and Khaled Khatab. 2020. "A Scoping Review of the Risk Factors Associated with Anaemia among Children Under Five Years in Sub-Saharan African Countries" *International Journal of Environmental Research and Public Health* 17, no. 23: 8829. https://doi.org/10.3390/ijerph17238829
- Obasohan, Phillipa E., Stephen J. Walters, Richard Jacques, and Khaled Khatab. 2020. "Risk Factors Associated with Malnutrition among Children Under-Five Years in Sub-Saharan African Countries: A Scoping Review" *International Journal of Environmental Research and Public Health* 17, no. 23: 8782. https://doi.org/10.3390/ijerph17238782
- Obasohan, Phillipa E., Stephen J. Walters, Richard Jacques, and Khaled Khatab. 2021. "A Scoping Review of Selected Studies on Predictor Variables Associated with the Malaria Status among Children under Five Years in Sub-Saharan Africa" *International Journal of Environmental Research and Public Health* 18, no. 4: 2119. https://doi.org/10.3390/ijerph18042119
- Obasohan, P.E.; Walters, S.J.; Jacques, R.; Khatab, K. Individual and Contextual Factors Associated with Malaria among Children 6-59 Months in Nigeria: A Multilevel Mixed Effect Logistic Model Approach. Preprints 2021, 2021080168 (doi: 10.20944/preprints202108.0168.v1). *International Journal of Environmental Research and Public Health* https://www.preprints.org/manuscript/202108.0168/v1
- Obasohan, P.E.; Walters, S.J.; Jacques, R.; Khatab, K. Individual, Household and Area Predictors of Anaemia among children 6-59 months of age in Nigeria (Being peer-reviewed with Public Health in Practice Journal)

3. Methods

- **This is a secondary analysis of a nationally representative of weighted sub-sample of 10,481 children 6-59 months whose data are from 2018 Nigerian Demographic and Health Survey (NDHS), and National Human Development Report (2018 NHDR).**
- **Three-level mixed effect ordinal logistic regression models were fitted to properly account for the overlapping relationships in the interplay between the six outcome variables, such that children at level-1 are nested in clusters at level-2, and nested in states at level-3.**

Fig 2: The Flow Map of Analysis Plan

3.1 Variables of interest

The outcome variable is the order of occurrence of multimorbidity in children classified as, 0, 1, 2, and 3 or more diseases. The predictors were grouped into child-, parental-, household-, and area-related variables

Fig 3: Asymmetric impression of Venn diagram representation of intersections of the six disease 2^6=64 sets) outcomes. A: Malaria, B: Cough, C: Diarrhoea, D: Malnutrition, E: Anaemia, F: Fever

3.2 Statistical Analysis

- A three-state multilevel model, such that individua (level-1) are nested in communities (at level-2), and nested in states (at level-3), to properly account for the overlapping relationships in the interplay between six disease outcomes, categorized as 'no disease', 'one-disease', 'two-diseases', and 'three or more diseases'.
- *Proportional odds assumption was naively tested, assumed and upheld, using mean difference of predicted values for each individual with no significance.*
- A 3-state multilevel mixed effect ordinal logistic regression model was preferred to a 2-state model using likelihood ratio test.
- Alternative methods for this analysis are: (i) Multilevel multinomial logistic, (ii) Poison logistics regression, (iii) Multivariate joint model, but there are shortfalls to these methods for this research design.

4.0 Results and Interpretations

Table 1: Prevalence of multimorbidity

Outcome variables (6-59 months)	Prevalence in sample	Number of diseases had	Prevalence N=10009 n (%)
Objectively measured variables		Had no disease	1267 (12.6%)
Anaemic	68.1% (6961/10221)	Had 1 disease	2697 (26.9%)
Malaria	35.5% (3617/10184)	Had 2 diseases	2670 (29.7%)
Malnourished	43.4% (4550/10481)	Had 3 or more diseases	3369 (33.7%)
		Null (Empty) Model	
Subjectively measured variables		Variance (level-3) Variance (level-2)	0.5843 0.6793
Cough	16.3% (1711/10478)	Intra-correlation coefficient (level-3)	0.128 (95% CI: 0.083-0.192)
Fever	26.3% (2751/10478)	Intra-correlation coefficient (level-2)	0.277 (95% CI: 0.232-0.328)
Diarrhoea	13.2% (1380/10478)	Likelihood ratio test	1828.28 (p<0.0001)

- **The proportion of total variation of multimorbidity explained by differences across the state (level-3), that is, the correlation between two children within the same state but different community is 0.128 (95%CI:0.083-0.193).**
- **Whereas, the correlation between two children in the same community and the same state is 0.277 (CI: 0.222-0.328).**
- **The likelihood ratio test of 1828.28 (p<0.0001), justified the fitting of multilevel over single level model.**
- **The child's sex, age, birth size, preceding birth interval, mother's work status, higher education, anaemia, and body mass index; father's work status,, number of under-5 in household, household wealth, head of household is middle aged, and resident in South East region were significant predictors of multimorbidity among children 6-59 months in Nigeria.**
- **However, place of residence (rural versus urban) was not a significant predictor (p=0.950).**
- **The odds of a female child having 'three or more diseases' versus combined of 'no disease/one disease/two diseases' are 0.76 (95%CI: 0.675-0.874), times lower than for a male child, when other variables are accounted for.**
- **Similarly, the richer the household [Poorer 0.78(0.62, 0.99); Middle 0.63(0.48, 0.83); Richer 0.55(0.40, 0.75); Richest 0.33(0.23, 0.48)], the less likely the child will contract 3 or more diseases versus combined of other statuses ('no disease/one disease/two diseases'), than a child from poorest household when other factors are held constant.**

4.1 Future Work

- **Post-estimation analyses, and evaluation for the goodness of fit of the various models fitted.**
- **Establish how much of the independent effects of area socioeconomic status (State multidimensional poverty index-level-3 variable) on multimorbidity is mediated by the effects of household socioeconomic status (level-1variable) on multimorbidity among children 6-59 months in Nigeria.**

5. Conclusion

This study found that more than one-third of children 6-59 months of age in Nigeria are living concurrently with 3 or more diseases. This is alarming and requires urgent attention through adequate policy formulations and implementations to curb further increase.

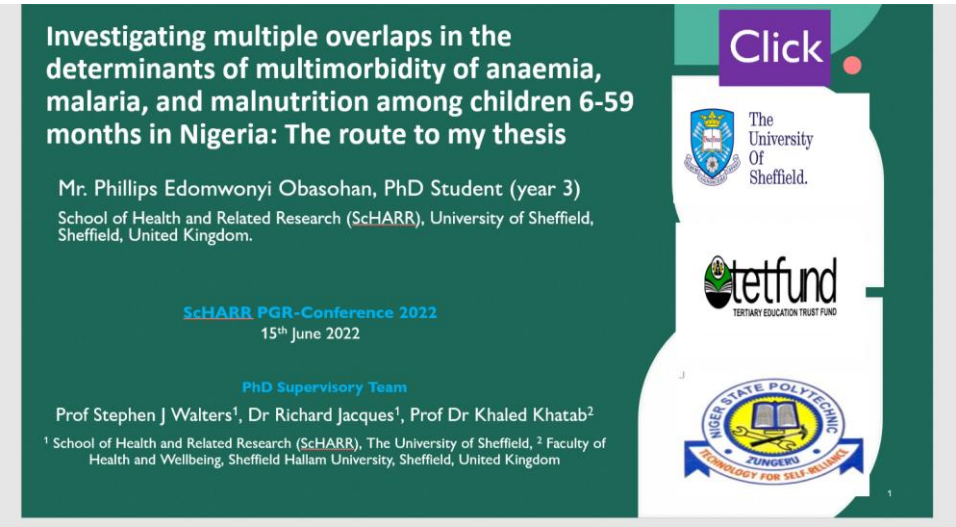
References

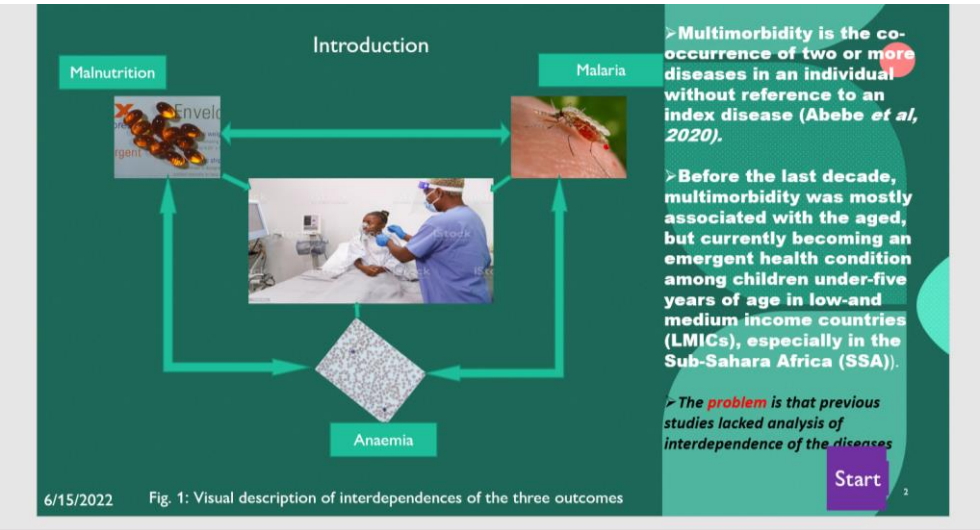
- **Abebe, F., Schneider, M., Asrat, B., & Ambaw, F. (2020). Multimorbidity of chronic non-communicable diseases in low- and middle-income countries: A scoping review. *Journal of Comorbidity, 10*, 2235042X20961919.**
- **Khatab, K., Adegboye, O., & Mohammed, T. I. (2016). Social and Demographic Factors Associated with Morbidities in Young Children in Egypt: A Bayesian Geo-Additive Semi-Parametric Multinomial Model. *PLOS ONE, 11*(7), e0159173. https://doi.org/10.1371/journal.pone.0159173**

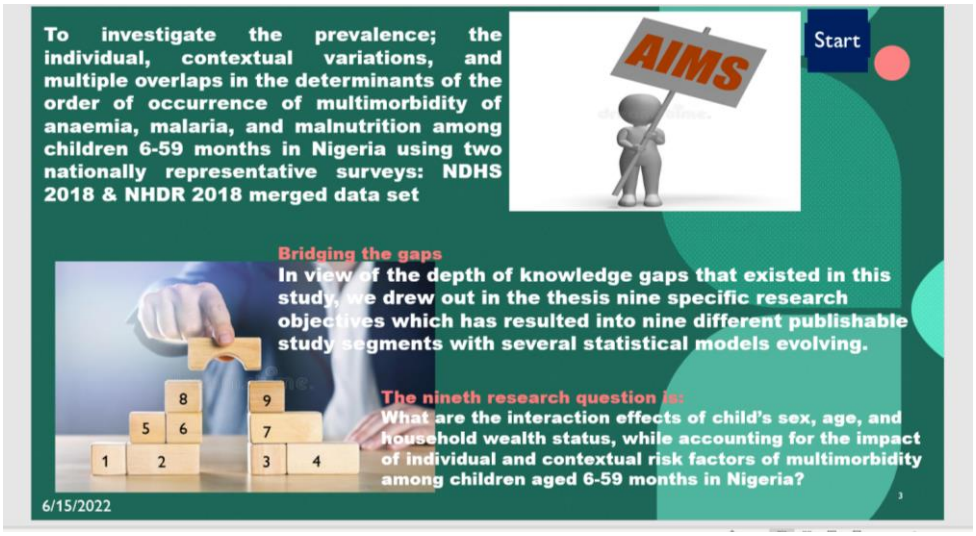
Acknowledgement

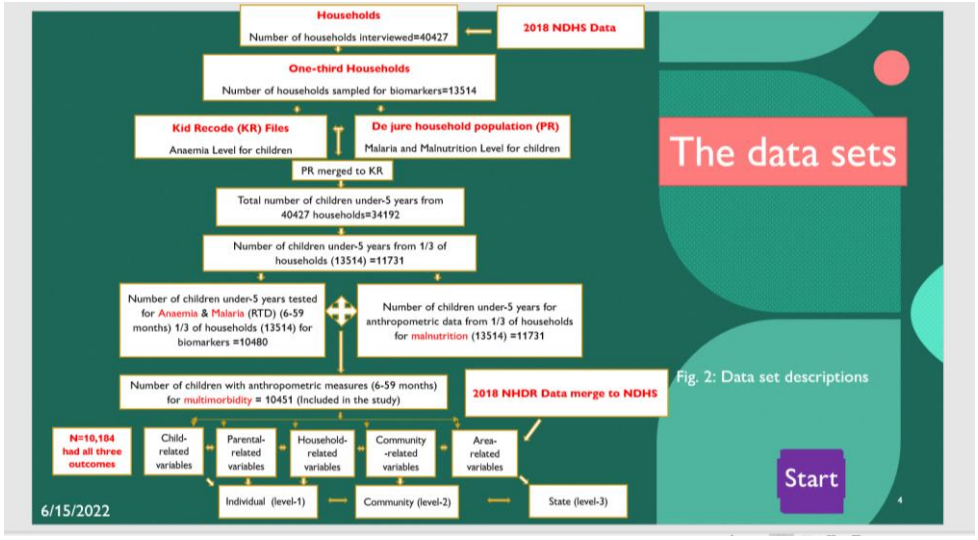
- **Bioinformatics & Evolutionary Genomics for the tools used in drawing the Asymmetric Venn-diagram**
- **RSS 2021 International Conference & ScHARR for the grant awarded to me to attend this conference**

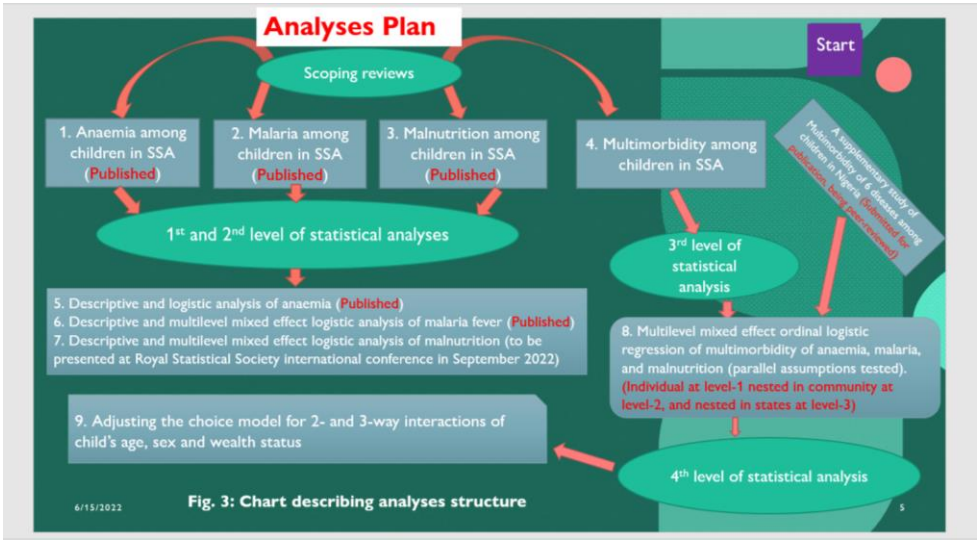
D.6: PowerPoint slides for paper presented at ScHARR PGR 2022 conference

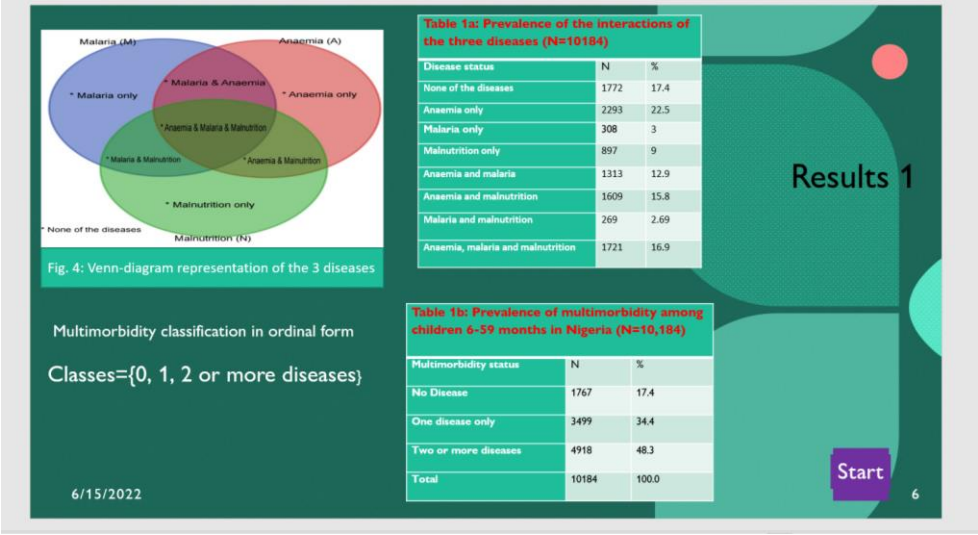







Households
Number of households interviewed=40427
2018 NDHS Data
One-third Households
Number of households sampled for biomarkers=13514
Kid Recode (KR) Files
Anaemia Level for children
De jure household population (PR)
Malaria and Malnutrition Level for children
PR merged to KR
Total number of children under-5 years from 40427 households=34192
Number of children under-5 years from 1/3 of households (13514) =11731
Number of children under-5 years tested for Anaemia & Malaria (RTD) (6-59 months) 1/3 of households (13514) for biomarkers =10480
Number of children under-5 years for anthropometric data from 1/3 of households for malnutrition (13514) =11731
Number of children with anthropometric measures (6-59 months) for multimorbidity = 10451 (Included in the study)
2018 NHDR Data merge to NDHS
N=10,184 had all three outcomes
Child-related variables
Parental-related variables
Household-related variables
Community-related variables
Area-related variables
Individual (level-1)
Community (level-2)
State (level-3)
6/15/2022
The data sets
Fig. 2: Data set descriptions
Start


Analyses Plan
Start
Scoping reviews
1. Anaemia among children in SSA (Published)
2. Malaria among children in SSA (Published)
3. Malnutrition among children in SSA (Published)
4. Multimorbidity among children in SSA
A supplementary study of Multimorbidity of 6 diseases among children in Nigeria (Submitted for publication, being peer-reviewed)
1st and 2nd level of statistical analyses
3rd level of statistical analysis
5. Descriptive and logistic analysis of anaemia (Published)
6. Descriptive and multilevel mixed effect logistic analysis of malaria fever (Published)
7. Descriptive and multilevel mixed effect logistic analysis of malnutrition (to be presented at Royal Statistical Society international conference in September 2022)
8. Multilevel mixed effect ordinal logistic regression of multimorbidity of anaemia, malaria, and malnutrition (parallel assumptions tested). (Individual at level-1 nested in community at level-2, and nested in states at level-3)
9. Adjusting the choice model for 2- and 3-way interactions of child's age, sex and wealth status
4th level of statistical analysis
6/15/2022
Fig. 3: Chart describing analyses structure


Malaria (M)
Anaemia (A)
Malnutrition (N)
* Malaria only
* Malaria & Anaemia
* Anaemia only
* Anaemia & Malaria & Malnutrition
* Malaria & Malnutrition
* Anaemia & Malnutrition
* Malnutrition only
* None of the diseases
Fig. 4: Venn-diagram representation of the 3 diseases
Table 1a: Prevalence of the interactions of the three diseases (N=10184)
Disease status | N | %
None of the diseases | 1772 | 17.4
Anaemia only | 2293 | 22.5
Malaria only | 308 | 3
Malnutrition only | 897 | 9
Anaemia and malaria | 1313 | 12.9
Anaemia and malnutrition | 1609 | 15.8
Malaria and malnutrition | 269 | 2.69
Anaemia, malaria and malnutrition | 1721 | 16.9
Results 1
Multimorbidity classification in ordinal form
Classes={0, 1, 2 or more diseases}
Table 1b: Prevalence of multimorbidity among children 6-59 months in Nigeria (N=10,184)
Multimorbidity status | N | %
No Disease | 1767 | 17.4
One disease only | 3499 | 34.4
Two or more diseases | 4918 | 48.3
Total | 10184 | 100.0
6/15/2022
Start

In all 31 models were fitted ((5+4+6+11) models + 5 interaction terms)

- Model 10 which contained all the variables considered in this analysis was adjudged as one with the best goodness of fit.
- The child's sex, age, birth size, preceding birth interval is 12-24 months, child is dewormed, had fever, mother's education status, is anaemic, and body mass index; household, household wealth, community wealth status, community distance to health facility, region and place of residence, were significant predictors of multimorbidity of anaemia, malaria, malnutrition among children 6-59 months in Nigeria.
- The proportional odds of a female child having '2 or more diseases' versus combined of '0/1 diseases' is 0.73 (95%CI: 0.67-0.80), times the proportional odds of a male child holding other variables constant.
- Similarly, the wealthier the household, [Poorer 0.78(0.62, 0.99); Middle 0.69 (0.56, 0.86); Richer 0.56(0.44, 0.72); Richest 0.38(0.29, 0.50)], the less likely the children will contract 2 or more diseases versus combined of other statuses, compared to children from poorest households.

Start

Results 2

Table 2: Multilevel mixed effect ordinal logistic

	Multimorbidity (N=7794)-Model 10 (Level 1, 2, & 3 factors only)		
Variables	AOR	p-value	95% CI
Child's sex			
Male	1		
Female	0.73	<0.001	0.67, 0.80
....	....	....	....
Household wealth index			
Poorest	1		
Poorer	0.86	0.12	0.72, 1.04
Middle	0.69	<0.001	0.56, 0.86
Richer	0.56	<0.001	0.44, 0.72
Richest	0.38	<0.001	0.29, 0.50
....	....	....	....

6/15/2022 7

(Child's sex, age, and household wealth quintiles) were classified in four possible interaction groups to include, three 2-way, and one 3-way classifications: child's sex and wealth status; child's sex and age; child's age and wealth status; and child's sex, age, and wealth status

Table 2: Distribution of model fit with interaction terms added

Model (N=7794)	Number of covariates	Log-likelihood	AIC	BIC
Model 11	Model 10 covariates + child's sex * wealth status	-6933.6	14015.1	14530.2
Model 12	Model 10 covariates + child's sex * age	-6933.4	14014.8	14529.9
Model 13	Model 10 covariates + child's age * wealth status	-6902.6	13977.3	14575.9
Model 14	Model 10 covariates + child's sex * wealth status + child's sex * age + child's age * wealth status	-6898.5	13985.03	14639.4
Model 15	Model 14 covariates + child's sex * age * wealth status	-6890.8	14001.6	14767.4

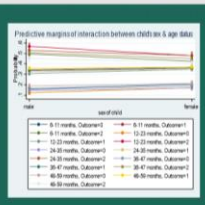
AIC=Akaike information criterion, BIC=Bayesian information criterion

6/15/2022

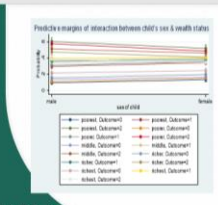
Research question 9:
What are the interaction effects of child's sex, age, and household socioeconomic status on the impact of individual and contextual risk factors of multimorbidity of anaemia, malaria, and malnutrition among children 6-59 months of age in Nigeria?

Start

8



(a) No interaction effect between child's sex and wealth quintiles



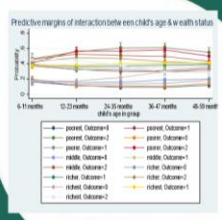
(b) No inte... between child's sex and age

(c) No interaction effect between child's sex, age wealth status

Fig. 5 (a-d): Graphs for interaction terms

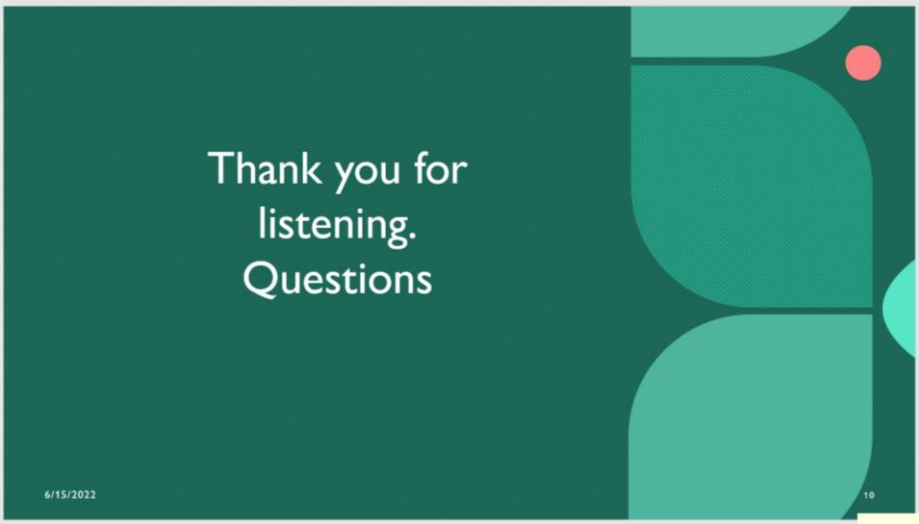
Interpretation of part result

The proportional odds of children aged 24-35 months cohabiting with '2 or more diseases' versus combined of '0/1 disease' and live in richest households was significantly 0.66 lower than the proportional odds for children aged 24-35 months and reside in poorest households when other covariates in model 10 (Chosen model) were held constant



(d) Interaction effect between child's age and wealth status

6/15/2022 9


Thank you for
listening.
Questions
6/15/2022
10

Appendix E: Computer coding for analyses

I acknowledged that some of the codes used in this thesis were extracted from different sources that addressed some specific problems. Some of these codes were obtained from Stata manual, Stata Forum, dhs userforum, etc. These codes are publicly available for use

E.1 Baseline description analyses

```
***I acknowledged that some parts of the coding were extracted from different sources especially from Stata forum and manuals******
***Merging Household file to children File****
***Use Household File Identifiers for PR***
use "D:\UNIVERSITY OF SHEFFIELD MATTERS\STATA DATA SET\NGPR7ADT\NGPR7AFL.DTA", clear
rename hv001 v001
rename hv002 v002
rename hvidx mergeid

sort v001 v002 mergeid
gen in_PR=1

save temp.dta, replace

***Use Children File Identifiers****

use "D:\UNIVERSITY OF SHEFFIELD MATTERS\STATA DATA SET\NGKR7AFL.DTA", clear

rename b16 mergeid
sort v001 v002 mergeid
gen in_KR=1

*** Merging the PR and KR Files****

merge m:1 v001 v002 mergeid using temp.dta

keep if in_PR==1 & in_KR==1
tab _merge

****Analysis of Description of Malnutrition among under-5 children in Nigeria*****

***Perform weighting to correct for over and under sample****
gen weight=v005/1000000
svyset [pw=weight], psu(v021) strata (v022)
svydes, single
replace v022=58 if v022==60

****Keep subsample of children under-5 years and child is alive****
keep if hc1>5 & hc1<60

***Recode under-5 child's age in group***
```

```
recode hc1 (0/5=0 "less 6 months")(6/11=1 "6-11 months")(12/23=2 "12-23
months")(24/35=3 "24-35 months")(36/47=4 "36-47 months")(48/59=5 "48-59 months"),
gen(chldage1)
label var chldage1 "child's age in group"
tab chldage1 [iw=weight]

***Recode under-5 age another way*******

recode hc1 (0/5=0 "less 6 months")(6/18=1 "6-18 months")(19/30=2 "19-30
months")(31/42=3 "31-42 months")(43/59=4 "43-59 months"), gen(chldage)
label var chldage "child's age in group"
tab chldage [iw=weight]

gen chage=.
replace chage=. if chldage==0
replace chage=1 if chldage==1
replace chage=2 if chldage==2
replace chage=3 if chldage==3
replace chage=4 if chldage==4
lab define chage 1 "6-18 months" 2"19-30 months" 3"31-42 months" 4"43-59 months"
label var chage "Age of child 6-59 months"
label values chage chage

******Age could be used as continous variable*******

***Tabulate Children under-5 by sex****
tab b4 [iw=weight]

****Recode of Outcome Variables*****

****Outcome variable 1*****
*** Malaria Status by Rapid Diagnostic Test****
codebook hml35
tab hml35 [iw=weight]

*** Malaria Status by Microscopic Blood Smear Examination****
codebook hml32
tab hml32 [iw=weight]

*****Test of independence between the two results*****
spearman hml35 hml32

****Outcome variable 2*****
****Anaemia Status****
codebook hw57
recode hw57(1/3=1 "Anaemic")(4=0 "Not Anaemic"), gen(anaesta)
label var anaesta "Anaemia status"
tab anaesta [iw=weight]
tab hw57 [iw=weight]
```

```
****Outcome variable 3*****
****Malnutrition Status***
***Children who stayed in the household the previous night and who have height and weight z-scores on all 3 measures****
gen eligch = 0
replace eligch = 1 if (hv103==1 & hc70 < 9996 & hc71 < 9996 & hc72 < 9996)

// child stunting calculation
codebook hc70
tab hc70 if hc70>9990,m
tab hc70 if hc70>9990,m nolabel
gen HAZ=hc70
replace HAZ=. if HAZ>=9996
gen stunted=0
replace stunted=0 if HAZ ~=.
replace stunted=1 if HAZ<-200
lab define stunted 0 "not anaemic" 1 "anaemic"
lab var stunted "Stunting Status of Children"

// child wasting calculation
codebook hc72
tab hc72 if hc72>9990,m
tab hc72 if hc72>9990,m nolabel
gen WAH=hc72
replace WAH=. if WAH>=9996
gen wasted=0
replace wasted=0 if WAH ~=.
replace wasted=1 if WAH<-200
lab define wasted 0 "not wasted" 1 "wasted"
lab var wasted "wasting Status of Children"

// child underweight calculation
codebook hc71
tab hc71 if hc71>9990,m
tab hc71 if hc71>9990,m nolabel
gen WAZ=hc71
replace WAZ=. if WAZ>=9996
gen underweight=0
replace underweight=0 if WAZ ~=.
replace underweight=1 if WAZ<-200
lab define underweight 0 "not underweight" 1 "underweight"
lab var underweight "Underweight Status of Children"

// child overweight calculation
codebook hc72
tab hc72 if hc72>9990,m
tab hc72 if hc72>9990,m nolabel
gen WAH2=hc72
replace WAH2=. if WAH2>=9996
gen overweight1=0
```

```
replace overweight1=0 if WAH2 ~=.
replace overweight1=1 if WAH2>200 & WAH2<9990
lab define overweight1 0 "not overweight" 1 "overweight"
lab var overweight "Overweight Status of Children"

tab stunted [iw=weight]
tab wasted [iw=weight]
tab underweight [iw=weight]
tab overweight [iw=weight]

***Generate Malnutrition Status*****
gen malnut=stunted+wasted+underweight+overweight
tab malnut
recode malnut(0=0 "well-nourished")(1/4=1 "poorly nourished"), gen(nutrista)
lab var nutrista "Nutrition Status of Children"
tab nutrista [iw=weight]
tab nutrista [iw=weight], nolabel

****Diarrhael Recode****
gen diarr=.
replace diarr=0 if h11==0
replace diarr=1 if h11==2
replace diarr=. if h11==3
lab define diarr 0 "No diarrhael" 1 "Had diarrhael"
lab var diarr "Diarrhael status"

****Cough Recode****
gen cough=.
replace cough=0 if h31==0
replace cough=1 if h31==2
replace cough=. if h31==8
lab var cough "Cough status"
lab define cough 0 "had no cough" 1 "Had cough"

gen fever=.
replace fever=0 if h22==0
replace fever=1 if h22==1
replace fever=. if h22==8
lab define fever 0 "No" 1 "Yes"
label var fever "Had Fever in last 2 weeks"

*****Recodes for Predictors or covariates*******

****Recode of Child Variables ****
recode m18 (1=0 "large size") (2/3=1 "Average size")(4/5=2 "small size")(6/max=3 "I don't
Know"), gen(bszgr)
lab var bszgr "Child perceived size at birth"

***Recode birth size*****
gen bszgr1=.
```

```
replace bszgr1=0 if bszgr==0
replace bszgr1=1 if bszgr==1
replace bszgr1=2 if bszgr==2
replace bszgr1=. if bszgr==3
lab define bszgr1 0 "large" 1 "Average" 2 "Small"
label var bszgr1 "Child's birth Size"

*****Child birth order****
recode bord (1=0 "1st") (2/3=1 "2nd or 3rd")(4/6=2 "4-6 th")(7/max=3 "7th+"), gen(brdgr)
lab var brdgr "Child Birth Order"

****Birth order can be used as continuous variable******

****Number of under-5 in household******
recode hv014 (0/3=0 "0-3") (4/6=1 "4-6")(7/max=2 "7th+"), gen(u5hhd)
lab var u5hhd "Under-5 in household"

****REcode of household size*****
recode hv009 (0/3=0 "0-3") (4/6=1 "4-6")(7/9=2 "7-9")(10/max=3 "more than 10"),
gen(hhdsz)
lab var hhdsz "household member size"

****Recode of place of delivery*****
recode m15 (11/12=0 "home")(21 22 23 26=1 "Public Health facility")(31 36=2 "Private
Health Facility"), gen(pladel)
lab var pladel "Place of Delivery"

gen pldel=.
replace pldel=0 if pladel==0
replace pldel=1 if pladel==1
replace pldel=2 if pladel==2
replace pldel=3 if pladel==96
lab define pldel 0 "home" 1 "Public Facility" 2 "Private facility" 3 "elsewhere"
lab var pldel "Place of child's del"

gen dworm=.
replace dworm=0 if h43==0
replace dworm=1 if h43==1
replace dworm=. if h43==8
lab define dworm 0 "No" 1 "Yes"
label var dworm "Took deworming drug in last 6months"

gen vita=.
replace vita=0 if h34==0
replace vita=1 if h34==1
replace vita=. if h34==8
lab define vita 0 "No" 1 "Yes"
label var vita "Took Vit A supplements"

gen ironsup=.
```

```
replace ironsup=0 if h42==0
replace ironsup=1 if h42==1
replace ironsup=. if h42==8
lab define ironsup 0 "No" 1 "Yes"
label var ironsup "Took Iron supplements"

recode v465 (1 2 5=0)(3 4 9=1)(96=2), gen(stooldisp)

gen stooldis1=.
replace stooldis1=0 if stooldisp==0
replace stooldis1=1 if stooldisp==1
replace stooldis1=. if stooldisp==2
lab define stooldis1 0 "Proper disposal" 1 "Improper disposal"
label var stooldis1 "Youngest Child's stool disposed Properly"


****Recode of Parental/Mother/Care-givers Variables ****
recode v013 (1/2=0 "15-24 years") (3/4=1 "25-34 years") (5/7=2 "35 years+"), gen(magegr)
label var magegr "Maternal age group in 10years"


****Use maternal age as given in data set v013*******

recode hv220 (min/34=0 "less 34 years")(35/44=2 "35-44 years")(45/55=3 "45-55
years")(56/max=4 "56 years+"), gen(hhagegr)
label var hhagegr "Household Head age group"

recode v212 (10/24=0 "10-24")(25/36=1 "25-36")(37/49=2 "37-49") (37/max=3 "37-49"),
gen(agefbth2)
label var agefbth2 "age at first birth"

recode b11(8/24=0 "8-24 months")(25/35=1 "25-35 months")(36/59=2 "36-59
months")(60/max=3 "60+ months"), gen(prbrthint)
label var prbrthint "preceeding birth interval"

*****New prebirthint*****
gen newprbth=.
replace newprbth=0 if brdgr==0
replace newprbth=1 if prbrthint==0
replace newprbth=2 if prbrthint==1
replace newprbth=3 if prbrthint==2
replace newprbth=4 if prbrthint==3
lab define newprbth 0 "None" 1 "8-24 months" 2 "25-35 months" 3 "36-59 months" 4 "60+
months", modify
label var newprbth "New prebirth interval"
label values newprbth newprbth


recode v130(1=0 "catholic")(2=1 "other christian")(3=2 "islam")(4/max=3
"traditionalist&others"), gen(relsta)
```

```
label var relsta "mother's religious status"

gen pworksta=.
replace pworksta=0 if v705==0
replace pworksta=1 if v705>0
lab define pworksta 0 "not working" 1 "working"
label var pworksta "Husband Work Status"

gen pedusta=.
replace pedusta=0 if v701==0
replace pedusta=1 if v701==1
replace pedusta=2 if v701==2
replace pedusta=3 if v701==3
replace pedusta=. if v701==8
lab define pedusta 0 "no education" 1 "primary" 2 "secondary" 3 "higher"
label var pedusta "mother's partner education status"

****Mother's Anaemia Status****
recode v457(1/3=1 "Anaemic")(4=0 "Not Anaemic"), gen(manaesta)
label var manaesta "Mother's Anaemia status"
tab manaesta [iw=weight], missing

gen mirontab=.
replace mirontab=0 if m45==0
replace mirontab=1 if m45==1
replace mirontab=. if m45==8
lab define mirontab 0 "no" 1 "yes"
label var mirontab "took iron tab during pregnancy"

recode m14 (0=0 "No ANC Visit") (1/3=1 "ANC Visit less WHO REC") (4/20=2 "ANC
Visit Met WHO REC")(21/max=3 "Dont Remember Visiting ANC"), gen(ancvis)
label var ancvis "ANC Visit"

gen ancvis1=.
replace ancvis1=0 if ancvis==0
replace ancvis1=1 if ancvis==1
replace ancvis1=2 if ancvis==2
replace ancvis1=. if ancvis==3
lab define ancvis1 0 "none" 1 "less who rec" 2 "met who rec"
label var ancvis1 "ANC visits during pregnancy"


recode v131(2 3 8=0 "Hausa/Fulani/KanuriSeribiri")(6=1 "Ibos")(10=2 "Yorubas")(else=3
"Others"), gen(ethgr2)
label var ethgr2 "Ethnicity"

***Recoding - Maternal Decision Making Level*****
gen healthcare=0
replace healthcare=1 if v743a==1
replace healthcare=2 if v743a==2
```

```
replace healthcare=3 if v743a==3
replace healthcare=4 if v743a>3 & v743a<10
gen lpurchase=0
replace lpurchase=1 if v743b==1
replace lpurchase=2 if v743b==2
replace lpurchase=3 if v743b==3
replace lpurchase=4 if  v743b>3 & v743b<10
gen dpurchase=0
replace dpurchase=1 if v743c==1
replace dpurchase=2 if v743c==2
replace dpurchase=3 if v743c==3
replace dpurchase=4 if v743c>3 & v743c<10
gen  fvisit=0
replace fvisit=1 if v743d==1
replace fvisit=2 if v743d==2
replace fvisit=3 if v743d==3
replace fvisit=4 if v743d>3 & v743d<10
gen auto1=0
replace auto1=2 if healthcare<3
replace auto1=1 if healthcare>2 & healthcare<10
gen auto2=0
replace auto2=2 if lpurchase<3
replace auto2=1 if lpurchase>2 & lpurchase<10
gen auto4=0
replace auto4=2 if fvisit<3
replace auto4=1 if fvisit>2 & fvisit<10
tab1 auto*
***Generating Maternal Autonomylevel****
gen autonomyscore1=auto1+auto2+auto4
tab autonomyscore1
su autonomyscore1
recode autonomyscore1 (3/4=0 "low Auto") (5/8=1 "more auto"), gen(autonomylevel1)
lab val autonomylevel1 autonomylevel1
tab autonomylevel1 [iw=weight], missing

**Generating Maternal BMI status*****
gen ht_flag=0
replace ht_flag=1 if v438>9000
gen preg_flag=0
replace preg_flag=1 if v213==1
gen months_since_last_birth=v008-b3
gen recent_birth_flag1=0
replace recent_birth_flag1=1 if months_since_last_birth <=2

gen bmi=v445/100
gen bmic=2 if bmi<18.5
replace bmic=1 if bmi>=18.5 & bmi<25
replace bmic=3 if bmi>=25 & bmi<30
replace bmic=4 if bmi>=30 & bmi<60
label define bmic 1"Normal" 2 "Underweight" 3"Overweight" 4"Obese"
```

```
label values bmic bmic
svy: tab bmic, count percent format(%4.1f) col

****Generate Maternal BMI*****

gen mbmi=bmic if ht_flag==0 & preg_flag==0 & recent_birth_flag1==0
label define mbmi 1 "Normal" 2 "underweight" 3 "Overweight" 4 "Obese"
label values mbmi mbmi


****Recode of Household Variables ****
gen shatoi1=.
replace shatoi1=0 if v160==0
replace shatoi1=1 if v160==1
replace shatoi1=. if v160==7
label define shatoi1 0 "No" 1 "Yes"
label var shatoi1 "Shared Toilet Facilities"

recode hv226(1/4=0)(5/10=1)(11/max=2), gen(cookfuel2)
label var cookfuel2 "Cooking Fuel Used"

gen cookfue=.
replace cookfue=0 if cookfuel2==0
replace cookfue=1 if cookfuel2==1
replace cookfue=. if cookfuel2==3
label define cookfue 0 "Elect&Gas" 1 "Biofuel"
label var cookfue "Type of cooking fuel"

***Recode floor material types***
recode hv213(11 12 96=0 "unimproved floor materials")(21 22 31 32 33 34 35=1 "improved
floor materials"), gen(floormat)
label var floormat "Floor Materials"

***Recode roof material types***
recode hv215(11 12 13 21 22 23 24 96=0 "unimproved roof materials")(31 32 33 34 35 36=1
"improved roof materials"), gen(roofmat)
label var roofmat "Roof Materials"

***Recode wall material types***
recode hv214(11 12 13 21 22 23 24 25 26 96=0 "unimproved wall materials")(31 32 33 34 35
36=1 "improved wall materials"), gen(wallmat)
label var wallmat "wall Materials"

***Recode Number of rooms for sleep***
recode hv216(1=0 "One-room")(2=1 "two rooms")(3=2 "three rooms")(4=3 "Four
rooms")(5/max=4 "Five+ rooms"), gen(rmsleep)
label var rmsleep "Number of rooms for sleep"

***Recode Scource of drinking water***
```

```
recode hv201(32 42 43 61 62 96=0 "unimproved drinking water")(11 12 13 14 21 31 41 51
71 92=1 "improved drinking water"), gen(watascou1)
label var watascou1 "source of drinking water"

***Recode type of toilet facility***
recode hv205(14 15 23 31 42 43 96=0 "unimproved toilet factories")(11 12 13 16 21 22 41=1
"improved toilet factories"), gen(toilfac1)
label var toilfac1 "type of toilet facility"

gen electr=.
replace electr=0 if v119==0
replace electr=1 if v119==1
replace electr=. if v119==3
lab define electr 0 "No" 1 "Yes"
label var electr "Household had electricity"

***Generating Cluster Variables****

*****Generating proportion of cluster wealth status**********
bysort v001: egen cuwealth1=mean(v190)
bysort v001: egen cuwe1= count(v190)


sum cuwealth1, detail          //you will find median

gen clwea3=.
replace clwea3=1 if cuwealth1<3
replace clwea3=2 if cuwealth1==3
replace clwea3=3 if cuwealth1>3

recode clwea3(1=0 "low") (2/3=1 "high"), gen(cluwealth2)
lab var cluwealth2 "Cluster wealth level"
lab values cluwealth2 cluwealth2
tab cluwealth2 [iw=weight]

******Generating cluster maternal education status*****
bysort v001: egen cumatedu2=mean(v106)
bysort v001: egen cumate2= count(v106)


sum cumatedu2, detail          //you will find median

gen clmated2=.
replace clmated2=1 if cumatedu2<1.2
replace clmated2=2 if cumatedu2==1.2
replace clmated2=3 if cumatedu2>1.2

recode clmated2(1=0 "low") (2/3=1 "high"), gen(clumated1)
lab var clumated1 "Cluster maternal education level"
lab values clumated1 clumated1
```

```
tab clumated1 [iw=weight]

*****Generating proportion of respondents with distance to health facility is no problem in cluster*****
recode v467d(1=0 "big problem")(2=1 "no big problem"), gen(dismed)
bysort v001: egen cudistmed=mean(dismed)
sum cudistmed, detail          //you will find median

gen cludistm=.
replace cludistm=0 if cudistmed<0.8
replace cludistm=1 if cudistmed>=0.8
lab define cludistm 0 "low" 1 "high"
lab var cludistm "low cluster distance to health facility"
lab values cludistm cludistm
tab cludistm [iw=weight]

****Generating proportion of respondent with no cluster household with bed net*******
recode hv227(0=1 "no bed net")(1=0 "Yes"), gen(bnet)
bysort v001: egen hdbnet=mean(bnet)
sum hdbnet, detail          //you will find median

gen cluhdbnet=.
replace cluhdbnet=0 if hdbnet<0.25
replace cluhdbnet=1 if hdbnet>=0.25

lab define cluhdbnet 0 "low" 1 "high"
lab var cluhdbnet "low cluster household with no bed net"
lab values cluhdbnet hdbnet

tab cluhdbnet [iw=weight]

***Recoding Area Variables using UNDP data set into NDHS****
***Classifying state by Multidimensional poverty Index*****

recode sstate(10 40 50=0 "Highly Deprived")(20 30 60 80 90 100 120 160 170=1 "Above averagely deprived")(70 110 130 150 280 300 330 340=2 "Averagely Deprived")(140 180 190 200 210 250 270 290 310 320=3 "Mildly Deprived")(220 230 240 260 350 360 370=4 "Lowest Deprived"), gen(mdpi)
label var mdpi "Multidimensional Poverty Index by State"

recode mdpi (0/1=0 "Highly deprived")(2/4=1 "Lowly Deprived"), gen(mdpi2)
label var mdpi2 "MDPI in 2 Cat"
tab mdpi2

recode sstate(10 20 30 50 60 90=0 "Lowest HDI")(40 80 100 110 120 130=1 "Low HDI")(70 160 170 180 190 210 260 280=2 "Average HDI")(150 200 220 230 240 250 270 290 300 310 320 330 350 370=3 "High HDI")(140 340 360=4 "Highest HDI"), gen(hdi)
label var hdi "Human Development Index by State"

recode hdi(0/1=0 "Low hdi")(2/4=1 "High hdi"), gen(hdi2)
```

```
label var hdi2 "HDI in 2 Cat"
tab hdi2

recode sstate(140 200 210 240 260 270 280 300 350 360=1 "Lowest GII")(160 250 290 310
320 330=2 "Low GII")(90 150 180 230=3 "Average GII")(20 30 40 70 80 100 110 130 170
220 340 370=4 "High GII")(10 50 60 120 190=5 "Highest GII"), gen(gii)
label var gii "Gender Inequality Index by State"
label values gii gii

tab gii
tab gii [iw=weight]

recode gii (1/2=1 "Lowest GII")(3=2 "Average GII")(4/5=3 "Highest GII"), gen(sgii)
lab var sgii "State genger inq index"
lab values sgii sgii

recode sgii (1/2=1 "Low GII")(3/5=2 "High GII"), gen(shd)

****Computation begins******
***Tabulate Under-five years Child Variables for analysis****
tabulate b4 [iweight=weight]
asdoc tabulate b4 [iweight = weight], append

tabulate chldage1 [iweight=weight]
asdoc tabulate chldage1 [iweight = weight], append

tabulate bszgr1 [iweight=weight]
asdoc tabulate bszgr1 [iweight = weight], append

tabulate newprbth [iweight=weight]
asdoc tabulate newprbth [iweight = weight], append

tabulate vita [iweight=weight]
asdoc tabulate vita [iweight = weight], append


***Supplement intakes****
tabulate ironsup [iweight=weight]
asdoc tabulate ironsup [iweight = weight], append

tabulate m4 [iweight=weight]
asdoc tabulate m4 [iweight = weight], append

tabulate dworm [iweight=weight]
asdoc tabulate dworm [iweight = weight], append


***other Cormordity*****
tabulate fever [iweight=weight]
asdoc tabulate fever [iweight = weight], append
```

```
tabulate cough [iweight=weight]
asdoc tabulate cough [iweight = weight], append

tabulate diarr [iweight=weight]
asdoc tabulate diarr [iweight = weight], append

tabulate pldel [iweight=weight]
asdoc tabulate pldel [iweight = weight], append


****observed Outcome of interest
tabulate hml35 [iweight=weight]
asdoc tabulate hml35 [iweight = weight], append

tabulate hw57 [iweight=weight]
asdoc tabulate hw57 [iweight = weight], append

tabulate anaesta [iweight=weight]
asdoc tabulate anaesta [iweight = weight], append

tabulate nutrista [iweight=weight]
asdoc tabulate nutrista [iweight = weight], append

tabulate stunted [iweight=weight]
asdoc tabulate stunted [iweight = weight], append

tabulate wasted [iweight=weight]
asdoc tabulate wasted [iweight = weight], append

tabulate underweight [iweight=weight]
asdoc tabulate underweight [iweight = weight], append

tabulate overweight1 [iweight=weight]
asdoc tabulate overweight1 [iweight = weight], append


***Tabulation of Parental/Care-givers Variables for analysi****
tabulate magegr [iweight=weight]
asdoc tabulate magegr [iweight = weight], append

tabulate v714 [iweight=weight]
asdoc tabulate v714 [iweight = weight], append

tabulate agefbth2 [iweight=weight]
asdoc tabulate agefbth2 [iweight = weight], append

tabulate v106 [iweight=weight]
asdoc tabulate v106 [iweight = weight], append
```

```
tabulate v504 [iweight=weight]
asdoc tabulate v504 [iweight = weight], append

tabulate autonomylevel1 [iweight=weight]
asdoc tabulate autonomylevel1 [iweight = weight], append

tabulate ancvis1 [iweight=weight]
asdoc tabulate ancvis1 [iweight = weight], append

tabulate relsta [iweight=weight]
asdoc tabulate relsta [iweight = weight], append

tabulate mirontab [iweight=weight]
asdoc tabulate mirontab [iweight = weight], append

tabulate manaesta [iweight=weight]
asdoc tabulate manaesta [iweight = weight], append

tabulate mbmi [iweight=weight]
asdoc tabulate mbmi [iweight = weight], append

***Paternal variables****
tabulate pworksta [iweight=weight]
asdoc tabulate pworksta [iweight = weight], append

tabulate pedusta [iweight=weight]
asdoc tabulate pedusta [iweight = weight], append

***Tabulation of Household Variables for analysis****
tabulate v190 [iweight=weight]
asdoc tabulate v190 [iweight = weight], append

tabulate  hhagegr [iweight=weight]
asdoc tabulate  hhagegr [iweight = weight], append

tabulate hv228[iweight=weight]
asdoc tabulate hv228 [iweight = weight], append

tabulate u5hhd [iweight=weight]
asdoc tabulate u5hhd [iweight = weight], append


tabulate rmsleep [iweight=weight]
asdoc tabulate rmsleep [iweight = weight], append

tabulate electr [iweight=weight]
asdoc tabulate electr [iweight = weight], append

tabulate watascou1 [iweight=weight]
asdoc tabulate watascou1 [iweight = weight], append
```

```
tabulate toilfac1 [iweight=weight]
asdoc tabulate toilfac1 [iweight = weight], append

tabulate cookfue [iweight=weight]
asdoc tabulate cookfue [iweight = weight], append

tabulate floormat [iweight=weight]
asdoc tabulate floormat [iweight = weight], append

tabulate wallmat [iweight=weight]
asdoc tabulate wallmat [iweight = weight], append

tabulate v151 [iweight=weight]
asdoc tabulate v151 [iweight = weight], append

tabulate shatoi1 [iweight=weight]
asdoc tabulate shatoi1 [iweight = weight], append

***Others added***
tabulate hv227 [iweight=weight]
asdoc tabulate hv227 [iweight = weight], append

tabulate hhdsz [iweight=weight]
asdoc tabulate hhdsz [iweight = weight], append

tabulate stooldis1 [iweight=weight]
asdoc tabulate stooldis1 [iweight = weight], append


***Tabulate derived cluster-related variables****
tabulate cluwealth2 [iweight=weight]
asdoc tabulate cluwealth2 [iweight = weight], append

tabulate cludistm [iweight=weight]
asdoc tabulate cludistm [iweight = weight], append

tabulate clumated1 [iweight=weight]
asdoc tabulate clumated1 [iweight = weight], append

tabulate cluhdbnet [iweight=weight]
asdoc tabulate cluhdbnet [iweight = weight], append

***Tabulate Area Variables
tabulate mdpi [iweight=weight]
asdoc tabulate mdpi [iweight = weight], append

tabulate hdi [iweight=weight]
asdoc tabulate hdi [iweight = weight], append
```

```
tabulate v101 [iweight=weight]
asdoc tabulate v101 [iweight = weight], append

tabulate v102 [iweight=weight]
asdoc tabulate v102 [iweight = weight], append

clear
```

E.2 Spatial maps coding for all the outcome variables of interest

```
******do.file to plot Risk map of proportion of malaria positive children age 6-59 months in
Nigeria*****
****The codes were adapted from the work of Siddha Raj Bhatta in
https://www.youtube.com/watch?v=LYAipHCEBy8****
ssc install spmap // This installs the spmap package in stata
ssc install shp2dta //  This installs the shp2dta package in stata  that is used to convert data
from shp file to dta format
clear
cd "D:\DATA ANALYSIS\New folder\map" //setting working directory
//getting the shape file of your interest
///https://spatialdata.dhsprogram.com/boundaries/#view=table&countryId=NG
///upload all the files to the working directory*****

shp2dta using sdr_subnational_boundaries, database(nigdb) coordinates(nigcoord) genid(id)
//saves the data in nigdb file,coordinated in nigeria coord file and renames id in nigid as
id******
use nigdb, clear
describe
use nigcoord, clear
describe

*****MALARIA MAPS*****
****Preliminary risk map for malaria positive without label*****
****Mala2_prop is the proportion of malaria positive children across the states & FCT****
use mala2_prop, clear
describe
use nigdb, clear
```

```
merge 1:1 id using mala2_prop
spmap proportion using nigcoord, id(id)
spmap proportion using nigcoord, id(id) fcolor(Reds) clnumber(5) title ("Malaria proportion
by States & FCT") legstyle(2) legend(region(lcolor(black))) plotregion(icolor(stone))
graphregion(icolor(stone))

spmap proportion using nigcoord, id(id) fcolor(Reds) clnumber(5) ocolor(Rainbow)
osize(medium) title ("Malaria proportion by States & FCT") legstyle(2)
legend(region(lcolor(black))) plotregion(icolor(stone)) graphregion(icolor(stone))

// risk map for malaria positive without with labels *****
shp2dta using sdr_subnational_boundaries, database(nigdb1) coordinates(nigcoord1)
genid(id1) genc(c)

use nigdb1, clear
merge 1:1 id using mala2_prop
save nigdb2.dta, replace

use nigdb2, clear
gen db=1
append using "nigdb2"
replace db=2 if db==.

***To label each state with malaria proportion values****
replace REGNAME =string(pos_malar, "%4.2f") if db==2

***To label each regional state with malaria proportion values****
replace OTHREGNA =string(mal_reg, "%4.2f") if db==2

save lab.dta, replace

****Create a unique identifier for the 74 observations and save ********
gen id1 = _n
save lab1.dta, replace
```

****Change to Green colors*******
****Risk map of malaria positive children by state of origin****
spmap pos_malar using nigcoord1, id(id1) label(data(lab1) xcoord(x_c) ycoord(y_c) label(REGNAME) by(db) size(*0.70 ..) pos(12 0) color(Blues2)) fcolor(Greens) clnumber(5) osize(medium) ocolor(Rainbow) title("Proportions of malaria positive by States & FCT", size(*1) color(white)) legstyle(2) legend(region(lcolor(BuRd))) plotregion(icolor(green)) graphregion(icolor(blue)) name(malarthesis_sta, replace)

*****Risk map of malaria positive children by region of rresidence*****
spmap mal_reg using nigcoord1, id(id1) label(data(lab1) xcoord(x_c) ycoord(y_c) label(OTHREGNA) by(db) size(*0.70 ..) pos(12 0) color(Blues2)) fcolor(Greens) clnumber(5) osize(medium) ocolor(Rainbow) title("Proportions of malaria positive children by region of residence", size(*0.8) color(white)) legstyle(2) legend(region(lcolor(BuRd))) plotregion(icolor(green)) graphregion(icolor(blue)) name(malarthesis_reg, replace)

*****ANAEMIA MAPS*****

To label each state with anaemia proportion values*
replace REGNAME =string(pos_anae, "%4.2f") if db==2

To label each regional state with anaemia proportion values*
replace OTHREGNA =string(ana_reg, "%4.2f") if db==2

save lab1.dta, replace

****Change to Green colors*******
****Risk map of anaemic children by state of origin****
spmap pos_anae using nigcoord1, id(id1) label(data(lab1) xcoord(x_c) ycoord(y_c) label(REGNAME) by(db) size(*0.70 ..) pos(12 0) color(Blues2)) fcolor(Reds) clnumber(5) osize(medium) ocolor(Rainbow) title("Proportions of anaemic children by States & FCT", size(*1) color(white)) legstyle(2) legend(region(lcolor(BuRd))) plotregion(icolor(green)) graphregion(icolor(blue)) name(anaethesis_sta, replace)

*****Risk map of anaemic children by region of rresidence*****
spmap ana_reg using nigcoord1, id(id1) label(data(lab1) xcoord(x_c) ycoord(y_c) label(OTHREGNA) by(db) size(*0.70 ..) pos(12 0) color(Blues2)) fcolor(Reds) clnumber(5) osize(medium) ocolor(Rainbow) title("Proportions of anaemic children by region of residence", size(*0.8) color(white)) legstyle(2) legend(region(lcolor(BuRd))) plotregion(icolor(green)) graphregion(icolor(blue)) name(anaethesis_reg, replace)

*****MALNUTRITION MAPS*****

To label each state with anaemia proportion values*
replace REGNAME =string(pro_poornour, "%4.2f") if db==2

To label each regional state with anaemia proportion values*
replace OTHREGNA =string(maln_reg, "%4.2f") if db==2

save lab1.dta, replace

****Change to Green colors*******
****Risk map of anaemic children by state of origin****
spmap pro_poornour using nigcoord1, id(id1) label(data(lab1) xcoord(x_c) ycoord(y_c) label(REGNAME) by(db) size(*0.70 ..) pos(12 0) color(Blues2)) fcolor(Greens) clnumber(5) osize(medium) ocolor(Rainbow) title("Proportions of poorly-nourished children by States & FCT", size(*1) color(white)) legstyle(2) legend(region(lcolor(BuRd))) plotregion(icolor(yellow)) graphregion(icolor(blue)) name(malnuthesis_sta, replace)

*****Risk map of anaemic children by region of residence*****
spmap maln_reg using nigcoord1, id(id1) label(data(lab1) xcoord(x_c) ycoord(y_c) label(OTHREGNA) by(db) size(*0.70 ..) pos(12 0) color(Blues2)) fcolor(Greens) clnumber(5) osize(medium) ocolor(Rainbow) title("Proportions of poorly-nourished children by region of residence", size(*0.8) color(white)) legstyle(2) legend(region(lcolor(BuRd))) plotregion(icolor(yellow)) graphregion(icolor(blue)) name(malnuthesis_reg, replace)

*****MULTIMORBIDITY MAPS*****

To label each state with MAMM proportion values*
replace REGNAME =string(pro_2dis, "%4.2f") if db==2

To label each regional state with MAMM proportion values*
replace OTHREGNA =string(reg_2dis, "%4.2f") if db==2

save lab1.dta, replace

****Change to Green colors*******
****Risk map of MAMM children by state of origin****
spmap pro_2dis using nigcoord1, id(id1) label(data(lab1) xcoord(x_c) ycoord(y_c) label(REGNAME) by(db) size(*0.70 ..) pos(12 0) color(Blues2)) fcolor(Reds) clnumber(5) osize(medium) ocolor(Rainbow) title("Proportions of children with MAMM by States & FCT", size(*1) color(white)) legstyle(2) legend(region(lcolor(BuRd))) plotregion(icolor(blue)) graphregion(icolor(green)) name(maMMthesis_sta, replace)

*****Risk map of MAMM children by region of rresidence*****
spmap reg_2dis using nigcoord1, id(id1) label(data(lab1) xcoord(x_c) ycoord(y_c) label(OTHREGNA) by(db) size(*0.70 ..) pos(12 0) color(Blues2)) fcolor(Greens) clnumber(5) osize(medium) ocolor(Rainbow) title("Proportions of children with MAMM by region of residence", size(*0.8) color(white)) legstyle(2) legend(region(lcolor(BuRd))) plotregion(icolor(green)) graphregion(icolor(reds)) name(maMMthesis_reg, replace)

clear

E.3 Codes for anaemia studies*****

****All computations done for anaemia study for children aged 6-59 months in Nigeria****
Merging Household file to children File*
Use Household File Identifiers for PR
use "D:\UNIVERSITY OF SHEFFIELD MATTERS\STATA DATA SET\NGPR7ADT\NGPR7AFL.DTA", clear

```
rename hv001 v001
rename hv002 v002
rename hvidx mergeid

sort v001 v002 mergeid
gen in_PR=1

save temp.dta, replace

***Use Children File Identifiers****

use "D:\UNIVERSITY OF SHEFFIELD MATTERS\STATA DATA
SET\NGKR7AFL.DTA", clear

rename b16 mergeid
sort v001 v002 mergeid
gen in_KR=1

*** Merging the PR and KR Files****

merge m:1 v001 v002 mergeid using temp.dta

keep if in_PR==1 & in_KR==1
tab _merge

****Analysis of Description of Malnutrition among under-5 children in Nigeria*****

***Perform weighting to correct for over and under sample****
gen weight=v005/1000000
svyset [pw=weight], psu(v021) strata (v022)
svydes, single
replace v022=58 if v022==60
```

```
****Keep subsample of children under-5 years and child is alive****
keep if hc1>5 & hc1<60


***Recode under-5 child's age in group***
recode hc1 (0/5=0 "less 6 months")(6/11=1 "6-11 months")(12/23=2 "12-23
months")(24/35=3 "24-35 months")(36/47=4 "36-47 months")(48/59=5 "48-59 months"),
gen(chldage1)
label var chldage1 "child's age in group"
tab chldage1 [iw=weight]

***Recode under-5 age another way*******

recode hc1 (0/5=0 "less 6 months")(6/18=1 "6-18 months")(19/30=2 "19-30
months")(31/42=3 "31-42 months")(43/59=4 "43-59 months"), gen(chldage)
label var chldage "child's age in group"
tab chldage [iw=weight]

gen chage=.
replace chage=. if chldage==0
replace chage=1 if chldage==1
replace chage=2 if chldage==2
replace chage=3 if chldage==3
replace chage=4 if chldage==4
lab define chage 1 "6-18 months" 2"19-30 months" 3"31-42 months" 4"43-59 months"
label var chage "Age of child 6-59 months"
label values chage chage


******Age could be used as continous variable*******

***Tabulate Children under-5 by sex****
tab b4 [iw=weight]
```

```
****Recode of Outcome Variables*****

****Outcome variable 1*****
*** Malaria Status by Rapid Diagnostic Test****
codebook hml35
tab hml35 [iw=weight]

*** Malaria Status by Microscopic Blood Smear Examination****
codebook hml32
tab hml32 [iw=weight]

*****Test of independence between the two results*****
spearman hml35 hml32

****Outcome variable 2*****
****Anaemia Status****
codebook hw57
recode hw57(1/3=1 "Anaemic")(4=0 "Not Anaemic"), gen(anaesta)
label var anaesta "Anaemia status"
tab anaesta [iw=weight]
tab hw57 [iw=weight]

****Outcome variable 3*****
****Malnutrition Status***
***Children who stayed in the household the previous night and who have height and weight
z-scores on all 3 measures****
gen eligch = 0
replace eligch = 1 if (hv103==1 & hc70 < 9996 & hc71 < 9996 & hc72 < 9996)

// child stunting calculation
codebook hc70
tab hc70 if hc70>9990,m
tab hc70 if hc70>9990,m nolabel
gen HAZ=hc70
```

```
replace HAZ=. if HAZ>=9996
gen stunted=0
replace stunted=0 if HAZ ~=.
replace stunted=1 if HAZ<-200
lab define stunted 0 "not anaemic" 1 "anaemic"
lab var stunted "Stunting Status of Children"

// child wasting calculation
codebook hc72
tab hc72 if hc72>9990,m
tab hc72 if hc72>9990,m nolabel
gen WAH=hc72
replace WAH=. if WAH>=9996
gen wasted=0
replace wasted=0 if WAH ~=.
replace wasted=1 if WAH<-200
lab define wasted 0 "not wasted" 1 "wasted"
lab var wasted "wasting Status of Children"

// child underweight calculation
codebook hc71
tab hc71 if hc71>9990,m
tab hc71 if hc71>9990,m nolabel
gen WAZ=hc71
replace WAZ=. if WAZ>=9996
gen underweight=0
replace underweight=0 if WAZ ~=.
replace underweight=1 if WAZ<-200
lab define underweight 0 "not underweight" 1 "underweight"
lab var underweight "Underweight Status of Children"

// child overweight calculation
codebook hc72
tab hc72 if hc72>9990,m
```

```
tab hc72 if hc72>9990,m nolabel
gen WAH2=hc72
replace WAH2=. if WAH2>=9996
gen overweight1=0
replace overweight1=0 if WAH2 ~=.
replace overweight1=1 if WAH2>200 & WAH2<9990
lab define overweight1 0 "not overweight" 1 "overweight"
lab var overweight "Overweight Status of Children"

tab stunted [iw=weight]
tab wasted [iw=weight]
tab underweight [iw=weight]
tab overweight [iw=weight]

***Generate Malnutrition Status*****
gen malnut=stunted+wasted+underweight+overweight
tab malnut
recode malnut(0=0 "well-nourished")(1/4=1 "poorly nourished"), gen(nutrista)
lab var nutrista "Nutrition Status of Children"
tab nutrista [iw=weight]
tab nutrista [iw=weight], nolabel

****Diarrhael Recode****
gen diarr=.
replace diarr=0 if h11==0
replace diarr=1 if h11==2
replace diarr=. if h11==3
lab define diarr 0 "No diarrhael" 1 "Had diarrhael"
lab var diarr "Diarrhael status"

****Cough Recode****
gen cough=.
replace cough=0 if h31==0
replace cough=1 if h31==2
```

```
replace cough=. if h31==8
lab var cough "Cough status"
lab define cough 0 "had no cough" 1 "Had cough"

gen fever=.
replace fever=0 if h22==0
replace fever=1 if h22==1
replace fever=. if h22==8
lab define fever 0 "No" 1 "Yes"
label var fever "Had Fever in last 2 weeks"

*****Recodes for Predictors or covariates*******
****Recode of Child Variables ****
recode m18 (1=0 "large size") (2/3=1 "Average size")(4/5=2 "small size")(6/max=3 "I don't
Know"), gen(bszgr)
lab var bszgr "Child perceived size at birth"

***Recode birth size*****
gen bszgr1=.
replace bszgr1=0 if bszgr==0
replace bszgr1=1 if bszgr==1
replace bszgr1=2 if bszgr==2
replace bszgr1=. if bszgr==3
lab define bszgr1 0 "large" 1 "Average" 2 "Small"
label var bszgr1 "Child's birth Size"

*****Child birth order****
recode bord (1=0 "1st") (2/3=1 "2nd or 3rd")(4/6=2 "4-6 th")(7/max=3 "7th+"), gen(brdgr)
lab var brdgr "Child Birth Order"

****Birth order can be used as continous variable******

****Number of under-5 in household******
recode hv014 (0/3=0 "0-3") (4/6=1 "4-6")(7/max=2 "7th+"), gen(u5hhd)
```

```
lab var u5hhd "Under-5 in household"

****Recode of household size*****
recode hv009 (0/3=0 "0-3") (4/6=1 "4-6")(7/9=2 "7-9")(10/max=3 "more than 10"),
gen(hhdsz)
lab var hhdsz "household member size"

****Recode of place of delivery*****
recode m15 (11/12=0 "home")(21 22 23 26=1 "Public Health facility")(31 36=2 "Private
Health Facility"), gen(pladel)
lab var pladel "Place of Delivery"

gen pldel=.
replace pldel=0 if pladel==0
replace pldel=1 if pladel==1
replace pldel=2 if pladel==2
replace pldel=3 if pladel==96
lab define pldel 0 "home" 1 "Public Facility" 2 "Private facility" 3 "elsewhere"
lab var pldel "Place of child's del"

gen dworm=.
replace dworm=0 if h43==0
replace dworm=1 if h43==1
replace dworm=. if h43==8
lab define dworm 0 "No" 1 "Yes"
label var dworm "Took deworming drug in last 6months"

gen vita=.
replace vita=0 if h34==0
replace vita=1 if h34==1
replace vita=. if h34==8
lab define vita 0 "No" 1 "Yes"
label var vita "Took Vit A supplements"
```

```
gen ironsup=.
replace ironsup=0 if h42==0
replace ironsup=1 if h42==1
replace ironsup=. if h42==8
lab define ironsup 0 "No" 1 "Yes"
label var ironsup "Took Iron supplements"

recode v465 (1 2 5=0)(3 4 9=1)(96=2), gen(stooldisp)

gen stooldis1=.
replace stooldis1=0 if stooldisp==0
replace stooldis1=1 if stooldisp==1
replace stooldis1=. if stooldisp==2
lab define stooldis1 0 "Proper disposal" 1 "Improper disposal"
label var stooldis1 "Youngest Child's stool disposed Properly"

****Recode of Parental/Mother/Care-givers Variables ****
recode v013 (1/2=0 "15-24 years") (3/4=1 "25-34 years") (5/7=2 "35 years+"), gen(magegr)
label var magegr "Maternal age group in 10years"

****Use maternal age as given in data set v013*******

recode hv220 (min/34=0 "less 34 years")(35/44=2 "35-44 years")(45/55=3 "45-55
years")(56/max=4 "56 years+"), gen(hhagegr)
label var hhagegr "Household Head age group"

***Use household head age as continous*****

recode v212 (10/24=0 "10-24")(25/36=1 "25-36")(37/49=2 "37-49") (37/max=3 "37-49"),
gen(agefbth2)
label var agefbth2 "age at first birth"

***Use age at first birth as continous variable****
```

```
recode b11(8/24=0 "8-24 months")(25/35=1 "25-35 months")(36/59=2 "36-59
months")(60/max=3 "60+ months"), gen(prbrthint)
label var prbrthint "preceeding birth interval"

*****New prebirthint*****
gen newprbth=.
replace newprbth=0 if brdgr==0
replace newprbth=1 if prbrthint==0
replace newprbth=2 if prbrthint==1
replace newprbth=3 if prbrthint==2
replace newprbth=4 if prbrthint==3
lab define newprbth 0 "None" 1 "8-24 months" 2 "25-35 months" 3 "36-59 months" 4 "60+
months", modify
label var newprbth "New prebirth interval"
label values newprbth newprbth

tab newprbth [iw=weight]

recode b12(8/24=0 "8-24 months")(25/35=1 "25-35 months")(36/59=2 "36-59
months")(60/max=3 "60+ months"), gen(subrthint)
label var subrthint "suceeding birth interval"

recode v130(1=0 "catholic")(2=1 "other christian")(3=2 "islam")(4/max=3
"traditionalist&others"), gen(relsta)
label var relsta "mother's religious status"

gen pworksta=.
replace pworksta=0 if v705==0
replace pworksta=1 if v705>0
lab define pworksta 0 "not working" 1 "working"
label var pworksta "Husband Work Status"

gen pedusta=.
replace pedusta=0 if v701==0
```

```
replace pedusta=1 if v701==1
replace pedusta=2 if v701==2
replace pedusta=3 if v701==3
replace pedusta=. if v701==8
lab define pedusta 0 "no education" 1 "primary" 2 "secondary" 3 "higher"
label var pedusta "mother's partner education status"

****Mother's Anaemia Status****
recode v457(1/3=1 "Anaemic")(4=0 "Not Anaemic"), gen(manaesta)
label var manaesta "Mother's Anaemia status"
tab manaesta [iw=weight], missing

gen mirontab=.
replace mirontab=0 if m45==0
replace mirontab=1 if m45==1
replace mirontab=. if m45==8
lab define mirontab 0 "no" 1 "yes"
label var mirontab "took iron tab during pregnancy"

recode m14 (0=0 "No ANC Visit") (1/3=1 "ANC Visit less WHO REC") (4/20=2 "ANC
Visit Met WHO REC")(21/max=3 "Dont Remember Visiting ANC"), gen(ancvis)
label var ancvis "ANC Visit"

gen ancvis1=.
replace ancvis1=0 if ancvis==0
replace ancvis1=1 if ancvis==1
replace ancvis1=2 if ancvis==2
replace ancvis1=. if ancvis==3
lab define ancvis1 0 "none" 1 "less who rec" 2 "met who rec"
label var ancvis1 "ANC visits during pregnancy"

recode v131(2 3 8=0 "Hausa/Fulani/KanuriSeribiri")(6=1 "Ibos")(10=2 "Yorubas")(else=3
"Others"), gen(ethgr2)
label var ethgr2 "Ethnicity"
```

```
***Recoding - Maternal Decision Making Level*****
gen healthcare=0
replace healthcare=1 if v743a==1
replace healthcare=2 if v743a==2
replace healthcare=3 if v743a==3
replace healthcare=4 if v743a>3 & v743a<10
gen lpurchase=0
replace lpurchase=1 if v743b==1
replace lpurchase=2 if v743b==2
replace lpurchase=3 if v743b==3
replace lpurchase=4 if  v743b>3 & v743b<10
gen dpurchase=0
replace dpurchase=1 if v743c==1
replace dpurchase=2 if v743c==2
replace dpurchase=3 if v743c==3
replace dpurchase=4 if v743c>3 & v743c<10
gen  fvisit=0
replace fvisit=1 if v743d==1
replace fvisit=2 if v743d==2
replace fvisit=3 if v743d==3
replace fvisit=4 if v743d>3 & v743d<10
gen auto1=0
replace auto1=2 if healthcare<3
replace auto1=1 if healthcare>2 & healthcare<10
gen auto2=0
replace auto2=2 if lpurchase<3
replace auto2=1 if lpurchase>2 & lpurchase<10
gen auto4=0
replace auto4=2 if fvisit<3
replace auto4=1 if fvisit>2 & fvisit<10
tab1 auto*
***Generating Maternal Autonomylevel****
gen autonomyscore1=auto1+auto2+auto4
```

```
tab autonomyscore1
su autonomyscore1
recode autonomyscore1 (3/4=0 "low Auto") (5/8=1 "more auto"), gen(autonomylevel1)
lab val autonomylevel1 autonomylevel1
tab autonomylevel1 [iw=weight], missing

**Generating Maternal BMI status*****
gen ht_flag=0
replace ht_flag=1 if v438>9000
gen preg_flag=0
replace preg_flag=1 if v213==1
gen months_since_last_birth=v008-b3
gen recent_birth_flag1=0
replace recent_birth_flag1=1 if months_since_last_birth <=2

gen bmi=v445/100
gen bmic=2 if bmi<18.5
replace bmic=1 if bmi>=18.5 & bmi<25
replace bmic=3 if bmi>=25 & bmi<30
replace bmic=4 if bmi>=30 & bmi<60
label define bmic 1"Normal" 2 "Underweight" 3"Overweight" 4"Obese"
label values bmic bmic
svy: tab bmic, count percent format(%4.1f) col

****Generate Maternal BMI*****

gen mbmi=bmic if ht_flag==0 & preg_flag==0 & recent_birth_flag1==0
label define mbmi 1 "Normal" 2 "underweight" 3 "Overweight" 4 "Obese"
label values mbmi mbmi

****Recode of Household Variables ****
gen shatoi1=.
replace shatoi1=0 if v160==0
replace shatoi1=1 if v160==1
```

```
replace shatoi1=. if v160==7
label define shatoi1 0 "No" 1 "Yes"
label var shatoi1 "Shared Toilet Facilities"

recode hv226(1/4=0)(5/10=1)(11/max=2), gen(cookfuel2)
label var cookfuel2 "Cooking Fuel Used"

gen cookfue=.
replace cookfue=0 if cookfuel2==0
replace cookfue=1 if cookfuel2==1
replace cookfue=. if cookfuel2==3
label define cookfue 0 "Elect&Gas" 1 "Biofuel"
label var cookfue "Type of cooking fuel"

***Recode floor material types***
recode hv213(11 12 96=0 "unimproved floor materials")(21 22 31 32 33 34 35=1 "improved floor materials"), gen(floormat)
label var floormat "Floor Materials"

***Recode roof material types***
recode hv215(11 12 13 21 22 23 24 96=0 "unimproved roof materials")(31 32 33 34 35 36=1 "improved roof materials"), gen(roofmat)
label var roofmat "Roof Materials"

***Recode wall material types***
recode hv214(11 12 13 21 22 23 24 25 26 96=0 "unimproved wall materials")(31 32 33 34 35 36=1 "improved wall materials"), gen(wallmat)
label var wallmat "wall Materials"

***Recode Number of rooms for sleep***
recode hv216(1=0 "One-room")(2=1 "two rooms")(3=2 "three rooms")(4=3 "Four rooms")(5/max=4 "Five+ rooms"), gen(rmsleep)
label var rmsleep "Number of rooms for sleep"
```

```
***Recode Scource of drinking water***
recode hv201(32 42 43 61 62 96=0 "unimproved drinking water")(11 12 13 14 21 31 41 51
71 92=1 "improved drinking water"), gen(watascou1)
label var watascou1 "source of drinking water"

***Recode type of toilet facility***
recode hv205(14 15 23 31 42 43 96=0 "unimproved toilet factories")(11 12 13 16 21 22 41=1
"improved toilet factories"), gen(toilfac1)
label var toilfac1 "type of toilet facility"

gen electr=.
replace electr=0 if v119==0
replace electr=1 if v119==1
replace electr=. if v119==3
lab define electr 0 "No" 1 "Yes"
label var electr "Household had electricity"

***Generating Cluster Variables****

*****Generating proportion of cluster wealth status**********
bysort v001: egen cuwealth1=mean(v190)
bysort v001: egen cuwe1= count(v190)

sum cuwealth1, detail          //you will find median
gen clwea3=.
replace clwea3=1 if cuwealth1<3
replace clwea3=2 if cuwealth1==3
replace clwea3=3 if cuwealth1>3

recode clwea3(1=0 "low") (2/3=1 "high"), gen(cluwealth2)
lab var cluwealth2 "Cluster wealth level"
lab values cluwealth2 cluwealth2
tab cluwealth2 [iw=weight]
```

******Generating cluster maternal education status*****

```
bysort v001: egen cumatedu2=mean(v106)
bysort v001: egen cumate2= count(v106)

sum cumatedu2, detail          //you will find median

gen clmated2=.
replace clmated2=1 if cumatedu2<1.2
replace clmated2=2 if cumatedu2==1.2
replace clmated2=3 if cumatedu2>1.2

recode clmated2(1=0 "low") (2/3=1 "high"), gen(clumated1)
lab var clumated1 "Cluster maternal education level"
lab values clumated1 clumated1
tab clumated1 [iw=weight]
```

*****Generating proportion of respondents with distance to health facility is no problem in cluster*****

```
recode v467d(1=0 "big problem")(2=1 "no big problem"), gen(dismed)
bysort v001: egen cudistmed=mean(dismed)
sum cudistmed, detail          //you will find median

gen cludistm=.
replace cludistm=0 if cudistmed<0.8
replace cludistm=1 if cudistmed>=0.8
lab define cludistm 0 "low" 1 "high"
lab var cludistm "low cluster distance to health facility"
lab values cludistm cludistm
tab cludistm [iw=weight]
```

****Generating proportion of respondent with no cluster household with bed net*******

```
recode hv227(0=1 "no bed net")(1=0 "Yes"), gen(bnet)
bysort v001: egen hdbnet=mean(bnet)
sum hdbnet, detail          //you will find median
```

```
gen cluhdbnet=.
replace cluhdbnet=0 if hdbnet<0.25
replace cluhdbnet=1 if hdbnet>=0.25

lab define cluhdbnet 0 "low" 1 "high"
lab var cluhdbnet "low cluster household with no bed net"
lab values cluhdbnet hdbnet

tab cluhdbnet [iw=weight]

***Recoding Area Variables using UNDP data set into NDHS****
***Classifying state by Multidimensional poverty Index*****

recode sstate(10 40 50=0 "Highly Deprived")(20 30 60 80 90 100 120 160 170=1 "Above
averagely deprived")(70 110 130 150 280 300 330 340=2 "Averagely Deprived")(140 180
190 200 210 250 270 290 310 320=3 "Mildly Deprived")(220 230 240 260 350 360 370=4
"Lowest Deprived"), gen(mdpi)
label var mdpi "Multidimensional Poverty Index by State"

recode mdpi (0/1=0 "Highly deprived")(2/4=1 "Lowly Deprived"), gen(mdpi2)
label var mdpi2 "MDPI in 2 Cat"
tab mdpi2

recode sstate(10 20 30 50 60 90=0 "Lowest HDI")(40 80 100 110 120 130=1 "Low HDI")(70
160 170 180 190 210 260 280=2 "Avverage HDI")(150 200 220 230 240 250 270 290 300
310 320 330 350 370=3 "High HDI")(140 340 360=4 "Highest HDI"), gen(hdi)
label var hdi "Human Development Index by State"

recode hdi(0/1=0 "Low hdi")(2/4=1 "High hdi"), gen(hdi2)
label var hdi2 "HDI in 2 Cat"
tab hdi2
```

```
recode sstate(140 200 210 240 260 270 280 300 350 360=1 "Lowest GII")(160 250 290 310
320 330=2 "Low GII")(90 150 180 230=3 "Average GII")(20 30 40 70 80 100 110 130 170
220 340 370=4 "High GII")(10 50 60 120 190=5 "Highest GII"), gen(gii)
label var gii "Gender Inequality Index by State"
label values gii gii

tab gii
tab gii [iw=weight]

recode gii (1/2=1 "Lowest GII")(3=2 "Average GII")(4/5=3 "Highest GII"), gen(sgii)
lab var sgii "State genger inq index"
lab values sgii sgii

recode sgii (1/2=1 "Low GII")(3/5=2 "High GII"), gen(shd)



******Proportion of diseases by states******
svy: tab v101 anaesta, count row pearson
svy: tab v101 hml35, count row pearson
svy: tab v101 nutrista, count row pearson

***Bar chart for anaemia status*****
graph bar [aweight = weight], over(hw57) blabel(bar) asyvars blabel(bar, format(%9.1f))
title(Prevalence of anaemia status in children 6-59 months) legend(on) name(anae, replace)

graph bar [aweight = weight], over(anaesta) blabel(bar) asyvars blabel(bar, format(%9.1f))
title(Prevalence of anaemia status in children 6-59 months) legend(on) name(anae1, replace)

graph bar [aweight = weight], over(v102) over(anaesta) asyvars blabel(bar, format(%9.1f))
title("Percentage of anaemic children by place of residence") name(anaepla, replace)

graph bar [aweight = weight], over(v101) over(anaesta) asyvars blabel(bar, format(%9.1f))
title("Percentage of anaemic children by place of residence") name(anaepla1, replace)
```

```
graph bar [aweight = weight], over(b4) over(anaesta) asyvars blabel(bar, format(%9.1f))
title("Percentage of anaemic children by gender") name(morbigen, replace)

graph bar [aweight = weight], over(chldage1) over(anaesta) asyvars blabel(bar,
format(%9.1f)) title("Percentage of anaemic children by age") name(anaecage1, replace)

*****relationship between child's variables and anaemia status*****
svy: tab b4 anaesta, count row pearson
asdoc tabulate b4 anaesta [iweight = weight], append

svy: tab chldage1 anaesta, count row pearson
asdoc tabulate chldage1 anaesta [iweight = weight], append

svy: tab bszgr1 anaesta, count row pearson
asdoc tabulate bszgr1 anaesta [iweight = weight], append

svy: tab brdgr anaesta, count row pearson
asdoc tabulate brdgr anaesta [iweight = weight], append

svy: tab newprbth anaesta, count row pearson
asdoc tabulate prbrthint anaesta [iweight = weight], append

svy: tab vita anaesta, count row pearson
asdoc tabulate vita anaesta [iweight = weight], append

svy: tab ironsup anaesta, count row pearson
asdoc tabulate ironsup anaesta [iweight = weight], append

svy: tab m4 anaesta, count row pearson
asdoc tabulate m4 anaesta [iweight = weight], append

svy: tab dworm anaesta, count row pearson
asdoc tabulate dworm anaesta [iweight = weight], append
```

svy: tab fever anaesta, count row pearson
asdoc tabulate fever anaesta [iweight = weight], append

svy: tab cough anaesta, count row pearson
asdoc tabulate cough anaesta [iweight = weight], append

svy: tab diarr anaesta, count row pearson
asdoc tabulate diarr anaesta [iweight = weight], append

svy: tab pldel anaesta, count row pearson
asdoc tabulate pldel anaesta [iweight = weight], append

****Table: Relationship between Parental variables and anaemia status
svy: tab magegr anaesta, count row pearson
asdoc tabulate magegr anaesta [iweight = weight], append

svy: tab v714 anaesta, count row pearson
asdoc tabulate v714 anaesta [iweight = weight], append

svy: tab agefbth2 anaesta, count row pearson
asdoc tabulate agefbth2 anaesta [iweight = weight], append

svy: tab v106 anaesta, count row pearson
asdoc tabulate v106 anaesta [iweight = weight], append

svy: tab v504 anaesta, count row pearson
asdoc tabulate v504 anaesta [iweight = weight], append

svy: tab autonomylevel1 anaesta, count row pearson
asdoc tabulate autonomylevel1 anaesta [iweight = weight], append

svy: tab v461 anaesta, count row pearson
asdoc tabulate v461 anaesta [iweight = weight], append

svy: tab ancvis1 anaesta, count row pearson
asdoc tabulate ancvis1 anaesta [iweight = weight], append

svy: tab relsta anaesta, count row pearson
asdoc tabulate relsta anaesta [iweight = weight], append

svy: tab ethgr2 anaesta, count row pearson
asdoc tabulate ethgr2 anaesta [iweight = weight], append

svy: tab mirontab anaesta, count row pearson
asdoc tabulate mirontab anaesta [iweight = weight], append

svy: tab manaesta anaesta, count row pearson
asdoc tabulate manaesta anaesta [iweight = weight], append

svy: tab mbmi anaesta, count row pearson
asdoc tabulate mbmi anaesta [iweight = weight], append

svy: tab pworksta anaesta, count row pearson
asdoc tabulate pworksta anaesta [iweight = weight], append

svy: tab pedusta anaesta, count row pearson
asdoc tabulate pedusta anaesta [iweight = weight], append

****Table: Relationship between Household variables and anaemia status
svy: tab v190 anaesta, count row pearson
asdoc tabulate v190 anaesta [iweight = weight], append

svy: tab hhagegr anaesta, count row pearson
asdoc tabulate hhagegr anaesta [iweight = weight], append

svy: tab hv228 anaesta, count row pearson

```
asdoc tabulate hv228 anaesta [iweight = weight], append

svy: tab u5hhd anaesta, count row pearson
asdoc tabulate u5hhd anaesta [iweight = weight], append

svy: tab rmsleep anaesta, count row pearson
asdoc tabulate rmsleep anaesta [iweight = weight], append

svy: tab electr anaesta, count row pearson
asdoc tabulate electr anaesta [iweight = weight], append

svy: tab watascou1 anaesta, count row pearson
asdoc tabulate watascou1 anaesta [iweight = weight], append

svy: tab toilfac1 anaesta, count row pearson
asdoc tabulate toilfac1 anaesta [iweight = weight], append

svy: tab cookfue anaesta, count row pearson
asdoc tabulate cookfue anaesta [iweight = weight], append

svy: tab floormat anaesta, count row pearson
asdoc tabulate floormat anaesta [iweight = weight], append

svy: tab roofmat anaesta, count row pearson
asdoc tabulate roofmat anaesta [iweight = weight], append

svy: tab wallmat anaesta, count row pearson
asdoc tabulate wallmat anaesta [iweight = weight], append

svy: tab v151 anaesta, count row pearson
asdoc tabulate v151 anaesta [iweight = weight], append

svy: tab shatoi1 anaesta, count row pearson
asdoc tabulate shatoi1 anaesta [iweight = weight], append
```

Others added

svy: tab hv227 anaesta, count row pearson

asdoc tabulate hv227 anaesta [iweight = weight], append

svy: tab hhdsz anaesta, count row pearson

asdoc tabulate hhdsz anaesta [iweight = weight], append

svy: tab stooldis1 anaesta, count row pearson

asdoc tabulate stooldis1 anaesta [iweight = weight], append

svy: tab v159 anaesta, count row pearson

asdoc tabulate v159 anaesta [iweight = weight], append

****Relationship between community-related variables and anaemia status*****

svy: tab cluwealth2 anaesta, count row pearson

asdoc tabulate cluwealth2 anaesta [iweight = weight], append

svy: tab cludistm anaesta, count row pearson

asdoc tabulate cludistm anaesta [iweight = weight], append

svy: tab clumated1 anaesta, count row pearson

asdoc tabulate clumated1 anaesta [iweight = weight], append

svy: tab cluhdbnet anaesta, count row pearson

asdoc tabulate cluhdbnet anaesta [iweight = weight], append

****Table: Relationship between Area variables and anaemia status

svy: tab mdpi anaesta, count row pearson

asdoc tabulate mdpi anaesta [iweight = weight], append

svy: tab hdi anaesta, count row pearson

asdoc tabulate hdi anaesta [iweight = weight], append

svy: tab gii anaesta, count row pearson
asdoc tabulate gii anaesta [iweight = weight], append

svy: tab v101 anaesta, count row pearson
asdoc tabulate v101 anaesta [iweight = weight], append

svy: tab v102 anaesta, count row pearson
asdoc tabulate v102 anaesta [iweight = weight], append

****Diagnostic Test*******
*****Multicollinearity check for all logistic analyses*******
*****All the variables extracted from the bivariate analysis (55)*****
collin b4 chldage1 bszgr1 brdgr newprbth vita ironsup m4 dworm anaesta hml35 nutrista fever cough diarr pldel magegr v714 agefbth2 v106 v504 autonomylevel1 v461 ancvis1 relsta ethgr2 mirontab manaesta mbmi pworksta pedusta v190 hhagegr hv228 u5hhd rmsleep electr watascou1 toilfac1 cookfue floormat roofmat wallmat v151 shatoi1 hv227 hhdsz stooldis1 v159 cluwealth2 cludistm clumated1 cluhdbnet mdpi hdi gii v101 v102

****After dropping multicollinear variables (48) *****
collin b4 chldage1 bszgr1 brdgr newprbth vita ironsup m4 dworm anaesta hml35 nutrista fever cough diarr pldel magegr v714 agefbth2 v106 v504 autonomylevel1 v461 ancvis1 relsta ethgr2 mirontab manaesta mbmi pworksta pedusta v190 hhagegr hv228 u5hhd rmsleep electr v151 hhdsz cluwealth2 cludistm clumated1 cluhdbnet mdpi hdi gii v101 v102

For each of the outcome variables, variable selection method applied*

*******ANAEMIA*******

****backward stepwise selection of variables for anaemia study**********

stepwise, pr(.2): logit anaesta i.b4 i.chldage1 i.bszgr1 i.brdgr i.newprbth i.vita i.ironsup i.m4 i.dworm i.hml35 i.nutrista i.fever i.cough i.diarr i.pldel i.magegr i.v714 i.agefbth2 i.v106 i.v504 i.autonomylevel1 i.v461 i.ancvis1 i.relsta i.ethgr2 i.mirontab i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr i.hv228 i.u5hhd i.rmsleep i.electr i.v151 i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.cluhdbnet i.mdpi i.hdi i.gii i.v101 i.v102

****Testing the goodness of fit from the backward selected variables using AIC and BIC******
melogit anaesta i.b4 i.chldage1 i.newprbth i.fever i.m4 i.hml35 i.nutrista i.pldel i.v106 i.v504 i.relsta i.ethgr2 i.manaesta i.mbmi i.pedusta i.v190 i.hv228 i.u5hhd i.rmsleep i.v151 i.hhdsz i.hdi i.gii i.v101 ||sstate: ||v001:, or

estat ic

****Forward stepwise selection of variables for anaemia study**********
stepwise, pe(.2): logit anaesta i.b4 i.chldage1 i.bszgr1 i.brdgr i.newprbth i.vita i.ironsup i.m4 i.dworm i.hml35 i.nutrista i.fever i.cough i.diarr i.pldel i.magegr i.v714 i.agefbth2 i.v106 i.v504 i.autonomylevel1 i.v461 i.ancvis1 i.relsta i.ethgr2 i.mirontab i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr i.hv228 i.u5hhd i.rmsleep i.electr i.v151 i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.cluhdbnet i.mdpi i.hdi i.gii i.v101 i.v102

****Testing the goodness of fit from the forward selected variables using AIC and BIC******
****This produced lower AIC & BIC****
melogit anaesta i.b4 i.chldage1 i.newprbth i.ironsup i.m4 i.dworm i.hml35 i.nutrista i.fever i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pedusta i.v190 i.hv228 i.u5hhd i.rmsleep i.v151 i.hhdsz i.hdi i.gii i.v101 ||sstate: ||v001:, or

estat ic

****Testing the goodness of fit from the forward + backward selected variables using AIC and BIC*********

melogit anaesta i.b4 i.chldage1 i.newprbth i.ironsup i.m4 i.dworm i.hml35 i.nutrista i.fever i.pldel i.v106 i.v504 i.relsta i.ethgr2 i.manaesta i.mbmi i.pedusta i.v190 i.hv228 i.v151 i.hhdsz i.cluwealth2 i.mdpi i.hdi i.gii i.v101 ||sstate: ||v001:, or

estat ic
Diagnostic test for LR tests for choice of number of levels in the multilevel analysis**

Multilevel Logistic Analysis**
*****Model 0 (Null model)*******
***** individual-level1 in community level 2 in State in level3*******
melogit anaesta || sstate: || v001:, or
estimate store m1a

***** individual-level 1 in community level 2*******
melogit anaesta || v001:, or
estimate store m3a

lrtest m3a m1a

***** individual-level 1 in community level 2*******
melogit anaesta || sstate:
estimate store m3b

lrtest m3b m1a

*****Balancing the sample size for all models from full model********
Full model with 25 variables***
This extracts the complete cases for anaemia study***
melogit anaesta i.b4 i.chldage1 i.newprbth i.ironsup i.m4 i.dworm i.hml35 i.nutrista i.fever i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pedusta i.v190 i.hv228 i.u5hhd i.rmsleep i.v151 i.hhdsz i.hdi i.gii i.v101 ||sstate: ||v001:, or
predict z
keep if z!=.
keep if anaesta!=.

Multilevel Logistic Analysis of anaemia among children 6-59 months of age in Nigeria**

*****Model 0 (Null model)*******

***** individual-level1 in community level 2 in State in level3*******

melogit anaesta || sstate: || v001:, or

estat icc

estat ic

****Model 1: Child-related variables only******

melogit anaesta i.b4 i.chldage1 i.newprbth i.ironsup i.m4 i.dworm i.hml35 i.nutrista i.fever i.pldel|| sstate: || v001:, or

estat icc

estat ic

****Model 2: Child-related + parental-related variables******

melogit anaesta i.b4 i.chldage1 i.newprbth i.ironsup i.m4 i.dworm i.hml35 i.nutrista i.fever i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pedusta|| sstate: || v001:, or

estat icc

estat ic

****Model 3: Child-related + parental-related + household-related variables******

melogit anaesta i.b4 i.chldage1 i.newprbth i.ironsup i.m4 i.dworm i.hml35 i.nutrista i.fever i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pedusta i.v190 i.hv228 i.u5hhd i.rmsleep i.v151 i.hhdsz|| sstate: || v001:, or

estat icc

estat ic

****Model 4: (Full model) Child-related + parental-related + household-related + area-related variables******

melogit anaesta i.b4 i.chldage1 i.newprbth i.ironsup i.m4 i.dworm i.hml35 i.nutrista i.fever i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pedusta i.v190 i.hv228 i.u5hhd i.rmsleep i.v151 i.hhdsz i.hdi i.gii i.v101 ||sstate: ||v001:, or

estat icc

```
estat ic


clear
```

E.4 Codes for malaria studies

```
****Thesis Data Description*****
***Merging Household file to children File****
***Use Household File Identifiers for PR***
use "D:\UNIVERSITY OF SHEFFIELD MATTERS\STATA DATA
SET\NGPR7ADT\NGPR7AFL.DTA", clear
rename hv001 v001
rename hv002 v002
rename hvidx mergeid

sort v001 v002 mergeid
gen in_PR=1

save temp.dta, replace

***Use Children File Identifiers****

use "D:\UNIVERSITY OF SHEFFIELD MATTERS\STATA DATA
SET\NGKR7AFL.DTA", clear

rename b16 mergeid
sort v001 v002 mergeid
gen in_KR=1

*** Merging the PR and KR Files****

merge m:1 v001 v002 mergeid using temp.dta

keep if in_PR==1 & in_KR==1
tab _merge

****Analysis of Description of Malnutrition among under-5 children in Nigeria*****

***Perform weighting to correct for over and under sample****
gen weight=v005/1000000
svyset [pw=weight], psu(v021) strata (v022)
svydes, single
replace v022=58 if v022==60


****Keep subsample of children under-5 years and child is alive****
keep if hc1>5 & hc1<60
```

```
***Recode under-5 child's age in group***
recode hc1 (0/5=0 "less 6 months")(6/11=1 "6-11 months")(12/23=2 "12-23
months")(24/35=3 "24-35 months")(36/47=4 "36-47 months")(48/59=5 "48-59 months"),
gen(chldage1)
label var chldage1 "child's age in group"
tab chldage1 [iw=weight]

***Recode under-5 age another way*******

recode hc1 (0/5=0 "less 6 months")(6/18=1 "6-18 months")(19/30=2 "19-30
months")(31/42=3 "31-42 months")(43/59=4 "43-59 months"), gen(chldage)
label var chldage "child's age in group"
tab chldage [iw=weight]

gen chage=.
replace chage=. if chldage==0
replace chage=1 if chldage==1
replace chage=2 if chldage==2
replace chage=3 if chldage==3
replace chage=4 if chldage==4
lab define chage 1 "6-18 months" 2"19-30 months" 3"31-42 months" 4"43-59 months"
label var chage "Age of child 6-59 months"
label values chage chage


******Age could be used as continous variable*******

***Tabulate Children under-5 by sex****
tab b4 [iw=weight]

****Recode of Outcome Variables*****

****Outcome variable 1*****
*** Malaria Status by Rapid Diagnostic Test****
codebook hml35
tab hml35 [iw=weight]

*** Malaria Status by Microscopic Blood Smear Examination****
codebook hml32
tab hml32 [iw=weight]

*****Test of independence between the two results*****
spearman hml35 hml32

****Outcome variable 2*****
****Anaemia Status****
codebook hw57
recode hw57(1/3=1 "Anaemic")(4=0 "Not Anaemic"), gen(anaesta)
```

```
label var anaesta "Anaemia status"
tab anaesta [iw=weight]
tab hw57 [iw=weight]

****Outcome variable 3*****
****Malnutrition Status***
***Children who stayed in the household the previous night and who have height and weight z-scores on all 3 measures****
gen eligch = 0
replace eligch = 1 if (hv103==1 & hc70 < 9996 & hc71 < 9996 & hc72 < 9996)


// child stunting calculation
codebook hc70
tab hc70 if hc70>9990,m
tab hc70 if hc70>9990,m nolabel
gen HAZ=hc70
replace HAZ=. if HAZ>=9996
gen stunted=0
replace stunted=0 if HAZ ~=.
replace stunted=1 if HAZ<-200
lab define stunted 0 "not anaemic" 1 "anaemic"
lab var stunted "Stunting Status of Children"


// child wasting calculation
codebook hc72
tab hc72 if hc72>9990,m
tab hc72 if hc72>9990,m nolabel
gen WAH=hc72
replace WAH=. if WAH>=9996
gen wasted=0
replace wasted=0 if WAH ~=.
replace wasted=1 if WAH<-200
lab define wasted 0 "not wasted" 1 "wasted"
lab var wasted "wasting Status of Children"


// child underweight calculation
codebook hc71
tab hc71 if hc71>9990,m
tab hc71 if hc71>9990,m nolabel
gen WAZ=hc71
replace WAZ=. if WAZ>=9996
gen underweight=0
replace underweight=0 if WAZ ~=.
replace underweight=1 if WAZ<-200
lab define underweight 0 "not underweight" 1 "underweight"
lab var underweight "Underweight Status of Children"
```

```
// child overweight calculation
codebook hc72
tab hc72 if hc72>9990,m
tab hc72 if hc72>9990,m nolabel
gen WAH2=hc72
replace WAH2=. if WAH2>=9996
gen overweight1=0
replace overweight1=0 if WAH2 ~=.
replace overweight1=1 if WAH2>200 & WAH2<9990
lab define overweight1 0 "not overweight" 1 "overweight"
lab var overweight "Overweight Status of Children"


tab stunted [iw=weight]
tab wasted [iw=weight]
tab underweight [iw=weight]
tab overweight [iw=weight]

***Generate Malnutrition Status*****
gen malnut=stunted+wasted+underweight+overweight
tab malnut
recode malnut(0=0 "well-nourished")(1/4=1 "poorly nourished"), gen(nutrista)
lab var nutrista "Nutrition Status of Children"
tab nutrista [iw=weight]
tab nutrista [iw=weight], nolabel

****Diarrhael Recode****
gen diarr=.
replace diarr=0 if h11==0
replace diarr=1 if h11==2
replace diarr=. if h11==3
lab define diarr 0 "No diarrhael" 1 "Had diarrhael"
lab var diarr "Diarrhael status"

****Cough Recode****
gen cough=.
replace cough=0 if h31==0
replace cough=1 if h31==2
replace cough=. if h31==8
lab var cough "Cough status"
lab define cough 0 "had no cough" 1 "Had cough"

gen fever=.
replace fever=0 if h22==0
replace fever=1 if h22==1
replace fever=. if h22==8
lab define fever 0 "No" 1 "Yes"
label var fever "Had Fever in last 2 weeks"
```

*****Recodes for Predictors or covariates*******

****Recode of Child Variables ****
recode m18 (1=0 "large size") (2/3=1 "Average size")(4/5=2 "small size")(6/max=3 "I don't Know"), gen(bszgr)
lab var bszgr "Child perceived size at birth"

Recode birth size**
gen bszgr1=.
replace bszgr1=0 if bszgr==0
replace bszgr1=1 if bszgr==1
replace bszgr1=2 if bszgr==2
replace bszgr1=. if bszgr==3
lab define bszgr1 0 "large" 1 "Average" 2 "Small"
label var bszgr1 "Child's birth Size"

*****Child birth order****
recode bord (1=0 "1st") (2/3=1 "2nd or 3rd")(4/6=2 "4-6 th")(7/max=3 "7th+"), gen(brdgr)
lab var brdgr "Child Birth Order"

****Birth order can be used as continous variable******

****Number of under-5 in household******
recode hv014 (0/3=0 "0-3") (4/6=1 "4-6")(7/max=2 "7th+"), gen(u5hhd)
lab var u5hhd "Under-5 in household"

****REcode of household size*****
recode hv009 (0/3=0 "0-3") (4/6=1 "4-6")(7/9=2 "7-9")(10/max=3 "more than 10"), gen(hhdsz)
lab var hhdsz "household member size"

****Recode of place of delivery*****
recode m15 (11/12=0 "home")(21 22 23 26=1 "Public Health facility")(31 36=2 "Private Health Facility"), gen(pladel)
lab var pladel "Place of Delivery"

gen pldel=.
replace pldel=0 if pladel==0
replace pldel=1 if pladel==1
replace pldel=2 if pladel==2
replace pldel=3 if pladel==96
lab define pldel 0 "home" 1 "Public Facility" 2 "Private facility" 3 "elsewhere"
lab var pldel "Place of child's del"

gen dworm=.
replace dworm=0 if h43==0
replace dworm=1 if h43==1
replace dworm=. if h43==8
lab define dworm 0 "No" 1 "Yes"

```
label var dworm "Took deworming drug in last 6months"

gen vita=.
replace vita=0 if h34==0
replace vita=1 if h34==1
replace vita=. if h34==8
lab define vita 0 "No" 1 "Yes"
label var vita "Took Vit A supplements"

gen ironsup=.
replace ironsup=0 if h42==0
replace ironsup=1 if h42==1
replace ironsup=. if h42==8
lab define ironsup 0 "No" 1 "Yes"
label var ironsup "Took Iron supplements"

recode v465 (1 2 5=0)(3 4 9=1)(96=2), gen(stooldisp)

gen stooldis1=.
replace stooldis1=0 if stooldisp==0
replace stooldis1=1 if stooldisp==1
replace stooldis1=. if stooldisp==2
lab define stooldis1 0 "Proper disposal" 1 "Improper disposal"
label var stooldis1 "Youngest Child's stool disposed Properly"


****Recode of Parental/Mother/Care-givers Variables ****
recode v013 (1/2=0 "15-24 years") (3/4=1 "25-34 years") (5/7=2 "35 years+"), gen(magegr)
label var magegr "Maternal age group in 10years"


****Use maternal age as given in data set v013*******

recode hv220 (min/34=0 "less 34 years")(35/44=2 "35-44 years")(45/55=3 "45-55
years")(56/max=4 "56 years+"), gen(hhagegr)
label var hhagegr "Household Head age group"

***Use household head age as continous*****

recode v212 (10/24=0 "10-24")(25/36=1 "25-36")(37/49=2 "37-49") (37/max=3 "37-49"),
gen(agefbth2)
label var agefbth2 "age at first birth"

***Use age at first birth as continous variable****

recode b11(8/24=0 "8-24 months")(25/35=1 "25-35 months")(36/59=2 "36-59
months")(60/max=3 "60+ months"), gen(prbrthint)
label var prbrthint "preceeding birth interval"

*****New prebirthint*****
```

```
gen newprbth=.
replace newprbth=0 if brdgr==0
replace newprbth=1 if prbrthint==0
replace newprbth=2 if prbrthint==1
replace newprbth=3 if prbrthint==2
replace newprbth=4 if prbrthint==3
lab define newprbth 0 "None" 1 "8-24 months" 2 "25-35 months" 3 "36-59 months" 4 "60+
months", modify
label var newprbth "New prebirth interval"
label values newprbth newprbth

tab newprbth [iw=weight]



recode b12(8/24=0 "8-24 months")(25/35=1 "25-35 months")(36/59=2 "36-59
months")(60/max=3 "60+ months"), gen(subrthint)
label var subrthint "suceeding birth interval"

recode v130(1=0 "catholic")(2=1 "other christian")(3=2 "islam")(4/max=3
"traditionalist&others"), gen(relsta)
label var relsta "mother's religious status"

gen pworksta=.
replace pworksta=0 if v705==0
replace pworksta=1 if v705>0
lab define pworksta 0 "not working" 1 "working"
label var pworksta "Husband Work Status"

gen pedusta=.
replace pedusta=0 if v701==0
replace pedusta=1 if v701==1
replace pedusta=2 if v701==2
replace pedusta=3 if v701==3
replace pedusta=. if v701==8
lab define pedusta 0 "no education" 1 "primary" 2 "secondary" 3 "higher"
label var pedusta "mother's partner education status"

****Mother's Anaemia Status****
recode v457(1/3=1 "Anaemic")(4=0 "Not Anaemic"), gen(manaesta)
label var manaesta "Mother's Anaemia status"
tab manaesta [iw=weight], missing

gen mirontab=.
replace mirontab=0 if m45==0
replace mirontab=1 if m45==1
replace mirontab=. if m45==8
lab define mirontab 0 "no" 1 "yes"
label var mirontab "took iron tab during pregnancy"
```

```
recode m14 (0=0 "No ANC Visit") (1/3=1 "ANC Visit less WHO REC") (4/20=2 "ANC Visit Met WHO REC")(21/max=3 "Dont Remember Visiting ANC"), gen(ancvis)
label var ancvis "ANC Visit"

gen ancvis1=.
replace ancvis1=0 if ancvis==0
replace ancvis1=1 if ancvis==1
replace ancvis1=2 if ancvis==2
replace ancvis1=. if ancvis==3
lab define ancvis1 0 "none" 1 "less who rec" 2 "met who rec"
label var ancvis1 "ANC visits during pregnancy"


recode v131(2 3 8=0 "Hausa/Fulani/KanuriSeribiri")(6=1 "Ibos")(10=2 "Yorubas")(else=3 "Others"), gen(ethgr2)
label var ethgr2 "Ethnicity"

***Recoding - Maternal Decision Making Level*****
gen healthcare=0
replace healthcare=1 if v743a==1
replace healthcare=2 if v743a==2
replace healthcare=3 if v743a==3
replace healthcare=4 if v743a>3 & v743a<10
gen lpurchase=0
replace lpurchase=1 if v743b==1
replace lpurchase=2 if v743b==2
replace lpurchase=3 if v743b==3
replace lpurchase=4 if  v743b>3 & v743b<10
gen dpurchase=0
replace dpurchase=1 if v743c==1
replace dpurchase=2 if v743c==2
replace dpurchase=3 if v743c==3
replace dpurchase=4 if v743c>3 & v743c<10
gen  fvisit=0
replace fvisit=1 if v743d==1
replace fvisit=2 if v743d==2
replace fvisit=3 if v743d==3
replace fvisit=4 if v743d>3 & v743d<10
gen auto1=0
replace auto1=2 if healthcare<3
replace auto1=1 if healthcare>2 & healthcare<10
gen auto2=0
replace auto2=2 if lpurchase<3
replace auto2=1 if lpurchase>2 & lpurchase<10
gen auto4=0
replace auto4=2 if fvisit<3
replace auto4=1 if fvisit>2 & fvisit<10
tab1 auto*
***Generating Maternal Autonomylevel****
gen autonomyscore1=auto1+auto2+auto4
```

```
tab autonomyscore1
su autonomyscore1
recode autonomyscore1 (3/4=0 "low Auto") (5/8=1 "more auto"), gen(autonomylevel1)
lab val autonomylevel1 autonomylevel1
tab autonomylevel1 [iw=weight], missing

**Generating Maternal BMI status*****
gen ht_flag=0
replace ht_flag=1 if v438>9000
gen preg_flag=0
replace preg_flag=1 if v213==1
gen months_since_last_birth=v008-b3
gen recent_birth_flag1=0
replace recent_birth_flag1=1 if months_since_last_birth <=2

gen bmi=v445/100
gen bmic=2 if bmi<18.5
replace bmic=1 if bmi>=18.5 & bmi<25
replace bmic=3 if bmi>=25 & bmi<30
replace bmic=4 if bmi>=30 & bmi<60
label define bmic 1"Normal" 2 "Underweight" 3"Overweight" 4"Obese"
label values bmic bmic
svy: tab bmic, count percent format(%4.1f) col

****Generate Maternal BMI*****

gen mbmi=bmic if ht_flag==0 & preg_flag==0 & recent_birth_flag1==0
label define mbmi 1 "Normal" 2 "underweight" 3 "Overweight" 4 "Obese"
label values mbmi mbmi


****Recode of Household Variables ****
gen shatoi1=.
replace shatoi1=0 if v160==0
replace shatoi1=1 if v160==1
replace shatoi1=. if v160==7
label define shatoi1 0 "No" 1 "Yes"
label var shatoi1 "Shared Toilet Facilities"

recode hv226(1/4=0)(5/10=1)(11/max=2), gen(cookfuel2)
label var cookfuel2 "Cooking Fuel Used"

gen cookfue=.
replace cookfue=0 if cookfuel2==0
replace cookfue=1 if cookfuel2==1
replace cookfue=. if cookfuel2==3
label define cookfue 0 "Elect&Gas" 1 "Biofuel"
label var cookfue "Type of cooking fuel"

***Recode floor material types***
```

```
recode hv213(11 12 96=0 "unimproved floor materials")(21 22 31 32 33 34 35=1 "improved
floor materials"), gen(floormat)
label var floormat "Floor Materials"

***Recode roof material types***
recode hv215(11 12 13 21 22 23 24 96=0 "unimproved roof materials")(31 32 33 34 35 36=1
"improved roof materials"), gen(roofmat)
label var roofmat "Roof Materials"

***Recode wall material types***
recode hv214(11 12 13 21 22 23 24 25 26 96=0 "unimproved wall materials")(31 32 33 34 35
36=1 "improved wall materials"), gen(wallmat)
label var wallmat "wall Materials"

***Recode Number of rooms for sleep***
recode hv216(1=0 "One-room")(2=1 "two rooms")(3=2 "three rooms")(4=3 "Four
rooms")(5/max=4 "Five+ rooms"), gen(rmsleep)
label var rmsleep "Number of rooms for sleep"

***Recode Scource of drinking water***
recode hv201(32 42 43 61 62 96=0 "unimproved drinking water")(11 12 13 14 21 31 41 51
71 92=1 "improved drinking water"), gen(watascou1)
label var watascou1 "source of drinking water"

***Recode type of toilet facility***
recode hv205(14 15 23 31 42 43 96=0 "unimproved toilet factories")(11 12 13 16 21 22 41=1
"improved toilet factories"), gen(toilfac1)
label var toilfac1 "type of toilet facility"

gen electr=.
replace electr=0 if v119==0
replace electr=1 if v119==1
replace electr=. if v119==3
lab define electr 0 "No" 1 "Yes"
label var electr "Household had electricity"

***Generating Cluster Variables****

*****Generating proportion of cluster wealth status**********
bysort v001: egen cuwealth1=mean(v190)
bysort v001: egen cuwe1= count(v190)


sum cuwealth1, detail          //you will find median

gen clwea3=.
replace clwea3=1 if cuwealth1<3
replace clwea3=2 if cuwealth1==3
replace clwea3=3 if cuwealth1>3
```

```
recode clwea3(1=0 "low") (2/3=1 "high"), gen(cluwealth2)
lab var cluwealth2 "Cluster wealth level"
lab values cluwealth2 cluwealth2
tab cluwealth2 [iw=weight]

******Generating cluster maternal education status*****
bysort v001: egen cumatedu2=mean(v106)
bysort v001: egen cumate2= count(v106)


sum cumatedu2, detail          //you will find median

gen clmated2=.
replace clmated2=1 if cumatedu2<1.2
replace clmated2=2 if cumatedu2==1.2
replace clmated2=3 if cumatedu2>1.2

recode clmated2(1=0 "low") (2/3=1 "high"), gen(clumated1)
lab var clumated1 "Cluster maternal education level"
lab values clumated1 clumated1
tab clumated1 [iw=weight]

*****Generating proportion of respondents with distance to health facility is no problem in
cluster*****
recode v467d(1=0 "big problem")(2=1 "no big problem"), gen(dismed)
bysort v001: egen cudistmed=mean(dismed)
sum cudistmed, detail          //you will find median

gen cludistm=.
replace cludistm=0 if cudistmed<0.8
replace cludistm=1 if cudistmed>=0.8
lab define cludistm 0 "low" 1 "high"
lab var cludistm "low cluster distance to health facility"
lab values cludistm cludistm
tab cludistm [iw=weight]

****Generating proportion of respondent with no cluster household with bed net*******
recode hv227(0=1 "no bed net")(1=0 "Yes"), gen(bnet)
bysort v001: egen hdbnet=mean(bnet)
sum hdbnet, detail          //you will find median

gen cluhdbnet=.
replace cluhdbnet=0 if hdbnet<0.25
replace cluhdbnet=1 if hdbnet>=0.25

lab define cluhdbnet 0 "low" 1 "high"
lab var cluhdbnet "low cluster household with no bed net"
lab values cluhdbnet hdbnet

tab cluhdbnet [iw=weight]
```

```
***Recoding Area Variables using UNDP data set into NDHS****
***Classifying state by Multidimensional poverty Index*****

recode sstate(10 40 50=0 "Highly Deprived")(20 30 60 80 90 100 120 160 170=1 "Above
averagely deprived")(70 110 130 150 280 300 330 340=2 "Averagely Deprived")(140 180
190 200 210 250 270 290 310 320=3 "Mildly Deprived")(220 230 240 260 350 360 370=4
"Lowest Deprived"), gen(mdpi)
label var mdpi "Multidimensional Poverty Index by State"

recode mdpi (0/1=0 "Highly deprived")(2/4=1 "Lowly Deprived"), gen(mdpi2)
label var mdpi2 "MDPI in 2 Cat"
tab mdpi2

recode sstate(10 20 30 50 60 90=0 "Lowest HDI")(40 80 100 110 120 130=1 "Low HDI")(70
160 170 180 190 210 260 280=2 "Avverage HDI")(150 200 220 230 240 250 270 290 300
310 320 330 350 370=3 "High HDI")(140 340 360=4 "Highest HDI"), gen(hdi)
label var hdi "Human Development Index by State"

recode hdi(0/1=0 "Low hdi")(2/4=1 "High hdi"), gen(hdi2)
label var hdi2 "HDI in 2 Cat"
tab hdi2

recode sstate(140 200 210 240 260 270 280 300 350 360=1 "Lowest GII")(160 250 290 310
320 330=2 "Low GII")(90 150 180 230=3 "Average GII")(20 30 40 70 80 100 110 130 170
220 340 370=4 "High GII")(10 50 60 120 190=5 "Highest GII"), gen(gii)
label var gii "Gender Inequality Index by State"
label values gii gii

tab gii
tab gii [iw=weight]

recode gii (1/2=1 "Lowest GII")(3=2 "Average GII")(4/5=3 "Highest GII"), gen(sgii)
lab var sgii "State genger inq index"
lab values sgii sgii

recode sgii (1/2=1 "Low GII")(3/5=2 "High GII"), gen(shd)



***Bar chart of prevalence of malaria*****
label values hml35 labels6
label def labels6 0 "RDT Negative", modify
label def labels6 1 "RDT Positive", modify

label values hml32 labels7
label def labels7 0 "Smear Negative", modify
label def labels7 1 "Smear Positive", modify
```

```
graph bar [aweight = weight], over(hml35) asyvars blabel(bar, format(%9.1f)) bargap(10)
name(c6, replace)
graph bar [aweight = weight], over(hml32) asyvars blabel(bar, format(%9.1f)) bargap(10)
name(c7, replace)

graph combine c6 c7, c(1) imargin(zero) title("Bar chart representing the prevalence of
malaria status") subtitle("by rapid diagnostic and blood smear tests") name(malaria, replace)

graph bar [aweight = weight], over(v102) over(hml35) asyvars blabel(bar, format(%9.1f))
title("Percentage of RDT positive by place of residence") name(malanapla, replace)

graph bar [aweight = weight], over(v101) over(hml35) asyvars blabel(bar, format(%9.1f))
title("Percentage of RDT positive children by place of residence") name(malapla1, replace)

graph bar [aweight = weight], over(b4) over(hml35) asyvars blabel(bar, format(%9.1f))
title("Percentage of RDT positive children by gender") name(malagen, replace)

graph bar [aweight = weight], over(chldage1) over(hml35) asyvars blabel(bar, format(%9.1f))
title("Percentage of RDT positive children by age") name(malacage1, replace)

graph bar [aweight = weight], over(hml35) over(chldage1) asyvars blabel(bar, format(%9.1f))
title("Percentage of RDT positive children by age") name(malacage2, replace)


*****relationship between child's variables and malaria*****
svy: tab b4 hml35, count row pearson
asdoc tabulate b4 hml35 [iweight = weight], append

svy: tab chldage1 hml35, count row pearson
asdoc tabulate chldage1 hml35 [iweight = weight], append

svy: tab bszgr1 hml35, count row pearson
asdoc tabulate bszgr1 hml35 [iweight = weight], append

svy: tab brdgr hml35, count row pearson
asdoc tabulate brdgr hml35 [iweight = weight], append

svy: tab newprbth hml35, count row pearson
asdoc tabulate prbrthint hml35 [iweight = weight], append

svy: tab vita hml35, count row pearson
asdoc tabulate vita hml35 [iweight = weight], append

svy: tab ironsup hml35, count row pearson
asdoc tabulate ironsup hml35 [iweight = weight], append

svy: tab m4 hml35, count row pearson
asdoc tabulate m4 hml35 [iweight = weight], append

svy: tab dworm hml35, count row pearson
```

```
asdoc tabulate dworm hml35 [iweight = weight], append

svy: tab fever hml35, count row pearson
asdoc tabulate fever hml35 [iweight = weight], append

svy: tab cough hml35, count row pearson
asdoc tabulate cough hml35 [iweight = weight], append

svy: tab diarr hml35, count row pearson
asdoc tabulate diarr hml35 [iweight = weight], append

svy: tab pldel hml35, count row pearson
asdoc tabulate pldel hml35 [iweight = weight], append


****Table :Relationship between Parental variables and malaria status
svy: tab magegr hml35, count row pearson
asdoc tabulate magegr hml35 [iweight = weight], append

svy: tab v714 hml35, count row pearson
asdoc tabulate v714 hml35 [iweight = weight], append

svy: tab agefbth2 hml35, count row pearson
asdoc tabulate agefbth2 hml35 [iweight = weight], append

svy: tab v106 hml35, count row pearson
asdoc tabulate v106 hml35 [iweight = weight], append

svy: tab v504 hml35, count row pearson
asdoc tabulate v504 hml35 [iweight = weight], append

svy: tab autonomylevel1 hml35, count row pearson
asdoc tabulate autonomylevel1 hml35 [iweight = weight], append

svy: tab v461 hml35, count row pearson
asdoc tabulate v461 hml35 [iweight = weight], append

svy: tab ancvis1 hml35, count row pearson
asdoc tabulate ancvis1 hml35 [iweight = weight], append

svy: tab relsta hml35, count row pearson
asdoc tabulate relsta hml35 [iweight = weight], append

svy: tab ethgr2 hml35, count row pearson
asdoc tabulate ethgr2 hml35 [iweight = weight], append

svy: tab mirontab hml35, count row pearson
asdoc tabulate mirontab hml35 [iweight = weight], append

svy: tab manaesta hml35, count row pearson
```

```
asdoc tabulate mhml35 hml35 [iweight = weight], append

svy: tab mbmi hml35, count row pearson
asdoc tabulate mbmi hml35 [iweight = weight], append

svy: tab pworksta hml35, count row pearson
asdoc tabulate pworksta hml35 [iweight = weight], append

svy: tab pedusta hml35, count row pearson
asdoc tabulate pedusta hml35 [iweight = weight], append


****Table :Relationship between Household variables and malaria status
svy: tab v190 hml35, count row pearson
asdoc tabulate v190 hml35 [iweight = weight], append

svy: tab hhagegr hml35, count row pearson
asdoc tabulate hhagegr hml35 [iweight = weight], append

svy: tab hv228  hml35, count row pearson
asdoc tabulate hv228 hml35 [iweight = weight], append

svy: tab u5hhd hml35, count row pearson
asdoc tabulate u5hhd hml35 [iweight = weight], append

svy: tab rmsleep hml35, count row pearson
asdoc tabulate rmsleep hml35 [iweight = weight], append

svy: tab electr hml35, count row pearson
asdoc tabulate electr hml35 [iweight = weight], append

svy: tab watascou1 hml35, count row pearson
asdoc tabulate watascou1 hml35 [iweight = weight], append

svy: tab toilfac1 hml35, count row pearson
asdoc tabulate toilfac1 hml35 [iweight = weight], append

svy: tab cookfue hml35, count row pearson
asdoc tabulate cookfue hml35 [iweight = weight], append

svy: tab floormat hml35, count row pearson
asdoc tabulate floormat hml35 [iweight = weight], append

svy: tab roofmat hml35, count row pearson
asdoc tabulate roofmat hml35 [iweight = weight], append

svy: tab wallmat hml35, count row pearson
asdoc tabulate wallmat hml35 [iweight = weight], append

svy: tab v151 hml35, count row pearson
```

```
asdoc tabulate v151 hml35 [iweight = weight], append

svy: tab shatoi1 hml35, count row pearson
asdoc tabulate shatoi1 hml35 [iweight = weight], append

***Others added***
svy: tab hv227 hml35, count row pearson
asdoc tabulate hv227 hml35 [iweight = weight], append

svy: tab hhdsz hml35, count row pearson
asdoc tabulate hhdsz hml35 [iweight = weight], append

svy: tab stooldis1 hml35, count row pearson
asdoc tabulate stooldis1 hml35 [iweight = weight], append

svy: tab v159 hml35, count row pearson
asdoc tabulate v159 hml35 [iweight = weight], append


****Relationship between cluster variables and malaria status*****
svy: tab cluwealth2 hml35, count row pearson
asdoc tabulate cluwealth2 hml35 [iweight = weight], append

svy: tab cludistm hml35, count row pearson
asdoc tabulate cludistm hml35 [iweight = weight], append

svy: tab clumated1 hml35, count row pearson
asdoc tabulate clumated1 hml35 [iweight = weight], append

svy: tab cluhdbnet hml35, count row pearson
asdoc tabulate cluhdbnet hml35 [iweight = weight], append


****Table :Relationship between Area variables and malaria status
svy: tab mdpi hml35, count row pearson
asdoc tabulate mdpi hml35 [iweight = weight], append

svy: tab hdi hml35, count row pearson
asdoc tabulate hdi hml35 [iweight = weight], append

svy: tab gii hml35, count row pearson
asdoc tabulate gii hml35 [iweight = weight], append

svy: tab v101 hml35, count row pearson
asdoc tabulate v101 hml35 [iweight = weight], append

svy: tab v102 hml35, count row pearson
asdoc tabulate v102 hml35 [iweight = weight], append

****MLR for MALARIA ANALYSES******
```

****backward stepwise selection of variables for malaria study**********

stepwise, pr(.2): logit hml35 i.b4 i.chldage1 i.bszgr1 i.newprbth i.vita i.ironsup i.m4 i.dworm i.nutrista i.anaesta i.fever i.cough i.diarr i.pldel i.magegr i.v714 i.agefbth2 i.v106 i.v504 i.autonomylevel1 i.v461 i.relsta i.ethgr2 i.mirontab i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr i.hv228 i.u5hhd i.rmsleep i.electr i.v151 i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.cluhdbnet i.mdpi i.hdi i.gii i.v101 i.v102

****Testing the goodness of fit from the backward selected variables using AIC and BIC******
melogit hml35 i.b4 i.chldage1 i.bszgr1 i.newprbth i.m4 i.dworm i.nutrista i.anaesta i.fever i.magegr i.agefbth2 i.v106 i.ethgr2 i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr i.hv228 i.u5hhd i.rmsleep i.v151 i.hhdsz i.cludistm i.mdpi i.hdi i.gii i.v101 i.v102 ||sstate: ||v001:, or

estat ic

****Forward stepwise selection of variables for malaria study**********
stepwise, pe(.2): logit hml35 i.b4 i.chldage1 i.bszgr1 i.newprbth i.vita i.ironsup i.m4 i.dworm i.nutrista i.anaesta i.fever i.cough i.diarr i.pldel i.magegr i.v714 i.agefbth2 i.v106 i.v504 i.autonomylevel1 i.v461 i.relsta i.ethgr2 i.mirontab i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr i.hv228 i.u5hhd i.rmsleep i.electr i.v151 i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.cluhdbnet i.mdpi i.hdi i.gii i.v101 i.v102

****Testing the goodness of fit from the forward selected variables using AIC and BIC******
melogit hml35 i.b4 i.chldage1 i.bszgr1 i.m4 i.dworm i.nutrista i.anaesta i.fever i.v106 i.relsta i.ethgr2 i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr i.hv228 i.rmsleep i.cluwealth2 i.cludistm i.mdpi i.hdi i.gii i.v101 i.v102 ||sstate: ||v001:, or

estat ic

****Testing the goodness of fit from the forward + backward selected variables using AIC and BIC*********
****This produced lower AIC & BIC****
melogit hml35 i.b4 i.chldage1 i.bszgr1 i.newprbth i.m4 i.dworm i.nutrista i.anaesta i.fever i.magegr i.agefbth2 i.v106 i.relsta i.ethgr2 i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr i.hv228 i.u5hhd i.rmsleep i.v151 i.hhdsz i.cluwealth2 i.cludistm i.mdpi i.hdi i.gii i.v101 i.v102 ||sstate: ||v001:, or

estat ic

*****Balancing the sample size for all models from backward stepwise *****
quietly: melogit hml35 i.b4 i.chldage1 i.bszgr1 i.newprbth i.m4 i.dworm i.nutrista i.anaesta i.fever i.magegr i.agefbth2 i.v106 i.ethgr2 i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr i.hv228 i.u5hhd i.rmsleep i.v151 i.hhdsz i.cludistm i.mdpi i.hdi i.gii i.v101 i.v102 ||sstate: ||v001:, or

predict y

```
keep if y!=.
keep if hml35!=.


******MLR of malaria******
******Model 1 (Null model)********
melogit hml35 ||sstate: ||v001:, or

estat icc
estat ic

***Model 2 (child-related variables****)
melogit hml35 i.b4 i.chldage1 i.bszgr1 i.newprbth i.m4 i.dworm i.nutrista i.anaesta i.fever
||sstate: ||v001:, or

estat icc
estat ic


******Model 3 (Child + parented-related model)********
melogit hml35 i.b4 i.chldage1 i.bszgr1 i.newprbth i.m4 i.dworm i.nutrista i.anaesta i.fever
i.magegr i.agefbth2 i.v106 i.ethgr2 i.manaesta i.mbmi i.pworksta i.pedusta ||sstate: ||v001:, or

estat icc
estat ic


******Model 4: LEVEL 1 (Child + parented + household-related model)********
melogit hml35 i.b4 i.chldage1 i.bszgr1 i.newprbth i.m4 i.dworm i.nutrista i.anaesta i.fever
i.magegr i.agefbth2 i.v106 i.ethgr2 i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr
i.hv228 i.u5hhd i.rmsleep i.v151 i.hhdsz ||sstate: ||v001:, or

estat icc
estat ic

******Model 5: LEVELS 1 + 2 (Child + parented + household-related + community-related
model)********
melogit hml35 i.b4 i.chldage1 i.bszgr1 i.newprbth i.m4 i.dworm i.nutrista i.anaesta i.fever
i.magegr i.agefbth2 i.v106 i.ethgr2 i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr
i.hv228 i.u5hhd i.rmsleep i.v151 i.hhdsz i.cludistm||sstate: ||v001:, or

estat icc
estat ic

******Model 6: LEVELS 1 + 2 + 3 (Child + parented + household-related + community +
Area-related model)******
melogit hml35 i.b4 i.chldage1 i.bszgr1 i.newprbth i.m4 i.dworm i.nutrista i.anaesta i.fever
i.magegr i.agefbth2 i.v106 i.ethgr2 i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr
i.hv228 i.u5hhd i.rmsleep i.v151 i.hhdsz i.cludistm i.mdpi i.hdi i.gii i.v101 i.v102 ||sstate:
||v001:, or
```

```
estat icc
estat ic


clear
```

E.5 Codes for malnutrition studies

```
****Thesis Data Description*****
***Merging Household file to children File****
***Use Household File Identifiers for PR***
use "D:\UNIVERSITY OF SHEFFIELD MATTERS\STATA DATA
SET\NGPR7ADT\NGPR7AFL.DTA", clear
rename hv001 v001
rename hv002 v002
rename hvidx mergeid

sort v001 v002 mergeid
gen in_PR=1

save temp.dta, replace

***Use Children File Identifiers****

use "D:\UNIVERSITY OF SHEFFIELD MATTERS\STATA DATA
SET\NGKR7AFL.DTA", clear

rename b16 mergeid
sort v001 v002 mergeid
gen in_KR=1

*** Merging the PR and KR Files****

merge m:1 v001 v002 mergeid using temp.dta

keep if in_PR==1 & in_KR==1
tab _merge

****Analysis of Description of Malnutrition among under-5 children in Nigeria*****

***Perform weighting to correct for over and under sample****
gen weight=v005/1000000
svyset [pw=weight], psu(v021) strata (v022)
svydes, single
replace v022=58 if v022==60


****Keep subsample of children under-5 years and child is alive****
keep if hc1>5 & hc1<60
```

```
***Recode under-5 child's age in group***
recode hc1 (0/5=0 "less 6 months")(6/11=1 "6-11 months")(12/23=2 "12-23
months")(24/35=3 "24-35 months")(36/47=4 "36-47 months")(48/59=5 "48-59 months"),
gen(chldage1)
label var chldage1 "child's age in group"
tab chldage1 [iw=weight]

***Recode under-5 age another way*******

recode hc1 (0/5=0 "less 6 months")(6/18=1 "6-18 months")(19/30=2 "19-30
months")(31/42=3 "31-42 months")(43/59=4 "43-59 months"), gen(chldage)
label var chldage "child's age in group"
tab chldage [iw=weight]

gen chage=.
replace chage=. if chldage==0
replace chage=1 if chldage==1
replace chage=2 if chldage==2
replace chage=3 if chldage==3
replace chage=4 if chldage==4
lab define chage 1 "6-18 months" 2"19-30 months" 3"31-42 months" 4"43-59 months"
label var chage "Age of child 6-59 months"
label values chage chage


******Age could be used as continous variable*******

***Tabulate Children under-5 by sex****
tab b4 [iw=weight]

****Recode of Outcome Variables*****

****Outcome variable 1*****
*** Malaria Status by Rapid Diagnostic Test****
codebook hml35
tab hml35 [iw=weight]

*** Malaria Status by Microscopic Blood Smear Examination****
codebook hml32
tab hml32 [iw=weight]

*****Test of independence between the two results*****
spearman hml35 hml32

****Outcome variable 2*****
****Anaemia Status****
codebook hw57
recode hw57(1/3=1 "Anaemic")(4=0 "Not Anaemic"), gen(anaesta)
label var anaesta "Anaemia status"
```

```
tab anaesta [iw=weight]
tab hw57 [iw=weight]

****Outcome variable 3*****
****Malnutrition Status***
***Children who stayed in the household the previous night and who have height and weight z-scores on all 3 measures****
gen eligch = 0
replace eligch = 1 if (hv103==1 & hc70 < 9996 & hc71 < 9996 & hc72 < 9996)


// child stunting calculation
codebook hc70
tab hc70 if hc70>9990,m
tab hc70 if hc70>9990,m nolabel
gen HAZ=hc70
replace HAZ=. if HAZ>=9996
gen stunted=0
replace stunted=0 if HAZ ~=.
replace stunted=1 if HAZ<-200
lab define stunted 0 "not anaemic" 1 "anaemic"
lab var stunted "Stunting Status of Children"


// child wasting calculation
codebook hc72
tab hc72 if hc72>9990,m
tab hc72 if hc72>9990,m nolabel
gen WAH=hc72
replace WAH=. if WAH>=9996
gen wasted=0
replace wasted=0 if WAH ~=.
replace wasted=1 if WAH<-200
lab define wasted 0 "not wasted" 1 "wasted"
lab var wasted "wasting Status of Children"


// child underweight calculation
codebook hc71
tab hc71 if hc71>9990,m
tab hc71 if hc71>9990,m nolabel
gen WAZ=hc71
replace WAZ=. if WAZ>=9996
gen underweight=0
replace underweight=0 if WAZ ~=.
replace underweight=1 if WAZ<-200
lab define underweight 0 "not underweight" 1 "underweight"
lab var underweight "Underweight Status of Children"
```

```
// child overweight calculation
codebook hc72
tab hc72 if hc72>9990,m
tab hc72 if hc72>9990,m nolabel
gen WAH2=hc72
replace WAH2=. if WAH2>=9996
gen overweight1=0
replace overweight1=0 if WAH2 ~=.
replace overweight1=1 if WAH2>200 & WAH2<9990
lab define overweight1 0 "not overweight" 1 "overweight"
lab var overweight "Overweight Status of Children"


tab stunted [iw=weight]
tab wasted [iw=weight]
tab underweight [iw=weight]
tab overweight [iw=weight]

***Generate Malnutrition Status*****
gen malnut=stunted+wasted+underweight+overweight
tab malnut
recode malnut(0=0 "well-nourished")(1/4=1 "poorly nourished"), gen(nutrista)
lab var nutrista "Nutrition Status of Children"
tab nutrista [iw=weight]
tab nutrista [iw=weight], nolabel

****Diarrhael Recode****
gen diarr=.
replace diarr=0 if h11==0
replace diarr=1 if h11==2
replace diarr=. if h11==3
lab define diarr 0 "No diarrhael" 1 "Had diarrhael"
lab var diarr "Diarrhael status"

****Cough Recode****
gen cough=.
replace cough=0 if h31==0
replace cough=1 if h31==2
replace cough=. if h31==8
lab var cough "Cough status"
lab define cough 0 "had no cough" 1 "Had cough"

gen fever=.
replace fever=0 if h22==0
replace fever=1 if h22==1
replace fever=. if h22==8
lab define fever 0 "No" 1 "Yes"
label var fever "Had Fever in last 2 weeks"
```

*****Recodes for Predictors or covariates*******

****Recode of Child Variables ****
recode m18 (1=0 "large size") (2/3=1 "Average size")(4/5=2 "small size")(6/max=3 "I don't Know"), gen(bszgr)
lab var bszgr "Child perceived size at birth"

Recode birth size**
gen bszgr1=.
replace bszgr1=0 if bszgr==0
replace bszgr1=1 if bszgr==1
replace bszgr1=2 if bszgr==2
replace bszgr1=. if bszgr==3
lab define bszgr1 0 "large" 1 "Average" 2 "Small"
label var bszgr1 "Child's birth Size"

*****Child birth order****
recode bord (1=0 "1st") (2/3=1 "2nd or 3rd")(4/6=2 "4-6 th")(7/max=3 "7th+"), gen(brdgr)
lab var brdgr "Child Birth Order"

****Birth order can be used as continous variable******

****Number of under-5 in household******
recode hv014 (0/3=0 "0-3") (4/6=1 "4-6")(7/max=2 "7th+"), gen(u5hhd)
lab var u5hhd "Under-5 in household"

****REcode of household size*****
recode hv009 (0/3=0 "0-3") (4/6=1 "4-6")(7/9=2 "7-9")(10/max=3 "more than 10"), gen(hhdsz)
lab var hhdsz "household member size"

****Recode of place of delivery*****
recode m15 (11/12=0 "home")(21 22 23 26=1 "Public Health facility")(31 36=2 "Private Health Facility"), gen(pladel)
lab var pladel "Place of Delivery"

gen pldel=.
replace pldel=0 if pladel==0
replace pldel=1 if pladel==1
replace pldel=2 if pladel==2
replace pldel=3 if pladel==96
lab define pldel 0 "home" 1 "Public Facility" 2 "Private facility" 3 "elsewhere"
lab var pldel "Place of child's del"

gen dworm=.
replace dworm=0 if h43==0
replace dworm=1 if h43==1
replace dworm=. if h43==8
lab define dworm 0 "No" 1 "Yes"
label var dworm "Took deworming drug in last 6months"

```
gen vita=.
replace vita=0 if h34==0
replace vita=1 if h34==1
replace vita=. if h34==8
lab define vita 0 "No" 1 "Yes"
label var vita "Took Vit A supplements"

gen ironsup=.
replace ironsup=0 if h42==0
replace ironsup=1 if h42==1
replace ironsup=. if h42==8
lab define ironsup 0 "No" 1 "Yes"
label var ironsup "Took Iron supplements"

recode v465 (1 2 5=0)(3 4 9=1)(96=2), gen(stooldisp)

gen stooldis1=.
replace stooldis1=0 if stooldisp==0
replace stooldis1=1 if stooldisp==1
replace stooldis1=. if stooldisp==2
lab define stooldis1 0 "Proper disposal" 1 "Improper disposal"
label var stooldis1 "Youngest Child's stool disposed Properly"


****Recode of Parental/Mother/Care-givers Variables ****
recode v013 (1/2=0 "15-24 years") (3/4=1 "25-34 years") (5/7=2 "35 years+"), gen(magegr)
label var magegr "Maternal age group in 10years"


****Use maternal age as given in data set v013*******

recode hv220 (min/34=0 "less 34 years")(35/44=2 "35-44 years")(45/55=3 "45-55
years")(56/max=4 "56 years+"), gen(hhagegr)
label var hhagegr "Household Head age group"

***Use household head age as continous*****

recode v212 (10/24=0 "10-24")(25/36=1 "25-36")(37/49=2 "37-49") (37/max=3 "37-49"),
gen(agefbth2)
label var agefbth2 "age at first birth"

***Use age at first birth as continous variable****

recode b11(8/24=0 "8-24 months")(25/35=1 "25-35 months")(36/59=2 "36-59
months")(60/max=3 "60+ months"), gen(prbrthint)
label var prbrthint "preceeding birth interval"

*****New prebirthint*****
gen newprbth=.
```

```
replace newprbth=0 if brdgr==0
replace newprbth=1 if prbrthint==0
replace newprbth=2 if prbrthint==1
replace newprbth=3 if prbrthint==2
replace newprbth=4 if prbrthint==3
lab define newprbth 0 "None" 1 "8-24 months" 2 "25-35 months" 3 "36-59 months" 4 "60+
months", modify
label var newprbth "New prebirth interval"
label values newprbth newprbth

tab newprbth [iw=weight]



recode b12(8/24=0 "8-24 months")(25/35=1 "25-35 months")(36/59=2 "36-59
months")(60/max=3 "60+ months"), gen(subrthint)
label var subrthint "suceeding birth interval"

recode v130(1=0 "catholic")(2=1 "other christian")(3=2 "islam")(4/max=3
"traditionalist&others"), gen(relsta)
label var relsta "mother's religious status"

gen pworksta=.
replace pworksta=0 if v705==0
replace pworksta=1 if v705>0
lab define pworksta 0 "not working" 1 "working"
label var pworksta "Husband Work Status"

gen pedusta=.
replace pedusta=0 if v701==0
replace pedusta=1 if v701==1
replace pedusta=2 if v701==2
replace pedusta=3 if v701==3
replace pedusta=. if v701==8
lab define pedusta 0 "no education" 1 "primary" 2 "secondary" 3 "higher"
label var pedusta "mother's partner education status"

****Mother's Anaemia Status****
recode v457(1/3=1 "Anaemic")(4=0 "Not Anaemic"), gen(manaesta)
label var manaesta "Mother's Anaemia status"
tab manaesta [iw=weight], missing

gen mirontab=.
replace mirontab=0 if m45==0
replace mirontab=1 if m45==1
replace mirontab=. if m45==8
lab define mirontab 0 "no" 1 "yes"
label var mirontab "took iron tab during pregnancy"
```

```
recode m14 (0=0 "No ANC Visit") (1/3=1 "ANC Visit less WHO REC") (4/20=2 "ANC Visit Met WHO REC")(21/max=3 "Dont Remember Visiting ANC"), gen(ancvis)
label var ancvis "ANC Visit"

gen ancvis1=.
replace ancvis1=0 if ancvis==0
replace ancvis1=1 if ancvis==1
replace ancvis1=2 if ancvis==2
replace ancvis1=. if ancvis==3
lab define ancvis1 0 "none" 1 "less who rec" 2 "met who rec"
label var ancvis1 "ANC visits during pregnancy"


recode v131(2 3 8=0 "Hausa/Fulani/KanuriSeribiri")(6=1 "Ibos")(10=2 "Yorubas")(else=3 "Others"), gen(ethgr2)
label var ethgr2 "Ethnicity"

***Recoding - Maternal Decision Making Level*****
gen healthcare=0
replace healthcare=1 if v743a==1
replace healthcare=2 if v743a==2
replace healthcare=3 if v743a==3
replace healthcare=4 if v743a>3 & v743a<10
gen lpurchase=0
replace lpurchase=1 if v743b==1
replace lpurchase=2 if v743b==2
replace lpurchase=3 if v743b==3
replace lpurchase=4 if  v743b>3 & v743b<10
gen dpurchase=0
replace dpurchase=1 if v743c==1
replace dpurchase=2 if v743c==2
replace dpurchase=3 if v743c==3
replace dpurchase=4 if v743c>3 & v743c<10
gen  fvisit=0
replace fvisit=1 if v743d==1
replace fvisit=2 if v743d==2
replace fvisit=3 if v743d==3
replace fvisit=4 if v743d>3 & v743d<10
gen auto1=0
replace auto1=2 if healthcare<3
replace auto1=1 if healthcare>2 & healthcare<10
gen auto2=0
replace auto2=2 if lpurchase<3
replace auto2=1 if lpurchase>2 & lpurchase<10
gen auto4=0
replace auto4=2 if fvisit<3
replace auto4=1 if fvisit>2 & fvisit<10
tab1 auto*
***Generating Maternal Autonomylevel****
gen autonomyscore1=auto1+auto2+auto4
```

```
tab autonomyscore1
su autonomyscore1
recode autonomyscore1 (3/4=0 "low Auto") (5/8=1 "more auto"), gen(autonomylevel1)
lab val autonomylevel1 autonomylevel1
tab autonomylevel1 [iw=weight], missing

**Generating Maternal BMI status*****
gen ht_flag=0
replace ht_flag=1 if v438>9000
gen preg_flag=0
replace preg_flag=1 if v213==1
gen months_since_last_birth=v008-b3
gen recent_birth_flag1=0
replace recent_birth_flag1=1 if months_since_last_birth <=2

gen bmi=v445/100
gen bmic=2 if bmi<18.5
replace bmic=1 if bmi>=18.5 & bmi<25
replace bmic=3 if bmi>=25 & bmi<30
replace bmic=4 if bmi>=30 & bmi<60
label define bmic 1"Normal" 2 "Underweight" 3"Overweight" 4"Obese"
label values bmic bmic
svy: tab bmic, count percent format(%4.1f) col

****Generate Maternal BMI*****

gen mbmi=bmic if ht_flag==0 & preg_flag==0 & recent_birth_flag1==0
label define mbmi 1 "Normal" 2 "underweight" 3 "Overweight" 4 "Obese"
label values mbmi mbmi


****Recode of Household Variables ****
gen shatoi1=.
replace shatoi1=0 if v160==0
replace shatoi1=1 if v160==1
replace shatoi1=. if v160==7
label define shatoi1 0 "No" 1 "Yes"
label var shatoi1 "Shared Toilet Facilities"

recode hv226(1/4=0)(5/10=1)(11/max=2), gen(cookfuel2)
label var cookfuel2 "Cooking Fuel Used"

gen cookfue=.
replace cookfue=0 if cookfuel2==0
replace cookfue=1 if cookfuel2==1
replace cookfue=. if cookfuel2==3
label define cookfue 0 "Elect&Gas" 1 "Biofuel"
label var cookfue "Type of cooking fuel"

***Recode floor material types***
```

```
recode hv213(11 12 96=0 "unimproved floor materials")(21 22 31 32 33 34 35=1 "improved
floor materials"), gen(floormat)
label var floormat "Floor Materials"

***Recode roof material types***
recode hv215(11 12 13 21 22 23 24 96=0 "unimproved roof materials")(31 32 33 34 35 36=1
"improved roof materials"), gen(roofmat)
label var roofmat "Roof Materials"

***Recode wall material types***
recode hv214(11 12 13 21 22 23 24 25 26 96=0 "unimproved wall materials")(31 32 33 34 35
36=1 "improved wall materials"), gen(wallmat)
label var wallmat "wall Materials"

***Recode Number of rooms for sleep***
recode hv216(1=0 "One-room")(2=1 "two rooms")(3=2 "three rooms")(4=3 "Four
rooms")(5/max=4 "Five+ rooms"), gen(rmsleep)
label var rmsleep "Number of rooms for sleep"

***Recode Scource of drinking water***
recode hv201(32 42 43 61 62 96=0 "unimproved drinking water")(11 12 13 14 21 31 41 51
71 92=1 "improved drinking water"), gen(watascou1)
label var watascou1 "source of drinking water"

***Recode type of toilet facility***
recode hv205(14 15 23 31 42 43 96=0 "unimproved toilet factories")(11 12 13 16 21 22 41=1
"improved toilet factories"), gen(toilfac1)
label var toilfac1 "type of toilet facility"

gen electr=.
replace electr=0 if v119==0
replace electr=1 if v119==1
replace electr=. if v119==3
lab define electr 0 "No" 1 "Yes"
label var electr "Household had electricity"

***Generating Cluster Variables****

*****Generating proportion of cluster wealth status**********
bysort v001: egen cuwealth1=mean(v190)
bysort v001: egen cuwe1= count(v190)


sum cuwealth1, detail          //you will find median

gen clwea3=.
replace clwea3=1 if cuwealth1<3
replace clwea3=2 if cuwealth1==3
replace clwea3=3 if cuwealth1>3
```

```
recode clwea3(1=0 "low") (2/3=1 "high"), gen(cluwealth2)
lab var cluwealth2 "Cluster wealth level"
lab values cluwealth2 cluwealth2
tab cluwealth2 [iw=weight]

******Generating cluster maternal education status*****
bysort v001: egen cumatedu2=mean(v106)
bysort v001: egen cumate2= count(v106)


sum cumatedu2, detail          //you will find median

gen clmated2=.
replace clmated2=1 if cumatedu2<1.2
replace clmated2=2 if cumatedu2==1.2
replace clmated2=3 if cumatedu2>1.2

recode clmated2(1=0 "low") (2/3=1 "high"), gen(clumated1)
lab var clumated1 "Cluster maternal education level"
lab values clumated1 clumated1
tab clumated1 [iw=weight]

*****Generating proportion of respondents with distance to health facility is no problem in
cluster*****
recode v467d(1=0 "big problem")(2=1 "no big problem"), gen(dismed)
bysort v001: egen cudistmed=mean(dismed)
sum cudistmed, detail          //you will find median

gen cludistm=.
replace cludistm=0 if cudistmed<0.8
replace cludistm=1 if cudistmed>=0.8
lab define cludistm 0 "low" 1 "high"
lab var cludistm "low cluster distance to health facility"
lab values cludistm cludistm
tab cludistm [iw=weight]

****Generating proportion of respondent with no cluster household with bed net*******
recode hv227(0=1 "no bed net")(1=0 "Yes"), gen(bnet)
bysort v001: egen hdbnet=mean(bnet)
sum hdbnet, detail          //you will find median

gen cluhdbnet=.
replace cluhdbnet=0 if hdbnet<0.25
replace cluhdbnet=1 if hdbnet>=0.25

lab define cluhdbnet 0 "low" 1 "high"
lab var cluhdbnet "low cluster household with no bed net"
lab values cluhdbnet hdbnet

tab cluhdbnet [iw=weight]
```

```
***Recoding Area Variables using UNDP data set into NDHS****
***Classifying state by Multidimensional poverty Index*****

recode sstate(10 40 50=0 "Highly Deprived")(20 30 60 80 90 100 120 160 170=1 "Above
averagely deprived")(70 110 130 150 280 300 330 340=2 "Averagely Deprived")(140 180
190 200 210 250 270 290 310 320=3 "Mildly Deprived")(220 230 240 260 350 360 370=4
"Lowest Deprived"), gen(mdpi)
label var mdpi "Multidimensional Poverty Index by State"

recode mdpi (0/1=0 "Highly deprived")(2/4=1 "Lowly Deprived"), gen(mdpi2)
label var mdpi2 "MDPI in 2 Cat"
tab mdpi2

recode sstate(10 20 30 50 60 90=0 "Lowest HDI")(40 80 100 110 120 130=1 "Low HDI")(70
160 170 180 190 210 260 280=2 "Avverage HDI")(150 200 220 230 240 250 270 290 300
310 320 330 350 370=3 "High HDI")(140 340 360=4 "Highest HDI"), gen(hdi)
label var hdi "Human Development Index by State"

recode hdi(0/1=0 "Low hdi")(2/4=1 "High hdi"), gen(hdi2)
label var hdi2 "HDI in 2 Cat"
tab hdi2

recode sstate(140 200 210 240 260 270 280 300 350 360=1 "Lowest GII")(160 250 290 310
320 330=2 "Low GII")(90 150 180 230=3 "Average GII")(20 30 40 70 80 100 110 130 170
220 340 370=4 "High GII")(10 50 60 120 190=5 "Highest GII"), gen(gii)
label var gii "Gender Inequality Index by State"
label values gii gii

tab gii
tab gii [iw=weight]

recode gii (1/2=1 "Lowest GII")(3=2 "Average GII")(4/5=3 "Highest GII"), gen(sgii)
lab var sgii "State genger inq index"
lab values sgii sgii

recode sgii (1/2=1 "Low GII")(3/5=2 "High GII"), gen(shd)



***Bar chart for malnutrition indicators combined*****
label values stunted labels1
label def labels1 0 "Not stunted", modify
label def labels1 1 "stunted", modify

label values wasted labels2
label def labels2 0 "Not wasted", modify
label def labels2 1 "wasted", modify

label values underweight labels3
```

```
label def labels3 0 "Not underweight", modify
label def labels3 1 "underweight", modify

label values overweight labels4
label def labels4 0 "Not overweight", modify
label def labels4 1 "Overweight", modify

label values nutrista labels5
label def labels5 0 "Well-nourished", modify
label def labels5 1 "poorly-nourished", modify

graph bar [aweight = weight], over(stunted) asyvars blabel(bar, format(%9.1f)) name(c1, replace)
graph bar [aweight = weight], over(wasted) asyvars blabel(bar, format(%9.1f)) name(c2, replace)
graph bar [aweight = weight], over(underweight) asyvars blabel(bar, format(%9.1f)) name(c3, replace)
graph bar [aweight = weight], over(overweight) asyvars blabel(bar, format(%9.1f)) name(c4, replace)
graph bar [aweight = weight], over(nutrista) asyvars blabel(bar, format(%9.1f)) name(c5, replace)

gr combine c1 c2 c3 c4 c5, c(1) imargin(zero) title("National prevalence of malnutrition status") subtitle("by stunting, wasting, underweight, overweight & nutrition status") name(malnut, replace)

graph bar [aweight = weight], over(v101) over(nutrista) asyvars blabel(bar, format(%9.1f)) title("Percentage of malnutrition status by region of residence") name(manutreg, replace)

graph bar [aweight = weight], over(v102) over(nutrista) asyvars blabel(bar, format(%9.1f)) title("Percentage of malnutrition status by place of residence") name(manupla, replace)

graph bar [aweight = weight], over(b4) over(nutrista) asyvars blabel(bar, format(%9.1f)) title("Percentage of nutrition status by gender") name(manugen, replace)

graph bar [aweight = weight], over(chldage1) over(nutrista) asyvars blabel(bar, format(%9.1f)) title("Percentage of nutrition status by age") name(manucage1, replace)


*****relationship between child's variables and malnutrition*****
svy: tab b4 nutrista, count row pearson
asdoc tabulate b4 nutrista [iweight = weight], append

svy: tab chldage1 nutrista, count row pearson
asdoc tabulate chldage1 nutrista [iweight = weight], append

svy: tab bszgr1 nutrista, count row pearson
asdoc tabulate bszgr1 nutrista [iweight = weight], append

svy: tab brdgr nutrista, count row pearson
```

```
asdoc tabulate brdgr nutrista [iweight = weight], append

svy: tab h10 nutrista, count row pearson
asdoc tabulate h10 nutrista [iweight = weight], append

svy: tab newprbth nutrista, count row pearson
asdoc tabulate prbrthint nutrista [iweight = weight], append

svy: tab vita nutrista, count row pearson
asdoc tabulate vita nutrista [iweight = weight], append

svy: tab ironsup nutrista, count row pearson
asdoc tabulate ironsup nutrista [iweight = weight], append

svy: tab m4 nutrista, count row pearson
asdoc tabulate m4 nutrista [iweight = weight], append

svy: tab dworm nutrista, count row pearson
asdoc tabulate dworm nutrista [iweight = weight], append

svy: tab fever nutrista, count row pearson
asdoc tabulate fever nutrista [iweight = weight], append

svy: tab cough nutrista, count row pearson
asdoc tabulate cough nutrista [iweight = weight], append

svy: tab diarr nutrista, count row pearson
asdoc tabulate diarr nutrista [iweight = weight], append

svy: tab pldel nutrista, count row pearson
asdoc tabulate pldel nutrista [iweight = weight], append


****Table :Relationship between Parental variables and malnutrition status
svy: tab magegr nutrista, count row pearson
asdoc tabulate magegr nutrista [iweight = weight], append

svy: tab v714 nutrista, count row pearson
asdoc tabulate v714 nutrista [iweight = weight], append

svy: tab agefbth2 nutrista, count row pearson
asdoc tabulate agefbth2 nutrista [iweight = weight], append

svy: tab v106 nutrista, count row pearson
asdoc tabulate v106 nutrista [iweight = weight], append

svy: tab v504 nutrista, count row pearson
asdoc tabulate v504 nutrista [iweight = weight], append

svy: tab autonomylevel1 nutrista, count row pearson
```

```
asdoc tabulate autonomylevel1 nutrista [iweight = weight], append

svy: tab v461 nutrista, count row pearson
asdoc tabulate v461 nutrista [iweight = weight], append

svy: tab ancvis1 nutrista, count row pearson
asdoc tabulate ancvis1 nutrista [iweight = weight], append

svy: tab relsta nutrista, count row pearson
asdoc tabulate relsta nutrista [iweight = weight], append

svy: tab ethgr2 nutrista, count row pearson
asdoc tabulate ethgr2 nutrista [iweight = weight], append

svy: tab mirontab nutrista, count row pearson
asdoc tabulate mirontab nutrista [iweight = weight], append

svy: tab manaesta nutrista, count row pearson
asdoc tabulate manaesta nutrista [iweight = weight], append

svy: tab mbmi nutrista, count row pearson
asdoc tabulate mbmi nutrista [iweight = weight], append

svy: tab pworksta nutrista, count row pearson
asdoc tabulate pworksta nutrista [iweight = weight], append

svy: tab pedusta nutrista, count row pearson
asdoc tabulate pedusta nutrista [iweight = weight], append


****Table :Relationship between Household variables and malnutrition status
svy: tab v190 nutrista, count row pearson
asdoc tabulate v190 nutrista [iweight = weight], append

svy: tab hhagegr nutrista, count row pearson
asdoc tabulate hhagegr nutrista [iweight = weight], append

svy: tab hv228  nutrista, count row pearson
asdoc tabulate hv228 nutrista [iweight = weight], append

svy: tab u5hhd nutrista, count row pearson
asdoc tabulate u5hhd nutrista [iweight = weight], append

svy: tab rmsleep nutrista, count row pearson
asdoc tabulate rmsleep nutrista [iweight = weight], append

svy: tab electr nutrista, count row pearson
asdoc tabulate electr nutrista [iweight = weight], append

svy: tab watascou1 nutrista, count row pearson
```

```
asdoc tabulate watascou1 nutrista [iweight = weight], append

svy: tab toilfac1 nutrista, count row pearson
asdoc tabulate toilfac1 nutrista [iweight = weight], append

svy: tab cookfue nutrista, count row pearson
asdoc tabulate cookfue nutrista [iweight = weight], append

svy: tab floormat nutrista, count row pearson
asdoc tabulate floormat nutrista [iweight = weight], append

svy: tab roofmat nutrista, count row pearson
asdoc tabulate roofmat nutrista [iweight = weight], append

svy: tab wallmat nutrista, count row pearson
asdoc tabulate wallmat nutrista [iweight = weight], append

svy: tab v151 nutrista, count row pearson
asdoc tabulate v151 nutrista [iweight = weight], append

svy: tab shatoi1 nutrista, count row pearson
asdoc tabulate shatoi1 nutrista [iweight = weight], append

***Others added***
svy: tab hv227 nutrista, count row pearson
asdoc tabulate hv227 nutrista [iweight = weight], append

svy: tab hhdsz nutrista, count row pearson
asdoc tabulate hhdsz nutrista [iweight = weight], append

svy: tab hv014 nutrista, count row pearson
asdoc tabulate hv014 nutrista [iweight = weight], append

svy: tab stooldis1 nutrista, count row pearson
asdoc tabulate stooldis1 nutrista [iweight = weight], append

svy: tab v159 nutrista, count row pearson
asdoc tabulate v159 nutrista [iweight = weight], append


****Relationship between cluster variables and malnutrition status*****
svy: tab cluwealth2 nutrista, count row pearson
asdoc tabulate cluwealth2 nutrista [iweight = weight], append

svy: tab cludistm nutrista, count row pearson
asdoc tabulate cludistm nutrista [iweight = weight], append

svy: tab clumated1 nutrista, count row pearson
asdoc tabulate clumated1 nutrista [iweight = weight], append
```

svy: tab cluhdbnet nutrista, count row pearson
asdoc tabulate cluhdbnet nutrista [iweight = weight], append

****Table :Relationship between Area variables and malnutrition status
svy: tab mdpi nutrista, count row pearson
asdoc tabulate mdpi nutrista [iweight = weight], append

svy: tab hdi nutrista, count row pearson
asdoc tabulate hdi nutrista [iweight = weight], append

svy: tab v101 nutrista, count row pearson
asdoc tabulate v101 nutrista [iweight = weight], append

svy: tab v102 nutrista, count row pearson
asdoc tabulate v102 nutrista [iweight = weight], append

svy: tab gii nutrista, count row pearson
asdoc tabulate gii nutri [iweight = weight], append

****MALNUTRITION*****

****backward stepwise selection of variables for malnutrition study**********

stepwise, pr(.2): logit nutrista i.b4 i.chldage1 i.bszgr1 i.newprbth i.vita i.ironsup i.m4 i.dworm i.hml35 i.anaesta i.fever i.cough i.diarr i.pldel i.magegr i.v714 i.agefbth2 i.v106 i.v504 i.autonomylevel1 i.v461 i.relsta i.ethgr2 i.mirontab i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr i.hv228 i.u5hhd i.rmsleep i.electr i.v151 i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.cluhdbnet i.mdpi i.hdi i.gii i.v101 i.v102

****Testing the goodness of fit from the backward selected variables using AIC and BIC******
melogit nutrista i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.hml35 i.anaesta i.cough i.diarr i.pldel i.v714 i.v106 i.ethgr2 i.manaesta i.mbmi i.pedusta i.v190 i.hhagegr i.rmsleep i.hhdsz i.cludistm i.cluhdbnet i.hdi i.gii i.v101 ||sstate: ||v001:, or

estat ic

****Forward stepwise selection of variables for anaemia study**********
stepwise, pe(.2): logit nutrista i.b4 i.chldage1 i.bszgr1 i.newprbth i.vita i.ironsup i.m4 i.dworm i.hml35 i.anaesta i.fever i.cough i.diarr i.pldel i.magegr i.v714 i.agefbth2 i.v106 i.v504 i.autonomylevel1 i.v461 i.relsta i.ethgr2 i.mirontab i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr i.hv228 i.u5hhd i.rmsleep i.electr i.v151 i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.cluhdbnet i.mdpi i.hdi i.gii i.v101 i.v102

****Testing the goodness of fit from the forward selected variables using AIC and BIC******
melogit nutrista i.b4 i.chldage1 i.bszgr1 i.newprbth i.hml35 i.anaesta i.cough i.diarr i.pldel i.v106 i.relsta i.ethgr2 i.manaesta i.mbmi i.pedusta i.v190 i.hhagegr i.rmsleep i.electr i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.cluhdbnet i.hdi i.gii i.v101 ||sstate: ||v001:, or

estat ic

****Testing the goodness of fit from the forward + backward selected variables using AIC and BIC*********
****This produced lower AIC & BIC****

melogit nutrista i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.hml35 i.anaesta i.cough i.diarr i.pldel i.v714 i.v106 i.relsta i.ethgr2 i.manaesta i.mbmi i.pedusta i.v190 i.hhagegr i.rmsleep i.electr i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.cluhdbnet i.hdi i.gii i.v101 i.v102 ||sstate: ||v001:, or

estat ic

predict z
keep if z!=.
keep if nutrista!=.

Diagnostic test for LR tests for choice of number of levels in the multilevel analysis**

Multilevel Logistic Analysis**
*****Model 0 (Null model)*******
***** individual-level1 in community level 2 in State in level3*******
melogit nutrista || sstate: || v001:, or
estimate store m1a

***** individual-level 1 in community level 2*******
melogit nutrista || v001:, or
estimate store m3

lrtest m3 m1a

***** individual-level 1 in community level 2*******
melogit nutrista || sstate:
estimate store m3b

lrtest m3b m1a

melogit nutrista || v001:
estimate store m3a

```
lrtest m3a m1a


***Multilevel Logistic Analysis of malnutrition among children 6-59 months of age in Nigeria*****
*****Model 1 (Null model)*******
***** individual-level1 in community level 2 in State in level3*******
melogit nutrista || sstate: || v001:, or
estat icc
estat ic

****Model 2: Child-related variables only******
melogit nutrista i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.hml35 i.anaesta i.cough i.diarr i.pldel|| sstate: || v001:, or
estat icc
estat ic

****Model 3: Child-related + parental-related variables******
melogit nutrista i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.hml35 i.anaesta i.cough i.diarr i.pldel i.v714 i.v106 i.relsta i.ethgr2 i.manaesta i.mbmi i.pedusta || sstate: || v001:, or
estat icc
estat ic

****Model 4: Child-related + parental-related + household-related variables******
melogit nutrista i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.hml35 i.anaesta i.cough i.diarr i.pldel i.v714 i.v106 i.relsta i.ethgr2 i.manaesta i.mbmi i.pedusta i.v190 i.hhagegr i.rmsleep i.hhdsz|| sstate: || v001:, or
estat icc
estat ic

****Model 5: (Full model) Child-related + parental-related + household-related + community-related variables******
melogit nutrista i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.hml35 i.anaesta i.cough i.diarr i.pldel i.v714 i.v106 i.relsta i.ethgr2 i.manaesta i.mbmi i.pedusta i.v190 i.hhagegr i.rmsleep i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.cluhdbnet  ||sstate: ||v001:, or
estat icc
estat ic


****Model 6: (Full model) Child-related + parental-related + household-related + community + area-related variables******
melogit nutrista i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.hml35 i.anaesta i.cough i.diarr i.pldel i.v714 i.v106 i.relsta i.ethgr2 i.manaesta i.mbmi i.pedusta i.v190 i.hhagegr i.rmsleep i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.cluhdbnet i.gii i.v101 i.v102 ||sstate: ||v001:, or
estat icc
estat ic

clear
```

E.6 Codes for multimorbidity studies

```
****Thesis Data Description*****
***Merging Household file to children File****
***Use Household File Identifiers for PR***
use "D:\UNIVERSITY OF SHEFFIELD MATTERS\STATA DATA
SET\NGPR7ADT\NGPR7AFL.DTA", clear
rename hv001 v001
rename hv002 v002
rename hvidx mergeid

sort v001 v002 mergeid
gen in_PR=1

save temp.dta, replace

***Use Children File Identifiers****

use "D:\UNIVERSITY OF SHEFFIELD MATTERS\STATA DATA
SET\NGKR7AFL.DTA", clear

rename b16 mergeid
sort v001 v002 mergeid
gen in_KR=1

*** Merging the PR and KR Files****

merge m:1 v001 v002 mergeid using temp.dta

keep if in_PR==1 & in_KR==1
tab _merge

****Analysis of Description of Malnutrition among under-5 children in Nigeria*****

***Perform weighting to correct for over and under sample****
gen weight=v005/1000000
svyset [pw=weight], psu(v021) strata (v022)
svydes, single
replace v022=58 if v022==60


****Keep subsample of children under-5 years and child is alive****
```

```
keep if hc1>5 & hc1<60


***Recode under-5 child's age in group***
recode hc1 (0/5=0 "less 6 months")(6/11=1 "6-11 months")(12/23=2 "12-23
months")(24/35=3 "24-35 months")(36/47=4 "36-47 months")(48/59=5 "48-59 months"),
gen(chldage1)
label var chldage1 "child's age in group"
tab chldage1 [iw=weight]

***Recode under-5 age another way*******

recode hc1 (0/5=0 "less 6 months")(6/18=1 "6-18 months")(19/30=2 "19-30
months")(31/42=3 "31-42 months")(43/59=4 "43-59 months"), gen(chldage)
label var chldage "child's age in group"
tab chldage [iw=weight]

gen chage=.
replace chage=. if chldage==0
replace chage=1 if chldage==1
replace chage=2 if chldage==2
replace chage=3 if chldage==3
replace chage=4 if chldage==4
lab define chage 1 "6-18 months" 2"19-30 months" 3"31-42 months" 4"43-59 months"
label var chage "Age of child 6-59 months"
label values chage chage


******Age could be used as continous variable*******

***Tabulate Children under-5 by sex****
tab b4 [iw=weight]

****Recode of Outcome Variables*****

****Outcome variable 1*****
*** Malaria Status by Rapid Diagnostic Test****
codebook hml35
tab hml35 [iw=weight]

*** Malaria Status by Microscopic Blood Smear Examination****
codebook hml32
tab hml32 [iw=weight]

*****Test of independence between the two results*****
spearman hml35 hml32

****Outcome variable 2*****
****Anaemia Status****
codebook hw57
```

```
recode hw57(1/3=1 "Anaemic")(4=0 "Not Anaemic"), gen(anaesta)
label var anaesta "Anaemia status"
tab anaesta [iw=weight]
tab hw57 [iw=weight]

****Outcome variable 3*****
****Malnutrition Status***
***Children who stayed in the household the previous night and who have height and weight z-scores on all 3 measures****
gen eligch = 0
replace eligch = 1 if (hv103==1 & hc70 < 9996 & hc71 < 9996 & hc72 < 9996)


// child stunting calculation
codebook hc70
tab hc70 if hc70>9990,m
tab hc70 if hc70>9990,m nolabel
gen HAZ=hc70
replace HAZ=. if HAZ>=9996
gen stunted=0
replace stunted=0 if HAZ ~=.
replace stunted=1 if HAZ<-200
lab define stunted 0 "not anaemic" 1 "anaemic"
lab var stunted "Stunting Status of Children"


// child wasting calculation
codebook hc72
tab hc72 if hc72>9990,m
tab hc72 if hc72>9990,m nolabel
gen WAH=hc72
replace WAH=. if WAH>=9996
gen wasted=0
replace wasted=0 if WAH ~=.
replace wasted=1 if WAH<-200
lab define wasted 0 "not wasted" 1 "wasted"
lab var wasted "wasting Status of Children"


// child underweight calculation
codebook hc71
tab hc71 if hc71>9990,m
tab hc71 if hc71>9990,m nolabel
gen WAZ=hc71
replace WAZ=. if WAZ>=9996
gen underweight=0
replace underweight=0 if WAZ ~=.
replace underweight=1 if WAZ<-200
lab define underweight 0 "not underweight" 1 "underweight"
lab var underweight "Underweight Status of Children"
```

```
// child overweight calculation
codebook hc72
tab hc72 if hc72>9990,m
tab hc72 if hc72>9990,m nolabel
gen WAH2=hc72
replace WAH2=. if WAH2>=9996
gen overweight1=0
replace overweight1=0 if WAH2 ~=.
replace overweight1=1 if WAH2>200 & WAH2<9990
lab define overweight1 0 "not overweight" 1 "overweight"
lab var overweight "Overweight Status of Children"


tab stunted [iw=weight]
tab wasted [iw=weight]
tab underweight [iw=weight]
tab overweight [iw=weight]

***Generate Malnutrition Status*****
gen malnut=stunted+wasted+underweight+overweight
tab malnut
recode malnut(0=0 "well-nourished")(1/4=1 "poorly nourished"), gen(nutrista)
lab var nutrista "Nutrition Status of Children"
tab nutrista [iw=weight]
tab nutrista [iw=weight], nolabel

****Diarrhael Recode****
gen diarr=.
replace diarr=0 if h11==0
replace diarr=1 if h11==2
replace diarr=. if h11==3
lab define diarr 0 "No diarrhael" 1 "Had diarrhael"
lab var diarr "Diarrhael status"

****Cough Recode****
gen cough=.
replace cough=0 if h31==0
replace cough=1 if h31==2
replace cough=. if h31==8
lab var cough "Cough status"
lab define cough 0 "had no cough" 1 "Had cough"

gen fever=.
replace fever=0 if h22==0
replace fever=1 if h22==1
replace fever=. if h22==8
lab define fever 0 "No" 1 "Yes"
label var fever "Had Fever in last 2 weeks"
```

```
*ssc install egenmore
egen  outmis= rcount(nutrista anaesta hml32 diarr cough fever), cond(@ == .)
egen  outindex= rcount(nutrista anaesta hml32 diarr cough fever), cond(@ == 1)
label variable outindex "Index of Overlapping 6 Outcomes)"
tab outindex outmis, row m

replace outindex=. if outmis> 0
tab outindex outmis, row m

*could do the same with severe

recode outindex (0=0) (1/6=1), gen(outen2sd)
label variable outen2sd "AF(Amaemia Malaria malnutrition cough Diarrhael and-or Fever)"
tab outen2sd

***Generating Outcome of Anaemia Malaria and Malnutrition*****
gen outc4=.
replace outc4=0 if nutrista==0 & anaesta==0 & hml35==0
replace outc4=1 if nutrista==1 & anaesta==0 & hml35==0
replace outc4=2 if nutrista==1 & anaesta==0 & hml35==1
replace outc4=3 if nutrista==1 & anaesta==1 & hml35==1
replace outc4=4 if nutrista==0 & anaesta==1 & hml35==1
replace outc4=5 if nutrista==0 & anaesta==1 & hml35==0
replace outc4=6 if nutrista==0 & anaesta==0 & hml35==1
replace outc4=7 if nutrista==1 & anaesta==1 & hml35==0

label define outc4 0 "None of the 3 diseases" 1 "Malnutrition Only" 2 "Malnutrition &
Malaria" 3 "The 3 diseases" 4 "Anaemia & malaria" 5 "Anaemia Only" 6 "Malaria Only" 7
"Malnutrition & Anaemia", modify
lab var outc4 "Composite scores for 3 outcomes"
label values outc4 outc4
tab outc4 [iw=weight]

**Recode multimorbidity in counts****
recode outc4(0=0 "No Disease")(1 5 6=1 "One disease only")(2 4 7=2 "Two diseases
only")(3=3 "Three diseases"), gen(outc3)
lab var outc3 "Composite scores in disease count"
label values outc3 outc3
tab outc3 [iw=weight]

recode outc4(0=0 "No Disease")(1 5 6=1 "morbidity status")(2 3 4 7=2 "mutimorbidity
status"), gen(outc2)
lab var outc2 "Composite scores mutimorbidity"
label values outc2 outc2
tab outc2 [iw=weight]


***Generating Outcome of Anaemia Malaria (smear) and Malnutrition*****
gen outc5=.
```

```
replace outc5=0 if nutrista==0 & anaesta==0 & hml32==0
replace outc5=1 if nutrista==1 & anaesta==0 & hml32==0
replace outc5=2 if nutrista==1 & anaesta==0 & hml32==1
replace outc5=3 if nutrista==1 & anaesta==1 & hml32==1
replace outc5=4 if nutrista==0 & anaesta==1 & hml32==1
replace outc5=5 if nutrista==0 & anaesta==1 & hml32==0
replace outc5=6 if nutrista==0 & anaesta==0 & hml32==1
replace outc5=7 if nutrista==1 & anaesta==1 & hml32==0

label define outc5 0 "None of the 3 diseases" 1 "Malnutrition Only" 2 "Malnutrition &
Malaria" 3 "The 3 diseases" 4 "Anaemia & malaria" 5 "Anaemia Only" 6 "Malaria Only" 7
"Malnutrition & Anaemia", modify
lab var outc5 "Composite scores for 3 outcomes"
label values outc5 outc5
tab outc5 [iw=weight]

recode outc5(0=0 "No Disease")(1 5 6=1 "morbidity status")(2 3 4 7=2 "mutimorbidity
status"), gen(outc2c5)
lab var outc2c5 "Composite scores mutimorbidity"
label values outc2c5 outc2c5
tab outc2c5 [iw=weight]


***Alternative for 3 outcomes******
recode outc4 (.=-9) (0=0) (1=1) (2=2) (3=3) (4=4) (5=5) (6=6) (7=7), gen(outcatwho)

label variable outcatwho "Anthropometric Failure Categories (-2SD) (WHO ref)"
label define outcatwho 0 "A-None of the 3" 1 "B-Malnut Only" 2 "C-Malnut & Malaria" 3
"D-Malnut, Anaesta & Malaria" 4 "E-Anaesta & hml32" 5 "F-Anaesta Only" 6 "G-Malaria
Only" 7 "H-Malnut & Anaesta", modify
lab var outcatwho "Composite scores for 3 outcomes"
label values outcatwho outcatwho
tab outcatwho [iw=weight]

*****Recodes for Predictors or covariates*******

****Recode of Child Variables ****
recode m18 (1=0 "large size") (2/3=1 "Average size")(4/5=2 "small size")(6/max=3 "I don't
Know"), gen(bszgr)
lab var bszgr "Child perceived size at birth"

***Recode birth size*****
gen bszgr1=.
replace bszgr1=0 if bszgr==0
replace bszgr1=1 if bszgr==1
replace bszgr1=2 if bszgr==2
replace bszgr1=. if bszgr==3
lab define bszgr1 0 "large" 1 "Average" 2 "Small"
label var bszgr1 "Child's birth Size"
```

```
*****Child birth order****
recode bord (1=0 "1st") (2/3=1 "2nd or 3rd")(4/6=2 "4-6 th")(7/max=3 "7th+"), gen(brdgr)
lab var brdgr "Child Birth Order"

****Birth order can be used as continous variable******

****Number of under-5 in household******
recode hv014 (0/3=0 "0-3") (4/6=1 "4-6")(7/max=2 "7th+"), gen(u5hhd)
lab var u5hhd "Under-5 in household"

****REcode of household size*****
recode hv009 (0/3=0 "0-3") (4/6=1 "4-6")(7/9=2 "7-9")(10/max=3 "more than 10"),
gen(hhdsz)
lab var hhdsz "household member size"

****Recode of place of delivery*****
recode m15 (11/12=0 "home")(21 22 23 26=1 "Public Health facility")(31 36=2 "Private
Health Facility"), gen(pladel)
lab var pladel "Place of Delivery"

gen pldel=.
replace pldel=0 if pladel==0
replace pldel=1 if pladel==1
replace pldel=2 if pladel==2
replace pldel=3 if pladel==96
lab define pldel 0 "home" 1 "Public Facility" 2 "Private facility" 3 "elsewhere"
lab var pldel "Place of child's del"

gen dworm=.
replace dworm=0 if h43==0
replace dworm=1 if h43==1
replace dworm=. if h43==8
lab define dworm 0 "No" 1 "Yes"
label var dworm "Took deworming drug in last 6months"

gen vita=.
replace vita=0 if h34==0
replace vita=1 if h34==1
replace vita=. if h34==8
lab define vita 0 "No" 1 "Yes"
label var vita "Took Vit A supplements"

gen ironsup=.
replace ironsup=0 if h42==0
replace ironsup=1 if h42==1
replace ironsup=. if h42==8
lab define ironsup 0 "No" 1 "Yes"
label var ironsup "Took Iron supplements"

recode v465 (1 2 5=0)(3 4 9=1)(96=2), gen(stooldisp)
```

```
gen stooldis1=.
replace stooldis1=0 if stooldisp==0
replace stooldis1=1 if stooldisp==1
replace stooldis1=. if stooldisp==2
lab define stooldis1 0 "Proper disposal" 1 "Improper disposal"
label var stooldis1 "Youngest Child's stool disposed Properly"


****Recode of Parental/Mother/Care-givers Variables ****
recode v013 (1/2=0 "15-24 years") (3/4=1 "25-34 years") (5/7=2 "35 years+"), gen(magegr)
label var magegr "Maternal age group in 10years"


****Use maternal age as given in data set v013*******

recode hv220 (min/34=0 "less 34 years")(35/44=2 "35-44 years")(45/55=3 "45-55
years")(56/max=4 "56 years+"), gen(hhagegr)
label var hhagegr "Household Head age group"

***Use household head age as continous*****

recode v212 (10/24=0 "10-24")(25/36=1 "25-36")(37/49=2 "37-49") (37/max=3 "37-49"),
gen(agefbth2)
label var agefbth2 "age at first birth"

***Use age at first birth as continous variable****

recode b11(8/24=0 "8-24 months")(25/35=1 "25-35 months")(36/59=2 "36-59
months")(60/max=3 "60+ months"), gen(prbrthint)
label var prbrthint "preceeding birth interval"

*****New prebirthint*****
gen newprbth=.
replace newprbth=0 if brdgr==0
replace newprbth=1 if prbrthint==0
replace newprbth=2 if prbrthint==1
replace newprbth=3 if prbrthint==2
replace newprbth=4 if prbrthint==3
lab define newprbth 0 "None" 1 "8-24 months" 2 "25-35 months" 3 "36-59 months" 4 "60+
months", modify
label var newprbth "New prebirth interval"
label values newprbth newprbth

tab newprbth [iw=weight]



recode b12(8/24=0 "8-24 months")(25/35=1 "25-35 months")(36/59=2 "36-59
months")(60/max=3 "60+ months"), gen(subrthint)
```

```
label var subrthint "suceeding birth interval"

recode v130(1=0 "catholic")(2=1 "other christian")(3=2 "islam")(4/max=3
"traditionalist&others"), gen(relsta)
label var relsta "mother's religious status"

gen pworksta=.
replace pworksta=0 if v705==0
replace pworksta=1 if v705>0
lab define pworksta 0 "not working" 1 "working"
label var pworksta "Husband Work Status"

gen pedusta=.
replace pedusta=0 if v701==0
replace pedusta=1 if v701==1
replace pedusta=2 if v701==2
replace pedusta=3 if v701==3
replace pedusta=. if v701==8
lab define pedusta 0 "no education" 1 "primary" 2 "secondary" 3 "higher"
label var pedusta "mother's partner education status"

****Mother's Anaemia Status****
recode v457(1/3=1 "Anaemic")(4=0 "Not Anaemic"), gen(manaesta)
label var manaesta "Mother's Anaemia status"
tab manaesta [iw=weight], missing

gen mirontab=.
replace mirontab=0 if m45==0
replace mirontab=1 if m45==1
replace mirontab=. if m45==8
lab define mirontab 0 "no" 1 "yes"
label var mirontab "took iron tab during pregnancy"

recode m14 (0=0 "No ANC Visit") (1/3=1 "ANC Visit less WHO REC") (4/20=2 "ANC
Visit Met WHO REC")(21/max=3 "Dont Remember Visiting ANC"), gen(ancvis)
label var ancvis "ANC Visit"

gen ancvis1=.
replace ancvis1=0 if ancvis==0
replace ancvis1=1 if ancvis==1
replace ancvis1=2 if ancvis==2
replace ancvis1=. if ancvis==3
lab define ancvis1 0 "none" 1 "less who rec" 2 "met who rec"
label var ancvis1 "ANC visits during pregnancy"


recode v131(2 3 8=0 "Hausa/Fulani/KanuriSeribiri")(6=1 "Ibos")(10=2 "Yorubas")(else=3
"Others"), gen(ethgr2)
label var ethgr2 "Ethnicity"
```

```
***Recoding - Maternal Decision Making Level*****
gen healthcare=0
replace healthcare=1 if v743a==1
replace healthcare=2 if v743a==2
replace healthcare=3 if v743a==3
replace healthcare=4 if v743a>3 & v743a<10
gen lpurchase=0
replace lpurchase=1 if v743b==1
replace lpurchase=2 if v743b==2
replace lpurchase=3 if v743b==3
replace lpurchase=4 if  v743b>3 & v743b<10
gen dpurchase=0
replace dpurchase=1 if v743c==1
replace dpurchase=2 if v743c==2
replace dpurchase=3 if v743c==3
replace dpurchase=4 if v743c>3 & v743c<10
gen  fvisit=0
replace fvisit=1 if v743d==1
replace fvisit=2 if v743d==2
replace fvisit=3 if v743d==3
replace fvisit=4 if v743d>3 & v743d<10
gen auto1=0
replace auto1=2 if healthcare<3
replace auto1=1 if healthcare>2 & healthcare<10
gen auto2=0
replace auto2=2 if lpurchase<3
replace auto2=1 if lpurchase>2 & lpurchase<10
gen auto4=0
replace auto4=2 if fvisit<3
replace auto4=1 if fvisit>2 & fvisit<10
tab1 auto*
***Generating Maternal Autonomylevel****
gen autonomyscore1=auto1+auto2+auto4
tab autonomyscore1
su autonomyscore1
recode autonomyscore1 (3/4=0 "low Auto") (5/8=1 "more auto"), gen(autonomylevel1)
lab val autonomylevel1 autonomylevel1
tab autonomylevel1 [iw=weight], missing

**Generating Maternal BMI status*****
gen ht_flag=0
replace ht_flag=1 if v438>9000
gen preg_flag=0
replace preg_flag=1 if v213==1
gen months_since_last_birth=v008-b3
gen recent_birth_flag1=0
replace recent_birth_flag1=1 if months_since_last_birth <=2

gen bmi=v445/100
gen bmic=2 if bmi<18.5
```

```
replace bmic=1 if bmi>=18.5 & bmi<25
replace bmic=3 if bmi>=25 & bmi<30
replace bmic=4 if bmi>=30 & bmi<60
label define bmic 1"Normal" 2 "Underweight" 3"Overweight" 4"Obese"
label values bmic bmic
svy: tab bmic, count percent format(%4.1f) col

****Generate Maternal BMI*****

gen mbmi=bmic if ht_flag==0 & preg_flag==0 & recent_birth_flag1==0
label define mbmi 1 "Normal" 2 "underweight" 3 "Overweight" 4 "Obese"
label values mbmi mbmi


****Recode of Household Variables ****
gen shatoi1=.
replace shatoi1=0 if v160==0
replace shatoi1=1 if v160==1
replace shatoi1=. if v160==7
label define shatoi1 0 "No" 1 "Yes"
label var shatoi1 "Shared Toilet Facilities"

recode hv226(1/4=0)(5/10=1)(11/max=2), gen(cookfuel2)
label var cookfuel2 "Cooking Fuel Used"

gen cookfue=.
replace cookfue=0 if cookfuel2==0
replace cookfue=1 if cookfuel2==1
replace cookfue=. if cookfuel2==3
label define cookfue 0 "Elect&Gas" 1 "Biofuel"
label var cookfue "Type of cooking fuel"

***Recode floor material types***
recode hv213(11 12 96=0 "unimproved floor materials")(21 22 31 32 33 34 35=1 "improved
floor materials"), gen(floormat)
label var floormat "Floor Materials"

***Recode roof material types***
recode hv215(11 12 13 21 22 23 24 96=0 "unimproved roof materials")(31 32 33 34 35 36=1
"improved roof materials"), gen(roofmat)
label var roofmat "Roof Materials"

***Recode wall material types***
recode hv214(11 12 13 21 22 23 24 25 26 96=0 "unimproved wall materials")(31 32 33 34 35
36=1 "improved wall materials"), gen(wallmat)
label var wallmat "wall Materials"

***Recode Number of rooms for sleep***
recode hv216(1=0 "One-room")(2=1 "two rooms")(3=2 "three rooms")(4=3 "Four
rooms")(5/max=4 "Five+ rooms"), gen(rmsleep)
```

```
label var rmsleep "Number of rooms for sleep"

***Recode Scource of drinking water***
recode hv201(32 42 43 61 62 96=0 "unimproved drinking water")(11 12 13 14 21 31 41 51
71 92=1 "improved drinking water"), gen(watascou1)
label var watascou1 "source of drinking water"

***Recode type of toilet facility***
recode hv205(14 15 23 31 42 43 96=0 "unimproved toilet factories")(11 12 13 16 21 22 41=1
"improved toilet factories"), gen(toilfac1)
label var toilfac1 "type of toilet facility"

gen electr=.
replace electr=0 if v119==0
replace electr=1 if v119==1
replace electr=. if v119==3
lab define electr 0 "No" 1 "Yes"
label var electr "Household had electricity"

***Generating Cluster Variables****

*****Generating proportion of cluster wealth status**********
bysort v001: egen cuwealth1=mean(v190)
bysort v001: egen cuwe1= count(v190)


sum cuwealth1, detail          //you will find median

gen clwea3=.
replace clwea3=1 if cuwealth1<3
replace clwea3=2 if cuwealth1==3
replace clwea3=3 if cuwealth1>3

recode clwea3(1=0 "low") (2/3=1 "high"), gen(cluwealth2)
lab var cluwealth2 "Cluster wealth level"
lab values cluwealth2 cluwealth2
tab cluwealth2 [iw=weight]

******Generating cluster maternal education status*****
bysort v001: egen cumatedu2=mean(v106)
bysort v001: egen cumate2= count(v106)


sum cumatedu2, detail          //you will find median

gen clmated2=.
replace clmated2=1 if cumatedu2<1.2
replace clmated2=2 if cumatedu2==1.2
replace clmated2=3 if cumatedu2>1.2
```

```
recode clmated2(1=0 "low") (2/3=1 "high"), gen(clumated1)
lab var clumated1 "Cluster maternal education level"
lab values clumated1 clumated1
tab clumated1 [iw=weight]

*****Generating proportion of respondents with distance to health facility is no problem in cluster*****
recode v467d(1=0 "big problem")(2=1 "no big problem"), gen(dismed)
bysort v001: egen cudistmed=mean(dismed)
sum cudistmed, detail          //you will find median

gen cludistm=.
replace cludistm=0 if cudistmed<0.8
replace cludistm=1 if cudistmed>=0.8
lab define cludistm 0 "low" 1 "high"
lab var cludistm "low cluster distance to health facility"
lab values cludistm cludistm
tab cludistm [iw=weight]

****Generating proportion of respondent with no cluster household with bed net*******
recode hv227(0=1 "no bed net")(1=0 "Yes"), gen(bnet)
bysort v001: egen hdbnet=mean(bnet)
sum hdbnet, detail          //you will find median

gen cluhdbnet=.
replace cluhdbnet=0 if hdbnet<0.25
replace cluhdbnet=1 if hdbnet>=0.25

lab define cluhdbnet 0 "low" 1 "high"
lab var cluhdbnet "low cluster household with no bed net"
lab values cluhdbnet hdbnet

tab cluhdbnet [iw=weight]

***Recoding Area Variables using UNDP data set into NDHS****
***Classifying state by Multidimensional poverty Index*****

recode sstate(10 40 50=0 "Highly Deprived")(20 30 60 80 90 100 120 160 170=1 "Above averagely deprived")(70 110 130 150 280 300 330 340=2 "Averagely Deprived")(140 180 190 200 210 250 270 290 310 320=3 "Mildly Deprived")(220 230 240 260 350 360 370=4 "Lowest Deprived"), gen(mdpi)
label var mdpi "Multidimensional Poverty Index by State"

recode mdpi (0/1=0 "Highly deprived")(2/4=1 "Lowly Deprived"), gen(mdpi2)
label var mdpi2 "MDPI in 2 Cat"
tab mdpi2

recode sstate(10 20 30 50 60 90=0 "Lowest HDI")(40 80 100 110 120 130=1 "Low HDI")(70 160 170 180 190 210 260 280=2 "Avverage HDI")(150 200 220 230 240 250 270 290 300 310 320 330 350 370=3 "High HDI")(140 340 360=4 "Highest HDI"), gen(hdi)
```

```
label var hdi "Human Development Index by State"

recode hdi(0/1=0 "Low hdi")(2/4=1 "High hdi"), gen(hdi2)
label var hdi2 "HDI in 2 Cat"
tab hdi2

recode sstate(140 200 210 240 260 270 280 300 350 360=1 "Lowest GII")(160 250 290 310
320 330=2 "Low GII")(90 150 180 230=3 "Average GII")(20 30 40 70 80 100 110 130 170
220 340 370=4 "High GII")(10 50 60 120 190=5 "Highest GII"), gen(gii)
label var gii "Gender Inequality Index by State"
label values gii gii

tab gii
tab gii [iw=weight]

recode gii (1/2=1 "Lowest GII")(3=2 "Average GII")(4/5=3 "Highest GII"), gen(sgii)
lab var sgii "State genger inq index"
lab values sgii sgii

recode sgii (1/2=1 "Low GII")(3/5=2 "High GII"), gen(shd)




***Bar chart of composite interactions of the three diseases***
graph bar [aweight = weight], over(outc4) asyvars blabel(bar, format(%9.1f)) bargap(10)
title(Prevalence of composite of the 3 diseases) legend(on) clegend(on span)
name(multimob2a, replace)

graph bar [aweight = weight], over(outc2) asyvars blabel(bar, format(%9.1f)) bargap(10)
title(Prevalence of composite of the 3 diseases) legend(on) clegend(on span)
name(multimob3a, replace)

***Bar charts for multimorbidity*****
graph bar [aweight = weight], over(v101) over(outc2) asyvars blabel(bar, format(%9.1f))
title("National percentage of MAMM children by region of residence") name(morbireg,
replace)

graph bar [aweight = weight], over(v102) over(outc2) asyvars blabel(bar, format(%9.1f))
title("National percentage of MAMM children by place of residence") name(morbipla,
replace)

graph bar [aweight = weight], over(outc2) over(v102) asyvars blabel(bar, format(%9.1f))
title("National percentage of MAMM Children by place of residence") name(morbipla1,
replace)
```

```
graph bar [aweight = weight], over(b4) over(outc2) asyvars blabel(bar, format(%9.1f))
title("National percentage of MAMM Children by gender") name(morbigen, replace)

graph bar [aweight = weight], over(chldage1) over(outc2) asyvars blabel(bar, format(%9.1f))
title("National percentage of MAMM Children by age") name(morbicage1, replace)


***Multimorbidity prevalence******
tabulate outc2 [iweight=weight]
asdoc tabulate outc2 [iweight = weight]



*****relationship between child's variables and multimorbidity*****
svy: tab b4 outc2, count row pearson
asdoc tabulate b4 outc2 [iweight = weight], append

svy: tab chldage1 outc2, count row pearson
asdoc tabulate chldage1 outc2 [iweight = weight], append

svy: tab bszgr1 outc2, count row pearson
asdoc tabulate bszgr1 outc2 [iweight = weight], append

svy: tab brdgr outc2, count row pearson
asdoc tabulate brdgr outc2 [iweight = weight], append

svy: tab h10 outc2, count row pearson
asdoc tabulate h10 outc2 [iweight = weight], append

svy: tab newprbth outc2, count row pearson
asdoc tabulate newprbth outc2 [iweight = weight], append

svy: tab vita outc2, count row pearson
asdoc tabulate vita outc2 [iweight = weight], append

svy: tab ironsup outc2, count row pearson
asdoc tabulate ironsup outc2 [iweight = weight], append

svy: tab m4 outc2, count row pearson
asdoc tabulate m4 outc2 [iweight = weight], append

svy: tab ironsup  outc2, count row pearson
asdoc tabulate ironsup outc2 [iweight = weight], append

svy: tab dworm outc2, count row pearson
asdoc tabulate dworm outc2 [iweight = weight], append

svy: tab fever outc2, count row pearson
asdoc tabulate fever outc2 [iweight = weight], append
```

svy: tab cough outc2, count row pearson
asdoc tabulate cough outc2 [iweight = weight], append

svy: tab diarr outc2, count row pearson
asdoc tabulate diarr outc2 [iweight = weight], append

svy: tab pldel outc2, count row pearson
asdoc tabulate pldel outc2 [iweight = weight], append

****Table: Relationship between Parental variables and multimorbidity status
svy: tab magegr outc2, count row pearson
asdoc tabulate magegr outc2 [iweight = weight], append

svy: tab v714 outc2, count row pearson
asdoc tabulate v714 outc2 [iweight = weight], append

svy: tab agefbth2 outc2, count row pearson
asdoc tabulate agefbth2 outc2 [iweight = weight], append

svy: tab v106 outc2, count row pearson
asdoc tabulate v106 outc2 [iweight = weight], append

svy: tab v504 outc2, count row pearson
asdoc tabulate v504 outc2 [iweight = weight], append

svy: tab autonomylevel1 outc2, count row pearson
asdoc tabulate autonomylevel1 outc2 [iweight = weight], append

svy: tab v461 outc2, count row pearson
asdoc tabulate v461 outc2 [iweight = weight], append

svy: tab ancvis1 outc2, count row pearson
asdoc tabulate ancvis1 outc2 [iweight = weight], append

svy: tab relsta outc2, count row pearson
asdoc tabulate relsta outc2 [iweight = weight], append

svy: tab ethgr2 outc2, count row pearson
asdoc tabulate ethgr2 outc2 [iweight = weight], append

svy: tab mirontab outc2, count row pearson
asdoc tabulate mirontab outc2 [iweight = weight], append

svy: tab manaesta outc2, count row pearson
asdoc tabulate manaesta outc2 [iweight = weight], append

svy: tab mbmi outc2, count row pearson
asdoc tabulate mbmi outc2 [iweight = weight], append

```
svy: tab pworksta outc2, count row pearson
asdoc tabulate pworksta outc2 [iweight = weight], append

svy: tab pedusta outc2, count row pearson
asdoc tabulate pedusta outc2 [iweight = weight], append
```

****Table: Relationship between Household variables and multimorbidity status

```
svy: tab v190 outc2, count row pearson
asdoc tabulate v190 outc2 [iweight = weight], append

svy: tab hhagegr outc2, count row pearson
asdoc tabulate hhagegr outc2 [iweight = weight], append

svy: tab hv228  outc2, count row pearson
asdoc tabulate hv228 outc2 [iweight = weight], append

svy: tab u5hhd outc2, count row pearson
asdoc tabulate u5hhd outc2 [iweight = weight], append

svy: tab rmsleep outc2, count row pearson
asdoc tabulate rmsleep outc2 [iweight = weight], append

svy: tab electr outc2, count row pearson
asdoc tabulate electr outc2 [iweight = weight], append

svy: tab watascou1 outc2, count row pearson
asdoc tabulate watascou1 outc2 [iweight = weight], append

svy: tab toilfac1 outc2, count row pearson
asdoc tabulate toilfac1 outc2 [iweight = weight], append

svy: tab cookfue outc2, count row pearson
asdoc tabulate cookfue outc2 [iweight = weight], append

svy: tab floormat outc2, count row pearson
asdoc tabulate floormat outc2 [iweight = weight], append

svy: tab roofmat outc2, count row pearson
asdoc tabulate roofmat outc2 [iweight = weight], append

svy: tab wallmat outc2, count row pearson
asdoc tabulate wallmat outc2 [iweight = weight], append

svy: tab v151 outc2, count row pearson
asdoc tabulate v151 outc2 [iweight = weight], append

svy: tab shatoi1 outc2, count row pearson
asdoc tabulate shatoi1 outc2 [iweight = weight], append
```

Others added
svy: tab hv227 outc2, count row pearson
asdoc tabulate hv227 outc2 [iweight = weight], append

svy: tab hhdsz outc2, count row pearson
asdoc tabulate hhdsz outc2 [iweight = weight], append

svy: tab stooldis1 outc2, count row pearson
asdoc tabulate stooldis1 outc2 [iweight = weight], append

svy: tab v159 outc2, count row pearson
asdoc tabulate v159 outc2 [iweight = weight], append

****Relationship between cluster variables and multimorbidity status*****
svy: tab cluwealth2 outc2, count row pearson
asdoc tabulate cluwealth2 outc2 [iweight = weight], append

svy: tab cludistm outc2, count row pearson
asdoc tabulate cludistm outc2 [iweight = weight], append

svy: tab clumated1 outc2, count row pearson
asdoc tabulate clumated1 outc2 [iweight = weight], append

svy: tab cluhdbnet outc2, count row pearson
asdoc tabulate cluhdbnet outc2 [iweight = weight], append

****Table: Relationship between Area variables and multimorbidity status
svy: tab mdpi outc2, count row pearson
asdoc tabulate mdpi outc2 [iweight = weight], append

svy: tab hdi outc2, count row pearson
asdoc tabulate hdi outc2 [iweight = weight], append

svy: tab gii outc2, count row pearson
asdoc tabulate gii outc2 [iweight = weight], append

svy: tab v101 outc2, count row pearson
asdoc tabulate v101 outc2 [iweight = weight], append

svy: tab v102 outc2, count row pearson
asdoc tabulate v102 outc2 [iweight = weight], append

*****Multilevel mixed effect ordinal logistic regression****
****Diagnostic Test*******
*****Multicollinearity check for all logistic analyses*******

*****All the variables extracted from the bivariate analysis (55)*****
collin b4 chldage1 bszgr1 brdgr newprbth vita ironsup m4 dworm anaesta hml35 nutrista fever cough diarr pldel magegr v714 agefbth2 v106 v504 autonomylevel1 v461 ancvis1 relsta ethgr2 mirontab manaesta mbmi pworksta pedusta v190 hhagegr hv228 u5hhd rmsleep electr watascou1 toilfac1 cookfue floormat roofmat wallmat v151 shatoi1 hv227 hhdsz stooldis1 v159 cluwealth2 cludistm clumated1 cluhdbnet mdpi hdi gii v101 v102

****After dropping multicollinear variables (48)*****
collin b4 chldage1 bszgr1 brdgr newprbth vita ironsup m4 dworm anaesta hml35 nutrista fever cough diarr pldel magegr v714 agefbth2 v106 v504 autonomylevel1 v461 ancvis1 relsta ethgr2 mirontab manaesta mbmi pworksta pedusta v190 hhagegr hv228 u5hhd rmsleep electr v151 hhdsz cluwealth2 cludistm clumated1 cluhdbnet mdpi hdi gii v101 v102

For each of the outcome variables, variable selection method applied*

Multimorbidity Analysis*****

*****MULTILEVEL MIXED EFFECT ORDINAL LOGISTIC REGRESSION******

****Forward stepwise selection of variables******
stepwise, pe(.2): ologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.hv228 i.u5hhd i.vita i.ironsup i.m4 i.dworm i.fever i.cough i.diarr i.pldel i.magegr i.v714 i.agefbth2 i.v106 i.v504 i.autonomylevel1 i.v461 i.relsta i.ethgr2 i.mirontab i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr i.rmsleep i.electr i.v151 i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.cluhdbnet i.mdpi i.hdi i.gii i.v101 i.v102, or

****AIC=14229.47, BIC=14655.13*********
meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.hv228 i.ironsup i.m4 i.fever i.v106 i.v504 i.relsta i.manaesta i.mbmi i.v190 i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.mdpi i.hdi i.gii i.v101 i.v102 ||sstate: ||v001:, or
estat ic

****backward stepwise selection of variables******
stepwise, pr(.2): ologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.hv228 i.u5hhd i.vita i.ironsup i.m4 i.dworm i.fever i.cough i.diarr i.pldel i.magegr i.v714 i.agefbth2 i.v106 i.v504 i.autonomylevel1 i.v461 i.relsta i.ethgr2 i.mirontab i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhagegr i.rmsleep i.electr i.v151 i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.cluhdbnet i.mdpi i.hdi i.gii i.v101 i.v102, or

****AIC=14011.16, BIC=14477.58*********
****The diff between AIC for backward and (Barkward+Forword) section is less than 2, and BIC for backward is smaller*****
Choosen selection**
meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.hv228 i.ironsup i.m4 i.dworm i.fever i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhdsz i.cludistm i.mdpi i.hdi i.gii i.v101 i.v102 ||sstate: ||v001:, or
estat ic

Backward+Forward*****
****AIC=14010.87, BIC=14498.15*********
meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.dworm i.fever i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hv228 i.v151 i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.mdpi i.hdi i.gii i.v101 i.v102 ||sstate: ||v001:, or
estat ic

*******Test of proportionality of ordinal logistic using predicted mean difference*****
*******Using set of variables from forward selection methods**********
ologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.hv228 i.ironsup i.m4 i.dworm i.fever i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhdsz i.cludistm i.mdpi i.hdi i.gii i.v101 i.v102, or

brant

predict y1
mean y1

*****After removing the variables that violated the non-proportionality*****
ologit outc2 i.b4 i.bszgr1 i.hv228 i.ironsup i.m4 i.dworm i.fever i.pldel i.v106 i.v504 i.relsta i.pworksta i.v190 i.hhdsz i.cludistm i.hdi i.v102, or

brant

predict y2
mean y2

******T-test of difference between mean y1 and mean y2 is not staitistically different****
ttest y1==y2

****Comparing 2-level model to 3-level model*********

*****Model 0 (Null model)*******

***** individual-level1 in community level2 in State in level3*******

meologit outc2 || sstate: || v001:

estimate store m1

estat icc
estat ic

****2-level ordinal logistic with community at level-2*****
meologit outc2 || v001:

```
estimate store m3

estat icc
estat ic

****The lrtest of difference using 2-level or 3-level shows that 3-level model is better*****
lrtest m1 m3


****Analysis to achieve equal sample sizes for all model*******

meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.hv228 i.ironsup i.m4 i.dworm i.fever
i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hhdsz i.cludistm
i.mdpi i.hdi i.gii i.v101 i.v102 ||sstate: ||v001:, or

predict z
keep if z!=.
keep if outc2!=.


***Multilevel mixed-effect Ordered Logistic Regression*****
*****Model 0 (Null model)*******
***** individual-level1 in household level2 in State in level3*******
meologit outc2 || sstate: || v001:

estimate store m2

estat icc
estat ic

****test of difference between using household or community at leve2****
****Using lrtest did not produce result because both has the same number of df=4******
****Checking the AICs and BICs, using community at level2 produced better fit*******
lrtest m2 m1

****2-level ordinal logistic with community at level-2*****
meologit outc2 || v001:

estimate store m3

estat icc
estat ic

****2-level ordinal logistic with household at level-2*****
meologit outc2 || v002:

estimate store m4

estat icc
```

```
estat ic

lrtest m3 m4

****The lrtest of difference using 2-level or 3-level shows that 3-level model is better*****
lrtest m1 m3


meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.dworm i.fever i.pldel
i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hv228 i.v151 i.hhdsz
i.cluwealth2 i.cludistm i.clumated1 i.mdpi i.hdi i.gii i.v101 i.v102 ||sstate: ||v001:, or
predict z
keep if z!=.


*****Model 0 (Null model)*******
***** individual-level1 in household level2 in State in level3*******
meologit outc2 || sstate: || v001:

estat icc
estat ic

*****Model 1 (Child-related variables only)*******
***** individual-level1 in community level2 in State in level3*******
meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.dworm i.fever i.pldel ||
sstate: || v001:, or

estat icc
estat ic

*****Model 2 (parental-related variables only)*******
***** individual-level1 in community level2 in State in level3*******
meologit outc2 i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta || sstate: || v001:,
or

estat icc
estat ic

*****Model 3 (Household-related variables only)*******
***** individual-level1 in community level2 in State in level3*******
meologit outc2 i.v190 i.hv228 i.v151 i.hhdsz || sstate: || v001:, or

estat icc
estat ic


*****Model 4 (community-related variables only)*******
***** individual-level1 in community level2 in State in level3*******
meologit outc2 i.cluwealth2 i.cludistm i.clumated1 || sstate: || v001:, or
```

```
estat icc
estat ic


*****Model 5 (area-related variables only)*******
***** individual-level1 in community level2 in State in level3*******
meologit outc2 i.mdpi i.hdi i.gii i.v101 i.v102 || sstate: || v001:, or

estat icc
estat ic

*****Model 6 (Child-related+parental-related variables only)*******
***** individual-level1 in community level2 in State in level3*******
meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.dworm i.fever i.pldel
i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta|| sstate: || v001:, or

estat icc
estat ic

*****Model 7 (Child-related+household-related variables only)*******
***** individual-level1 in community level2 in State in level3*******
meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.dworm i.fever i.pldel
i.v190 i.hv228 i.v151 i.hhdsz|| sstate: || v001:, or

estat icc
estat ic

*****Model 8 (Child-related+parental-related + household-related variables only)*******
***** individual-level1 in community level2 in State in level3*******
meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.dworm i.fever i.pldel
i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hv228 i.v151 i.hhdsz||
sstate: || v001:, or

estat icc
estat ic

*****Model 9 (Child-related+parental-related + household-related + community-related
variables only)*******
***** individual-level1 in community level2 in State in level3*******
meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.dworm i.fever i.pldel
i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hv228 i.v151 i.hhdsz
i.cluwealth2 i.cludistm i.clumated1|| sstate: || v001:, or

estat icc
estat ic

*****Model 10 (Child-related+parental-related + household-related + community-related +
area-related variables only)*******
***** individual-level1 in community level2 in State in level3*******
```

```
meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.dworm i.fever i.pldel
i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hv228 i.v151 i.hhdsz
i.cluwealth2 i.cludistm i.clumated1 i.mdpi i.hdi i.gii i.v101 i.v102 || sstate: || v001:, or

estat icc
estat ic
```

```
*****Model 11 = Model 10 + interactions between gender and household wealth
status******
*****individual-level1 in community level2 in State in level3*******
quietly: meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.dworm i.fever
i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hv228 i.v151
i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.mdpi i.hdi i.gii i.v101 i.v102 i.b4#i.v190|| sstate:
|| v001:, or

margins i.b4#i.chldage1
marginsplot, ytitle(Prob(MAMM outcomes), size(*0.75)) title(Predictive margins of
interactions between child's sex & wealth status, size(*0.80)) name(gr1, replace)
```

```
*****Model 12 = Model 10 + interactions between gender and child's age status******
*****individual-level1 in community level2 in State in level3*******
quietly: meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.dworm i.fever
i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hv228 i.v151
i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.mdpi i.hdi i.gii i.v101 i.v102 i.b4#i.chldage1||
sstate: || v001:, or

margins i.b4#i.chldage1
marginsplot, ytitle(Prob(MAMM outcomes), size(*0.75)) title(Predictive margins of
interactions between child's sex & age, size(*0.80)) name(gr2, replace)

estat icc
estat ic
```

```
*****Model 13 = Model 10 + interactions between child's age & household wealth
status******
*****individual-level1 in community level2 in State in level3*******
quietly: meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.dworm i.fever
i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hv228 i.v151
i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.mdpi i.hdi i.gii i.v101 i.v102 i.chldage1#i.v190||
sstate: || v001:, or

margins i.chldage1#i.v190
marginsplot, ytitle(Prob(MAMM outcomes), size(*0.75)) title(Predictive margins of
interactions between child's age & wealth status, size(*0.80))

estat icc
```

```
estat ic

*****Model 14 = Model 10 + all the 2-ways interactions between gender, age and household wealth status******
*****individual-level1 in community level2 in State in level3*******
meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.dworm i.fever i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hv228 i.v151 i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.mdpi i.hdi i.gii i.v101 i.v102 i.b4#i.v190 i.b4#i.chldage1 i.chldage1#i.v190|| sstate: || v001:, or

estat icc
estat ic

*****Model 15 = Model 10 + all the 2-ways and 3-ways interactions between gender, age and household wealth status******
*****individual-level1 in community level2 in State in level3*******
meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.dworm i.fever i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hv228 i.v151 i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.mdpi i.hdi i.gii i.v101 i.v102 i.b4#i.v190 i.b4#i.chldage1 i.chldage1#i.v190 i.b4#i.chldage1#i.v190 || sstate: || v001:, or

estat icc
estat ic




***Multiple imputation analysis*****
***Distribution of missed tables summary****

misstable sum outc2 b4 chldage1 bszgr1 newprbth hv228 ironsup m4 dworm fever pldel v106 v504 relsta manaesta mbmi pworksta pedusta v190 hhdsz cludistm mdpi hdi gii v101 v102

***Distribution of misstable pattern******
misstable pat outc2 b4 chldage1 bszgr1 newprbth hv228 ironsup m4 dworm fever pldel v106 v504 relsta manaesta mbmi pworksta pedusta v190 hhdsz cludistm mdpi hdi gii v101 v102

****Multiple imputation data set up****
mi set wide

****registering the variables with missing data*****
mi register imputed outc2 bszgr1 newprbth hv228 ironsup dworm fever v504 manaesta mbmi pedusta

****Registering the variable with complete observations****
mi register regular b4 chldage1 m4 pldel v106 relsta pworksta v190 hhdsz cludistm mdpi hdi gii v101 v102
```

Generate the missing binary codes for the variable with most missing values**
gen r_mbi=(mbmi!=.)

xi: logistic r_mbi i.pedusta

xi: logistic r_mbi i.v504

xi: logistic r_mbi i.outc2

xi: logistic r_mbi i.manaesta

xi: logistic r_mbi i.bszgr1

xi: logistic r_mbi i.hv228

xi: logistic r_mbi i.dworm

xi: logistic r_mbi i.newprbth

xi: logistic r_mbi i.ironsup

xi: logistic r_mbi i.fever

*****ChiSq test for MCAR-of assocaition with missingness*******

tab pedusta r_mbi, chi2 row

tab v504 r_mbi, chi2 row

tab outc2 r_mbi, chi2 row

tab manaesta r_mbi, chi2 row

tab bszgr1 r_mbi, chi2 row

tab hv228 r_mbi, chi2 row

tab dworm r_mbi, chi2 row

tab newprbth r_mbi, chi2 row

xi: logit r_mbi i.b4 i.outc2 i.bszgr1 i.newprbth i.hv228 i.ironsup i.dworm i.fever i.v504 i.manaesta i.pedusta

mi impute chained (mlogit) outc2 bszgr1 newprbth hv228 ironsup dworm fever v504 manaesta mbmi pedusta=i.b4 i.chldage1 i.m4 i.pldel i.v106 i.relsta i.pworksta i.v190 i.hhdsz i.cludistm i.mdpi i.hdi i.gii i.v101 i.v102, add(10) rseed(12345)

mi estimate, cmdok: meologit outc2 i.b4 i.chldage1 i.bszgr1 i.newprbth i.ironsup i.m4 i.dworm i.fever i.pldel i.v106 i.v504 i.relsta i.manaesta i.mbmi i.pworksta i.pedusta i.v190 i.hv228 i.v151 i.hhdsz i.cluwealth2 i.cludistm i.clumated1 i.mdpi i.hdi i.gii i.v101 i.v102 || sstate: || v001:, or

****Analysis of improvement in the predictive power of mbmi in complete records using AUC*****
xi: logit r_mbi i.b4 i.outc2 i.bszgr1 i.hv228 i.ironsup i.dworm i.fever i.v504 i.pedusta
lroc, nograph

xi: logit r_mbi i.b4 i.outc2 i.bszgr1 i.hv228 i.ironsup i.dworm i.fever i.v504 i.manaesta i.pedusta
lroc, nograph

xi: logit r_mbi i.b4 i.outc2 i.bszgr1 i.newprbth i.hv228 i.ironsup i.dworm i.fever i.v504 i.manaesta i.pedusta
lroc, nograph

Remove outcome variable**
xi: logit r_mbi i.b4 i.bszgr1 i.newprbth i.hv228 i.ironsup i.dworm i.fever i.v504 i.manaesta i.pedusta
lroc, nograph

Add the outcome variable*
xi: logit r_mbi i.b4 i.outc2 i.bszgr1 i.newprbth i.hv228 i.ironsup i.dworm i.fever i.v504 i.manaesta i.pedusta
lroc, nograph

clear