

Dietary Assessment and Prevention of Hypertension in Nigeria

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Declaration

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The candidate confirms that the work submitted is his own, except where work which has formed part of jointly authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

Co-authored publications

Chapter two

Dietary factors and hypertension risk in West Africa: a systematic review and meta-analysis of observational studies (2023). **Nimisoere P. Batubo**, J. Bernadette Moore, Michael A. Zulyniak. *Journal of Hypertension*, 41(9), 1376–1388.

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Empowering Healthcare Professionals in West Africa— A feasibility study and qualitative assessment of a dietary screening tool to identify adults at high risk of hypertension. (2024). **Nimisoere P. Batubo**, Nnenna M. Nwanze, Chizindu A. Alikor, Carolyn I. Auma, J. Bernadette Moore, Michael A. Zulyniak. *PLOS ONE*, 19(4), e0294370. <https://doi.org/10.1371/journal.pone.0294370>

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Chapter six

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Abstract

Background: This PhD developed validated, culturally-appropriate dietary screening tools for hypertension for clinicians to assess dietary intake and offer personalised dietary advice to patients to improve hypertension prevention and long-term cardiovascular health in Nigeria.

Methods: The PhD used a mixed-method design with quantitative and qualitative assessment strategies to evaluate epidemiological and clinical evidence and patients' and healthcare professionals' feedback on the dietary screening tools.

Findings: Study one found that a high intake of salt, red meat, dietary fats, junk foods, and alcohol was associated with increased odds of hypertension by 17-76%, whereas a high fruit and vegetable intake reduced the odds of hypertension by 20% in West Africa. This evidence supported the development of the Nigerian dietary screening tool (NiDST). In study two, most ($\geq 94\%$) patients and healthcare professionals reported clarity, ease of use, culturally-appropriate, and relevance of the (NiDST) with high adherence (88%), short completion time (< 8 minutes) and promising feasibility of integration in clinical practice ($>83\%$). In addition, the NiDST demonstrated good agreement with 24-hour dietary recall, confirming its validity and reliability. Building on this, study three simplified the NiDST to create the Nigerian diet risk score (NiDRS). Each unit increase in the NiDRS was associated with a 2-fold increase in the odds of hypertension (OR: 2.04, 95%CI: 1.16, 3.58, $p=0.013$). Moreover, the NiDRS demonstrated a strong predictive accuracy (AUC) of 92% in correctly identifying individuals at high risk of hypertension. In addition, atherogenic lipids, c-reactive protein, and homocysteine mediated the relationship between the NiDRS and mean arterial blood pressure by 47-71%. Collectively, these refined tools have a high adherence rate (92%), short completion time (< 5 minutes) and improved patient-clinician engagement and communication on dietary discussion, as affirmed by all patients and clinicians in study four.

Conclusion: This PhD delivers the 25-item NiDST and 11-item NiDRS for hypertension, to quickly identify individuals at risk of hypertension. Along with dietary counselling and behavioural changes, these tools have the potential to improve poor dietary habits, reduce hypertension prevalence, and improve overall cardiovascular health in Nigeria.

Keywords: Hypertension, cardiovascular diseases, dietary screening tool, diet risk score, dietary factors, clinical practice, Nigeria, West Africa.

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List of abbreviations

Abbreviation/Acronyms	Definitions
24DR	24-hour dietary recall
AC	Atherogenic Coefficient
ACE	Angiotensin converting enzyme
AIP	Atherogenic Index of Plasm
Ang-I	Angiotensin-I
Ang-II	Angiotensin-II
AT1 receptors	Angiotensin-1 receptors
AUC	Area under the curve
BMI	Body mass index
CAD	Coronary artery disease
CHD	Coronary heart disease
CI	Confidence interval
CKD	Chronic kidney disease
CRI-I	Castelli Risk Index I
CRI-II	Castelli Risk index II
CRP	C-reactive protein
CRR	Cardiac risk ratio
CVD	Cardiovascular disease
DASH	Dietary approaches to stop hypertension
DBP	Diastolic blood pressure
DCA	Decision curve analysis
DQI	Diet Quality Index
ECF	Extracellular fluid
ESRD	End-stage renal disease
FFQ	Food Frequency Questionnaire
GDP	Guanosine diphosphate
GM	Gross misclassification
GPCR	G-protein-coupled receptor
GTP	Guanosine triphosphate
HCY	Homocysteine
HDL	High-density lipoprotein
HDL-C	High-density lipoprotein cholesterol

HEA	Healthy eating approach
HR	Hazard ratio
ICC	Intraclass correlation coefficient
IL-17A	Interleukin-17 alpha
IL-1B	Interleukin-1 beta
IL-6	Interleukin 6
IQR	Interquartile range
LDL	Low-density lipoprotein
LDL-C	Low-density Lipoprotein-Cholesterol
LMIC	Low and Middle-Income Countries
LOA	Limits of agreement
MAP	Mean arterial pressure
MI	Myocardial infarction
MIDI	Measurement Instrument for Determinants of Innovations
mmHg	Millimetre mercury
NaPi-IIa/ NaPi-IIc	Sodium-phosphate cotransporter isoform-2a/c
NCDs	Non-Communicable Diseases
NHE3	Sodium hydrogen exchanger-3
NiDRS	Nigerian diet risk score
NiDST	Nigerian dietary screening tool
NO	Nitric oxide
OR	Odds ratio
PAD	Peripheral arterial disease
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analysis
PICO	Patient/Population, Intervention, Comparison, Outcome
PVD	Peripheral vascular disease
RAAS	Renin-angiotensin-aldosterone system
RCTs	Randomised control trials
RGS	Regulator G-protein
ROC	Receiver operating characteristics
ROS	Reactive oxygen species
RR	Risk ratio
RSUTH	Rivers State University Teaching Hospital
SBP	Systolic blood pressure

SD	Standard deviation
SE	Standard error
SNS	Sympathetic nervous system
TC	Total cholesterol
THDL	Total HDL-C Cholesterol ratio
TMA	Trimethylamine
TMAO	Trimethylamine N-oxide
TNF-α	Tissue necrotic factor alpha
UK	United Kingdom
US	United States
VLDL	Very low-density lipoprotein
VLDL-C	Very low-density lipoprotein-cholesterol
WHO	World Health Organisation
xMED	Mediterranean Diet Score

Scientific contributions from this PhD

Published peer-reviewed articles

Batubo, Nimisoere P; Moore, J. Bernadette; Zulyniak, Michael A. (2023). Dietary factors and hypertension risk in West Africa: a systematic review and meta-analysis of observational studies. *Journal of Hypertension* 41(9): p 1376-1388. <http://doi.org/10.1097/HJH.0000000000003499>.

Batubo, Nimisoere P; Moore, J. Bernadette; Zulyniak, Michael A. (2024). Dietary assessment and prevention of hypertension in Nigeria: Protocol for a retrospective cross-sectional study for the development and validation of a food frequency questionnaire for clinical use. *PLOS ONE*, 19(4), e0292561. <https://doi.org/10.1371/journal.pone.0292561>

Nimisoere P. Batubo, Nnenna M. Nwanze, Chizindu A. Alikor, Carolyn I. Auma, J. Bernadette Moore, Michael A. Zulyniak. (2024). Empowering Healthcare Professionals in West Africa— A feasibility study and qualitative assessment of a dietary screening tool to identify adults at high risk of hypertension. (2024). *PLOS ONE*, 19(4), e0294370. <https://doi.org/10.1371/journal.pone.0294370>

Peer-review articles submitted

Nimisoere P. Batubo, Carolyn I. Auma, J. Bernadette Moore, and Michael A. Zulyniak. Validity and reproducibility of a culturally tailored dietary screening tool for hypertension risk in Nigerian healthcare. *BMJ Public Health* (Submitted, bmjph-2024-001279).

Nimisoere P. Batubo, Carolyn I. Auma, J. Bernadette Moore, and Michael A. Zulyniak. Evaluating Modifiable Hypertension Risk in Nigerian Adults — The Nigerian Diet Risk Score. *European Heart Journal* (Submitted, EURHEARTJ-D-24-01285).

Peer-review articles under development

Nimisoere P. Batubo, Carolyn I. Auma, J. Bernadette Moore, and Michael A. Zulyniak. The Nigerian dietary screening tool (NiDST): A step towards improved patient-clinician communication in Nigerian hospitals: A Pilot implementation study. (Submission June 2024).

Conference presentations

Nutrition Futures Conference, 2022: Association between dietary salt and hypertension in West Africa: A meta-analysis: **Nimisoere P. Batubo,** J. Bernadette Moore, and Michael A. Zulyniak.

European Congress on Obesity, 2023: Associations between dietary factors and hypertension risk in West Africa: A systematic review and meta-analysis of cross-sectional studies. **Nimisoere P. Batubo**, J. Bernadette Moore, and Michael A. Zulyniak. <https://doi.org/10.1159/000530456>

European Congress on Obesity, 2024: Adherence to a dietary risk score and hypertension risk among adults in Nigeria: **Nimisoere P. Batubo**, Carolyn I. Auma, J. Bernadette Moore, and Michael A. Zulyniak.

Organisation of the thesis

This PhD thesis was constructed around a series of article manuscripts, each representing a significant milestone in my PhD research. The thesis comprises seven chapters, each serving a distinct objective in advancing dietary assessment and prevention of hypertension in Nigeria.

Chapter one comprises a general introduction and a narrative literature review that highlight the subject areas that frame this PhD thesis. That is, hypertension, diet-induced hypertension, the nutritional transition, and dietary intervention. Within the narrative literature review is a contextual background of the case study country, Nigeria, a low-income sub-Saharan African country. This chapter also presents the research gaps identified, which form the rationale, aims, questions, and objectives for carrying out this PhD research.

Chapter two (study one) is a systematic review and meta-analysis (SRMA) undertaken to: (i) identify foods, diets, and nutrients in West Africa, including Nigeria and their association with hypertension risk; and (ii) synthesise the evidence of the association between dietary factors and hypertension in West Africa. Findings resulting from the SRMA are presented, and the main findings from the study are discussed. Additionally, the findings were used to create the food list to develop the Food Frequency Questionnaire (FFQ) underpinning the study described in Chapter three.

Chapter three (phase one of study two) describes the feasibility and acceptability of integrating the FFQ dietary screening tool into a clinical setting in Nigeria to assess stakeholders' (patients and healthcare professionals) perceived perspective of introducing a novel culturally-appropriate dietary screening tool into routine clinical practice. The methods used, and findings are presented in this chapter. Implications for policy and practice resulting from the findings are also highlighted. The findings were also used to refine the FFQ for the validation study in chapter four.

Chapter four (phase two of study two) presents the relative validation and reproducibility of the refined FFQ dietary screening tool to establish the: (i) validity of the tool against multiple repeat 24-hour dietary recalls; and (ii) reproducibility at two different point time. The methods used, findings and implications for policy and practice are presented in this chapter. The findings were used to further refine the dietary screening tool, referred to as the Nigerian dietary screening tool (NiDST), to assess dietary intake of adult Nigerians in clinical settings and underpin the study described in Chapter five.

Chapter five (study three), real-time dietary screening, using the Nigerian dietary screening tool (NiDST) to: (i) derive and validate the utility of a dietary risk score (NiDRS) for hypertension in Nigeria; and (ii) evaluate the predictive performance of NiDRS alongside a panel of clinical predictors and biomarkers for hypertension. The methods used, and findings are presented in this chapter. Implications for policy and practice resulting from the findings are also highlighted.

Chapter six (study four), real-time dietary screening, consultation and dietary counselling were undertaken using the NiDST in a single-centre pilot implementation study to assess: (i) the ability of the screening tool to enhance patient-clinician communication regarding dietary discussion in clinical settings; and (ii) evaluate the barriers to and facilitators of implementation. The methods used, and findings are presented in this chapter. Implications for policy and practice resulting from the findings are also highlighted.

Chapter seven, the final chapter, integrates the results from the quantitative and qualitative studies undertaken in this PhD within the context of the narrative literature review. By drawing on findings from the four studies, this chapter highlights the contribution of this PhD thesis to the wider literature beyond Nigeria on validated, culturally-appropriate dietary screening tools and diet risk scores. Implications for policy and practice of the PhD findings and future research are also presented.

Chapter one

Introduction and literature review

This chapter establishes the foundation for developing a culturally-appropriate dietary assessment tool to address the rising prevalence of hypertension in Nigeria. The chapter first describes the growing burden of hypertension and its impact globally and in Nigeria, underscoring the importance of dietary interventions. Secondly, the pathogenesis of hypertension, including diet-induced hypertension, was discussed. Next, the rationale and significance of the study are highlighted. The chapter then concludes with a summary of the identified research gaps, research aim, questions, and objectives addressed in this PhD, as well as an overview of the research strategies employed.

1.1. Introduction

Hypertension (commonly called high or elevated blood pressure) is defined as a sustained elevation of blood pressure $\geq 140/90$ mmHg (World Health Organization, 2023). Hypertension is the leading preventable risk factor for cardiovascular disease (CVD) and kidney disease worldwide, contributing to an estimated 11.3 million overall deaths and 10.8 million cardiovascular disease-related deaths in 2021 (Vaduganathan et al., 2022). The burden of hypertension in low-and middle-income countries (LMIC), including sub-Saharan African countries, is rapidly increasing due to population growth, ageing, physical inactivity, and poor dietary habits, with a cumulative estimated prevalence of hypertension in Africa currently standing at approximately 30.8% (Bosu et al., 2019; Peer et al., 2021; Bayarara et al., 2023). In Nigeria alone, the most populous nation on the continent, hypertension prevalence is more than doubled in the last 20 years, from 11.2% in 1997 to 30.9% in 2020, affecting nearly one in three adults (Akinkugbe, 1997; Odili et al., 2020; Adeloye et al., 2021). These estimates indicate that up to 27.5 million people in Nigeria are currently affected by hypertension (Adeloye et al., 2021). Despite these figures, less than 11% of hypertensive adults in Nigeria achieve recommended blood pressure control (i.e., $\leq 120/80$ mmHg) as a result of poor access to healthcare, high cost of medication, non-adherence to pharmacological therapy, and poor diet (Ogah et al., 2012; Oguoma et al., 2015; Adeloye et al., 2021).

On a global scale, poor diet now ranks as the major modifiable risk factor for mortality, accounting for eight million deaths and responsible for 40% of cardiovascular disease (CVD)-related deaths globally in 2021 (Vaduganathan et al., 2022; Zhang et al., 2023). Indeed, poor diet has been attributed to nearly one-third of all cardiovascular disease cases (Dong et al., 2022). Furthermore, studies have demonstrated that dietary patterns low in

fruits, vegetables, and whole grains and high in red and processed meat, refined sugars, and salt are the leading determinants of hypertension and CVD, in addition to other non-communicable diseases (NCDs) (Schwingshackl et al., 2017; Vaduganathan et al., 2022). Given that Nigeria is currently experiencing a high rate of population growth, ageing population, low physical activity levels and unhealthy dietary patterns (characterised by diets high intake of salt, unhealthy dietary fat and oils, refined sugar and alcohol, while concomitantly low in ‘fruit and vegetables’, and dietary fibre), the rising prevalence of hypertension in Nigeria is partly attributed to a dietary and epidemiological transition (Aduroja et al., 2022; Ogundeji et al., 2023; Petrikova et al., 2023). This posits diet as a major modifiable risk factor in Nigeria to address the rising prevalence of hypertension.

In response to the growing prevalence of non-communicable diseases (NCDs), Nigeria outlined the National Nutritional Guidelines to combat all NCDs, including hypertension (Federal Ministry of Health, 2014). However, the translation of these guidelines into actionable advice for clinicians has been challenging, possibly because: (i) clinicians and other healthcare professionals in Nigeria have not been provided with an effective dietary strategy or tool to evaluate or provide culturally-appropriate dietary information for patients; and (ii) the evidence used to inform the Nigerian Nutritional Guidelines is based on evidence weighted towards non-African studies, which may not be appropriate to manage the contribution of diet towards the rising trend of hypertension in Nigeria. As such, most clinicians and other members of the Nigerian healthcare team do not routinely assess patients’ dietary intake during clinical care because of the: (i) lack of region-specific nutrition guidance for clinicians; (ii) inadequate time to evaluate diet; (iii) clinical workload; (iv) low physician confidence; and (v) inadequate teaching materials and training (Kushner, 1995; Kolasa and Rickett, 2010; Ahmed et al., 2016; Aspry et al., 2018). However, studies have shown that brief nutritional training and lifestyle counselling, along with the use of a rapid dietary assessment (screening) tool, can effectively mitigate these barriers (Vadiveloo, M. et al., 2020; Vadiveloo, M.K. et al., 2023).

Dietary screening tools provide an avenue for an efficient and valid assessment of dietary intake, which can enable clinicians and other healthcare professionals to identify actionable dietary modifications appropriate for patients without requiring advanced nutritional training to intervene (Gibson, 2022; Vadiveloo, M.K. et al., 2023). Such an assessment tool should be: (i) valid and reliable; (ii) rapid/brief; (iii) feasible to administer; (iv) able to effectively and accurately assess dietary intake; (v) have clinical

support; and (vi) associated with long-term improvement in diet (Vadiveloo, M. et al., 2020; Lichtenstein et al., 2021; Vadiveloo, M.K. et al., 2023). Therefore, a logical first step to support dietary changes in Nigeria is an evidence-based, validated and rapid culturally-appropriate dietary screening tool.

Currently, in Nigeria, no such culturally-appropriate validated and rapid dietary screening tools used by clinicians and other healthcare professionals to assess dietary intake in patients in clinical practice. The existing tools in Nigeria, such as Food Frequency Questionnaires (FFQs) and 24-hour dietary recalls, are comprehensive and require considerable time for administration and analysis, limiting their feasibility in busy clinic settings (Sharma et al., 1999; Oguntona and Akinyele, 2002; Samson et al., 2023). Moreover, other Western diet-based tools often fail to capture Nigerian traditional foods like yam, plantain, soups and stews, and other local meals and do not acknowledge the cooking habits in Nigeria that can modify diet-health associations (Sharma et al., 1999; Oguntona and Akinyele, 2002; Okeke et al., 2009; Petrikova et al., 2023; Samson et al., 2023). Conversely, screening tools like the Rapid Eating Assessment for Participants (REAP) (Segal-Isaacson et al., 2004) offer efficiency but lack validation in the unique Nigerian diet, highlighting the necessity for culturally-appropriate tools attuned to the local food culture in Nigeria (Gilbert and Khokhar, 2008; Satia, 2010). To address this: (i) an understanding of the dietary factors associated with the risk of hypertension in Nigeria is needed to confirm current recommendations and improve current dietary assessment strategies; then, based on this understanding; and (ii) develop a culturally-appropriate and rapid/brief valid dietary screening tool to support clinicians, patients, and researchers to combat hypertension in Nigeria.

The previous section established the foundational understanding of hypertension and diet and dietary screening in clinical practice. In the next section, I give a more detailed overview of hypertension, its causes, and the types of clinical hypertension and provide more details on the diagnosis of hypertension.

1.2. Overview of hypertension

Hypertension stands as a widespread and significant public health concern globally. Hypertension is a clinical condition characterised by sustained elevated blood pressure levels, with a systolic blood pressure ≥ 140 mmHg or a diastolic blood pressure ≥ 90 mmHg (Mills et al., 2016; World Health Organization, 2021). Hypertension is often asymptomatic (i.e., without symptoms) in its early stages and can remain undiagnosed for years. However, it can progressively lead to functional and structural abnormalities,

including heart, vascular, and renal abnormalities, leading to premature morbidity and mortality (Kearney et al., 2005; Lawes et al., 2008; Giles et al., 2009; Whelton et al., 2018). Despite its silent nature, hypertension is the leading risk factor for morbidity and mortality (Forouzanfar et al., 2017). The aetiology of hypertension is multifactorial, involving the interactions between genetic, environmental, and lifestyle factors. Clinically, hypertension is classified as either essential or non-essential. While essential (i.e., primary) hypertension, accounting for most cases, has no identifiable cause and is likely influenced by genetic predisposition and environmental factors, non-essential (i.e., secondary) hypertension results from an underlying medical condition or medication use (Carey et al., 2018).

1.3. Diagnosis of hypertension

The diagnostic criterion for hypertension involves accurate blood pressure measurement, with a diagnostic threshold of systolic blood pressure ≥ 140 and diastolic blood pressure ≥ 90 mmHg (Jones et al., 2020). The gold standard for blood pressure measurement is to use direct invasive intra-arterial measurement (Pickering et al., 2005). However, non-invasive brachial cuff sphygmomanometry is the standard clinical practice to measure blood pressure (Jones et al., 2020). To minimise variability, the measurement is taken from the individual in a comfortable sitting position after 5 minutes of rest, with the arm supported at heart level without constrictive clothing. The reading is taken twice (one minute apart) to document baseline blood pressure (Whelton et al., 2018). Out-of-office monitoring through 24-hour ambulatory or home monitoring may provide a more representative picture of control of blood pressure throughout daily life activities (Jones et al., 2020). Moreover, white coat hypertension (i.e., blood pressure $>20/10$ mmHg between clinic readings and average daytime home or ambulatory measurements) can mask hypertension and blood pressure variability, and it is better characterised through out-of-office monitoring (Whelton et al., 2018; Jones et al., 2020). **Table 1.1** presents different guidelines used in the classification of hypertension.

Table 1. 1. Classification of hypertension based on different guidelines.

Classification System	SBP (mmHg)	DBP (mmHg)	Interpretation
American College of Cardiology/ American Heart Association (Whelton et al., 2018)	<120	<80	Normal
	120-129	<80	Elevated
	130-139	80-89	Hypertension stage 1
	≥ 140	≥ 90	Hypertension stage 2
International Society of Hypertension (ISH)/World Health Organisation (WHO) (World Health Organization, 2021)	<130	<85	Normal
	130-139	85-89	High normal
	140-159	90-99	Grade 1 hypertension
	≥ 160	≥ 100	Grade 2 hypertension

Note: The World Health Organisation (WHO) classification system is used in Nigeria's clinical setting to grade individuals with hypertension. SBP: Systolic blood pressure; DBP: Diastolic blood pressure.

The following sections discuss the types of clinical hypertension and aetiology (i.e., causes) of hypertension, delineating between modifiable and non-modifiable risk factors.

1.4. Types of clinical hypertension

Clinically, hypertension is grouped into two categories: (i) essential (or primary) hypertension and (ii) non-essential (or secondary) hypertension. Primary hypertension accounts for about 90-95% of hypertension with sustained elevated blood pressure $\geq 140/90$ mmHg with no known single cause (Carey et al., 2018). However, primary hypertension typically develops gradually over time and is thought to result from a complex interplay between genetic, environmental, lifestyle risk factors (including overweight and obesity, sedentary lifestyle, and unhealthy diet) and chronic stress (Carey et al., 2018). These factors collectively or individually impact various physiological and biochemical mechanisms such as cardiac output, vascular resistance, renin-angiotensin-aldosterone system (RAAS), autonomic nervous systems and neurohumoral factors (e.g., bradykinin, endothelin, endothelial-derived relaxing factor, nitric oxide, atrial natriuretic peptide) to increase the blood pressure (Carey et al., 2018; Whelton et al., 2018). On the other hand, secondary hypertension accounts for 5-10% of all cases of hypertension. Secondary hypertension is characterised by sustained elevated blood pressure $\geq 140/90$ mmHg due to an identifiable underlying medical condition, including renovascular abnormalities, endocrine (e.g., pheochromocytoma or primary aldosteronism) abnormalities, or single gene mutations (Carey et al., 2018). In this thesis, the term 'hypertension' will be used to refer to both primary and secondary hypertension unless otherwise stated.

1.5. Aetiology of hypertension

As highlighted in section 1.2, hypertension is a multifactorial disease whose aetiology is influenced by a complex interplay between a combination of myriad factors, which can be categorised as modifiable and non-modifiable (**Figure 1.1**). Modifiable risk factors are characteristics or behaviours that individuals can actively change or control to reduce their risk of developing adverse health outcomes (e.g., hypertension), while for non-modifiable risk factors, these characteristics are inherent or predetermined by genetic, biological, or environmental factors. The individuals cannot alter these factors through lifestyle changes or interventions.

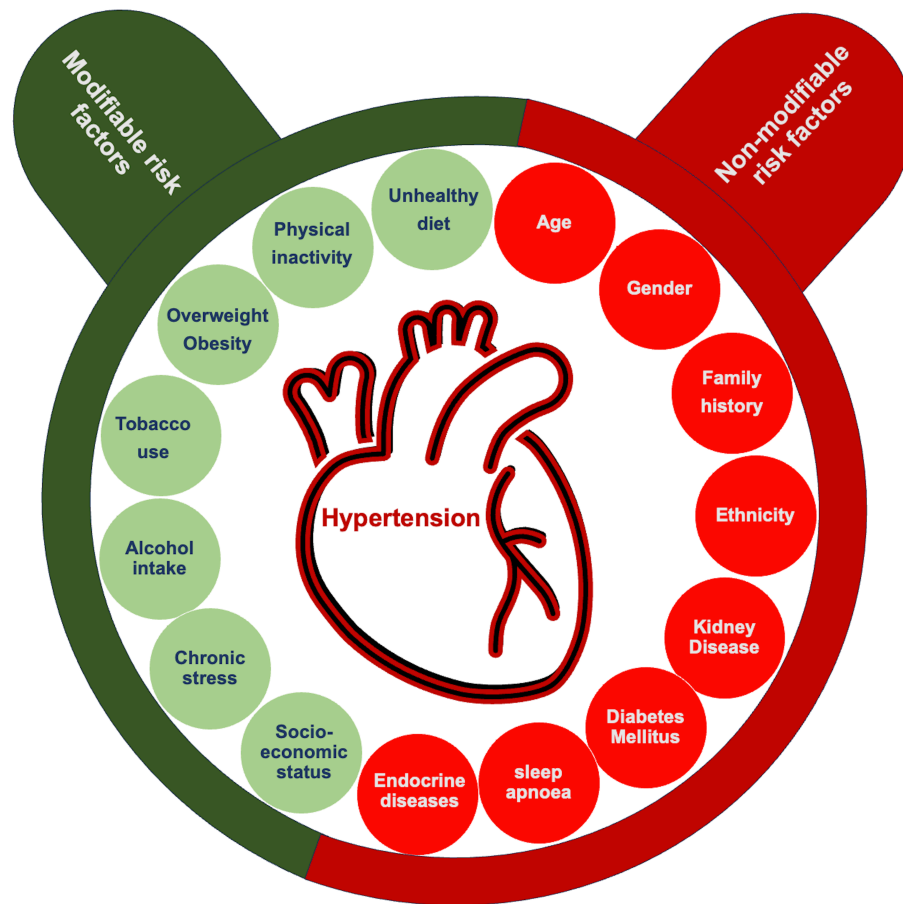


Figure 1. 1. Aetiological classification of risk factors associated with hypertension.

1.5.1. Modifiable risk factors

Modifiable risk factors play a significant role in the pathophysiology and progression of hypertension, making them important targets for preventive interventions (**Figure 1.1**). Among the key modifiable risk factors, overweight and obesity are potent drivers of hypertension (Hall, J.E. et al., 2012; Hall, M.E. et al., 2014; Hall, J.E. et al., 2015; Huby et al., 2015). Excess adiposity, particularly visceral adipose tissue, is associated with the dysregulation of adipokines (e.g., leptin, adiponectin), pro-inflammatory cytokines (e.g., tumour necrosis factor- α (TNF- α), interleukin-6 (IL-6)) and insulin resistance, which collectively promote sodium retention through renin-angiotensin-aldosterone system (RAAS) activation, sympathetic nervous system activation (increased catecholamines level), vascular endothelial dysfunction through inflammation, and oxidative stress induction (e.g., ROS), leading to elevated blood pressure (Hall, J.E. et al., 2012; Hall, M.E. et al., 2014; Hall, J.E. et al., 2015; Huby et al., 2015). Another modifiable risk factor is a sedentary lifestyle characterised by insufficient physical activity, resulting in low energy expenditure, which contributes to overweight and obesity (more so visceral obesity), insulin resistance, and dyslipidaemia, all of which are implicated in the pathogenesis of hypertension (Pescatello et al., 2004; Cornelissen and Smart, 2013).

Regular physical activity within the World Health Organisation (WHO) recommendations (i.e., at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity aerobic physical activity per week), on the other hand, enhances endothelial function, reduces sympathetic tone, and improves insulin sensitivity, thereby exerting antihypertensive effects (Pescatello et al., 2004; Cornelissen and Smart, 2013).

Dietary factors also play a crucial role in the pathogenesis of hypertension, with a high intake of unhealthy foods (*see section 1.7 for details*) being a well-established modifiable risk factor (Sacks et al., 2001). For instance, a high intake of dietary salt/sodium disrupts sodium homeostasis, causing expansion of the blood volume, arterial stiffness, and renin-angiotensin-aldosterone system activation, all of which contribute to hypertension (He, F.J. and MacGregor, 2010; Whelton et al., 2018). Conversely, adherence to a healthy dietary pattern rich in fruits, vegetables, whole grains, and low-fat dairy products, such as the Dietary Approaches to Stop Hypertension (DASH) dietary pattern, has been shown to lower blood pressure through its protective effects on vascular function and sodium-potassium balance (Appel et al., 1997; Sacks et al., 2001).

Furthermore, excessive alcohol consumption is associated with an increased risk of hypertension, primarily through its effects on sympathetic activation, RAAS activation, and vascular dysfunction (Beilin and Puddey, 2006; Puddey and Beilin, 2006; Puddey et al., 2019). Tobacco smoking, on the other hand, promotes endothelial dysfunction, oxidative stress, inflammation, and arterial stiffness, all of which contribute to the pathogenesis of hypertension (Messner and Bernhard, 2014). Moreover, exposure to second-hand smoke has been shown to increase blood pressure levels in non-smokers, highlighting the importance of tobacco control measures for the prevention of hypertension (Barnoya and Glantz, 2005). Lastly, psychosocial factors, such as chronic psychological stress, depression, and social isolation, have all been implicated in the development of hypertension through their effects on sympathetic nervous activation, hypothalamic-pituitary-adrenal axis dysregulation, and unhealthy coping behaviours (Chida and Steptoe, 2010; Meng et al., 2012).

1.5.2. Non-modifiable risk factors

Non-modifiable risk factors also significantly contribute to the development and progression of hypertension. Understanding these non-modifiable risk factors is important for identifying individuals at higher risk of cardiovascular diseases, including hypertension, and implementing appropriate preventive strategies. One of the primary non-modifiable risk factors for hypertension is age. A study by Reckelhoff (2023)

reported that advancing age is strongly associated with an increased risk of hypertension in both men and women, with most hypertension cases occurring in individuals over the age of 65. The author also reported that, after menopause, blood pressure and the risk of hypertension increase more in women than men of similar age and ethnic background (Reckelhoff, 2023). These age-related or gender-related blood pressure increases are attributed to physiological changes, such as arterial stiffness and endothelial dysfunction, decreased vascular compliance, hormonal changes (i.e., loss of oestrogen and progesterone along with reductions in testosterone) after menopause or > 60 years and renal function decline and alteration of the renin-angiotensin-aldosterone system (Connelly et al., 2022; Reckelhoff, 2023).

Moreover, family history and genetic factors also play a significant role in hypertension susceptibility (Lifton, 1996; Manosroi and Williams, 2019). A family history of hypertension is considered a strong independent risk factor for hypertension and cardiovascular disease, reflecting shared genetic and environmental influences among relatives (Ranasinghe et al., 2015; Valerio et al., 2016). Moreover, ethnicity is another non-modifiable risk factor associated with increased risk of hypertension. For example, Africans, African Americans, and South Asians have been reported to have a higher prevalence of hypertension and are at increased risk of developing complications such as stroke and chronic kidney disease (Lackland and Weber, 2015; Pursnani and Merchant, 2020). Furthermore, variations in specific genes encoding for proteins in the renin-angiotensin-aldosterone system, such as angiotensinogen, angiotensin-converting enzyme (ACE), and angiotensin-II receptor type-1, can influence blood pressure regulation (Paillard et al., 1999; He, W.J. et al., 2015). Genetic variations in ion channels, such as voltage-gated calcium and potassium channels, impact the excitability of vascular smooth muscle cells and thus affect vascular tone and blood pressure (Nieves-Cintron et al., 2018; Huang et al., 2020). Additionally, variations in genes encoding for renal sodium transporters can alter renal sodium reabsorption, leading to expansion of blood volume and elevated blood pressure (Doris, 2000; Patel et al., 2017; Georg B Ehret, 2022). These genetic variations often exhibit polygenic inheritance patterns, involving multiple genes with small individual effects contributing to overall hypertension susceptibility.

Building upon the exploration of the aetiology of hypertension, the next section discusses the intricate pathophysiological mechanisms underlying hypertension, including the roles of kidney function, vascular function, neural function, and the influence of reactive oxygen species and inflammatory cytokines.

1.6. Pathophysiology of hypertension

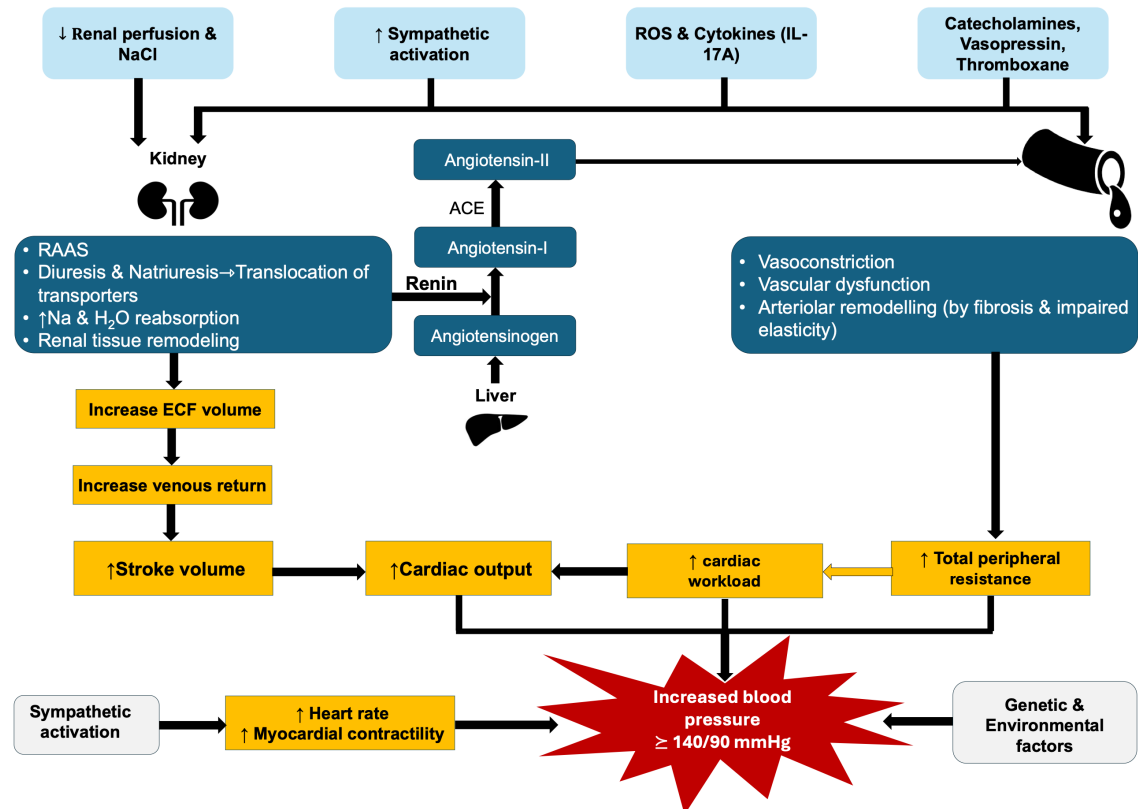


Figure 1. 2 Role of multiple risk factors in the pathophysiology of hypertension.

ROS: Reactive oxygen species, NaCl: Sodium chloride; RAAS: Renin-angiotensin-aldosterone system; Na: Sodium; H₂O: Water, ACE: Angiotensin converting enzyme; ↑: Increase

The specific mechanisms initiating and sustaining elevation of blood pressure are complex and multifactorial (**Figure 1.2**). However, physiologically, hypertension results from an imbalance between determinants of cardiac output and peripheral vascular resistance (Carey et al., 2018; Whelton et al., 2018). Cardiac output (i.e., the volume of blood pumped out of the heart per unit of time) is dependent on the stroke volume (i.e., the volume of blood ejected by the heart with each contraction) and heart rate (i.e., the number of heartbeats per minute) (Beavers et al., 2001; Carey et al., 2018; Whelton et al., 2018). On the other hand, peripheral vascular resistance is influenced by: (i) blood viscosity; (ii) elasticity of blood vessels; and (iii) vascular tone; which are mediated by serum electrolytes, neural, and neurohormonal factors (DeLong C, 2023; Trammel JE, 2023). As illustrated in **Figure 1.2**, various factors, such as genetic and environmental, including diet, play an important role (*see section 1.5.2*) in the pathogenesis of hypertension by inducing: (i) endothelial dysfunction, (ii) arterial remodelling, (iii) activation of renin-angiotensin-aldosterone, (iv) sympathetic nervous systems activation, (v) oxidative stress, (vi) chronic inflammation, (vii) insulin resistance and other mechanisms that alter haemodynamics, thereby raising blood pressure over time.

1.6.1. Role of kidney function in hypertension

The kidney plays a crucial role in regulating blood pressure through several mechanisms, which, if dysfunctional or altered, can contribute to the development of hypertension (**Figure 1.2**). One of the mechanisms through which the kidneys regulate blood pressure is the renin-angiotensin-aldosterone system (Castrop et al., 2010). The kidney produces renin, an enzyme from the juxtaglomerular cells of the afferent arteriole, which is released in response to: (i) a reduction in renal perfusion pressure; (ii) low sodium chloride delivery to the macula densa cells; or (iii) an increase in sympathetic nervous system stimulation. Renin cleaves angiotensinogen produced by the liver to angiotensin I (Ang I), which is rapidly converted into Angiotensin-II (Ang-II) by the action of angiotensin-converting enzyme (Fyhrquist et al., 1995; Castrop et al., 2010). Angiotensin II is a potent vasoconstrictor and activator of the sympathetic neural system, which causes a rise in blood pressure by binding to angiotensin II type 1 receptors (AT1 receptor) on target cells, including vascular smooth muscle cells and sympathetic neurons (Fyhrquist et al., 1995). Ang-II, through several intracellular signalling (e.g., increase in intracellular Ca^{2+} concentration and activation of calmodulin and protein kinase C) in vascular smooth muscle, results in smooth muscle contraction and vasoconstriction (Beever et al., 2001). Additionally, increased sympathetic outflow from the brainstem through the release of catecholamine (e.g., norepinephrine) at sympathetic nerve terminals, further enhancing tubular sodium reabsorption, renin release, and increase vasomotor tone depending on the intensity of nerve traffic to induce hypertension (DiBona, 2000; Beever et al., 2001; Cao et al., 2015).

Another role the kidney plays in hypertension is to reset or alter pressure diuresis and natriuresis mechanisms, which help to normalise the blood pressure in acute hypertension. For instance, in acute elevation of blood pressure, the sodium transporters (e.g., sodium hydrogen exchanger-3 (NHE3) and the sodium-phosphate cotransporter isoform-2 (NaPi-IIa, and NaPi-IIc)) are retracted from the luminal cell membrane to the base of the apical microvilli in the proximal tubule where they cannot participate in sodium reabsorption in the nephrons. However, in chronic elevation of blood pressure, these transporters are translocated to the apical microvilli, where they enhance sodium reabsorption, likely contributing to the maintenance of high blood pressure over time (Bautista et al., 2004; McDonough and Nguyen, 2015). Furthermore, Dietary factors can alter these renal mechanisms of blood pressure control. For instance, fruits and vegetables may influence kidney function to protect against hypertension due to their high

potassium, phytochemical and antioxidant content by counteracting the effect of sodium and sodium reabsorption (Slavin and Lloyd, 2012; Liu, 2013). On the other hand, foods high in sodium, saturated fats, and refined carbohydrates may induce hypertension by adversely affecting kidney function either directly or indirectly through the production of ROS and pro-inflammatory cytokines and sympathetic nervous system activation (Guyton, 1991; Knepper and Brooks, 2001; Grillo et al., 2019; Marketou et al., 2019; Patik et al., 2021) (*see section 1.8 for a more detailed description*).

1.6.2. Role of vascular function in hypertension

Vascular disturbances also play a role in the pathogenesis of hypertension (**Figure 1.2**). Various vasoconstrictor hormones, such as angiotensin-II, catecholamines, thromboxane, and vasopressin, cause alterations in vascular function by promoting vasoconstriction by modulating genes involved in the G-protein-coupled receptor (GPCR) signalling pathway, which regulates vascular tone (Gurley et al., 2010). As reported by Gurley et al. (2010), the regulators of G-protein signalling (RGS) proteins induce GTP hydrolysis to GDP and terminate the G-protein signalling cascade responsible for vascular tone regulation. This process inhibits the downstream signalling cascades and leads to prolonged and exaggerated vasoconstrictor responses, resulting in increased vascular resistance and elevation of blood pressure (Gurley et al., 2010). Additionally, impaired vasodilatation through the reduction of endothelium-dependent vasodilatation due to reduced production of: (i) prostacyclin, (ii) nitric oxide, and (iii) endothelium-derived hyperpolarising factor leads to endothelial dysfunction (Touyz, 2000; Harrison et al., 2010; Wilcox, 2012; Li, Q. et al., 2015). Endothelial dysfunction refers to impaired function of the endothelial cells of the blood vessels, affecting vascular health, vascular tone, blood flow, inflammation and coagulation process and significantly contributes to the pathogenesis of hypertension through vasoconstriction and increased vascular resistance (Touyz, 2000; Harrison et al., 2010; Wilcox, 2012; Li, Q. et al., 2015).

Furthermore, arteriolar remodelling (i.e., structural changes in the arterioles) driven by processes such as cell migration and vascular smooth hypertrophy mediated by the direct action of Ang-II, catecholamines, oxidative signalling, and pro-inflammatory cytokines (e.g., interleukin-6 and tumour necrosis factor-alpha), results in the narrowing of the arteriolar lumens, leading to increased vascular resistance and contributes to the development hypertension (Heagerty et al., 2010; Li, L. et al., 2015). Additionally, diets have been implicated in vascular disturbances, contributing to increased blood pressure. For instance, consumption of high-fat, high-sugar diets and ultra-processed foods causes

the production of ROS and cytokines, impaired nitric oxide bioavailability, and enhanced production of vasoconstrictors like endothelin-1, contributing to hypertension (Yudkin et al., 1999; Kim et al., 2005; Hajjar and Gotto, 2013; Klop et al., 2013; Ghosh et al., 2017; Wali et al., 2020). *(see section 1.8 for a more detailed description)*.

1.6.3. Role of neural function in hypertension

The nervous system, particularly the autonomic nervous system, plays a critical role in the regulation of blood pressure and the pathogenesis of hypertension (**Figure 1.2**) (Beever et al., 2001). For example, the activation of the sympathetic nervous system (SNS) increased vascular tone, cardiac function, renal function, and central sympathetic outflow. Therefore, an aberration in neural output from the sympathetic nervous system contributes to hypertension through mechanisms such as: (i) vasoconstriction, (ii) alterations in renal sodium handling, and (iii) tachycardia (i.e., heart rate > 100 beats/minute). Increased sympathetic outflow activates the renin-angiotensin-aldosterone, increased production of reactive oxygen species (ROS) and pro-inflammatory cytokines such as interleukin-6 and tumour necrosis factor-alpha (Ferrario and Strawn, 2006). These humoral factors lead to endothelial dysfunction, enhanced vasoconstriction and sodium reabsorption and retention and contribute to elevated blood pressure (DiBona, 2000; Grassi et al., 2015; Langwieser et al., 2015).

Furthermore, Ang-II and ROS migrate into the brain stem nuclei and enhance sympathetic neural tone activation and sympathetic outflow, contributing to further vasoconstriction and vascular remodelling, increased renin production and enhanced renal sodium resorption and inflammation (McCubbin et al., 1965; Cao et al., 2020). In addition, intake of food containing saturated fats, trans fats, processed meat, and snacks can directly or indirectly (due to the production of metabolites such as ROS and pro-inflammatory cytokines) activate the sympathetic nervous system, leading to increased sympathetic outflow, causing vasoconstriction and sodium reabsorption, which in turn elevates blood pressure (Stamler et al., 1986; Vogel et al., 1997; Yudkin et al., 1999; Roach et al., 2004; Kim et al., 2005; Hajjar and Gotto, 2013; Klop et al., 2013; Ghosh et al., 2017; Wali et al., 2020; Mehar et al., 2023) *(see section 1.8 for a more detailed description)*.

1.6.4. Role of reactive oxygen species and pro-inflammatory cytokines in hypertension

Reactive oxygen species (ROS) such as superoxide anion ($O_2^{\bullet-}$), hydroxyl radical ($\bullet OH$), hydrogen peroxide (H_2O_2), and singlet oxygen ($^1O_2$) are highly reactive oxygen-containing molecules (Ray et al., 2012). They are generated as natural by-products of

cellular metabolism or through cellular (such as vascular cells, including endothelial cells, smooth muscle cells, and leukocytes) response to cytokines, xenobiotics, dietary factors, and metabolic by-products (Ray et al., 2012). ROS oxidatively inactivate nitric oxide synthase and oxidises tetrahydrobiopterin, a critical cofactor for nitric oxide synthase. This leads to enhanced vasoconstriction, alteration of vascular stiffening, and remodelling (Somers et al., 2000; Wu et al., 2016). In addition, ROS can transmigrate into the renal interstitium and disrupt renal function, facilitating renal sodium reabsorption by modulating the activity of sodium transporters in the renal tubules, such as sodium-hydrogen exchangers, sodium-glucose transporters, sodium-hydrogen exchanger 3, the sodium-potassium-chloride cotransporter and the epithelial sodium channel in the distal nephron segments regulated by aldosterone (Gonzalez-Vicente et al., 2019). This leads to increased extracellular fluid volume (ECF), venous return, and cardiac output, which contribute to overall elevated blood pressure. Moreover, ROS contribute to (i) activation of matrix metalloproteinases, promoting tissue remodelling, and (ii) neuronal activation in the subfornical organ and brain stem, thereby altering the neural control of the kidney (Rajagopalan et al., 1996; Lob et al., 2013; Araujo and Wilcox, 2014; Carvalho-Galvao et al., 2019).

Furthermore, studies have reported the involvement of innate and adaptive immune cells (e.g., macrophages, neutrophils, T and B cells) in the development of hypertension. These cells transmigrate into the renal interstitium and vascular interstitium, releasing potent factors such as pro-inflammatory cytokines (e.g., tumour necrosis factor- α (TNF- α), interleukin-6 (IL-6), interleukin 17A (IL-17A), and interleukin-1 β (IL-1 β)), ROS, and matrix metalloproteinases (Madhur et al., 2010; Nguyen et al., 2013; Wu et al., 2014). These mediators modulate renal and vascular function and structure, thereby influencing: (i) renal tubular handling of sodium; (ii) sodium reabsorption and retention; and (iii) impaired vascular elasticity and fibrosis, contributing to increased vascular resistance and hypertension over time (Madhur et al., 2010; Nguyen et al., 2013; Wu et al., 2014). Additionally, the consumption of high-fat diets, processed foods, and refined sugars can promote ROS production within cells. For example, the metabolism of dietary fats and sugars produces ROS, contributing to oxidative stress and inflammation in the vasculature through pro-inflammatory mediators, which in turn contribute to hypertension development (Stamler et al., 1986; Vogel et al., 1997; Yudkin et al., 1999; Roach et al., 2004; Kim et al., 2005; Hajjar and Gotto, 2013; Klop et al., 2013; Ghosh et al., 2017; Wali et al., 2020; Mehar et al., 2023) (*see section 1.8 for more detail*).

Expanding upon the intricate pathophysiological mechanisms explored in the previous section, the next discussion will focus on the significant impact of dietary factors on hypertension, investigating both the benefits of a healthy diet and the negative effects of unhealthy diets on blood pressure regulation.

1.7. Association between dietary factors and hypertension

Dietary factors and patterns vary across regions and cultures and play a significant role in the development, progression, and management of hypertension, contributing to differences in hypertension prevalence and cardiovascular disease outcomes worldwide (Sacks et al., 2001).

1.7.1. Healthy diet and hypertension

Healthy diets, characterised by high consumption of fruits, vegetables, whole grains, lean proteins, low-fat and fat-free dairy, low red meat, and unsaturated fats, are associated with lower blood pressure levels and cardiovascular risk across diverse populations (World Health Organization, 2018; U.S. Department of Health and Human Services and U.S Department of Agriculture, 2020). For instance, the Mediterranean diet consisting of varieties of plant-based foods such as fruits, vegetables, legumes, nuts, seeds, whole grains, healthy fats from olive oil, nuts (almonds, walnuts), and seeds have been associated with reduced risk of hypertension and cardiovascular disease outcomes (Estruch et al., 2018). Specifically, among 7447 participants at risk of cardiovascular diseases conducted between October 1, 2003, and December 1, 2010, demonstrated that a Mediterranean diet supplemented with extra-virgin olive oil and nuts was associated with reduced blood pressure and incidence of CVDs with a hazard ratio of 0.70 (95% CI: 0.54, 0.92) and 0.72 (95%CI: 0.54, 0.96), respectively (Estruch et al., 2018).

Evidence from observational studies

Observational studies conducted worldwide have provided substantial quantitative evidence of the links between diet and hypertension across diverse populations. One notable observational study was the International Study of Macro/Micro-nutrients and Blood Pressure (INTERMAP), a large-scale investigation involving 6875 adult male and female participants from multiple countries. This study demonstrated significant associations between higher sodium intake directly related to elevated blood pressure, as indicated by the increase in systolic BP associated with a 2-standard deviation higher 24-hour urinary sodium excretion (118.7 mmol), which was found to be 3.7 mmHg higher (Stamler et al., 2018). Similarly, the China Kadoorie Biobank study, conducted among a

large cohort of 451,665 participants, reported that daily consumption of fresh fruits had lower systolic blood pressure (-4.0 mmHg) with an adjusted hazard ratio of 0.60 (95%CI: 0.54, 0.67), 0.66 (95% CI: 0.58, 0.75), 0.75 (95% CI: 0.72, 0.79), and 0.64 (95% CI: 0.56, 0.74) for cardiovascular death, incident major coronary events, ischemic stroke, and haemorrhagic stroke, respectively (Du et al., 2016). Not least, a recent meta-analysis focusing on West Africa (Batubo et al., 2023) (*detailed in Chapter 3*) and involving 31 studies with 48,809 participants demonstrated that high consumption of fruits and vegetables is inversely associated with hypertension, with an odds ratio of 0.80 (95% CI: 0.72, 0.89).

In sum, these observational studies provide robust quantitative evidence of the associations between dietary factors and blood pressure, underscoring the importance of promoting healthy dietary patterns rich in fruits, vegetables, whole grains, and healthy fats as part of comprehensive strategies for hypertension prevention and management on a global scale.

Evidence from randomised control trials (RCTs)

A clinical trial of the effects of dietary patterns on blood pressure reported that among the 133 subjects with hypertension, the combination diet (i.e., diet rich in fruits, vegetables, and low-fat dairy products and with reduced saturated and total fat) significantly reduced the systolic and diastolic blood pressure by -11.4 and -5.5-mmHg more, respectively, compared to the control diet (rich in fruits and vegetables) and among 326 subjects without hypertension, the corresponding reductions were -3.5 mmHg and -2.1 mmHg (Appel et al., 1997). Additionally, the OmniHeart Randomized trial, a follow-up to the DASH study, investigated the effects of three different macronutrient compositions within the DASH diet: a carbohydrate-rich diet, a protein-rich diet, and an unsaturated fat-rich diet among 164 adults. The study reported that an unsaturated fat diet significantly decreased mean systolic blood pressure by 1.3 mmHg for non-hypertensive individuals and 2.9 mmHg for hypertensive compared with the carbohydrate diet. Additionally, the protein diet further decreased mean systolic blood pressure by 1.4 mmHg for non-hypertensive individuals and 3.5 mmHg among those with hypertension, compared with the carbohydrate diet (Appel et al., 2005). In summary, collectively, these studies demonstrated that the intake of healthy diet with unsaturated fat, protein, and low carbohydrates produced the greatest reductions in systolic and diastolic blood pressure.

Furthermore, a meta-analysis of RCTs has demonstrated consistent associations between specific dietary components and blood pressure levels. For example, a meta-analysis of

17 RCTs among 2561 participants conducted by Saneai et al. reported that the DASH diet significantly reduced systolic blood pressure by -6.74 mmHg (95%CI: -8.25, -5.23) and diastolic blood pressure by -3.54 mmHg (95%CI: -4.29, -2.79) (Saneai et al., 2014). Similarly, another meta-analysis conducted by Cowell et al. (2021), among 4137 participants in 19 RCTs, reported that the Mediterranean diet reduced systolic and diastolic blood pressure by -1.4 mmHg (95% CI: -2.40 to -0.39 mmHg) and -1.5 mmHg (95% CI: -2.74 to -0.32 mmHg) compared to the control. These meta-analyses demonstrated that healthy dietary patterns such as DASH and the Mediterranean diet were associated with reduced systolic and diastolic pressure.

1.7.2. Unhealthy diet and hypertension

Unhealthy food items and nutrients, including sugar-sweetened beverages, red meat, processed meat, ultra-processed foods, saturated fats, trans-fat, and salt/sodium, are associated with increased incidences of non-communicable diseases and mortality globally (Masters W. A., 2016; GBD 2017 Diet Collaborators, 2019). The Western dietary pattern, characterised by a high intake of refined carbohydrates, red meat, added sugars, processed foods and unhealthy fats, has become increasingly prevalent in many countries and is linked to the rising burden of hypertension and cardiovascular disease (Mozaffarian et al., 2011; Mozaffarian et al., 2014; Sun, J. et al., 2014). For example, a study by Mendonca et al. (2017) among 14790 Spanish adults reported that individuals who consume high amounts of ultra-processed foods such as carbonated drinks, processed meat, biscuits, candy, 'instant' packaged soups and noodles, sweet or savoury packaged snacks, and sugared milk and fruit drinks, had a higher risk of developing hypertension by 21%, compared to low consumers (HR= 1.21, 95%CI: 1.06, 1.37). The globalisation of fast-food chains and the widespread availability of processed foods, even in countries like Nigeria, have contributed to the adoption of unhealthy dietary habits, further exacerbating the global epidemics of cardiovascular risk, including hypertension (Popkin and Hawkes, 2016). For instance, in the aforementioned meta-analysis of 31 observation studies among 48,809 participants in West Africa conducted by Batubo et al., high consumption of dietary fats, red meat, salt, junk foods, and alcohol increased the odds of hypertension by 17-76%, compared to low consumptions in West Africa (Batubo et al., 2023). Similarly, another meta-analysis by Micha et al., among 1,218,280 participants from 20 studies, reported that processed meat intake was associated with a 42% increased risk of coronary heart disease.

Building upon the discussion of the physiological and molecular pathways influencing blood pressure regulation (*section 1.6*) and the exploration of the association between dietary factors and hypertension risk (*section 1.7*), the next section discussed the pathophysiology of diet-induced hypertension, examining the specific roles of various dietary factors in the process.

1.8. Pathophysiology of diet-induced hypertension

The pathophysiology of diet-induced hypertension is a complex mechanism influenced by various dietary factors and their by-products of either digestion or metabolism. These dietary factors and their corresponding by-products cause the generations of myriad intracellular mediators and products that significantly modulate different molecular or biochemical pathways to induce hypertension, as previously highlighted in section 1.6 in this PhD (Kass et al., 2012; Estruch et al., 2018). Therefore, understanding the underlying pathophysiological mechanisms of diet-induced hypertension is necessary for targeted interventions, such as adopting healthy dietary behaviours targeted at salt/sodium reduction, reducing intake of ultra-processed foods, promoting intake of potassium-rich foods, reducing overweight and obesity, and targeting diet-hypertension biomarkers, e.g., blood lipids (Kass et al., 2012; Estruch et al., 2018).

1.8.1. Role of fruits and vegetables in hypertension

Fruits and vegetables play a significant role in preventing hypertension and cardiovascular diseases due to their rich content of phytochemicals (e.g., carotenoids, flavonoids, phenolic acids, glucosinolates, resveratrol), vitamins (e.g., folate and vitamins B2, B6, and B12), minerals (e.g., potassium, selenium, magnesium, and calcium), and dietary fibre (Slavin and Lloyd, 2012; Liu, 2013). Several studies have demonstrated the protective effects against hypertension and cardiovascular diseases. For instance, a prospective cohort study conducted by Akpa et al. (2022) among 16,445 indigenous Africans reported that sufficient (12-29 servings/week) and high (≥ 30 servings/week) consumption of vegetables were inversely associated with hypertension with odds ratio of 0.80 (95%CI: 0.73, 0.88), and 0.81 (95%CI: 0.72, 0.92), respectively, compared to low consumption (< 6 servings/week) (Akpa et al., 2022). Similarly, a meta-analysis of 18 prospective studies with 451,291 participants reported an inverse association between fruit and vegetable consumption and hypertension risk, with a risk ratio of 0.93 (95%CI: 0.89, 0.98) (Madsen et al., 2023).

Fruits and vegetables exert beneficial effects on blood pressure regulation through various mechanisms, including enhancing vascular endothelial function, improving baroreflex

sensitivity, and promoting antioxidant activity. For example, minerals like potassium, calcium, magnesium, and selenium found in fruits and vegetables have been demonstrated to through antioxidant effects from fruit and vegetables combat reactive oxygen species (ROS) and pro-inflammatory cytokines to neutralising their harmful effects, preserve endothelial function, mitigate inflammation, and promote vascular health and vasodilation (Satake et al., 2004; Houston, 2011; Cunha et al., 2012; Chen, L. et al., 2020; Rudrapal et al., 2022; Xiong et al., 2023). (*see section 1.6 for more details*).

1.8.2. Role of dietary salt and sodium in hypertension

Dietary salt and sodium have long been recognised as major contributing factors in the development of hypertension (Bibbins-Domingo et al., 2010). For instance, a meta-analysis of observational studies conducted by Subasinghe et al. involving 18 studies among 134,916 participants demonstrated that high salt intake was associated with hypertension with increased odds of hypertension with an effect size of 1.42 (95%CI: 1.19, 1.69) and 1.07, (95% CI: 1.04, 1.10) in urban and rural populations, respectively (Subasinghe et al., 2016). Similarly, another meta-analysis of 50 clinical trials demonstrated that salt substitution and nutrition education significantly reduced systolic and diastolic blood pressure by -7.44 mmHg and -3.77 mmHg, respectively (Aliasgharzadeh et al., 2022).

Salt triggers several physiological and biochemical pathways to increase blood pressure. Firstly, salt intake directly increases plasma sodium levels and promotes sodium reabsorption in renal tubules. This leads to the expansion of extracellular fluid volume and subsequent increased venous return and cardiac output, ultimately contributing to increased blood pressure (Guyton, 1991; Knepper and Brooks, 2001; Grillo et al., 2019). Secondly, salt/sodium activates the renin-angiotensin-aldosterone system, resulting in the production of angiotensin-II (Ang-II), which constricts the systemic and renal vessels to raise blood pressure (Gonsalez et al., 2018). Ang-II also stimulates the release of aldosterone and antidiuretic hormones to enhance sodium and water reabsorption in the distal tubules, thus further increasing extracellular fluid volume and elevating blood pressure (Harrison-Bernard, 2009). Lastly, high salt intake induces oxidative stress within cells by promoting the production of reactive oxygen species and inflammatory cytokines (such as interleukin-6 and tumour necrosis factor-alpha), which causes: (i) renal fibrosis and (ii) renal and vascular endothelial dysfunction, characterised by reduced nitric oxide and prostacyclin bioavailability. These mediators contribute to endothelial activation and inflammation, resulting in increased vascular stiffness, resistance, and increased blood

pressure (Somers et al., 2000; Wu et al., 2016; Marketou et al., 2019; Patik et al., 2021). (*see section 1.6 for more details*).

1.8.3. Role of dietary fat in hypertension

High dietary fat intake, particularly saturated fats and trans-fats has been linked with an increased risk of cardiovascular disease and hypertension. This link is thought to be mediated primarily by disturbances in the metabolism of fats, leading to increased plasma concentrations of low-density lipoprotein cholesterol (LDL-c), triglyceride, and total cholesterol (Siri-Tarino et al., 2010). The major sources of dietary fats in Nigeria are palm (red) oil, beans with palm oil, egusi soup, Ogbono soup, Akara, Agidi, full-fat dairy products and red meat (Akinbule et al., 2022). A reduction in dietary fat intake as part of total energy intake ($\leq 30\%$ total fat, $\leq 10\%$ saturated fat, and $\leq 1\%$ trans-fat) has been identified as a preventive measure against the risk of developing hypertension and CVDs (WHO, 2003; Astrup et al., 2019). Several studies have investigated the association between dietary fats and oils intake and hypertension risk. For example, a previous prospective cohort study conducted among 1,086 Chinese adults demonstrated that a high fat intake was associated with 40% increased odds of hypertension (OR=1.40, 95%CI: 1.12, 1.75) compared with low-intake individuals (Yuan et al., 2020).

These unhealthy fats exert adverse effects on blood pressure regulation through various pathways, such as: (i) the promotion of endothelial dysfunction characterised by reduced bioavailability of nitric oxide and prostacyclin; (ii) heightened oxidative stress and inflammation through the production of reactive oxygen species and pro-inflammatory cytokines such as interleukin-6 and tumour necrosis factor-alpha leading to systemic and renal vascular endothelial dysfunction and vascular inflammation; and (iii) insulin resistance in peripheral tissues, such as skeletal muscle, Liver, and adipose tissue (Yudkin et al., 1999; Kim et al., 2005; Hajjar and Gotto, 2013; Klop et al., 2013; Ghosh et al., 2017; Wali et al., 2020). Overall, these interconnected molecular mechanisms highlight the significant role of unhealthy fats, particularly saturated and trans fats, in the pathogenesis of hypertension (*see section 1.6 for details*).

1.8.4. Role of ‘junk’ foods in hypertension

Junk foods is a moniker to describe foods that are high in fat, sugar, and salt. Alternatively called ‘convenient’ or ‘Western’ foods, these are typically ultra-processed (by the NOVA scale (Carlos A Monteiro et al., 2016)) and include pan-fried or deep-fried such as burgers, fries, pizza, and fried chicken, as well as sugary snacks like candy, pastries, cookies, and sugary drinks. High consumption of these foods has repeatedly been associated with an

increased risk of obesity, type 2 diabetes, cardiovascular diseases, and hypertension (Halton et al., 2006; Sun, Y. et al., 2019; Lane et al., 2024). For instance, a prospective cohort study conducted by Kang and Kim reported a positive association between high fried food consumption (fried meat including chicken, pork, beef, and fried vegetables, fish and shellfish) and hypertension risk, with an odds ratio of 1.62 (95%CI: 1.11, 2.37) in men and 2.20 (95%CI: 1.21, 4.00) in women with greater than twice/week consumption compared with those who rarely consumed fried food (Kang and Kim, 2016).

Junk foods are typically high in unhealthy fats (e.g., saturated fats and trans-fats), refined carbohydrates, salt/sodium, and calories, all of which can adversely affect blood pressure regulation and cardiovascular health (Mehar et al., 2023). Moreover, the process of frying food in fats and oils heated at high temperatures induces physicochemical changes to food items through oxidation, pyrolysis, polymerisation, hydrolysis, and isomerisation, leading to the formation of harmful compounds such as acrolein, advanced glycation end-products, polycyclic aromatic hydrocarbons, hydroperoxides, and trans fatty acids (Soriguer et al., 2003; Bhardwaj et al., 2011). The constituents of junk foods and other by-products contribute to the development of hypertension and cardiovascular diseases through the combination of multiple pathways, including vascular endothelial dysfunction, marked oxidative stress and inflammation, dyslipidaemia and atherosclerosis, and insulin resistance (Yudkin et al., 1999; Kim et al., 2005; Hajjar and Gotto, 2013; Klop et al., 2013; Ghosh et al., 2017; Wali et al., 2020). Additionally, the high sodium content in junk foods can lead to sodium retention, fluid retention, and increased blood volume, ultimately raising blood pressure (Stamler et al., 1986; Vogel et al., 1997; Roach et al., 2004). (*see section 1.6 for more details*).

1.8.5. Role of red and processed meat in hypertension

Several studies have reported the association between meat consumption and the risk of hypertension and cardiovascular disease. For instance, a meta-analysis of prospective studies conducted by Schwingshackl et al. reported a positive association between consumption of 100-gram red meat/day and 50-gram processed meat/day and risk of hypertension with a risk ratio of 1.15 (95%CI: 1.02, 1.28) for red meat in seven studies with 97,745 incident hypertension cases, whereas in 5 studies with 97441 incident hypertension cases, the risk ratio was 1.12 (95% CI: 1.00, 1.26) for processed meat, for highest intake compared with the lowest intake categories (Schwingshackl et al., 2017). High intake of red meat and processed meat consumption increases the risk of hypertension and cardiovascular disease due to their high content of saturated fats,

cholesterol, and sodium, which contribute to oxidative stress and inflammation (Stamler et al., 1996; Stamler et al., 1997; Stamler et al., 2002).

Moreover, processing of meat under high temperatures (e.g., grilling, frying or broiling) can result in the production of various compounds such as iron, glycation, and lipoxidation end-products, including heterocyclic amines, advanced glycosylation end-products, and acrylamides. These compounds trigger: (i) impairment of insulin activity and (ii) vascular and renal endothelial inflammation and oxidation, leading to vascular dysfunction. Collectively, these factors and mediators lead to an increase in vascular resistance and dysregulation of sodium and water balance, leading to an increase in extracellular fluid volume and cardiac output and contributing to increased blood pressure (Tuomainen et al., 1997; Fernandez-Real et al., 1998; Hua et al., 2001; Wang et al., 2008). Additionally, L-carnitine, abundant in red meat, is metabolised by gut bacteria into trimethylamine (TMA), which can be converted into trimethylamine oxide (TMAO) by hepatic flavin-containing monooxygenase enzymes. TMAO has been associated with endothelial dysfunction, inflammation, oxidative stress, and dyslipidaemia, all of which are implicated in the pathogenesis of hypertension (Koeth et al., 2013). (*see section 1.6 for details*).

1.8.6. Role of refined carbohydrates in hypertension

Carbohydrate intake, particularly refined carbohydrates such as sugars and processed grains without fibres and nutrients, has been implicated with an increased risk of hypertension and cardiovascular disease through several potential mechanisms (He, D. et al., 2021; Qi et al., 2021). For example, a meta-analysis by Jo et al. (2023) across 23 studies demonstrated that individuals with the highest consumption of carbohydrates had a 1.15-fold increased risk of CVD (HR: 1.15, 95%CI: 1.07, 1.23) compared to those with the lowest intake (Jo and Park, 2023). In addition, a Swedish population-based prospective cohort consisting of 25,877 participants from the Malmö Diet and Cancer Study reported that consuming added sugar > 20% of total energy intake was linked with increased risk of coronary events compared to the lowest intake category with a hazard ratio of 1.39 (95%CI: 1.09, 1.78), and increased stroke risk compared to intakes between 7.5-10% total energy with hazard ratio of 1.31 (95%CI: 1.03, 1.66) (Janzi et al., 2020). Furthermore, high consumption of refined carbohydrates has been linked to weight gain, a known risk factor for hypertension, as it can lead to an increase in blood volume and potentially increase cardiac output (WHO, 2003; Qi et al., 2021). Moreover, being overweight and obese is associated with an increased risk of insulin resistance, which can

elevate insulin levels and be implicated in hypertension (He, D. et al., 2021). Reducing free sugar intake to less than 10-15% of total energy intake has been shown to reduce the risk of hypertension and other NCDs (WHO, 2003; World Health Organization, 2015).

1.8.7. Role of micronutrients in hypertension

Micronutrient deficiencies may be associated with hypertension risk by affecting vasoactive compound synthesis, oxidative stress, insulin sensitivity and endothelial function. As highlighted in section 1.8.1, higher intakes of potassium, calcium, magnesium, dietary fibre, carotenoids, and vitamin C are associated with lower hypertension prevalence (Cappuccio et al., 1995; Ma et al., 1995; Allender et al., 1996). Potassium counteracts sodium-induced fluid retention, while magnesium relaxes vascular smooth muscle and plays a key role in regulating vascular tone and insulin-mediated glucose uptake (Kris-Etherton et al., 2004). Calcium regulates renin-angiotensin-aldosterone, and vitamin D influences calcium absorption. Antioxidant vitamins C and E and carotenoids reduce oxidative damage and improve vasodilation (Kris-Etherton et al., 2004). Bioactive plant compounds like flavonoids found in fruit, vegetable, whole grain, and nut intake are also protective phytonutrients against hypertension (Chen, L. et al., 2020; Xiong et al., 2023). (*see section 1.6 for details*).

1.8.8. Role of alcohol in hypertension

Alcohol consumption is a commonly practised lifestyle factor with significant implications for cardiovascular health, including its role in hypertension. Numerous epidemiological studies have reported positive associations between alcohol consumption and hypertension risk. For example, a meta-analysis of nonexperimental cohort studies by Di Federico et al. (2023) among 19548 participants reported that the average systolic blood pressure was 1.25 and 4.90 mmHg, and diastolic blood pressure was 1.14 and 3.10 mmHg higher for 12 and 48 grams of daily alcohol consumption, compared with no consumption (Di Federico et al., 2023). The mechanisms underlying the effects of alcohol on blood pressure regulation are multifaceted. For instance, acute alcohol consumption can lead to vasodilation and a temporary reduction in blood pressure, attributed to the initial inhibition of sympathetic nervous system activity and the release of vasodilatory mediators such as nitric oxide and prostacyclin. However, high or chronic consumption of alcohol has been demonstrated to increase blood pressure through: (i) disruption of the renin-angiotensin-aldosterone system; (ii) sympathetic nervous system activation and release of catecholamines; and (iii) endothelial dysfunction due to heightened oxidative

stress and inflammation (Puddey et al., 1985; Puddey et al., 1999; Rehm et al., 2010; Husain et al., 2014; Roerecke et al., 2018).

At early stages, hypertension can be asymptomatic and left untreated, which can lead to severe complications. The following section will shift focus to discuss some of the complications that are associated with uncontrolled or long-standing hypertension.

1.9. Complication of hypertension

One of the primary concerns associated with hypertension is its detrimental effects on the blood vessels of the major end organs of the body. Long-standing hypertension or uncontrolled hypertension puts a significant strain on these end organs, thus causing structural changes in the vasculature of the organs, including the heart, brain, kidneys, and eyes, that can lead to severe complications such as coronary artery disease, cardiac failure, cerebrovascular accident (stroke), chronic kidney disease (CKD) and end-stage renal disease (ESRD), hypertensive retinopathy etc. (Lackland and Weber, 2015).

1.9.1. Cardiovascular complications

As highlighted in section 1.2, uncontrolled or long-standing hypertension significantly affects the cardiovascular system. Globally, hypertension is a major modifiable risk factor for various cardiovascular complications (including cerebrovascular accident (stroke), myocardial infarction (MI), heart failure, and peripheral arterial disease (PAD)), which is a leading cause of morbidity and mortality globally (O'Donnell et al., 2016; Kjeldsen, 2018). Sustained elevated blood pressure contributes to the development of atherosclerosis and thrombosis, increasing the risk of ischemic stroke. At the same time, hypertension-induced arteriolar damage and microaneurysm formation predispose individuals to haemorrhagic stroke (O'Donnell et al., 2016). Another cardiovascular complication is Myocardial infarction (MI), commonly known as a heart attack. MI results from a blockage of blood flow to parts of the heart, leading to inadequate blood supply to the myocardium, resulting in reduced nutrient and oxygen supply (myocardial ischaemia) and necrosis (i.e. cell death) (Roger, 2007; Benjamin et al., 2019).

Moreover, hypertension can accelerate the progression of atherosclerosis (i.e., a chronic and progressive accumulation of plaque consisting of deposits of fats, cholesterol, calcium, and other substances within the wall of the arteries) and coronary artery disease (CAD) (a condition characterised by the narrowing or obstruction of the coronary arteries due to plaque accumulation) (Herrington et al., 2016; Ralapanawa and Sivakanesan, 2021). Both atherosclerosis and CAD predispose an individual to MI (Benjamin et al.,

2019). Furthermore, heart failure, also known as congestive heart failure, is characterised by impaired cardiac function and inadequate tissue perfusion, and it is a common complication resulting from uncontrolled hypertension (Savarese et al., 2023). Long-standing elevation of blood pressure places overload on the heart, leading to left ventricular hypertrophy, diastolic dysfunction, and eventually heart failure with reduced ejection fraction (Oh and Cho, 2020). Additionally, peripheral arterial disease (PAD), also known as peripheral vascular disease (PVD), is a clinical condition associated with hypertension, characterised by narrowing or blockage of the peripheral arteries outside the heart, manifested by reduced blood flow to the limbs, and increased risk of lower extremity amputations (Shu and Santulli, 2018; Gupta and Patel, 2022).

Globally, cardiovascular diseases (CVDs) remain the leading causes of death, amounting to approximately 17.8 million deaths worldwide in 2017 (Mensah et al., 2019). Hypertension alone accounts for 10.8 million cardiovascular deaths and 11.3 million overall deaths in 2021 worldwide (Vaduganathan et al., 2022). In Nigeria, there is a steady rise in the prevalence of cardiovascular diseases. The prevalence of cardiovascular disease in 2000 was 6.3% and rose to 6.6% in 2019 (IHME, 2019). In most clinical settings in Nigeria, the common CVDs are stroke, heart failure, hypertensive heart disease, and acute coronary syndrome, constituting 51.2, 36.2, 11.3 and 1.6%, respectively (Mbakwem et al., 2023). The burden of CVD attributable to hypertension is substantial, with a significant proportion of hypertensive cases progressing to CVDs (Vaduganathan et al., 2022). For instance, a study conducted in Nigeria found that approximately 61.5% of hypertensive patients developed heart failure (Ojji et al., 2009). Given this strong association between hypertension and CVD, reducing hypertension prevalence and improving blood pressure control could have a profound impact on reducing CVD-related morbidity and mortality in Nigeria.

1.9.2. Renal complications

Chronic kidney disease (CKD) is a long-term medical condition characterised by gradual and progressive damage to the kidney, resulting in a gradual decline in kidney microarchitecture and function over time, with a global prevalence of 9.1% in 2017 (Cockwell and Fisher, 2020; Chen, A. et al., 2021). Hypertension and diabetes are the leading drivers of CKD, contributing to the progression of renal dysfunction and end-stage renal disease (ESRD) (Cockwell and Fisher, 2020; Chen, A. et al., 2021). Sustained and uncontrolled elevation of blood pressure damages the renal microvasculature, leading to glomerular sclerosis, tubulointerstitial fibrosis, and progressive loss of renal function

(Go et al., 2004). Hypertensive nephropathy is characterised by proteinuria (i.e., protein in the urine), haematuria (i.e., blood in the urine), and declining glomerular filtration rate, ultimately resulting in renal failure (Jafar et al., 2001; Go et al., 2004). Hypertension induces kidney damage by: (i) disrupting the renin-angiotensin-aldosterone system; (ii) renal endothelial dysfunction and inflammation due to heightened ROS and inflammatory cytokines; and (iii) renal vascular damage (Brenner et al., 2001; Hamrahian and Falkner, 2017).

1.9.3. Other complications

Hypertension is associated with other complications, including retinopathy and cognitive decline. Hypertensive retinopathy (i.e., damage to the retina due to hypertension) is characterised by sclerotic retinal arteriolar narrowing, arteriolar wall opacification, compression of the venules, and fluid exudation) (Wong and Mitchell, 2004; Liew et al., 2023). Severe hypertensive retinopathy may lead to vision impairment or blindness and serves as a marker of end-organ damage in hypertensive individuals (Wong and Mitchell, 2004). Additionally, hypertension has also been implicated in the pathogenesis of cognitive decline and dementia, which is a gradual and progressive deterioration in cognitive function over time, which includes various mental processes such as memory, attention, reasoning, language, and decision-making, including Alzheimer's disease and vascular dementia (Gorelick et al., 2011). Sustained elevation of blood pressure over time accelerates the progression of cerebrovascular disease, leading to cerebral hypoperfusion, microinfarctions, and neurodegeneration, ultimately contributing to cognitive impairment and dementia (Gorelick et al., 2011).

Having discussed some of the complications arising from uncontrolled and long-standing hypertension, the next section will delve briefly into the treatment and management strategies employed to address hypertension.

1.10. Treatment and management of hypertension

Over the years, several management protocols have been implemented in the management of hypertension and hypertension-associated complications. For effective blood pressure control, adherence to both pharmacologic and non-pharmacological therapies is crucial, but adherence rates are generally suboptimal among individuals (NICE, 2019). Additionally, behavioural counselling and interventions to promote medication and lifestyle modification adherence are important aspects of hypertension management. Early detection and treatment are critical to prevent complications of end-organ damage

in the cerebral, cardiac, renal, and vascular systems through sustained elevated blood pressure (NICE, 2019).

1.10.1. Non-pharmacology therapy

Non-pharmacologic therapy emphasises the use of diet and other lifestyle modifications in the prevention and control of blood pressure, including dietary adjustment, exercise, weight control and moderation of alcohol (Neter et al., 2003; Cornelissen and Smart, 2013; Whelton et al., 2018). Lifestyle modification has been recommended for all individuals with or without hypertension, especially individuals with prehypertension, stage one hypertension, or grade one hypertension (NICE, 2019; American Heart Association, 2023; World Health Organization, 2023). Dietary adjustment may include consuming fruits, vegetables, whole grains, lean proteins, low-fat dairy products, and reducing the intake of salt/sodium, saturated fat/trans-fats, refined sugar, highly processed foods, moderating alcohol intake and smoking cessation (World Health Organization, 2018; NICE, 2019). For instance, the World Health Organisation recommends: (i) consumption of at least 400 grams or five portions of fruits and vegetables daily; (ii) limiting total fat intake to < 30% of total energy intake, with saturated fats below 10% and trans-fats below 1%, while replacing them with unsaturated fats; (iii) reduce salt intake to less than 5 g per day, while increasing potassium intake through fresh fruits and vegetables; and (iv) limit free sugar intake to less than 5-10% of total energy intake, avoiding high-sugar foods and beverages (World Health Organization, 2018). Additionally, weight control modification should include increased physical activity. These lifestyle modifications or behavioural changes may effectively lower blood pressure and reduce the need for anti-hypertensive medication. The treatment goal is to reduce blood pressure <140/80mmHg and minimise future cardiovascular complications (NICE, 2019; Unger et al., 2020).

1.10.2. Pharmacological therapy

In addition to non-pharmacological therapy, pharmacological interventions play a significant role in regulating blood pressure in hypertension management, particularly in individuals with stage 1 and 2 hypertension or those at high cardiovascular risk (Whelton et al., 2018; NICE, 2019). Antihypertensive medications include diuretics, angiotensin-converting enzyme inhibitors, calcium channel blockers, beta-blockers, and angiotensin receptor blockers, commonly prescribed to reduce blood pressure and the risk of cardiovascular complications (Whelton et al., 2018; NICE, 2019). Most patients may require combination therapy with two or more antihypertensive medications of different

classes to effectively reduce and maintain the blood pressure to the required level. For effective blood pressure control, adherence to both pharmacologic and non-pharmacological therapies is crucial, but adherence rates are generally suboptimal among individuals (Whelton et al., 2018; NICE, 2019). Additionally, behavioural counselling and interventions to promote medication and lifestyle modification adherence are important aspects of hypertension management. Early detection and treatment is critical to prevent complications of end-organ damage in the cerebral, cardiac, renal and vascular systems through sustained elevated blood pressure (NICE, 2019).

1.10.3. Prevention of hypertension

Population strategies for preventing hypertension or reducing the risk of disease progression and complications focus on promoting the reduction of key modifiable risk factors such as overweight/obesity, salt/sodium, highly processed and refined sugars, and alcohol and tobacco, and promote physical activity (Whelton et al., 2018; NICE, 2019). Reduction of these modifiable risks is known to reduce: (i) individual risk of hypertension; (ii) maintained steady blood pressure; and (iii) reduced hypertensive-related complications, as discussed in section 1.2 of this thesis. Several policies, such as regulatory, fiscal, and educational policies, have been formulated systemically to tackle the prevention of these modifiable risks associated with hypertension at a societal level (Whelton et al., 2018; NICE, 2019). Moreover, screening programs enable early detection and treatment of pre-hypertension before progression to hypertension (Schmidt et al., 2020). At the individual level, lifestyle counselling on dietary adjustment, exercise, stress management, and avoidance of smoking and heavy drinking could prevent the early onset of hypertension, especially in high-risk groups (Ojangba et al., 2023).

Furthermore, regular blood pressure monitoring allows prompt response to emerging elevation of blood pressure. Workplace wellness programs, community-based interventions, and self-monitoring promote healthy lifestyles for hypertension prevention (Carey et al., 2018).

The next section discusses methods for estimating dietary intake among individuals or groups, including laboratory and field-based approaches, and their strengths and limitations.

1.11. Estimating dietary intakes

Diet and nutrition are linked to human health and diseases. However, accurately estimating dietary intake can be challenging due to multiple factors (Subar et al., 2015).

Dietary intake refers to the consumption of food and beverages, including snacks by an individual over a specified period, typically ranging from a single mealtime to several days, weeks, months, or years (Rutishauser, 2005; Welch, 2005). Assessing dietary intake aims to quantitatively measure the amount of energy and nutrients available in food for human metabolism (Rutishauser, 2005). Several methods have been designed to estimate individual dietary intake. Here, the laboratory and field dietary assessment methods will be discussed.

1.11.1. Laboratory methods of dietary intake assessment

Laboratory methods estimate food and beverage consumption using body fluid biomarkers to measure nutrient consumption and metabolism objectively and quantitatively (Rutishauser, 2005). These methods can involve determining nutrient levels by analysing biological samples, such as blood, urine, or tissue samples, for metabolic or biochemical markers and dietary biomarkers indicative of dietary intake (Rutishauser, 2005; Shim et al., 2014). While laboratory methods are often regarded as objective dietary assessment methods (i.e., they provide more precise and reliable data), they are typically characterised by: (i) higher costs; (ii) physically invasive; (iii) need advanced technologies; and (iv) need specialised expertise. Consequently, these methods are infrequently utilised in low- and middle-income countries, including Nigeria (Rutishauser, 2005; Shim et al., 2014; Gibson, 2022). On the other hand, field dietary assessment methods are usually employed in both low- and middle-income countries and most high-income countries because they are less expensive and invasive.

1.11.2. Field methods of dietary intake assessment

The field methods for assessing dietary intake obtained dietary information from individuals at home or free-living, which offer practical, cost-effective, and less invasive approaches to estimating data on individuals' food consumption patterns (Rutishauser, 2005). Due to their lower cost and less invasive nature, field-based dietary assessment methods are more commonly employed in low- and middle-income countries (including Nigeria) and most high-income countries, as highlighted in section 1.11.1. Various field dietary assessment methods are available and can be classified in several ways. For the purpose of this PhD, Rutishauser (2005) classification of field dietary assessment methods was used: (i) food intake record as it occurs (e.g. menu record, estimated record, weighed record); and (ii) food intake recall after it has occurred (e.g., 24-hour recall, diet history, Food Frequency Questionnaire) (Thompson, F. E. and Byers, 1994; Rutishauser, 2005).

1.11.2.1. Dietary records

Dietary records can be of different types, such as food menus, estimated and weighed records, and dietary data by recording all foods and beverages consumed over a specified period, typically several days to a week (Rutishauser, 2005; Gurinović et al., 2017). Menu records only record the type and frequency of food consumed without specifying the quantities. Estimated diet records involve recording all food consumed over a specified period, typically one to seven days, while a weighed record involves measuring food as it is consumed (weighed inventory) or recording detailed weights of ingredients, final cooked weights of prepared foods, amounts eaten, and any plate waste (precise weighing method) (Rutishauser, 2005; Gurinović et al., 2017). One of the primary advantages of dietary records is their ability to provide detailed and accurate information about an individual's dietary intake, including portion sizes, timing of meals, and food choices (Rutishauser, 2005; Shim et al., 2014). However, dietary records are subject to limitations: (i) dietary records rely on participants' ability to accurately record their intake, which can be influenced by factors like forgetfulness, social desirability bias, and the burden of recording; (ii) to ensure accurate and detailed data, respondents must be trained to record adequately the food items consumed, and (iii) individuals may alter their eating behaviours while keeping the diary, leading to potential inaccuracies in reported intake (Rutishauser, 2005; Shim et al., 2014; Gurinović et al., 2017). For these reasons, food records may not be ideal dietary assessment methods in clinical practice.

1.11.2.2. 24-hour dietary recall

The 24-hour dietary recall (24DR) is one of the most commonly used dietary assessment methods. The 24DR is also used as a reference or gold standard in validating other dietary assessment tools such as the Food Frequency Questionnaire (FFQ) (Rutishauser, 2005; Gibson, 2022). The widespread use of the 24DR is attributed to several advantages such as its cost-effectiveness, relative ease of administration, not invasive, independence of literacy skills, and minimal burden on respondents (Rutishauser, 2005; Thompson, F.E. and Subar, 2013; Gibson, 2022). Moreover, the 24DR can provide data on actual dietary intake over a 24-hour period, but it is limited in capturing dietary intake over an extended period (Rutishauser, 2005; Shim et al., 2014). To elicit information on habitual intake and account for day-to-day variations, authors propose multiple non-consecutive days 24DR, including one weekend day (Rutishauser, 2005; Gibson, 2022). The 24DR's dependence on the interviewer's skill to prompt recall is another limitation, making the interviewer prone to bias, and it can be time-consuming compared to the FFQ (Shim et al., 2014).

Therefore, while the 24-hour dietary recall is valuable for in-depth dietary assessment in research contexts, it may not be recommended for rapid dietary screening in clinical practice, particularly to assess diet-related diseases.

1.11.2.3. Food Frequency Questionnaire (FFQ)

The Food Frequency Questionnaire (FFQ) is a dietary assessment method designed to capture individuals' long-term dietary habits and frequency of food consumption over a specified period extending up to one year (Thompson, F. E. and Byers, 1994; Gibson, 2022). This extended timeframe allows for assessing dietary patterns and trends, making the FFQ particularly useful for identifying the associations between diet and diseases such as cardiovascular disease, hypertension, and other NCDs (Thompson, F. E. and Byers, 1994). Moreover, the FFQs are the principal dietary assessment methods, suitable for large-scale epidemiological studies and population-level assessments for the following reasons: (i) understanding diseases-diet relationships over a long time, allowing for the assessment of long-term or usual food intake, thereby reducing errors introduced by 24-hour recalls; and (ii) FFQs can be cost-effective; and (iii) relatively simple to administer either self-administered, reducing the need for trained interviewers and minimising respondent burden (Thompson, F. E. and Byers, 1994; Teufel, N.I., 1997; Thompson, F.E. and Subar, 2013).

Despite its advantage, the FFQ reliance on participants' memory may introduce recall bias and inaccuracies, particularly for foods consumed infrequently or in irregular quantities. (Thompson, F. E. and Byers, 1994). Additionally, the predetermined food list of the FFQ may not capture some foods consumed by individuals, especially culturally specific or seasonal foods, leading to underestimation or misclassification of dietary intake. However, the FFQ remains the preferred method for dietary assessment in clinical practice for the following reasons. Firstly, it evaluates long-term dietary habits and patterns, making it suitable for establishing diet-disease links over an extended period, unlike the 24-hour recall or dietary history (Thompson, F. E. and Byers, 1994; Teufel, N.I., 1997; Gibson, 2022). Secondly, the FFQ's design and format may allow healthcare professionals and researchers with minimal nutrition knowledge to interpret data effectively and efficiently, facilitating its adoption into patient care plans and identifying potential areas for intervention (Welch, 2005; Shim et al., 2014). Thirdly, the FFQ can be administered relatively easily and quickly, either by trained staff or self-administered, reducing the need for personnel and extensive resources, highlighting its potential to be used in routine clinical practice (Thompson, F. E. and Byers, 1994; Teufel, N.I., 1997;

Gibson, 2022). This advantage puts the FFQ above other field methods to be utilised during patients' clinic appointments and consultations. Lastly, the FFQ has been shown to provide reasonable estimates of dietary intake that can inform personalised dietary advice and recommendations and empower them to make informed choices about their nutrition and lifestyle (Thompson, F. E. and Byers, 1994; Franco et al., 2019; Gibson, 2022). For these reasons, as well as those previously highlighted regarding its strengths, the FFQ was used as the dietary assessment method in this PhD.

The next section will address the necessity for culturally-appropriate dietary assessment tools, highlighting the limitations of generic tools in the Nigerian context and emphasising the need for tailored approaches.

1.11.3. Culturally-appropriate dietary assessment tools

A dietary assessment tool may lead to underestimation or misclassification of dietary intake if the tool does not fully capture the cultural diversity of foods consumed by the population being studied. Culturally-appropriate dietary assessment tools are methodological instruments designed to evaluate an individual's dietary intake while considering their cultural background, beliefs, practices, and food preferences (Hankin and Wilkens, 1994; Teufel, N.I., 1997). These tools are designed to capture culturally sensitive foods and beverages and serving or portion sizes unique to the population under study (Sawyer et al., 1995; Jerome, 1997). This ensures that: (i) food lists, portion sizes, questions, and other assessment components resonate with participants; (ii) improvement of the cultural competency of the tools; and (iii) engagement with the population under study. For these reasons, using culturally-appropriate dietary assessment tools is significant in accurately estimating dietary intake in a culturally diverse population like Nigeria.

1.11.4. Limitations of generic dietary assessment tools for Nigeria

Dietary assessment methods used to address diet-related diseases successfully in one population cannot merely be replicated in other populations. For instance, generic approaches like the Dietary Approaches to Stop Hypertension (DASH) and Healthy Eating Approach (HEA) were originally validated in Euro-American populations and have been shown effectiveness. These tools may not be seamlessly translated into the Nigerian cultural context due to several factors (Teufel, N.I., 1997; Bertoni et al., 2011). Firstly, the Nigerian socio-cultural landscape, with over 250 ethnic groups, significantly differs from Western contexts, uniquely influencing dietary behaviours, food availability, and lifestyle practices (Ministry of Foreign Affairs Nigeria, 2024). This divergence limits

the applicability of the DASH or HEA in Nigeria. Secondly, the effectiveness of DASH and HEA relies heavily on factors such as food availability and accessibility, which may vary across regions (Bertoni et al., 2011). For example, certain foods or ingredients commonly consumed in one culture may be scarce or absent in another, leading to challenges in accurately estimating dietary intake. Lastly, in epidemiologic studies relying on self-report behaviours, misinterpretation of questions and miscommunications can compromise the quality and accuracy of the collected data (Teufel, N.I., 1997). For these reasons, adopting these generic approaches without considering cultural nuances may hinder their effectiveness and relevance in estimating dietary intake among the Nigerian population.

1.11.5. Culturally-appropriate dietary assessment tools for Nigerians

As discussed in sections 1.11.3 and 1.11.4, sociocultural, economic, and culinary factors significantly influence dietary choices and health outcomes in Nigeria and other African countries (Whitelock and Ensaff, 2018; Miassi et al., 2022). Consequently, culturally-appropriate dietary assessment methods developed considering these factors will resonate well with these populations, thus enhancing the adoption and effectiveness of the tool in capturing usual dietary intake. Therefore, a culturally-appropriate tool that resonates with the study population can be developed by involving stakeholders (e.g., patients, healthcare professionals, and community leaders) by considering culture-specific food lists, food groups, and serving or portion sizes (Teufel, N.I., 1997). To this end, this PhD will employ these strategies to design culturally-appropriate dietary assessment tool to assess dietary intake among Nigerian adults in clinical settings.

Transitioning from this section, the following section describes the purpose and importance of this PhD by elucidating the rationale and the significance of this PhD.

1.12. Rationale of the PhD research

The rising prevalence of hypertension in Nigeria, from 8.6% in 1995 to 36.1% in 2020 and the rapid dietary transition from healthy food to unhealthy foods highlight the urgent need for effective prevention strategies (Adeloye et al., 2021; Chukwu and Dogbe, 2023). This rise in hypertension prevalence is partly attributed to increasing unhealthy dietary practices in Nigeria (Petrikova et al., 2023), such as high intake of salt/sodium, unhealthy fats, ultra-processed foods, refined sugars, and alcohol, coupled with low fruit and vegetable consumption with a lack of physical activity exacerbating the situation (Adeloye et al., 2022; Batubo et al., 2023). Furthermore, poor diet remains the leading cause of death from modifiable risk factors contributing to the global burden of disease

more than tobacco and any other health risk (GBD Risk Factors Collaborators, 2020). This underscores the significance of global public health challenges posed by poor diet. In addition, dietary risk factors were responsible for 22% (approximately eight million) of all deaths among adults and approximately seven million cardiovascular disease-related deaths in 2021 (Vaduganathan et al., 2022). The potential for substantial reductions in healthcare costs and improvements in quality of life through population-wide improvements in diet quality offers a compelling rationale for increasing the delivery of dietary assessment, nutrition education, and dietary counselling by clinicians and healthcare professionals across various healthcare settings, including Nigeria (Scrafford et al., 2019).

Moreover, several studies have shown the negative impact of low nutrition knowledge on diet quality. At the same time, clinician-delivered dietary advice has been demonstrated to impact dietary habits and cardiometabolic risk factors positively (Force et al., 2017; Patnode et al., 2017; Force et al., 2020). For instance, studies have demonstrated that higher diet quality among US adults is significantly and consistently associated with an 11-28% reduction in risk of all-cause mortality, including cardiovascular diseases (CVD) and cancer, regardless of the educational and income level of the individual (Liese et al., 2015). Similarly, a study conducted among 744 participants in the population-based cohort of the Moli-sani project (with 24,325 citizens of Molise, a region placed between Central and Southern Italy) demonstrated that higher nutritional knowledge was significantly associated with increased adherence to the Mediterranean dietary pattern and a lowered prevalence of obesity among adults in the Southern Italian region, highlighting the pivotal role of nutrition education and dietary counselling in enhancing diet quality (Bonaccio et al., 2013). This underscores the importance of integrating dietary assessment and counselling into clinical practice. Additionally, various guidelines and recommendations, including those from the Nigerian National Strategic Plan of Action for Nutrition, the Centre for Disease Control, the United States Preventive Services Task Force, and the American Heart Association, advocate for dietary counselling by clinicians and other healthcare professionals in clinical practice (Lin et al., 2014; Arnett et al., 2019; Teufel, F. et al., 2020; Federal Ministry of Health, 2021).

Recent evidence has demonstrated the efficacy of brief dietary counselling in enhancing diet quality and reducing cardiometabolic risk factors, with even short interventions leading to significant improvements in diet quality (Ockene et al., 1999; Lin et al., 2014; Vadiveloo, M. et al., 2020; Vadiveloo, M.K. et al., 2023). Given the observed suboptimal

diet quality among individuals with chronic diseases like hypertension and CVDs, outpatient clinic diet counselling becomes essential in both primary and secondary prevention in clinical settings (Li et al., 2013; Teo et al., 2013; Vadiveloo, M. et al., 2020). Additionally, dietary screening tools have shown promise in measuring dietary changes associated with behavioural interventions, further supporting their integration into clinical practice (Peterson et al., 2008). In essence, evidence-based dietary screening and counselling play a pivotal role in enhancing diet quality and mitigating cardiometabolic risk factors. In Nigeria, clinicians often lack culturally-appropriate and effective strategies or tools to identify patients at risk and offer regionally specific dietary guidance to patients, and existing evidence-based recommendations may not be applicable to the diverse sociocultural landscape of Nigeria (Abaraogu et al., 2016). This gap underscores the necessity for culturally-appropriate and validated dietary assessment tools that can be practically implemented in clinical practice for effective hypertension prevention and management in Nigeria.

1.13. Significance of the PhD research

Addressing dietary behaviours is critical for mitigating hypertension risk and improving overall cardiovascular health outcomes in Nigeria. Despite acknowledging the significant role of diet in NCDs, including hypertension and CVD prevention, translating the 2014 Nigerian National Nutritional Guidelines into actionable advice by clinicians and other healthcare professionals in clinical settings has been challenging (Federal Ministry of Health, 2014). As highlighted in the previous section, studies have indicated that brief dietary assessment and counselling significantly improve diet quality, leading to an overall improvement in various health markers such as body weight, cholesterol, fasting serum glucose concentrations, blood pressure, and incident diabetes (Lin et al., 2014; Liese et al., 2015; Arnett et al., 2019). For instance, Sotos-Prieto et al. demonstrated that adherence to three diet quality scores (i.e., Alternative Healthy Eating Index, Alternative Mediterranean Diet Score, and Dietary Approaches to Stop Hypertension) among US men and women resulted in 7-8% lower CVD risk among US individuals who have greatest improvement in diet quality scores, compared to those with relatively stable diet quality over four years (Sotos-Prieto et al., 2015). Meanwhile, such tools to identify patients at risk and offer regionally specific dietary guidance to patients are lacking in clinical practice in Nigeria.

This PhD holds critical significance in addressing important needs and knowledge gaps regarding (i) the rising prevalence of hypertension in Nigeria; (ii) the attributable poor

diet; and (iii) the lack of a valid and reliable culturally-appropriate dietary screening tool and diet risk score for clinicians and other healthcare professionals in clinical practice to identify and stratify individuals at risk of hypertension and provide personalised dietary advice to patients in Nigeria. This PhD research aims to address these gaps by developing validated and rapid (or brief) culturally-appropriate dietary assessment tools specifically for use by clinicians, patients, and researchers across Nigeria (Vadiveloo, M. et al., 2020; Vadiveloo, M.K. et al., 2023). These tools were designed to: (i) support clinicians and other healthcare professionals with a systematic approach to assessing dietary intake and identifying modifiable dietary risk factors contributing to hypertension in Nigeria; (ii) estimate an individual's overall risk of hypertension; (iii) facilitate clinician-patient discussions about diet; (iv) clinicians and other healthcare professionals to provide personalised dietary recommendations to patients; and (v) improvement in individual's dietary behaviour.

Moreover, integrating the tools into routine clinical practice has the potential to improve overall patients' health outcomes by empowering them to minimise their level of risk, reduce healthcare costs, and enhance the quality of life for individuals living with or at risk of hypertension and cardiovascular diseases (Vadiveloo, M. et al., 2020; Vadiveloo, M.K. et al., 2023). Additionally, the study seeks to contribute to the growing body of evidence on the effectiveness of dietary interventions in hypertension prevention and management. Ultimately, the findings of this research have the potential to catalyse positive changes in dietary behaviour, improve hypertension and cardiovascular health outcomes, and reduce the burden of hypertension in Nigeria.

1.14. Identification of gaps in the literature

In Nigeria, a Sub-Saharan African country, there is an epidemiological transition highlighted by rapid dietary changes and their associated implications on cardiovascular health, including hypertension. Despite the recognised importance of dietary interventions in NCD management, including hypertension, evidence on culturally-appropriate dietary assessment tools for estimating dietary intake by healthcare professionals in clinical practice is lacking in Nigeria. To this end, the following research gaps were identified in the literature in the Nigerian context:

1. There is limited evidence of the association between dietary factors and hypertension risk in Nigeria, which is needed to confirm current recommendations and improve dietary assessment strategies.

2. There is a lack of rapid and validated culturally-appropriate dietary assessment tools for use in clinical practice in Nigeria to effectively estimate dietary intake and provide personalised dietary advice to patients.
3. The existing dietary assessment tools, such as Food Frequency Questionnaires (FFQs) and 24-hour dietary recalls, are lengthy, time-consuming, and not feasible to administer during busy outpatient clinics in Nigeria.
4. Other validated dietary assessment methods such as the DASH, HEA, xMED, and DQI are predominantly based on Western diets. They fail to capture Nigerian staple and traditional foods, cooking habits, and food culture. Also, they are not validated in clinical settings in Nigeria.

1.15. Research aims, questions and objectives

1.15.1. Research aim

The overall aim of this PhD was three-fold: (i) to develop and deliver a validated culturally-appropriate rapid dietary screening tool and a diet risk score for use by clinicians, patients, and researchers across Nigeria; and (ii) to facilitate dietary discussion and provision of personalised dietary advice to patients with or at risk of hypertension; and (iii) empower Nigerian citizens to improve their diet and take an active role in hypertension prevention and long-term cardiovascular health.

1.15.2. Research questions

The following research questions were identified from the research gaps.

1. What dietary factors are associated with hypertension risk in Nigeria?
2. Is a rapid and culturally-appropriate dietary screening tool useful for clinicians and patients in a Nigerian clinic?
3. Can the dietary screening tool be simplified to reduce completion time?

1.15.3. Research objectives

To address the overall aim and research questions, this PhD set the following research objectives:

1. To conduct a systematic review and meta-analysis to synthesise the evidence on the association between dietary factors and hypertension in Nigeria and other West African countries.

2. To evaluate the feasibility and acceptability of integrating a culturally-appropriate Food Frequency Questionnaire (FFQ) dietary screening tool into clinical practice among patients and healthcare professionals in Nigeria.
3. To evaluate the agreement between the dietary screening tool and multiple 24-hour dietary recalls to assess the relative validity and reproducibility of the FFQ in estimating dietary intake among adult patients in clinical settings in Nigeria.
4. To use the dietary screening tool to derive a Nigerian diet risk score (NiDRS) for hypertension to facilitate clinical use and patient assessment and underscore key areas for dietary improvement in Nigeria.
5. To evaluate the impact of the use of the Nigerian dietary screening tools in patient-clinician communication and barriers to and facilitators of implementation in clinical settings in Nigeria.

The next section discussed a brief summary of the research strategy employed in this PhD in order to bind the included article manuscripts into a single whole. The detailed research methodologies and approaches, data collections and statistical analyses employed in this PhD research are exhaustively discussed in each chapter of the included manuscripts (*see chapters two to six*).

1.16. Overview of the PhD research strategy

This PhD research utilises a combination of systematic review and meta-analysis, a mixed-method with qualitative and quantitative approach, and a robust validation protocol across four interconnected studies to develop and deliver a validated, culturally-appropriate dietary screening tool and diet risk score for hypertension for use by clinicians, patients, and researchers across Nigeria and to assess the feasibility of implementation of these tools in a clinical setting in Nigeria. The flowchart in **Figure 1.3** illustrates the PhD research framework for the identified gaps, research aims, questions, and objectives. The overall aim of PhD was achieved in four interconnected studies, as illustrated in **Figure 1.3**.

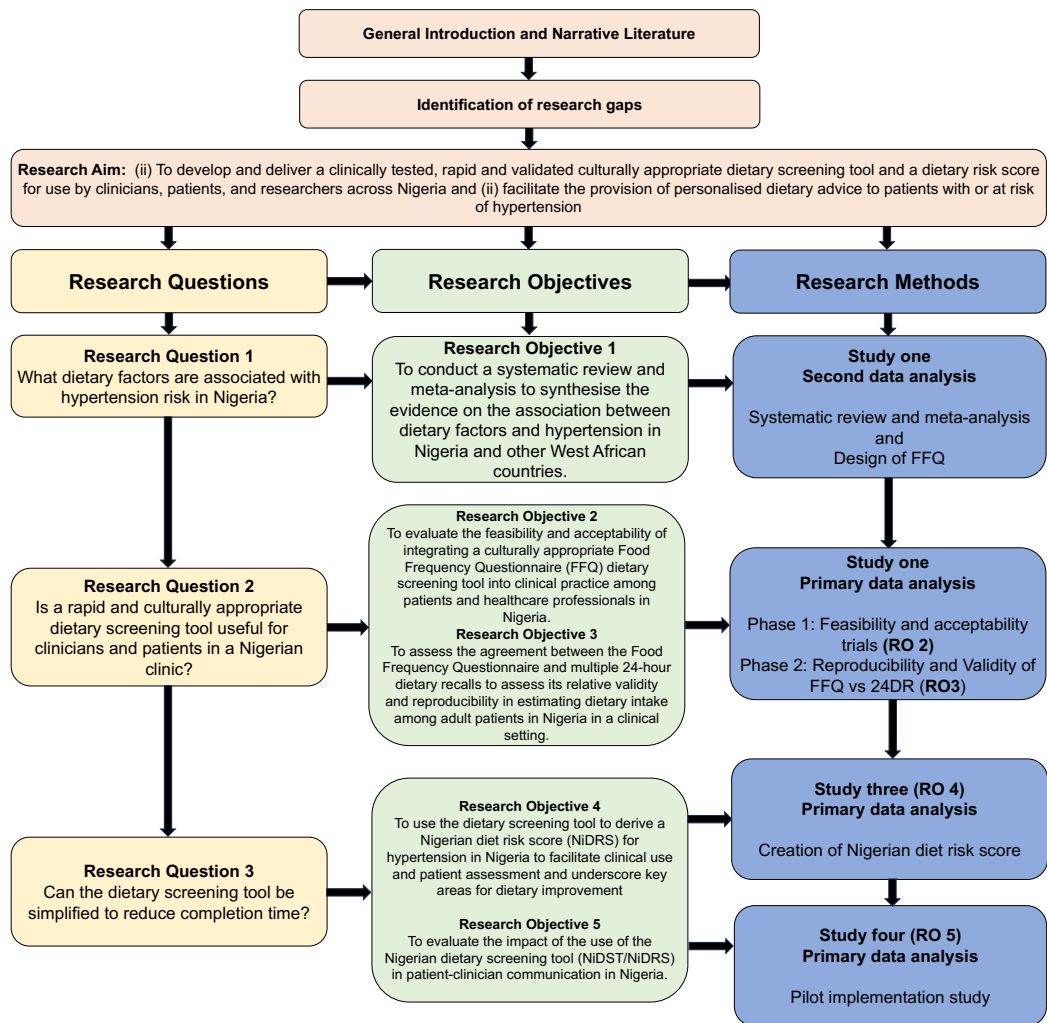


Figure 1. 3. Flowchart framework of the PhD research

NiDST: Nigerian dietary screening tool; NiDRS: Nigeria diet risk score, FFQ: Food Frequency Questionnaire; 24DR: 24-hour dietary recall

1.16.1. Study one

The initial study involves a systematic review and meta-analysis to synthesise existing evidence on the association between nutrients, foods, and diet with hypertension risk in West African populations, including Nigeria. A comprehensive search of databases such as PubMed, Scopus, Web of Science and Ovid Medline was conducted to identify relevant articles. Data extraction was performed independently by two reviewers, and random effects model meta-analyses were employed to calculate pooled effect estimates. This allowed for: (i) identifying and summarising the dietary factors significantly associated with hypertension; and (ii) inform the design of a culturally-appropriate dietary assessment tool— the Food Frequency Questionnaire (FFQ), along with the National Nutritional Guidelines for Non-communicable Diseases Prevention of Nigeria and Ghana (Ministry of Health, 2012; Federal Ministry of Health, 2014; Ahn and Kang, 2018).

1.16.2. Study two

Following the findings from the systematic review and meta-analysis and the development of the FFQ in study one, a qualitative feasibility clinical trial was conducted in a clinical setting in Nigeria in phase one of study two with patients ($n=58$) and healthcare professionals ($n=35$) to: (i) assess the acceptability of the novel FFQ; (ii) feasibility of integration into clinical settings; (iii) explore barriers of and facilitators to integration into Nigerian hospitals and clinics; and (iv) gather information to refine the FFQ. Participants completed the FFQ, and feedback was collected. The findings from phase one were used to refine the tool to ensure that the FFQ is tailored to the Nigerian population. With 58 patients completing two repeated FFQs three weeks apart and three repeated non-consecutive 24-hour dietary recalls, phase two of study two focuses on the validation of the refined tool by evaluating the agreement between the FFQ and 24-hour dietary recalls (24DR) (**Figure 1.3**). This validation process confirms the effectiveness, accuracy, and precision of the FFQ in measuring dietary intake in the Nigerian population in clinical settings.

1.16.3. Study three

In study three, the validated culturally-appropriate dietary screening tool (Nigerian dietary screening tool) from study two was utilised to develop a diet risk score to predict hypertension risk. A cross-sectional study was conducted with adult patients ($n=151$) in a clinical setting (RSUTH). Participants completed the FFQ and underwent clinical measurements (such as blood pressure, body weight and height, and waist circumference), with a subgroup of patients ($n=91$) providing blood samples for estimation of biomarkers such as lipid profiles, serum electrolytes, urea, creatine, c-reactive protein, and homocysteine. Linear and logistic regression models were used to identify dietary factors significantly associated with hypertension and developed a scoring system based on these significant dietary factors to create the Nigerian diet risk score (NiDRS) for hypertension and assess the association between the NiDRS and hypertension (**Figure 1.3**). The NiDRS predictive accuracy was assessed using receiver operating characteristic (ROC) curves. This study resulted in a practical risk stratification tool for hypertension risk assessment.

1.16.4. Study four

The final study evaluated the feasibility and preliminary effectiveness of implementing the NiDST/NiDRS in a clinical setting. A pilot qualitative implementation study was conducted with 151 patients and 20 clinicians in a real-time clinical setting. The tool was integrated into routine clinical assessments, and dietary counselling was provided based

on the results. Qualitative data were collected from participating clinicians and patients through semi-structured feedback questionnaires, interviews and focus group discussions to assess perceived patient-clinician communication and barriers to and facilitators of implementation of the NiDST/NiDRS in Nigerian clinical practice (**Figure 1.3**). This study assesses the practicality of these tools in real-world settings and gathers insights for larger-scale implementation.

1.16.5. Study setting

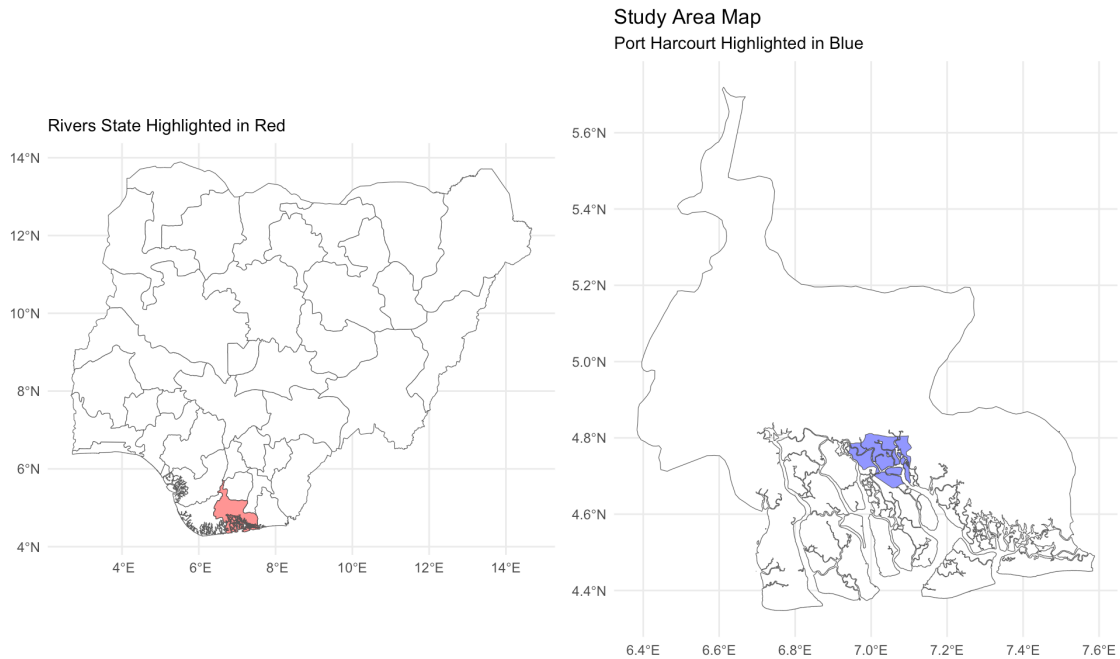


Figure 1. 4. Study location map of Port Harcourt, Rivers State, Nigeria

The map showcases the geographical boundaries of Nigeria, with Rivers State outlined in red, focusing on Port Harcourt, the capital city of Rivers State, highlighted in purple.

The study was conducted in Port Harcourt, Rivers State, Nigeria. Nigeria, with an estimated population of over 210 million in 2021, is the most populous country in Africa. Nigeria consists of 36 states and the Federal capital territory (Abuja), including Rivers State (Ritchie, 2023). Port Harcourt, the state capital of Rivers State, is the fourth largest city in Nigeria, with an estimated population of over seven million in 2022 (Statista, 2023). These PhD studies were conducted within the Department of Family Medicine and Internal Medicine outpatient clinics of Rivers State University Teaching Hospital (RSUTH) in Port Harcourt, Rivers State, Nigeria (**Figure 1.4**). RSUTH is a referral centre that serves as a tertiary healthcare facility, providing medical services to patients across Rivers State and neighbouring regions, including Abia State, Bayelsa State, and Akwa Ibom State. In summary, this hospital was selected due to its central location, diverse patient socio-demographics, and accessibility to patients and medical records for data collection.

1.16.6. Ethical considerations

The study protocol underwent review by two ethics boards. First, the Business, Earth & Environment, Social Sciences (AREA FREC) Committee at the University of Leeds, Leeds, United Kingdom, and second, the Rivers State University Teaching Hospital (RSUTH) Research Ethics Committee in Port Harcourt, Rivers State, Nigeria. Approvals were granted by both the University of Leeds (0484 on 28/04/2023) and RSUTH (RSUTH/REC/2023316 on 30/03/2023). After the completion of study two and further refinement of study instruments (i.e., the dietary screening tool), an amendment was submitted to the Business, Environment, Social Sciences BESS+FREC Faculty Research Ethics Committee (FREC) detailing the area of amendment, such as refinement of the tool, blood samples to be collected for biomarker estimation, and update on the consent form. Approval was granted (BESS+FREC 2023-0976-1111 976) on 24/11/2023. Additionally, the protocol and trial were registered at *clinicaltrials.gov* (with registration number: NCT05973760), and the protocol was reviewed and published in PLOS ONE (Batubo et al., 2024). Furthermore, all participants (patients and healthcare professionals) in the clinical trial provided written informed consent before participating in the study. As a token of appreciation, participants in studies two, three and four received a monetary token of thanks. The ethics approval documents for studies two, three and four used in this PhD research are attached as **Appendix A.1, A.2, and A.3.**

1.17. Summary

Hypertension stands as a significant public health burden globally and in Nigeria. The epidemiological and dietary transition has led to a steady rise in the prevalence of hypertension, with a reported prevalence of 36.1% in 2019. Healthy food groups such as fruits, vegetables, legumes, whole grains, and lean proteins offer protective benefits against hypertension. At the same time, unhealthy dietary behaviours (poor diets), characterised by high intake of salts, saturated fats/trans-fats, red meat/processed meat, refined sugar, and ultra-processed foods, have been positively associated with hypertension risk in Sub-Saharan Africa, including Nigeria. To combat the rising trend of hypertension in Nigeria, there is a need for the implementation of dietary assessment and counselling by healthcare professionals in clinical settings. To this end, the 2014 National Nutritional Guidelines were formulated in Nigeria to combat NCDs. However, translating these guidelines into actionable plans to support patients was challenging for healthcare professionals. Dietary assessment and recommendations in clinical practice have been demonstrated to reduce the prevalence of diet-disease-related conditions. However, a

notable additional challenge in clinical practice in Nigeria is the lack of readily available rapid and culturally-appropriate dietary screening tools. This gap hinders clinicians' ability to assess patients' dietary behaviour and provide targeted interventions. To address these challenges, creating and integrating a rapid and validated culturally-appropriate dietary screening tool for clinicians and other healthcare professionals can effectively identify individuals at risk of hypertension and provide personalised dietary advice tailored to their dietary needs in Nigerian clinical care.

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Chapter two

Dietary factors and hypertension risk in West Africa: A systematic review and meta-analysis of observational studies

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2.1. Abstract

Background: Contrary to North America and Europe, the prevalence of hypertension is rising in West Africa. Although diet is implicated as a contributor to this trend, nutritional guidelines in West Africa are not tailored to address this concern. This study aimed to address this limitation by investigating dietary factors common to West Africa and evaluating their association with hypertension.

Methods: PubMed, Scopus, Web of Science, and Medline were searched to identify studies that investigated diet and hypertension in West African adults. All meta-analyses used a generic inverse-variance random effects model, with subgroup analyses by age, BMI, and study location, and were performed in R.

Results: 3298 studies were identified, of which 31 ($n=48,809$ participants) satisfied inclusion criteria – all cross-sectional. Meta-analyses of the association between dietary factors and hypertension included: dietary fat (OR=1.76; 95% CI:1.44,2.14; $p<0.0001$), red meat (OR=1.51; 95% CI: 1.04, 2.18; $p = 0.03$), junk-food (OR=1.41; 95% CI: 1.19, 1.67; $p < 0.0001$), dietary salt (OR= 1.25; 95% CI: 1.12, 1.40; $p<0.0001$), alcohol (OR= 1.17; 95% CI: 1.03, 1.32; $p= 0.013$), and ‘fruits and vegetables’ (OR=0.80; 95% CI: 0.72, 0.89; $p < 0.01$). Subgroup analyses suggested that ‘fruit and vegetable’ consumption is less protective in the elderly.

Conclusion: High consumption of dietary salt, red meat, dietary fat, junk food, and alcohol are associated with increased odds of hypertension, whereas high fruit and vegetable appear protective. This region-specific evidence will support the development of nutritional assessment tools for clinicians, patients, and researchers aiming to reduce hypertension in West Africa.

Keywords: Hypertension, meta-analysis, West Africa, dietary factors, systematic review

¹ The erratum is in production to correct the published 95% confidence interval (CI) for ‘fruits and vegetables’, that was incorrectly reported as “0.24, 1.17” rather than “0.72, 0.89”, as in Figure 2.2.

2.2. Introduction

Hypertension, defined as a sustained elevation of blood pressure $\geq 140/90$ mmHg, remains the leading preventable risk factor for cardiovascular disease and the number one cause of death globally (Mills et al., 2016). Approximately 40% of people aged 30-79 years have hypertension, corresponding to one in three adults (~1.3 billion in 2019), with two-thirds of cases living in low- and middle-income countries, including African countries (Ferdinand, 2020; World Health Organization, 2021). The most recent WHO data show that the African region has the highest prevalence of hypertension (35.5%), while the Americas have the lowest (18%) (WHO, 2022). From 2010 to 2019, the UK and China experienced a decrease in hypertension rates of 6.25% and 16.3%, respectively (Conor Stewart, 2022; Zhang, M. et al., 2023), while in the US age-adjusted prevalence of hypertension among adults increased has been relatively consistent since 2009 (~32%) (Muntner et al., 2022). Conversely, West African countries, like Nigeria, have consistently seen an increase in hypertension rates. Recent data indicates a 15.3% increase in hypertension rates in Nigeria from 2010 to 2019. This rise in hypertension rates is attributed to more diagnoses, an ageing population, physical inactivity and poor dietary habits, which has also coincided with an increase in heart disease, stroke, and chronic kidney disease in West African countries (Adedoyin et al., 2008; Ike, 2009; Adeloye and Basquill, 2014; World Health Organization, 2021)

This increased trend in hypertension in Nigeria and other West African countries has been partly attributed to increased unhealthy dietary practices (consumption of a diet that is high salt/sodium, low potassium consumption, unhealthy dietary fat and oils, refined sugar, alcohol, and low 'fruit and vegetable') and lack of physical activity (Cappuccio et al., 2006; Mills et al., 2016; Lebbie et al., 2017; Diarz et al., 2020; Akpa et al., 2022). Indeed, diet has been attributed to nearly one-third of all hypertension cases (Geleijnse et al., 2005). This positions diet as a major risk factor of interest in West Africa for reducing hypertension prevalence. In the UK, from 2003 to 2011, government and industry initiatives led to mean reductions in salt (-1.4 g/day) and increased fruit and vegetable ($+0.2$ portion/day) intake, which coincided with reductions in mean blood pressure (systolic = -2.7 ± 0.34 mmHg; diastolic = -1.1 ± 0.23 mmHg), stroke (-42%), and ischaemic heart disease mortality (-40%) (He et al., 2014). In response, Nigeria and other West African countries outlined national nutritional guidelines to combat all non-communicable diseases (NCDs), including hypertension (Ministry of Health, 2009; Federal Ministry of Health, 2014); however, the translation of these guidelines into

actionable advice for clinicians for combating hypertension specifically has been a challenge, possibly because (i) clinicians in Nigeria and other West African countries have not been provided with an effective strategy to provide regionally-specific dietary information to their patients, and (ii) the evidence used to inform West African diet recommendations is based on evidence weighted towards studies from non-African countries which may not be translatable or applicable to manage the contribution of diet towards the rising trend of hypertension risk in Nigeria and other West African countries.

To address this, an understanding of the dietary habits and risk of hypertension in Nigeria and other West African countries is needed to confirm current recommendations and improve current dietary assessment strategies to combat hypertension. Therefore, this study aimed to undertake a systematic review and meta-analysis to provide regionally specific evidence relating to the association between dietary factors and hypertension risk in West Africa that can be used to inform the development of nutritional assessment tools for clinicians, patients, and researchers and contribute towards reducing the prevalence of hypertension in West Africa.

2.3. Materials and Methods

First, we performed a pilot study and evaluated the summaries of the articles we identified through our search on PubMed, and which fulfilled the eligibility criteria. This step enabled us to obtain an outline of the key aspects that ought to be encompassed in the review and helped us to prepare the protocol for the systematic review and meta-analysis.

2.3.1. Study design and registration

The strategy for the systematic review and meta-analysis was predefined with PROSPERO (CRD42022339736), which followed the guidelines for the Meta-analyses of observational epidemiological studies (Stroup et al., 2000), and Preferred Reporting Items for Systematic review and Meta-Analysis (PRISMA) 2015 (Shamseer et al., 2015).

2.3.2. Literature search strategy

The systematic literature search was performed using a structured PICO (population, intervention, comparison, and outcome) framework and Medical Subject Headings (MESH) indexing with key terms (and synonyms thereof). The PICO elements included the targeted West African nations (P), high dietary exposure (I), low dietary exposure (C), and hypertension/high blood pressure (O). A comprehensive search was conducted across PubMed, Ovid Medline, Scopus, and Web of Science, to identify studies published between January 2000 and February 2023. The full search strategy used for PubMed is

given in **Table S2.1** in the supplementary material. To ensure that no relevant studies were missed, the citation lists of included studies were searched to identify additional relevant studies that meet the inclusion criteria.

2.3.3. Outcome measures

Four of the most prevalent adverse outcomes of blood pressure were chosen as outcomes of interest for this review and meta-analysis. These included high systolic blood pressure, high diastolic blood pressure, high mean arterial blood pressure, and high pulse pressure.

2.3.4. Study selection

Observational studies with summary data (odds ratios (OR), relative risks (RR), or hazard ratios (HRs) with corresponding 95% confidence intervals (CI), p-value, means with standard deviation or standard error) that addressed any dietary intervention on hypertension or high blood pressure in healthy West African populations with participants aged ≥ 18 years were included in the study. Studies were excluded if the data were: hypertensive subjects alone, animal and cells studies, non-West African populations, non-investigative studies (such as editorials, reviews, and conference abstracts), pregnancy studies, cardiovascular diseases (such as stroke, myocardial infarction) or studies in cancer populations, studies that are not related to diet, food or nutrition, studies involving only alcohol, smoking, or biomarkers of diet. The screening of ‘title and abstract’ and ‘full text’ was performed in duplicate in DistillerSR version 2.35 (DistillerSR. Version 2.35, 2022).

2.3.5. Data collection and extraction

Using a standardised form, data from each study were independently extracted by two reviewers for all variables. Dietary factors identified from the observational studies were analysed separately. Information extracted from each study included: study details (first author, year of publication, geographic location, number of participants, number of cases, study design), demographic information related to confounding (e.g., age, sex, country, health status), anthropometric data (e.g., body mass index (BMI), methods of quantifying and measuring diet, types of measurements and the studies outcomes (blood pressure), univariable or multivariable effect estimate (RRs, HRs, or ORs including the corresponding CIs), and adjusted covariates. Where multiple analytical models were provided, effect estimates from fully adjusted were extracted. When the risk estimates for participants were reported separately for men and women in a study or for similar food

groups in this same population, the ORs were combined using a fixed-effect model (Borenstein et al., 2009).

2.3.6. Quality assessment

To assess the quality of the studies, a modified Newcastle-Ottawa Scale (NOS) adapted for cross-sectional studies was used to evaluate the study quality of cross-sectional studies of the included studies (Raúl Herzog et al., 2013). The scale assesses the selection of participants, comparability of groups, and assessment of outcomes. A total of 0-9 was assigned to each study based on the number of stars, with a higher score indicating higher quality. The risk of bias assessment was carried out independently by two researchers. Disagreements between researchers were resolved by a third researcher.

2.3.7. Data synthesis and analysis

To derive summary odds ratios (ORs) and 95% confidence intervals (CIs), we applied a meta-analysis to investigate the associations of the dietary factors of the highest consumers compared with the lowest consumers using the generic inverse-variance weighted random-effects model. Using an inverse variance method, we calculated the standard errors for the logarithm odds ratio of each study. This was, in turn, considered the estimated variance of the logarithm odds ratio. The DerSimonian-Laird estimator (DL) was used to estimate the between-study variance (τ^2) in the random-effects model (DerSimonian and Laird, 1986). In the meta-analyses with < 5 studies, the Hartung-Knapp-Sidik-Jonkman (HKSJ) random effects model was also used. Additionally, where ≤ 3 studies were available for meta-analysis, a fixed effects model was also performed to retain power, and Bonferroni correction was applied where necessary (Tobias et al., 2012; IntHout et al., 2014; Jackson et al., 2017).

The heterogeneity between studies was evaluated using Cochran's Q statistics (Cochran, 1954) and the I^2 statistic, with uncertainty intervals, where $I^2 > 50\%$ indicated significant statistical heterogeneity (Higgins and Thompson, 2002; Higgins et al., 2003; Borenstein et al., 2009). Subgroup analyses and meta-regression were conducted to explore potential sources of heterogeneity by pre-specified characteristics and hypertension confounders: (i) Body mass index (BMI) ($\text{BMI} < 25 \text{ kg/m}^2$ vs $\geq 25 \text{ kg/m}^2$), (ii) the mean age of the study population (mean age: < 50 vs ≥ 50 years) and (iii) the study location. Sensitivity analysis was performed when $I^2 > 50\%$ to estimate the influence of a single study on the overall pooled results by systematically omitting a single study and observing its influence on the overall effect size.

Publication bias was done by funnel plots inspection, where ≥ 10 studies were available for a single meta-analysis. Where publication bias was visibly apparent further analyses (Egger's regression and rank correlation test) were undertaken to estimate the effect of reporting bias on study results using the standard error of the observed outcomes as predictors, which are used to check for funnel plot asymmetry (Begg and Mazumdar, 1994; Sterne and Egger, 2005). The trim-and-fill method was also used to correct publication bias if detected. Where no significant effects were found, post-hoc power analyses were undertaken using fixed-effects ($\tau^2 = 0$) or random-effects ($\tau^2 > 0$) methods. Power $\geq 80\%$ was considered adequate (Borenstein et al., 2009). All statistical analyses were performed using meta-package (version 6.0-0) (Balduzzi et al., 2019) in R (R Core Team, 2020).

2.4. Results

2.4.1. Literature search

The literature search and study selection processes are summarised in the PRISMA flow diagram in **Figure 2.1**. A total of 5883 records were identified from the initial database search (Medline =1371, PubMed=1644, Scopus =1599, Web of Science =1269). After removing duplicates ($n=2585$ records) and those that did not fit the inclusion criteria ($n=3187$), 123 articles, including 12 articles retrieved from other sources, were retrieved for full-text screening, from which 31 studies were included in the meta-analysis.

2.4.2. Study characteristics

In total, 31 cross-sectional studies conducted in West Africa were included in the meta-analysis — Nigeria ($n=13$), Ghana ($n=8$), Côte d'Ivoire ($n=1$), Benin Republic ($n=3$), Cameroon ($n=2$), Burkina Faso ($n=3$), and Togo ($n=1$) — with an age range of 20-55 years (mean age = 41 years) and an average BMI of 25.9 kg/m² (**Table 2.1**). A total of 48,290 participants were included in the studies (of which 12,223 were diagnosed with hypertension), with sample sizes ranging from 134 to 9,367. The studies covered a range of dietary factors, with 17 reporting on fruit and vegetable intake (i.e., “healthy foods”) and numerous “unhealthy foods”, including six on junk food (fried and fast food), four on red meat, five on dietary fats (fatty food), 10 on dietary salt, and eight on alcohol consumption.

The studies employed various dietary assessment instruments to assess dietary intake (**Table 2.1 and S2.2**). Eight studies used food frequency questionnaires (FFQs) to evaluate dietary intake. These FFQs included the validated Food and Agricultural

Organization FFQ (FAO-FFQ), validated FFQ based on reference values from the International Network of Food Data System and the US Department of Agriculture National Nutrition Database, the SIREN/AWFGEN study FFQ, and the WHO standard 24-hour dietary recall questionnaire (Nkondjock and Bizome, 2010; Makinde and Babalola, 2011; Obasohan et al., 2019; Oyekale, 2019; Shokunbi and Ukangwa, 2021; Akpa et al., 2022). Of the 10 studies that employed the WHO Stepwise instrument, different combinations of questions to assess the intake of salt, fruits and vegetables, snacks, sweets, fried foods, fats and oils, or alcohol were used (*detailed in Table 2.1*) (Pancha Mbouemboue et al., 2016; Menyanu et al., 2017; Soubeiga, Joseph Kouesyandé et al., 2017; Oguoma et al., 2018; Olawuyi and Adeoye, 2018; Desormais et al., 2019; Sackou et al., 2019; Akoklannou A. H et al., 2020; Oladoyinbo et al., 2020; Charity E. C et al., 2021; Diendéré et al., 2022; Diendere et al., 2022). Furthermore, 12 studies used either non-published or validated structured questionnaires to assess dietary intake (Yayehd et al., 2013; Ofili et al., 2015; Ugwuja et al., 2015; Boakye et al., 2017; Acheampong et al., 2019; Owiredu et al., 2019; Anto et al., 2020; Colette A. et al., 2020; Ayogu, R. N. B. et al., 2021; Ayogu, Rufina N B and Nwodo, 2021; Dorgbetor et al., 2022).

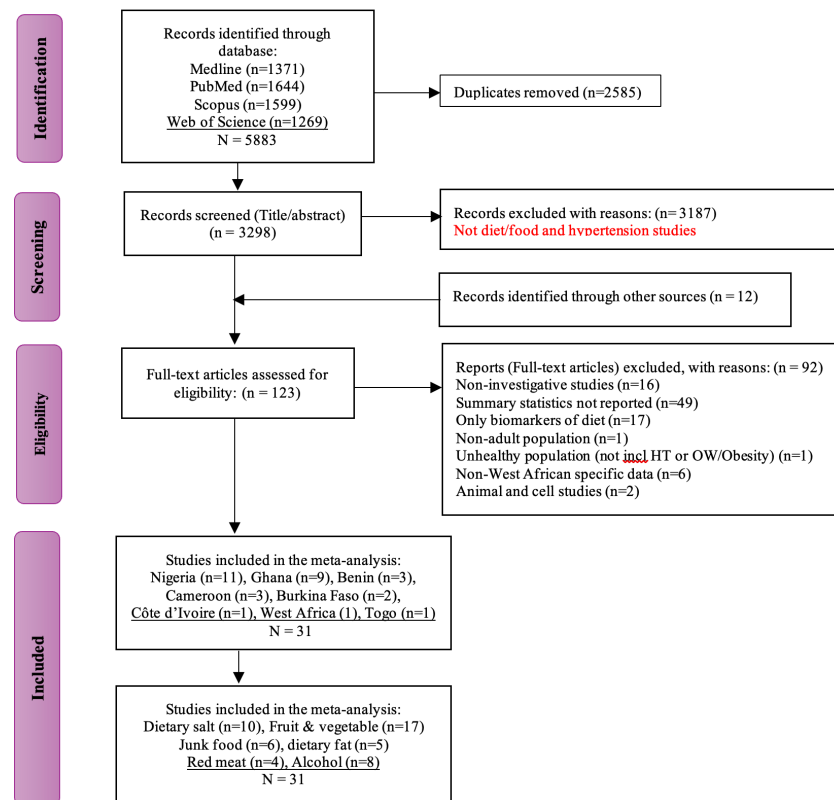


Figure 2. 1. PRISMA flowchart.

A total of 5883 studies were identified through database searches, and an additional 12 studies were identified through manual searches. After removing duplicates and screening titles and abstracts, 123 studies were assessed for eligibility. Of these, 31 studies met the inclusion criteria and were included in the meta-analysis. HT, hypertension; incl: including; OW, overweight.

Table 2. 1. Characteristics of included studies investigating the association between dietary factors and hypertension in West Africa

S/N	Ref	Study location	Dietary Assessment instrument used (specific items queried)	Mean age (years)	BMI (Kg/m ²)	Sample size	Cases	Dietary factor	Effect sizes
									OR (95% CI)
1	Anto, et al, 2020	Ghana	Not published or validated structured questionnaire (Fast food, alcohol*)	44	29	527	204	Fast food, alcohol*	FF= 2.43 (1.18; 5.02)
2	Sackou et al., 2019	Côte d'Ivoire	WHO STEP survey (FV, and alcohol only)	34	30	360	67	Fruit & vegetables, alcohol	FV= 0.87 (0.22; 3.45) Alcohol= 0.82 (0.47; 1.41)
3	Ugwuja et al., 2015	Nigeria	Not published or validated structured questionnaire (Red meat, fish, *alcohol)	42	24	271	62	Red meat, fish, *alcohol	Meat= 2.55 (1.11; 5.83)
4	Oguoma et al., 2018	Nigeria	WHO STEP survey (FV, alcohol, *oil)	40		417	34	Fruit & vegetables, alcohol, *oil	FV= 0.94 (0.90; 0.98) Alcohol=1.85 (1.18–2.88)
5	Olawuyi, 2018	Nigeria	WHO STEP survey (FV, and Binge alcohol only)	43	27	606	201	Fruit & Vegetables, Binge drinking	FV= 0.91 (0.48; 1.72), FV= 1.10 (0.58; 2.08) Binge=2.98 (1.00; 8.91)
6	Acheampong et al., 2019	Ghana	Not published or validated Structured questionnaire (salt, alcohol, fruit, and fast food)	50	28	216	73	Salt, Fruit, Fast food, alcohol	FV= 0.32 (0.11; 0.93) Salt= 1.34 (0.64; 2.81) FF= 1.45 (0.69; 3.05) Alcohol= 1.55 (0.77; 3.12)
7	Obasohan et al., 2019	Nigeria	Food and Agricultural organisation FFQ (FAO-FFQ; validated) (fast food only)	41	26	476	208	Fast Food	FF=1.28 (0.80; 2.03)
8	Menyanu et al., 2017	Ghana	WHO STEP survey (salt only)	58	26	4675	1444	salt	Salt=1.11 (0.95;1.30)
9	Desormais et al., 2019	Benin	WHO STEP survey (FV, salt, and alcohol)	43	24	1777	584	Fruit &vegetable Salt, Alcohol	FV= 0.97(0.69;1.36) Salt=1.23 (1.00;1.50) Alcohol=1.19; 0.94; 1.53)
10	Ayogu and Ezeh, 2021	Nigeria	Not published or validated Structured questionnaire (fruit, vegetable, nut, legume, and ^b alcohol)	42	27	517	195	Fruit, vegetable, nut, legume, ^b alcohol	FV= 0.77 (0.54; 1.09) F= 0.47 (0.19;1.15) V= 0.63 (0.34;1.18)

									Nut= 0.61 (0.32;1.16) Legume= 0.69(0.35;1.36)
11	Ofil et al., 2015	Nigeria	Not published or validated structured questionnaire (salt, fat, and alcohol)	53	25	134	59	Salt, fat, alcohol	Salt= 1.59 (0.79;3.20) Fat=1.60 (0.54;4.75) Alcohol= 1.10 (0.55; 2.20)
12	Nkondjock, 2010	Cameroon	Validated FFQ based on International Network of Food Data System and US Department of Agriculture National Nutrition Database (fruit and vegetable, meat, *[tubers, doughnuts, fish & seafood, legumes, spices and herbs, white bread, whole grains, rice, pasta, soft drinks, coffee, tea, sugar, honey and jam, cakes and cookies, sweets, ships and popcorn, poultry, Milk, alcohol oils and fats, supplements]	37	27	571	223	Fruit & vegetable, red meat	FV= 0.82 (0.20; 2.19) Meat= 1.35 (0.74; 2.47)
13	Pancha Mbouemboue, 2016	Cameroon	WHO STEPS survey (salt and ^b alcohol).	36	30	700	143	Salt, ^a alcohol	Salt= 1.05 (0.52; 2.07)
14	Chukwu et al., 2021	Nigeria	WHO STEP survey (FV, salt and only)	39	28	410	205	Fruit, vegetable, salt intake	FV= 0.15 (0.09, 0.27) Salt= 2.50 (1.23; 5.05)
15	Oladoyinbo et al., 2020	Nigeria	WHO STEP (adapted) survey (snack, sweets, fried food, and alcohol)	35	23	300	144	Snack, puff puff, sweet, fried foods	FF= 1.35 (0.29; 1.65)
16	Ayogu and Ezech, 2021	Nigeria	Not published or validated Structured questionnaire (fruit, vegetable, nut, legume, and ^b alcohol)	42	27	517	195	Fruit, vegetable, nut, legume, ^b alcohol	FV= 0.77 (0.54; 1.09) F= 0.47 (0.19;1.15) V= 0.63 (0.34;1.18) Nut= 0.61 (0.32;1.16) Legume= 0.69(0.35;1.36) ^b Alcohol= 2.04 (0.80; 5.20)

17	Ayogu and Nwodo, 2021	Nigeria	Not published or validated structured questionnaire (Snacks, fried/baked food, fruits, vegetables, and ^b alcohol)	20	23	401	76	Snacks, baked food products, fruits, vegetables, ^b alcohol	FF= 3.15 (0.61; 16.26) SD= 1.57 (0.62; 3.93) Fruit= 0.53 (0.24; 1.17)
18	Akoklannou et al., 2015	Benin	WHO STEP survey (FV, salt, fatty food, and alcohol)	35	24	717	238	Salt, Fatty food, Fruits and vegetables, alcohol	Salt= 1.54 (1.07; 2.21) Fruit= 0.75 (0.37; 1.52) Fat= 2.07 (0.94; 4.54) Alcohol= 1.04 (0.83; 1.30)
19	Soubeiga et al., 2017	Burkina Faso (Rural)	WHO STEP survey (Butter/lard/margarine/oil)	44	32	3600	553	Butter, lard, margarine, vegetable oil	Fat=1.98(1.22; 3.22)
20	Yayehd et al., 2013	Togo	Not published or validated structured questionnaire (salt and alcohol only)	49	30	2002	734	Salt, alcohol	Salt= 1.40 (1.13; 1.72) Alcohol= 1.21 (0.97; 1.51)
21	Colette et al., 2020	Benin	Not published or validated structured questionnaire (salt, fruit and vegetable, and alcohol)	40	24	540	154	Salt, fat, fruit & vegetable, alcohol	Fruit= 0.83 (0.56; 1.23] Salt= 3.45 (2.22;5.06) Fat= 1.81 (1.17; 2.81) Alcohol= 2.00 (0.97; 4.12)
22	Boakye et al., 2017	Ghana	Not published or validated structured questionnaire (salt, fruit, vegetables, oil, animal meat, *alcohol)	44	25	242	90	Salt, fruit & vegetable, oil, meat, *alcohol	Salt= 1.53(1.05; 2.22) Fruit= 0.66 (0.52; 0.85), Veg= 0.83 (0.64; 1.08), Meat=1.40 (0.69; 2.83) oil= 1.65 (1.25; 2.19)
23	Owiredu, 2019	Ghana	Not published or validated structured questionnaire (fruit, vegetable)	46	27	204	100	FV	FV= 0.66 (0.35; 1.25) Low FV=1.51(0.80;2.84)

24	Dorgbetor et al., 2022	Ghana	Not published or validated structured questionnaire (salt)	36	24	5662	918	Salted fish	Salt=1.06 (0.90; 1.24)
25	Diendere et al., 2022	Burkina Faso	WHO STEP survey (FV, and *alcohol)	44	24	4187	774	Fruit, vegetable	FV= 0.36 (0.15; 0.83) Low FV= 2.8 1.2–6.7
26	Akpa et al., 2022	Nigeria	SIREN/ AWFGEN study FFQ (vegetable)	55.4	24	3215	1727	Vegetables	V= 0.96 (0.59; 1.57)
27	Akpa et al., 2022	Ghana	SIREN/ AWFGEN study FFQ (vegetable)	53.7	26	3214	1240	Vegetables	V= 0.97 (0.77; 1.23)
28	Akpa et al., 2022	Burkina Faso	SIREN/ AWFGEN study FFQ (vegetable)	49.8	21	2097	345	Vegetables	V= 1.09 (0.13; 9.19)
29	Shokunbi et al., 2021	Nigeria	WHO standard 24-hour dietary recall questionnaire (carbonated drink, Puff-puff, Eggs, fruits, vegetables, Beef)	20		488	145	Puff-puff, eggs, fruits, vegetables, beef	Meat= 2.87(1.92; 4.28) FF= 1.08 (0.68; 1.71) FV= 0.71 (0.38; 1.32)
30	Makinde, 2011	Nigeria	Validated FFQ (meat, fruit, vegetable, processed can meat)	34	24	397	39	Meat	Meat= 0.87 (0.37, 1.96)
31	Oyekale, 2019	Ghana	Validated FFQ (meat)	26	24	9367	1244	Salted meat	β = 0.06, z= 2.03, Meat= 1.06 (1.00, 1.12)
	Total			41	25.9	48290	12223		

Abbreviations: CS= Cross-sectional study; CI: Confidence interval; FF: Fried/fast food; FV: fruit and vegetable; V: vegetable; β : Beta-coefficient; z: Z-score; NA: Not available; FFQ: Food frequency questionnaire; SD: Sugary drink; SIREN: Stroke Investigative Research and Educational Network; AWI-Gen: Africa Wits-INDEPTH partnership for Genomic. *Studies did not provide data on all items within the FFQ. ^bStudies did not compare low vs high consumption.

2.4.3. Healthy foods

2.4.3.1. Fruit and vegetable consumption

Seventeen cross-sectional studies with 19,675 participants reported on the association between fruit and vegetable consumption with the risk of hypertension – 6,376 (32.4%) adults had hypertension. The types of fruit and vegetable investigated were not specified. Mean effect sizes ranged from 0.32 to 1.09. The overall meta-analysis suggested that consuming high amounts of fruit and vegetable was associated with 20% reduced odds of hypertension (OR=0.80; 95% CI: 0.72, 0.89; $p < 0.0001$, $I^2 = 0\%$) compared to low consumers (**Figure 2.2**). No heterogeneity or potential publication bias was evident in the funnel plot (**Figure S2.1**), rank correlation test ($p=0.17$), or Egger's regression test ($p = 0.18$). The subgroup analysis and meta-regression indicated that while a protective effect of fruit and vegetable consumption against hypertension was observed in all West African nations, age significantly moderated the association between fruit and vegetable consumption and hypertension. It may be less pronounced in individuals aged ≥ 50 years. However, this may be due to fewer studies in the subgroup of individuals aged ≥ 50 years. Conversely, BMI and study location did not appear to modify the association (**Table S2.4** and **Figures S2.2** and **S2.3**).

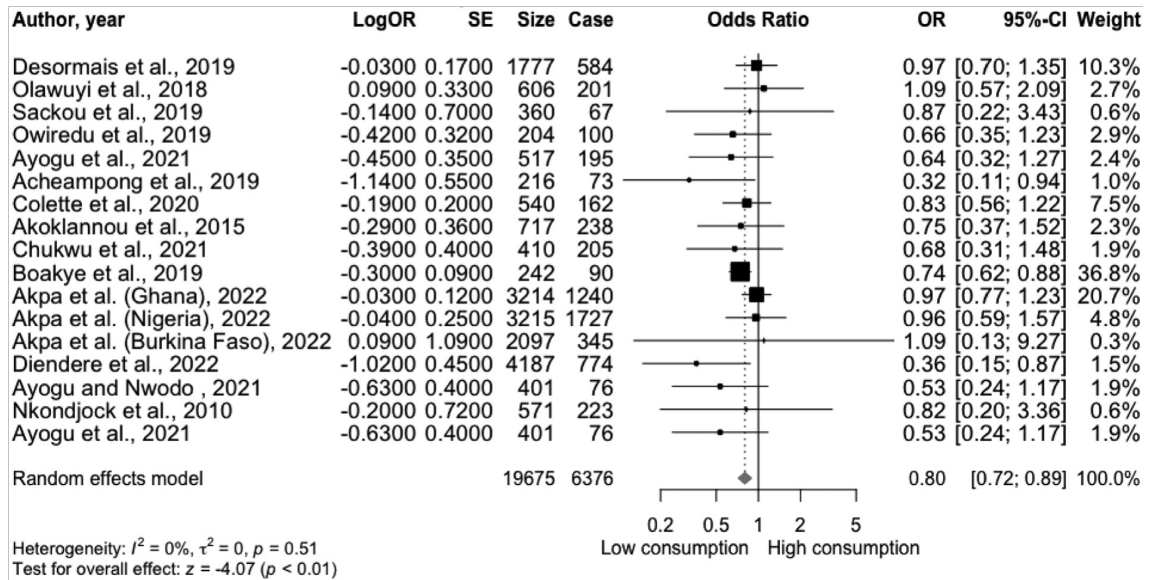


Figure 2. 2. Forest plot of studies that reported on the association between fruit and vegetable consumption and hypertension.

The forest plot illustrates the effect sizes of the association between fruits and vegetables consumption and hypertension in West Africa. Case: cases of hypertension; C: confidence interval; logOR: log odds ratio; OR: odds ratio; SE: standard error; Size: sample size (number of participants).

2.4.4. Unhealthy foods

2.4.4.1. Junk food consumption

In the meta-analysis of the association between junk food and the risk of hypertension in West Africa, 6 cross-sectional studies were analysed with 2,321 participants, of which 781 (33.6%) had hypertension. Junk food was defined as fried food (fried rice, fried chicken, beef, fried yam, and potatoes), fast food, fried snacks (puff-puff, fries, chips), cakes, and burgers. The mean effect sizes across individual studies ranged from 1.28 to 4.95. The meta-analysis demonstrated that consumption of high amounts of junk food was associated with increased odds of hypertension by 41% (OR=1.41; 95% CI: 1.19, 1.67; $p < 0.0001$, $I^2=0\%$) compared to low consumers in West Africa (**Figure 2.3**). No heterogeneity or publication bias was observed (**Figure S2.4**), rank correlation test ($p=0.06$), or Egger's regression test ($p=0.26$). The subgroup analysis and meta-regression did not suggest a moderating effect by mean population age, BMI, or study location (**Table S2.5** and **Figures S2.5** and **S2.6**).

2.4.4.2. Red meat consumption

The meta-analysis of four cross-sectional studies investigating the relationship between red meat consumption and hypertension in West Africa included 10,451 participants, with 1,620 (15.5%) cases of hypertension. Red meat was defined as unprocessed meats from cows, goats, pork, and sheep. The mean effect sizes from the individual studies ranged from 1.06 to 2.56. The meta-analysis suggested that high red meat consumption was associated with a 51% increase in the odds of hypertension (OR=1.51; 95% CI: 1.04, 2.18; $p=0.03$, $I^2=27\%$) compared to low consumers with a moderate amount of heterogeneity (**Figure 2.3**). No heterogeneity or publication bias was observed (**Figure S2.7**), rank correlation test ($p=0.72$), or Egger's regression test ($p=1.00$). Subgroup analysis and meta-regression did not suggest moderating effect of mean age, BMI, and study location on the association between the consumption of red meat and hypertension (**Table S2.6** and **Figures S2.8** and **S2.9**).

2.4.4.3. Dietary fat consumption

The meta-analysis of 5 cross-sectional studies examining the association between dietary fat and hypertension in West Africa included 5,233 participants, including 1,094 (20.9%) cases of hypertension. Dietary fat was defined as saturated oil, coconut oil, palm and palm oil, butter, lard, margarine, and groundnut oil. Effect sizes from the individual studies ranged from 1.60 to 2.08. The meta-analysis demonstrated that high dietary fat

consumption was associated with 76% higher odds of hypertension (OR=1.76; 95% CI: 1.44, 2.14; $p<0.0001$, $I^2 = 0\%$) compared to low consumers (**Figure 2.3**). No heterogeneity or publication bias was demonstrated by the funnel plot (**Figure S2.10**), Egger's regression test ($p=0.89$), and Begg's test ($p=0.48$) in the meta-analysis. Subgroup analysis and meta-regression did not suggest a moderating effect on the mean population age, BMI, or study location (**Table S2.7** and **Figures S2.11 and S2.12**).

2.4.4.4. Dietary salt consumption

A total of 10 cross-sectional studies ($n=16,535$ participants) reported on the association between dietary salt and hypertension risk – 4497 (27.2%) adults had hypertension. Mean effect sizes ranged from 1.05 to 2.51. The analysis revealed that high consumption of dietary salt increased the odds of hypertension by 25% in West Africa (OR= 1.25; 95% CI: 1.12, 1.40; $p<0.0001$, $I^2=30\%$) compared to low consumers with moderate amount heterogeneity (**Figure 2.3**). No potential publication bias was evident in the funnel plot (**Figure S2.13**), rank correlation test ($p=0.05$), or Egger's regression test ($p=0.31$). Subgroup analysis and meta-regression suggested that mean age, BMI, and study location did not seem to modify the association, as shown in **Table S2.8** and **Figures S2.14 and S2.15**.

2.4.4.5. Alcohol consumption

A total of 8 cross-sectional studies ($n= 6,263$ participants, including 2,119 (33.8%) cases of hypertension) reported on the association between alcohol and odds of hypertension were included in the meta-analysis, with effect sizes ranging from 0.82 to 2.03. Compared to low consumers, the meta-analysis demonstrated that high consumption of alcohol increased the odds of hypertension by 17% (OR= 1.17, 95% CI: 1.03, 1.32; $p= 0.013$, $I^2 = 0\%$) (**Figure 2.3**). No heterogeneity or publication bias was demonstrated by the funnel plot (**Figure S2.16**), Egger's regression test ($p=0.46$), and rank correlation test ($p=0.17$) in the meta-analysis. Subgroup analysis and meta-regression did not suggest a moderating effect on the mean population age, BMI, or study location (**Table S2.9** and **Figures S2.17 and S2.18**).

2.4.5. Data quality

The quality was assessed using a modified Newcastle-Ottawa Scale (NOS) for cross-sectional studies (Raúl Herzog et al., 2013). The criteria for allocating stars (out of a total of 9 stars) awarded to each study according to this NOS criteria can be found in **Table**

S2.3. The 30 studies included in the meta-analysis were rated with high quality (score 7-9) and a low bias risk.

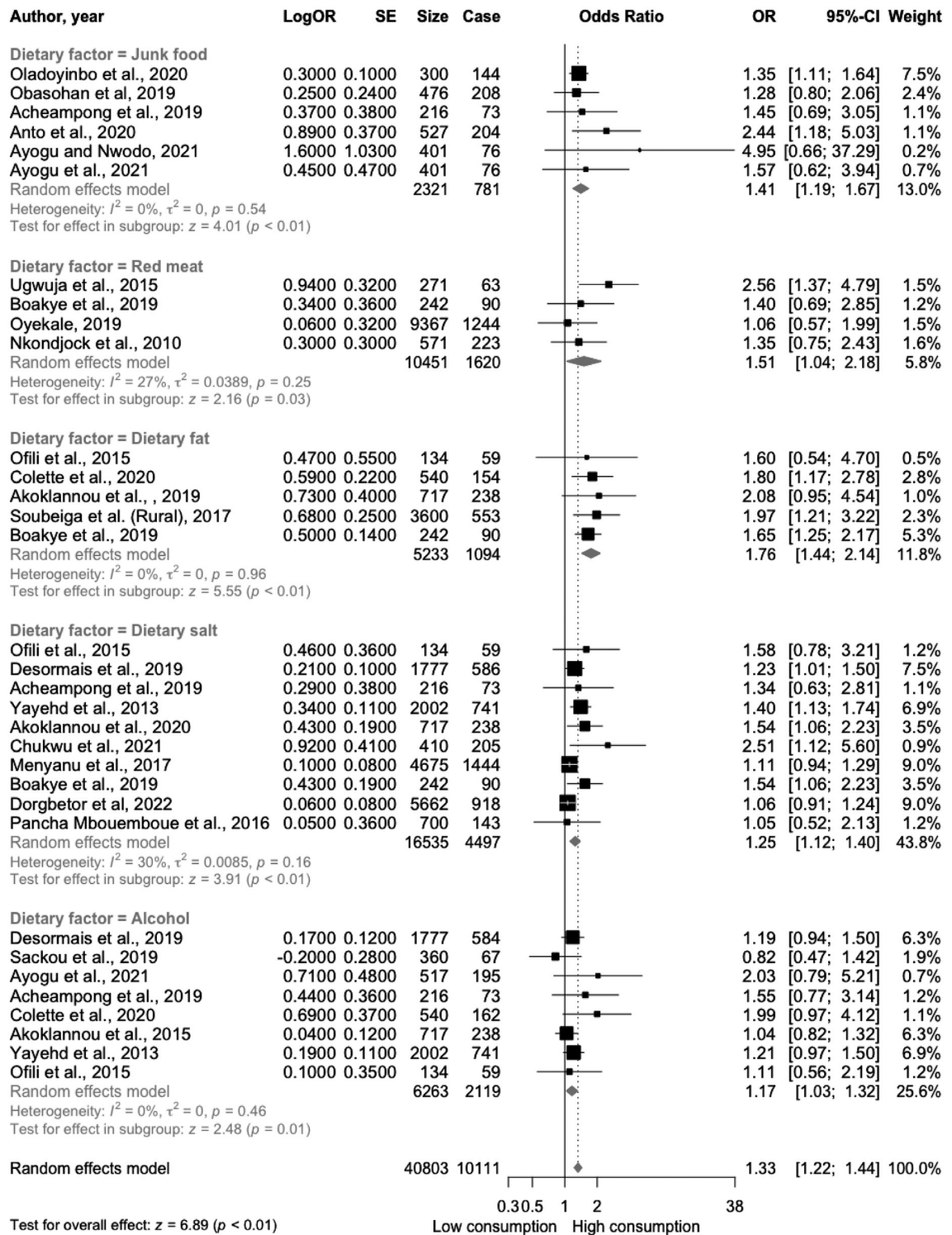
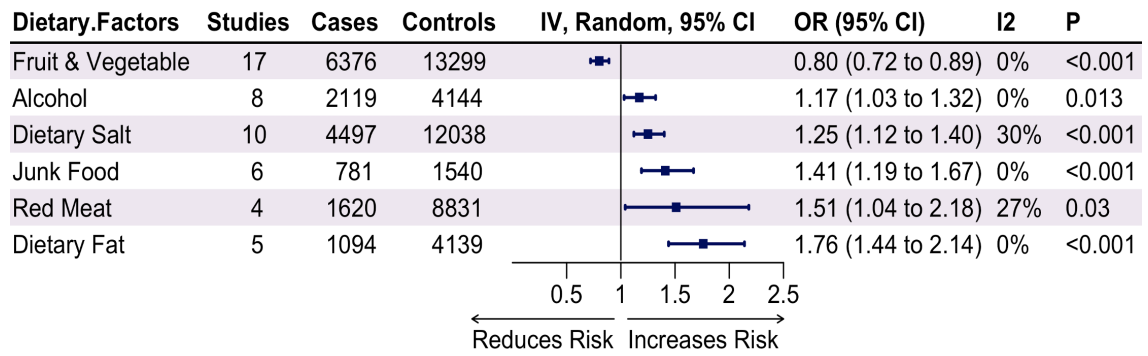


Figure 2. 3. Forest plot of the association between unhealthy food consumption and hypertension.



The forest plot illustrates the effect size of the association between unhealthy food groups (such as junk food, red meat, dietary fat, dietary salt, and alcohol) consumption and hypertension risk in West Africa. Case: cases of hypertension; CI: confidence interval; logOR: log odds ratio; OR: odds ratio; SE: standard error; Size: sample size (number of participants).

2.5. Discussion

This systematic review and meta-analysis provide regional-specific evidence to support nutritional guidelines and the development of prevention strategies and tools to reduce the prevalence of hypertension in West Africa. Thirty-one (31) cross-sectional studies with 48,290 adults in West Africa (12,223 cases of hypertension), were meta-analysed to investigate the association between common dietary factors (such as fruit and vegetables, dietary salt, junk food, red meat, dietary fat, and alcohol) and hypertension. Remarkably, this is the first meta-analysis to synthesise and analyse the impact of dietary factors on hypertension in adults living in West Africa. The results suggest that high consumption of dietary fat, red meat, junk food, dietary salt, and alcohol are associated with increased odds of hypertension, while high fruit and vegetable consumption is protective. Sensitivity analyses within all dietary factors indicate robust and consistent associations.

2.5.1. Healthy foods

2.5.1.1. Fruits and vegetables

For single “healthy” food available for analysis, fruit and vegetables, we report that high fruit and vegetable intake is associated with decreased odds of hypertension. This is consistent with previous meta-analyses conducted in other regions of the world, such as those conducted by Wu et al. and Schwingshackl et al. (Wu et al., 2016; Schwingshackl et al., 2017). Schwingshackl et al. reported a decrease in hypertension risk for high vegetable (RR=0.96; 95% CI: 0.91, 1.01) and fruit intake (RR: 0.93; 95% CI: 0.87, 1.00) based on 7 cohort studies with 94,772 incident cases of hypertension (Schwingshackl et al., 2017), while Wu et al. found a decreased hypertension risk based on 6 cohort studies (RR= 0.87; 95% CI: 0.79, 0.95) (Wu et al., 2016). While both studies reported some heterogeneity, likely due to differences in study locations and cultures, the absence of

major heterogeneity in our analysis suggests that the associations are relatively consistent across West African nations. However, we did observe that the protective effects of fruits and vegetables may be less pronounced in elderly individuals, which is interesting and warrants further investigation. The results of our meta-analysis agree with biochemical evidence that reports the beneficial effects of phytochemicals, vitamins, minerals, and fibres (which are rich in fruit and vegetables) on vascular function and reduced risk of hypertension (Whelton and Klag, 1989; Camoes et al., 2010; Tamai et al., 2011; Juraschek et al., 2012; Aburto et al., 2013; Chen et al., 2013; Liu, 2013; Toh et al., 2013; Helelo et al., 2014; Verly et al., 2014; Ashworth et al., 2015).

2.5.2. Unhealthy Foods

Numerous food groups were identified that have previously been negatively associated with hypertension (i.e., unhealthy foods): junk food, red meat, dietary fats, dietary salt, and alcohol.

2.5.2.1. Junk food

Based on 6 cross-sectional studies with 2,321 participants, we report that high consumption of junk food is associated with increased odds of hypertension in West African adults. This finding agrees with biochemical evidence that has linked junk foods, which often contain high amounts of saturated and trans fats, sodium, and by-products of oxidation, which can induce increased blood pressure in different mechanisms (Fillion and Henry, 1998; Soriguer et al., 2003; Wang, L. et al., 2010; Bhardwaj et al., 2011; Song et al., 2015; Grillo et al., 2019; Qin et al., 2020). In addition, our work agrees with previous work from outside West Africa. A cross-sectional study in Korea reported that incremental increases in fried food consumption associated with elevated blood pressure in men (OR=1.62; 95% CI: 1.11, 2.37; $P_{trend}=0.045$) and (OR=2.20; 95% CI: 1.21, 4.00; $P_{trend}=0.040$) women (Kang and Kim, 2016), while a meta-analysis of 11 studies (8 cohort and 3 cross-sectional studies) involving 222,544 participants reported that fried food increased risk of hypertension compared to low consumers (Qin et al., 2022). The absence of heterogeneity in our meta-analysis of the association between junk food and hypertension in West Africa suggests that the findings are robust and not influenced by factors such as study design, population characteristics, or other potential sources of variation. However, it is important to note that the number of studies included in the meta-analysis is relatively small.

2.5.2.2. Red meat

Our meta-analysis contributes to the growing body of evidence on the association between red meat consumption and hypertension. We found that high consumption of red meat was associated with increased odds of hypertension in West African adults. This is consistent with previous meta-analyses involving 7 cohort studies with 97,745 hypertension cases, albeit with higher heterogeneity (RR=1.15; 95% CI: 1.02, 1.28; $I^2 = 84\%$) (Schwingshackl et al., 2017). Similarly, Zhang et al. conducted a meta-analysis of 9 cohort studies and reported that high consumption of red meat was associated with an increased risk of hypertension (RR=1.22, 95% CI: 1.11, 1.35) and substantial heterogeneity ($I^2 = 75\%$) (Zhang, Y. and Zhang, 2018). Our meta-analysis observed less heterogeneity with the confounders examined not significantly modifying the observed association. The biological effect of high meat consumption on hypertension is supported by the components found in meat, such as saturated fat, cholesterol, high sodium levels in processed meat, haem iron, and substances formed during cooking or processing of meat, such as heterocyclic amines, advanced glycosylation end-products, acrylamides, and trimethylamine-N-oxide (Stamler et al., 1986; Stamler et al., 1996; Stamler et al., 1997; Tuomainen et al., 1997; Fernandez-Real et al., 1998; Hua et al., 2001; Stamler et al., 2002; Koeth et al., 2013; Wang, Y. et al., 2014). These components can affect blood lipids and lead to insulin resistance and inflammation, ultimately increasing the risk of hypertension.

2.5.2.3. Dietary fats

Our meta-analysis of 5 cross-sectional studies supports this evidence and indicates that in West Africa, high consumption of dietary fat is associated with increased odds of hypertension. This agrees with prospective cohort studies that have reported increased odds of hypertension (up to 40%) in population subgroups that consume high quantities of dietary fat (Wang, L. et al., 2010; Yuan et al., 2020). While our analysis was unable to differentiate between saturated and unsaturated fats, traditional cooking methods in West Africa typically involve the use of palm and palm kernel oils, groundnut oil, coconut oil, butter, and animal fat, which are all high in saturated and trans fats, which are most strongly associated with hypertension risk (Wang, L. et al., 2010; Ofili et al., 2015; Soubeiga, J. K. et al., 2017; Kingsley Boakye et al., 2019; Akoklannou A. H et al., 2020). This aligns with biochemical and pathophysiological evidence that suggests that diets high in saturated- and trans-fats can lead to elevated levels of blood LDL-cholesterol and triglycerides, the development of atheroma in blood vessel walls, oxidative stress,

inflammation of the vessel walls, reduced vascular elasticity, and increased vascular resistance, ultimately leading to hypertension (Stamler et al., 1986; Vogel et al., 1997; Light et al., 1999; Jennings et al., 2004).

2.5.2.4. Dietary salt

Our meta-analysis suggests that higher consumers of dietary salt in West Africa are more likely to be hypertensive compared to limited salt consumers. Our findings are consistent with previous meta-analyses that report (i) increased risk of hypertension among individuals with a high dietary salt intake that live in rural and urban populations of low to middle-income countries (Subasinghe et al., 2016) and (ii) an almost 4-fold increase in odds of hypertension among 23 studies in China (Zhang, Y. et al., 2021). Despite some heterogeneity between the studies we analysed, this was not driven by study differences in age, BMI, and study location. Overall, our results align with the posited pathophysiology effects of salt/sodium on hypertension through its effect on renal salt and water retention, elevated plasma sodium levels, and increased salt sensitivity, which leads to the expansion of extracellular fluid volume, microvascular endothelial inflammation, and structural changes in autonomic and small resistant arteries, and increased systemic peripheral resistance and functional abnormalities of the cardiovascular system and hypertension (Girardin et al., 1980; Guyton, 1991; Eljovich et al., 2016; Kurtz et al., 2017; Grillo et al., 2019; Marketou et al., 2019; O'Donnell et al., 2020).

2.5.2.5. Alcohol

Finally, our meta-analysis found that high alcohol consumption, exceeding 2 drinks per day for males and 1 drink per day for females, is associated with increased odds of hypertension in West Africa. This finding is consistent with previous studies conducted outside West Africa, which reported an unfavourable association between alcohol consumption and hypertension. A meta-analysis of 20 cohort studies (n=361,254 participants and 90,160 incident cases of hypertension) reported that alcohol consumption increases the risk of hypertension between men (RR=1.19; 95%CI: 1.07, 1.31) and women RR=1.42; 95%CI: 1.22-1.66) who drank >2 drinks per day in comparison with abstainers with a significant amount of heterogeneity (Roerecke et al., 2018). The absence of heterogeneity or publication bias and a lack of moderating effects of mean population age, BMI, or study location on the association suggests the robustness of the association across West African nations. Pathophysiological evidence supports our findings, as alcohol stimulates renin release, which produces angiotensin II, a potent vasoconstrictor,

and aldosterone increases sodium retention and water reabsorption (Oparil et al., 2003; Puddey et al., 2019). Furthermore, alcohol metabolism produces reactive oxygen species (ROS) and reactive nitrogen species (RNS), which can lead to oxidative damage to the endothelium and vascular smooth muscle, resulting in impaired vascular function and increased vascular resistance (Tsuji et al., 1992; Husain et al., 2011) and increase blood pressure over time.

2.5.3. Alignment with current guidelines

This systematic review and meta-analysis provide regional support to the dietary recommendations set forth by the World Health Organisation (WHO) and the 2014 Nigerian National Nutritional Guidelines for the reduction of hypertension. The recommendations include consuming at least 400g or five portions of fruits and vegetables per day, limiting salt intake to less than 5g per day, reducing consumption of fried and fast foods, restricting red meat consumption to no more than 350-500g or three portions per week and avoiding processed meat, keeping total dietary fat intake to less than 30% of the total energy intake and limiting the intake of alcohol to ≤ 2 drinks/day for men and ≤ 1 drink/day for women in the US and less than <14 units in the UK (WHO, 2003; WHO, 2012; Federal Ministry of Health, 2014; Mozaffarian et al., 2014; World Cancer Research Fund, 2018; World Health Organization, 2018; Astrup et al., 2019). These findings provide region-specific evidence into dietary factors and hypertension risk and identified 6 dietary factors (dietary salt, junk food, dietary fat, red meat, and alcohol) as hypertension-inducing dietary factors and fruit and vegetables as protective against hypertension.

2.5.4. Strengths and limitations

This systematic review and meta-analysis evaluated the association between dietary factors and hypertension across West Africa has notable limitations that could not be avoided: (i) only cross-sectional data was available for this meta-analysis, which cannot confirm a cause-and-effect relationship; (ii) all studies relied on participant dietary recall and non-standardized dietary assessment, which are subject to bias and can potentially affect the accuracy of the dietary data; (iii) the majority of the studies in this meta-analysis reported food groups rather than specific foods, which may lead to inaccurate assumptions about specific foods since foods within the same group can impact health differently; and, (iv) the small number of studies and the limited variation in moderators (e.g., age or BMI) may have limited our ability to uncover some associations. Nonetheless, our study has several notable strengths worth mentioning: (1) this is the first systematic review and

meta-analysis to evaluate the association between dietary factors and hypertension across West Africa. This unique focus enables a more compressive overview of the current state of research in West Africa; (2) despite focussing on a specific region of Africa, a large number of studies and participants were included in this meta-analysis, providing a comprehensive understanding of the topic. This inclusion allows for a broad analysis of the impact of diet on hypertension; (3) a diverse selection of dietary factors was identified that reflected food groups common to healthy and unhealthy patterns enabling a broad analysis of the impact of diet on hypertension; and (4) analyses were critically appraised for risk of bias and power to ensure high-quality.

2.5.5. Conclusion

This systematic review and meta-analysis demonstrated that high consumption of dietary salt, red meat, junk food, dietary fat, and alcohol are associated with an increased likelihood of hypertension in West Africa. In contrast, high fruit and vegetable consumption appears protective. The results of this study will offer regional-specific evidence for developing clinical nutritional assessment tools for clinicians, patients, and researchers and reduce the ever-increasing trend of hypertension in West Africa.

2.6. Chapter summary

This chapter investigated the association between dietary factors and hypertension among 48,290 participants in West Africa across 31 cross-sectional studies with 12,233 (25%) of hypertension cases, using a systematic review and meta-analysis approach. The study demonstrated significant associations between certain food groups and hypertension, including:

1. Six food groups were identified, one healthy food (e.g., fruits and vegetables) and five unhealthy foods (e.g., dietary fat, red meat, junk foods, dietary salt, and alcohol).
2. Fruits and vegetables reduced the odds of hypertension by 20%.
3. Dietary fats, red meat, junk food, dietary salt and alcohol are all associated with increased odds (17 to 76%) of hypertension.

This regional evidence informed the development of a culturally-appropriate food frequency questionnaire to assess dietary intake for individuals with or without hypertension that was evaluated in the next chapter.

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Chapter three

Feasibility study and qualitative assessment of a dietary screening tool for identifying high risk of hypertension in West Africa. A case study in Nigeria.

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3.1. Abstract

Dietary risks significantly contribute to hypertension in West Africa. Food frequency questionnaires (FFQs) can provide valuable dietary assessment but require rigorous validation and careful design to facilitate usability. This study assessed the feasibility and interest of a dietary screening tool for identifying adults at high risk of hypertension in Nigeria. Fifty-eight (58) consenting adult patients with hypertension and their caregivers and 35 healthcare professionals from a single-centre Nigerian hospital were recruited to complete a 27-item FFQ at two-time points and three 24-hour recalls for comparison in a mixed method study employing both quantitative questionnaires and qualitative techniques to elicit free form text. Data analyses were conducted using R software version 4.3.1 and NVivo version 14. The trial was registered with *ClinicalTrials.gov*: NCT05973760. The mean age of patients was 42.6 ± 11.9 years, with an average SBP of 140.3 ± 29.8 mmHg and a BMI of 29.5 ± 7.1 Kg/m². The adherence rate was 87.9%, and the mean completion time was 7:37 minutes. 96.6% of patients found the FFQ easy to complete, comprehensive, and valuable. A minority reported difficulty (3.4%), discomfort (10.3%), and proposed additional foods (6.9%). Healthcare professionals considered the dietary screening tool very important (82.9%) and expressed a willingness to adopt the tool, with some suggestions for clarification. Patients and healthcare professionals found the screening tool favourable for dietary counselling in hypertension care. The tailored dietary screening tool (FFQ) demonstrated promising feasibility for integration into clinical care as assessed by patients and healthcare professionals. Successful implementation may benefit from proactive time management and addressing training needs. This user-centred approach provided key insights to refine FFQ and set the foundation for ongoing validity testing and evaluation in clinical practice.

Keywords: Food frequency questionnaire, feasibility study, hypertension risk, screening tool, West Africa.

3.2. Introduction

Hypertension is the leading preventable risk factor for cardiovascular disease, responsible for over 10 million deaths annually (Forouzanfar et al., 2017). Approximately 40% of people aged 30-79 years have hypertension, with two-thirds of cases living in low- and middle-income countries, including African countries (WHO, 2021). West Africa experiences a disproportionately high hypertension burden, with prevalence estimates ranging from 19% to 50% in adults (Dzudie et al., 2012; Ataklte et al., 2015; Adeloye et al., 2021). In Nigeria, hypertension prevalence rose 17% between 2010 and 2019 to affect 1 in 4 adults (Akinlua et al., 2015; Odili et al., 2020; World Health Organization, 2021). Yet <30% of hypertensive adults in Nigeria achieve recommended blood pressure control (Oguoma et al., 2015; Adeloye et al., 2021), driven by poor healthcare access, high medication costs, and non-adherence to anti-hypertensive medications (Whelton et al., 2018).

Unhealthy diets constitute a major modifiable risk factor for hypertension in Nigeria (Forouzanfar et al., 2017; Zhou et al., 2017; Zhou et al., 2021). Our previous work provides region-specific evidence that elevated consumption of salt, red meat, processed foods, fried foods, fat, and alcohol are associated with an increased likelihood of hypertension in Nigeria and other West African countries, while fruits, vegetables, and nuts appeared protective (Batubo et al., 2023). In line with this evidence, we have developed a dietary screening tool for clinical use to identify individuals at high risk of hypertension based on their self-reported dietary habits (Adeloye et al., 2021). This is a key first step in West Africa, where inadequate tools for clinicians, low screening rates, and limited awareness levels among the population contribute to delayed diagnosis and intervention for hypertension (Ogah et al., 2012; Ataklte et al., 2015). Interestingly, although generalised dietary screening tools are available, culturally tailored dietary questionnaires are often more accurate and reliable (Willett, W.C. et al., 1985; Murphy et al., 2002; Goulet et al., 2004). Therefore, our dietary tool offers a unique and valuable opportunity for healthcare professionals in West Africa to accurately capture patient dietary habits and mitigate hypertension morbidity and mortality earlier in life (Wilson and Jungner, 1968; Liberati et al., 2009; Ogah et al., 2012; Ataklte et al., 2015; Schmidt et al., 2020).

The validation and implementation of clinical dietary screening tools are challenging — constrained by workflow integration difficulties, data interpretation, healthcare professional training and time limitations (Ball et al., 2010; Cahill et al., 2020). To

surmount these barriers, it is imperative to ensure that a study (i) minimises the risk of bias and (ii) ensures that the tools and methods are acceptable and appropriate for participants (i.e., healthcare professionals and patients) before evaluating the efficacy of the tool. Therefore, this study aimed to assess the feasibility and acceptability of this West African-tailored dietary tool in a clinical setting for screening individuals at risk of hypertension in Nigeria.

3.3. Materials and methods

3.3.1. Study design and setting

This study utilised a single-centre, cross-sectional feasibility study with a mixed methods design combining quantitative and qualitative approaches to evaluate the acceptability, practicality, and perceived utility of implementing a screening tool for dietary assessment in routine clinical practice for hypertension management. The study was conducted in the outpatient (Family Medicine and Internal Medicine) clinics of Rivers State University Teaching Hospital (RSUTH), Port Harcourt, Rivers State, Nigeria. Patients interested in the study were referred directly by healthcare professionals to the study team or through recruitment fliers and posters. Eligibility was determined using a structured questionnaire. The full inclusion and exclusion criteria are presented in **Table 3.1**. Eligible patients were then allocated to either hypertension or non-hypertension categories. The study lasted for 4 weeks. We adhered to SPIRIT guidelines for reporting clinical trials (Chan et al., 2013).

3.3.2. Participant recruitment

The patients were recruited during routine clinic visits over 4 weeks between June and July 2023 through recruitment posters displayed in key areas of the hospital, clinician referrals, and engaging discussions during morning briefing sessions where vital signs are taken from patients in the internal medicine and family medicine departments of Rivers State University Teaching Hospital (RSUTH). The healthcare professionals identified eligible participants based on study criteria and informational posters and referred interested participants to the study team for further screening. In total, 90 patients expressed interest in the study and were screened for eligibility, which yielded 66 patients. Additionally, 35 healthcare professionals were recruited through informational files distributed in the hospital and presentations at clinic meetings.

3.3.3. Ethics approval and informed consent

The study protocol was submitted to the following ethics boards. Business, Earth & Environment, Social Sciences (AREA FREC) Committee, University of Leeds, Leeds,

United Kingdom on 21st March 2023, and the Rivers State University Teaching Hospital Research Ethics Committee in Port Harcourt, Nigeria on 20th March 2023 and granted final approval with the approval number: 0484 on 28/04/2023 and approval number: RSUTH/REC/2023316 on 30/03/2023 respectively. All participants provided informed consent to participate in this research study. Before enrolment, every patient read a simplified version of the participant information sheet. They were given an opportunity to engage with the study staff to ensure informed consent to participate in the study. Subsequently, all 66 patients provided written informed consent before participating in the study. The healthcare professionals gave written informed consent to provide qualitative feedback on the screening tools. The trial was registered at *clinicaltrials.gov* (Trial Registration: NCT05973760).

Table 3. 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Age between 18 and 70 years	Individuals < 18 years or > 70 years of age
Men and women	Pregnant women or intend to become pregnant or breastfeeding woman
Hypertensive or non-hypertensive individual	Diagnosis of other chronic diseases such as cancer, diabetes, renal failure, endocrine diseases, and previous and recent history of
Individuals who have been residents in Nigeria for the past 2 years.	Cardiovascular disease (CVD) and stroke.
Ability to read, write, and communicate over the phone in English	Individuals on dietary restriction or recent changes to their diet or food
Individuals who gave their consent to participate.	Individuals who are currently enrolled in other studies

3.3.4. Study protocol

The study was a single-center feasibility study conducted among adult outpatients (Family Medicine and Internal Medicine) clinics of the Rivers State University Teaching Hospital in Nigeria between July 2023 and August 2023. Participants were seen at a screening visit 1-4 weeks to assess eligibility per established inclusion/exclusion criteria before the dietary assessment (**Table 3.1**). If eligibility criteria were met, the patients were allocated into hypertensive and normotensive groups based on their current hypertension status, and informed consent was obtained from participants. The feasibility of the screening tool was evaluated in a small number of participants ($n=101$) consisting of 66 patients and 35 healthcare professionals (**Figure 3.1**).

In the week one post-allocation study visit, participants underwent baseline assessments consisting of demographic and health questionnaires, anthropometric measurements (height and weight), and blood pressure evaluation. The participant's height and body weight were measured two times using a standard stadiometer (model number: DG2301,

China). The body mass index (BMI) was calculated from the measurement of the height and body weight of each patient. The participant's blood pressure was measured two times in the non-dominant arm using an automated mercury sphygmomanometer (model number: ZK-BB68, Shenzhen, China).

On the second study visit, eligible patients and healthcare professionals filled out the screening tools (27-item semi-quantitative food frequency questionnaire) (**Table S3.1**). Alongside the screening tool, the first 24-hour dietary recall (24HR) was used to garner dietary intake data from the patients. Finally, on the third study visit, eligible patients and healthcare professionals completed a one-time survey examining the completion rates, clarity of questions, ease of use, cultural appropriateness and difficulty encountered while answering the questions. Additionally, the healthcare professionals provide qualitative feedback on the clinical relevance, their perceptions surrounding the integration of the screening tool into clinical practice and the potential impact of the screening tool on patient care in Nigerian healthcare settings and suggest improvements to optimise the questionnaire's effectiveness for the prevention and dietary management of hypertension. The healthcare professional's survey was adapted from previous studies on clinical adoption of health technologies (Portz et al., 2019). Questions utilised a 5-point Likert-type scale and open-ended formats.

3.3.5. Dietary screening tool (FFQ)

The screening tool for this study was a semi-quantitative food frequency questionnaire (FFQ) containing 27 food groups covering common Nigerian and other West African foods and dishes informed by our previous systematic review and meta-analysis on dietary factors associated with hypertension in West Africa (Batubo et al., 2023) and the Nigerian and Ghana National Nutrition guidelines on non-communicable disease prevention (Ministry of Health, 2012; Federal Ministry of Health, 2014) (**Table S3.1**). For each food group, participants reported consumption frequency 'on a typical week' over the past month or so, and answers corresponded to one out of four options, with categories ranging from 'rarely or never', '1-2 times/week', '3-5 times/week', 'daily', and 'more than once per day'. Additional questions related to salt intake behaviour were appended to the FFQ. The FFQ was self-administered. According to the Flesch-Kincaid scale, the reading level was at a 6th-grade level (Flesch, 1948).

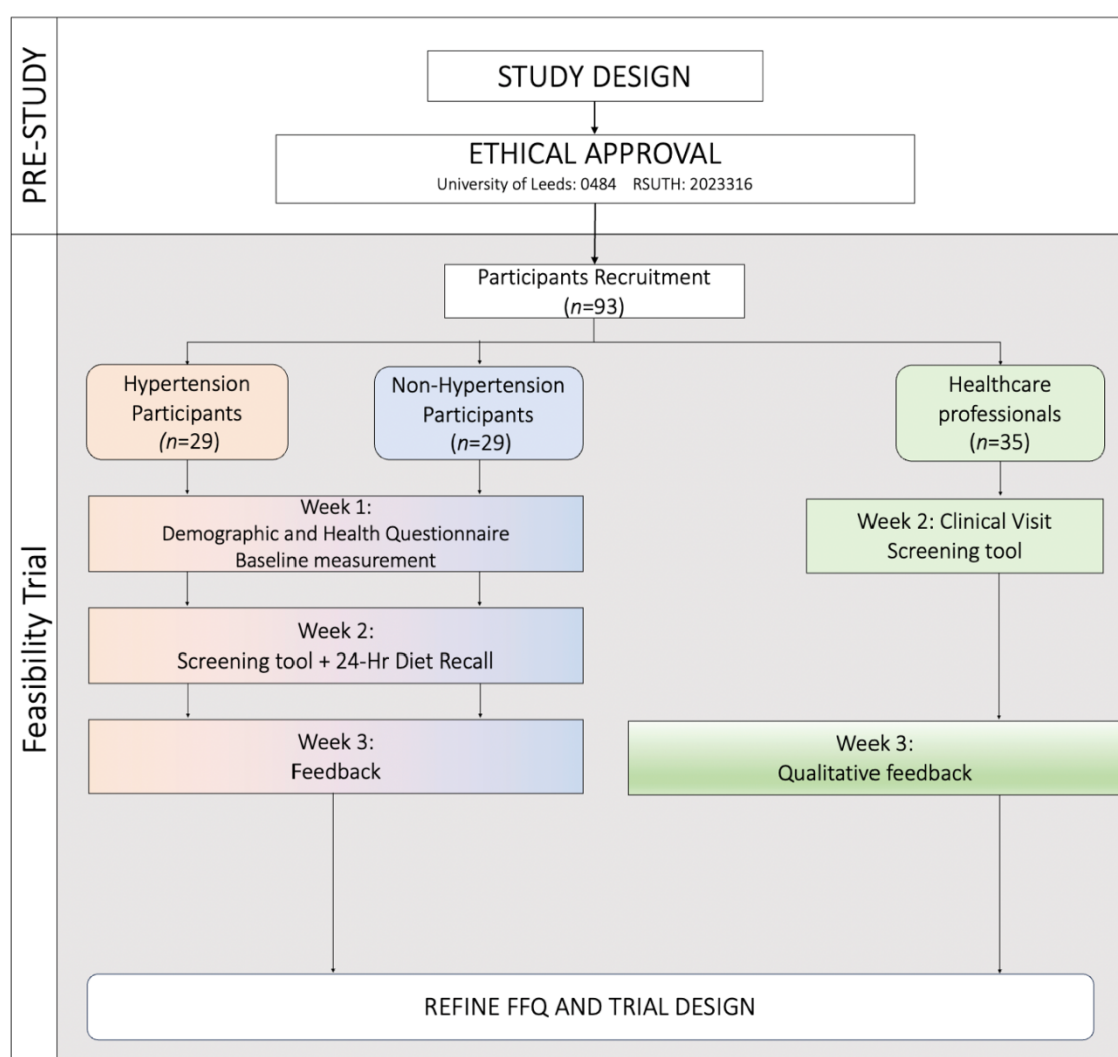


Figure 3. 1. Participant selection and sequence of assessments flowchart.

FFQ: Food Frequency Questionnaire, BP: Blood pressure, H: Height; n: Number; RSUTH: Rivers State University Teaching Hospital; W: Weight. 24 HR: 24-hour dietary recalls,

3.3.6. Participant compensation

Patients and healthcare professionals received a gift card incentive of £5 (approximately ₦6,000) after completing the third study visit involving the FFQ and surveys. Healthcare professionals received a gift card incentive of £5 (₦6,000) upon completing the one-time feasibility and perceptions survey about the screening tool. Participants were blinded to this payment until after the completion of the study, and it did not affect the compliance and decision of the participants.

3.3.7. Sample size and sampling technique

The target sample size was 50 patients allocated into hypertensive and non-hypertensive groups, with a ratio of 1:1 between groups. This was estimated based on published recommendations for feasibility studies and qualitative research to allow for sufficient power for the validation analyses and achieving thematic saturation for qualitative

feedback (Willett, W., 2009; Adebamowo et al., 2017; Steinemann et al., 2017; Mertens et al., 2019) and was adjusted to account for up to a 20% dropout rate (Thabane et al., 2010; Gupta et al., 2016). For healthcare professionals providing qualitative feedback, a sample of 25 was deemed adequate to capture the full range of feedback questions and enable thematic saturation based on previous research indicating that approximately 20-30 participants are needed to reach saturation and informational redundancy in qualitative interview studies, beyond which limited additional themes emerge (Thabane et al., 2010; Gupta et al., 2016).

3.3.8. Data analysis

The quantitative and qualitative analyses were conducted in R version 4.3.1 (R Core Team, 2020) and NVivo version 14 (Lumivero, 2020), respectively. The quantitative data were exported to R statistical software and analysed using descriptive statistics, including frequencies, means, and standard deviations. Completion rates, retention and adherence were analysed as percentages. The mean completion time between the first and second visits was calculated. Patient and healthcare professionals' responses to 5-point Likert scale questions were analysed as means and standard deviations.

Qualitative responses from the healthcare professionals underwent thematic analysis to identify common themes through an iterative process and stepwise process of open coding, categorisation, and consensus building among analysts (Forman J and Damschroder L., 2008; Vaismoradi et al., 2013). First, the qualitative feedback from healthcare professionals, which was collected through open-ended questionnaires and interviews, transcribed verbatim, was entered into Microsoft Excel for organisation by participant group. The responses were then imported into NVivo 14 qualitative analysis software (Lumivero, 2020) for thematic analysis. This followed an iterative process, which involved initial open coding to extract broad themes, focused coding to categorise responses under identified themes, constant comparison between groups, and saturation assessment.

Two independent coders analysed the data to enhance rigour. Any inconsistencies between coders were resolved through in-discussion and consensus building to achieve full agreement on emerging themes and sub-themes related to feasibility, usability, cultural appropriateness, limitations, and integration considerations. The coders compared their independent coding and discussed discrepancies until reaching a consensus on the themes, sub-themes, and representative quotes. The themes were quantified by calculating the percentage of participants mentioning each theme.

Representative quotes were identified. The results were reported as mean $\pm$ SD and median for continuous data and n (%) for categorical data, and p -values <0.05 were considered statistically significant.

3.4. Results

3.4.1. Patient's feasibility outcomes

3.4.1.1. Patient's characteristics

Ninety patients were initially screened; 66 met the inclusion criteria, provided informed consent, and enrolled in the study. Twenty-four patients were excluded (10 were on dietary restriction, six had a recent change of diet, and eight were aged less than 18 years). After exclusions, 58 patients completed the study, including 40 women (69%) and 18 men (31%). Eight patients were excluded due to incomplete FFQ data (**Figure 3.2**). The mean age was 42.6 ± 11.9 years, with males averaging 40.5 ± 12.1 years and females 43.5 ± 11.8 years. Educational levels ranged from primary schooling (3.4%) to postgraduate degrees (24.1%). Regarding marital status, 67.2% were married, 31.0% were single, and 1.7% were widowed. Employment displayed diversity, with 24.1% self-employed and 37.9% in government positions. Over half (55.2%) reported a family history of hypertension, indicating a potential inherited predisposition. Additionally, 50% had hypertension, varying from under one year (31.0%) to over five years (41.4%). Only 22 (75.9%) of the 29 patients with hypertension were on antihypertensive medications (**Table 3.2**).

Table 3.3 presents the cross-sectional measurements of the patients' anthropometric and blood pressure measurements to assess health status and potential risk factors associated with hypertension. On average, the patients had a body weight of 79.4 ± 17.2 kg. Men weighed more, with an average of 87.3 ± 19.0 kilograms, compared to women, who averaged 75.8 ± 15.2 kilograms. The overall height averaged 1.65 ± 0.1 meters, with males being taller at 1.77 ± 0.1 meters as opposed to females, whose height averaged at 1.60 ± 0.1 meters. The mean Body mass index (BMI) calculated was 29.5 ± 7.1 kg/m². The average systolic and diastolic blood pressure were 140.3 ± 22.9 mmHg and 87.4 ± 17.3 mmHg, respectively, across all patients.

3.4.1.2. Retention and adherence

Of the 66 enrolled patients, 58 completed the screening tools (FFQ) during the initial and follow-up study visits, with a retention and adherence rates of 87.9%, demonstrating a high level of participant engagement and commitment throughout the study duration

(**Figure 3.2**). Notably, eight participants faced challenges in adhering to the study protocols, resulting in instances of non-adherence. Specifically, five participants completed the initial Food Frequency Questionnaire (FFQ) but could not proceed with the second FFQ due to work schedule constraints. Additionally, three participants did not provide complete 24-hour recall ($n=3$) and were excluded in the final analysis of the result.

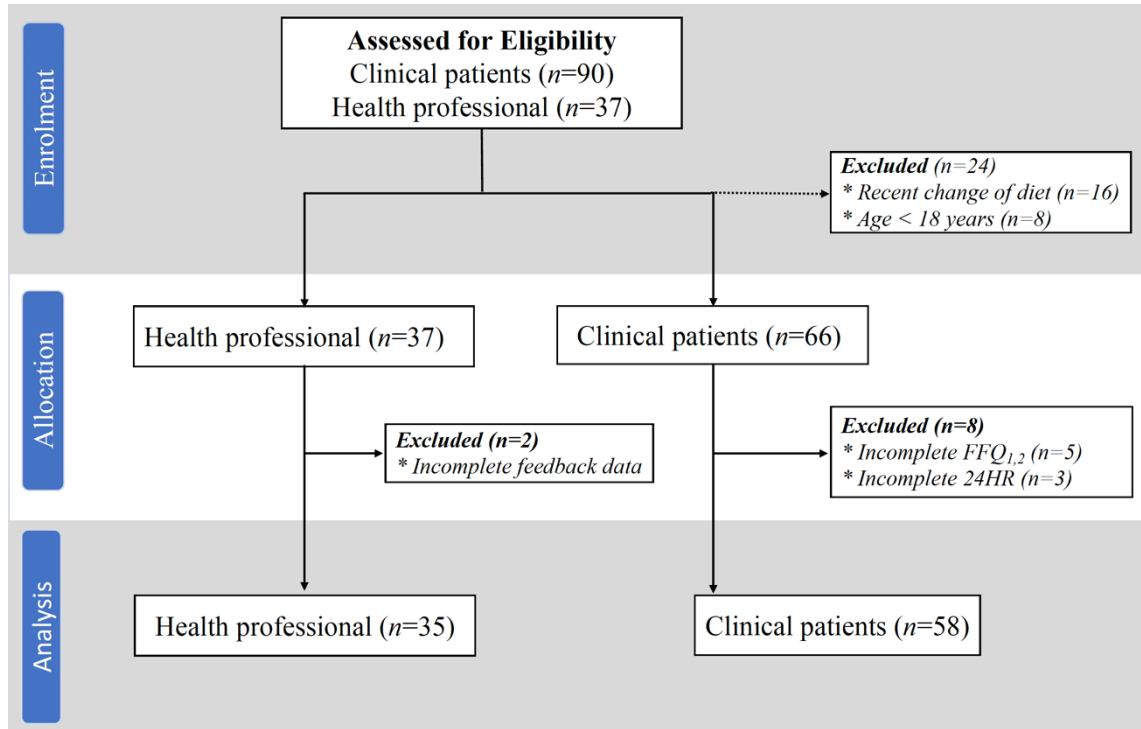


Figure 3. 2. Patient recruitment and enrolment flowchart.

FFQ: Food frequency questionnaire, 24HR: 24-hour dietary recall, n: number.

3.4.1.3. Completion rates and time

The completion rate for the 27-item FFQ was 100% (66 patients) at the first study visit. At three weeks, the completion rate was 87.9% (58/66 patients) (**Figure 3.2**). The mean time to complete the FFQ was 7.71 ± 2.51 minutes at the first study visit and 7.03 ± 2.03 minutes at three weeks (**Table 3.3**). Time to complete decreased over time as patients became more familiar with the process.

Table 3. 2. Sociodemographic characteristics of patients (n=58)

Characteristics	Overall	Men	Women
Age (years), mean $\pm$ SD	42.6 $\pm$ 11.9	40.5 $\pm$ 12.1	43.5 $\pm$ 11.8
Sex, n (%)	58 (100)	18 (31.0)	40 (69.0)
Education n (%)			
Primary	2 (3.4)	0	2 (3.40)
Secondary	12 (20.7)	2 (3.45)	10 (17.20)
High school	4 (6.9)	2 (3.45)	2 (3.45)
University	26 (44.8)	9 (15.50)	17 (29.30)
Postgraduate	14 (24.1)	5 (8.62)	9 (15.50)
Marital status, n (%)			
Married	39 (67.2)	10 (17.2)	29 (50.0)
Single	18 (31.0)	8 (13.8)	10 (17.2)
Widow	1 (1.7)	0	1 (1.7)
Employment, n (%)			
Homemaker	3 (5.2)	0	3 (5.2)
Student	3 (5.2)	1 (1.7)	2 (3.5)
Unemployed	3 (5.2)	0	3 (5.2)
None-paid	1 (1.7)	0	1 (1.7)
Self-employed	14 (24.1)	2 (3.5)	12 (20.7)
Non-governmental	9 (15.5)	3 (5.2)	6 (10.3)
Government	22 (37.9)	10 (17.2)	12 (20.7)
Retired	3 (5.2)	1 (1.7)	2 (3.5)
Family history of Hypertension, n (%)			
No	26 (44.8)	10 (17.2)	16 (27.6)
Yes	32 (55.2)	8 (13.8)	24 (41.4)
Hypertension n (%)			
No	29 (50.0)	9 (15.5)	20 (34.5)
Yes	29 (50.0)	9 (15.5)	20 (34.5)
Years of hypertension n (%)			
< 1 year	9 (31.0)	3 (5.2)	7 (12.1)
1-5 years	8 (27.6)	2 (3.5)	5 (8.6)
> 5 years	12 (41.4)	3 (5.2)	9 (15.5)
Antihypertensive medications use n (%)			
No	7 (24.1)	2 (6.9)	5 (17.2)
Yes	22 (75.9)	6 (20.7)	16 (55.2)

Data are presented as: n= frequency, %= percentage, mean $\pm$ SD= Standard deviation

Table 3. 3. Cross-sectional measurements of patients (n=58)

Characteristics	Overall	Men (n=18)	Women (n=40)
Height (m)	1.65 $\pm$ 0.1	1.77 $\pm$ 0.1	1.60 $\pm$ 0.1
Body weight (kg)	79.4 $\pm$ 17.2	87.3 $\pm$ 19.0	75.8 $\pm$ 15.2
Blood pressure			
SBP (mmHg)	140.3 $\pm$ 29.8	143.3 $\pm$ 24.7	138.9 $\pm$ 23.8
DBP (mmHg)	87.4 $\pm$ 17.3	90.5 $\pm$ 19.6	86.0 $\pm$ 16.2
Body mass index (kg/m ²)	29.5 $\pm$ 7.1	28.2 $\pm$ 5.9	29.6 $\pm$ 7.5
Completion Time			
Mean	7.37 $\pm$ 2.28	7.50 $\pm$ 2.42	7.38 $\pm$ 2.27
First visit	7.71 $\pm$ 2.51	7.83 $\pm$ 2.71	7.65 $\pm$ 2.46
Second visit	7.03 $\pm$ 2.03	7.33 $\pm$ 1.64	6.90 $\pm$ 2.18

Data are presented as: mean $\pm$ SD= standard deviation; p-value between men and women at $p < 0.05$

3.4.2. Patients feedback

Patient's perspectives on FFQ usability and efficacy are provided in **Table 3.4**. Most patients (96.6%) found the FFQ clear, appropriate, and easy to use. However, a minority (3.4%) reported some questions as unclear, especially on 'more than once a day' and salt intake frequency options ('never/rarely', 'Sometimes', 'Usually' and 'Always'). Additionally, 10.3% expressed sensitivity to certain questions on topics like fruit intake and salt use behaviours. However, most (82.8%) were comfortable with the FFQ. For example, regarding fruit intake, one participant stated:

"I feel uncomfortable because I don't normally eat fruit and vegetables because of financial constraints" regarding fruit intake" (female, 45 years, >5 years hypertensive).

On salt use, another shared:

"Most of my meals I bought from a food vendor, and I don't know that it is important to check the amount of salt in food labels" (male, 34 years, non-hypertensive).

Regarding comprehensive food coverage, 6.9% noted missing items like unripe plantain, corn flour, Tofu (soybeans), and Ukwa (breadfruit). Just 1.7% reported technical difficulties influencing responses. Notably, 96.6% of participants believed that the questionnaire provided a comprehensive assessment of their food intake, highlighting its effectiveness, and an equally high percentage (96.6%) considered it useful for healthcare professionals in providing personalised nutritional support to patients.

3.4.3. Healthcare professional's feasibility outcomes

3.4.3.1. Healthcare professional characteristics

In total, 37 healthcare professionals enrolled in the feasibility survey of the FFQ. Thirty-five completed the survey. Two were excluded due to incomplete data (**Figure 3.2**). Years of experience ranged from 3 years to 20 years in practice.

3.4.3.2. Perceived importance and current practices

The survey results demonstrated the importance of dietary assessment among healthcare professionals for effective hypertension management (**Table 3.5**). All healthcare professionals (100%) considered dietary assessment as 'very important or important', underscoring its recognition as a crucial component in hypertension management. 71.4% of healthcare professionals reported conducting a routine dietary assessment in clinical practice occasionally as part of hypertension management; however, a smaller proportion of healthcare professionals conduct dietary assessments monthly (11.4%) or weekly evaluations (11.4%), while only a minority (5.7%) never performed assessments.

Table 3. 4. Patients feedback on the screening tool (FFQ) (n=58)

Feedback responses	Yes, n (%)	No, n (%)
Clarity, appropriate, and easy to use	6 (10.3)	52 (89.7)
Unclear or difficult questions	10 (17.2)	48 (82.8)
Discomfort and sensitivity in questions	4 (6.9)	54 (93.1)
Missing foods or beverages	1 (1.7)	57 (98.3)
Technical difficulties and factors influencing responses	56 (96.6)	2 (3.4)
Feedback responses	56 (96.6)	2 (3.4)

Data are presented as: n= frequency, %= percentage

3.4.3.3. Current practices and confidence in tool usage

The survey assessed the confidence level among healthcare professionals in interpreting and applying dietary data for decisions regarding hypertension care, as outlined in **Table 3.5**. Most (77.2%) expressed ‘confident or very confident’. However, a notable portion, 17.1%, expressed a neutral stance, while 5.7% conveyed uncertainty. These findings suggest various confidence levels among healthcare professionals in utilising dietary data. Furthermore, over half (51.4%) encountered difficulties analysing patients' dietary intake to determine hypertension risks and make dietary recommendations. This highlights the complexity involved in existing dietary assessment tools. In contrast, 48.6% did not encounter such challenges, indicating a balanced distribution of experiences among healthcare professionals. When evaluating healthcare professionals' awareness of culturally specific dietary screening or assessment tools tailored for hypertension in Nigeria, a significant majority (57.1%) indicated either the absence of such tools or noted that available tools lacked cultural specificity. Meanwhile, 40% were uncertain about the existence of any dietary assessment tools. Only a small minority (2.9%) answered that culturally specific tools exist.

3.4.3.4. Clarity and user-friendliness of the FFQ

The results from questions examining the perceived clarity of the new dietary assessment tool are presented in **Table 3.5**. An overwhelming majority (97.1%) of healthcare professionals found the questions easy to understand and straightforward, indicating a high level of clarity in the questionnaire. Only a small minority (2.9%) reported difficulty, specifically with questions about salt intake behaviour, suggesting an overall positive response regarding comprehensibility. Additionally, the survey assessed whether any questions posed challenges or were unclear for participants (**Table 3.5**). Once again, a majority (82.9%) reported no issues, underscoring the high level of clarity and user-friendliness in the questionnaire. However, a minority (17.1%) found some questions unclear.

3.4.3.5. Perceived utility of the dietary assessment tool

In assessing the healthcare professional's perceived relevance of the dietary tool for identifying and addressing dietary factors contributing to hypertension among patients as outlined in **Table 3.5**. Most healthcare professionals found it relevant (51.4%) or highly relevant (42.9%). Some were uncertain (2.9%) or neutral (2.9%). Overall, the results underscore the perceived potential of the tool for effectively targeting dietary factors associated with hypertension. Regarding the perceived value of the tool's information for formulating individualised dietary recommendations for patients, most healthcare professionals (97.1%) deemed it valuable (**Table 3.5**). Only a small minority expressed a neutral stance (2.9%) (**Table 3.5**). This indicates a consensus among healthcare professionals regarding the high value of the data obtained through the tool for tailoring dietary advice to individual patients.

Table 3. 5. Healthcare professional's feedback on the feasibility of integrating the FFQ into clinical practice.

S/N	Variables	Category	n (%)
1	Importance of dietary assessment	Very important	29 (82.9)
		Important	6 (17.1)
2	Dietary assessment in practices	Monthly	4 (11.4)
		Never	2 (5.7)
		Occasionally	25 (71.4)
		Weekly	4 (11.4)
3	Confidence in utilizing dietary data	Confident	19 (54.3)
		Very confident	8 (22.9)
		Neutral	6 (17.1)
		Not sure	2 (5.7)
4	Challenges in assessing food intake	No	17 (48.6)
		Yes	18 (51.4)
5	Existence of culturally specific tools	No specific tools	13 (37.1)
		Yes, but not culturally specific	7 (20.0)
		Not sure	14 (40.0)
		Yes, culturally specific tools are available	1 (2.9)
6	Clarity of questions	Yes	34 (97.1)
		No	1 (2.9)
7	Difficulty of questions	No	29 (82.9)
		Yes	6 (17.1)
8	Relevance of the new dietary tool (FFQ)	Highly relevant	15 (42.9)
		Relevant	18 (51.4)
		Neutral	1 (2.9)
		Not sure	1 (2.9)
9	How valuable is the new tool (FFQ)	Very valuable	20 (57.1)
		Valuable	14 (40.0)
		Neutral	1 (2.9)

Data are presented as: n= frequency, %= percentage

3.4.3.6. Perceived feasibility and acceptability

The perception of the healthcare professionals on the feasibility and acceptability of integrating the newly introduced dietary assessment tool, the Food Frequency Questionnaire (FFQ), into their clinical workflows and patient consultations is detailed in **Table 3.6**. Among the healthcare professionals, a significant majority (82.9%) expressed confidence in the feasibility of integrating the tool (FFQ) into routine clinical practice. However, a small proportion (11.4%) were neutral or unfeasible (2.9%). Furthermore, in assessing the potential impacts on workflow, most healthcare professionals (85.7%) believed the integration would be feasible without disrupting established workflows. However, some uncertainty existed, with 14.3% expressing uncertainty about potential impacts and 2.9% asserting that it would be infeasible without affecting workflow. These findings collectively demonstrate an optimistic outlook on the feasibility of integrating the FFQ into the routine workflow of healthcare professionals.

Moreover, the survey assessed the potential challenges that healthcare professionals foresaw in integrating the FFQ into their clinical practice (**Table 3.6**). Encouragingly, nearly half of the healthcare professionals (48.6%) believed there would be no discernible challenges, indicating an overall positive outlook. However, a significant portion (28.6%) expressed uncertainty, highlighting the need for comprehensive training and support programs to address potential concerns. Additionally, 22.9% of respondents anticipated challenges, underscoring the importance of proactive measures to identify and mitigate potential obstacles during the integration process.

In terms of the likelihood of successful implementation of the tool in routine clinical practice in Nigeria, the majority (94.3%) of healthcare professionals demonstrated a high degree of confidence, asserting that the implementation of the FFQ for personalised dietary counselling and assessment would ‘very likely or likely’, reflecting substantial confidence in the tool's potential to enhance patient outcomes and contribute meaningfully to hypertension management. Only a marginal proportion (2.9%) maintained a neutral stance, indicating a need for targeted efforts to address any reservations or uncertainties. Similarly, only 2.9% deemed success to be ‘very unlikely’, further affirming the overall confidence in the potential benefits of the FFQ (**Table 3.6**). This reflects substantial confidence in the tool's potential to improve patient outcomes and meaningfully contribute to hypertension management.

Table 3. 6. Perceived implementation and challenges of the new tool

S/N	Variables	Category	n (%)
1	Perceived feasibility of integration	No	1 (2.9)
		Not sure	5 (14.3)
		Yes	29 (82.9)
2	Impact on workflow	Feasible	24 (68.6)
		Highly feasible	6 (17.1)
		Neutral	4 (11.4)
		Not feasible	1 (2.9)
3	Foreseeable challenges in integration	No	17 (48.6)
		Not sure	10 (28.6)
		Yes	8 (22.9)
4	Likelihood of implementation	Very likely	17 (48.6)
		Likely	16 (45.7)
		Neutral	1 (2.9)
		Very unlikely	1 (2.9)

Data are presented as: n= frequency, %= percentage

3.4.4. Healthcare professional's feedback

The qualitative feedback provided by the healthcare professionals yielded six themes that emerged from the content analysis of fragments and statements. These themes encompassed a comprehensive exploration of various aspects pertaining to screening tools, including knowledge of dietary screening tools, the effectiveness of existing screening tools, challenges in assessing dietary habits, essential features of a dietary screening tool, perceived benefits, and challenges of integration of the tool, and perceived implementation and suggestions.

3.4.4.1. Knowledge of dietary screening tools

This theme, 'knowledge of dietary screening tools,' assessed the healthcare professionals' familiarity with alternative tailored dietary assessment tools and interventions for hypertension management. The healthcare professionals (97.1%) predominantly conveyed a lack of prior engagement with alternative dietary assessment tools (**Table 3.5**). Their responses consistently indicated a dearth of previous experience or utilisation of such tools, with many explicitly stating "no" or indicating a lack of familiarity. One healthcare professional stated:

"I haven't really used any specific dietary tools before. It's quite new to me, to be honest" (male, 43 years, clinician).

Notably, 94.3% of healthcare professionals expressed interest in the new screening tool (FFQ), underscoring its perceived potential benefits, particularly its cultural adaptability (**Table 3.5**). Additionally, some healthcare professionals provided constructive feedback, suggesting improvements such as a more comprehensive representation of foods from

northern Nigeria and enhanced functionality that does not rely on internet access. In this regard, one healthcare professional remarked:

“I find the new screening tool quite intriguing. It seems adaptable to our cultural context, which is really important. However, it would be great to see more foods from the northern region of Nigeria included” (female, 42 years, clinician).

3.4.4.2. Effectiveness of existing assessment tools

The majority of healthcare professionals (97.1%) indicated a paucity or unfamiliarity with culturally tailored dietary tools for capturing indigenous foods and difficulties in quantifying some specific diets in cultural meals (**Table 3.5**). Furthermore, some healthcare professionals emphasised the need for a simplified tool in the form of a pamphlet or checklists with culturally adapted foods that can effectively address poor dietary habits: In this regard, a clinician stated:

“I find that the existing dietary tools don't really consider our cultural context. There's a gap when it comes to addressing indigenous foods, which are a significant part of our diet. Plus, quantifying the amount of salt and other diets in our cultural dishes using these tools can be quite challenging” (female, 42 years, clinician).

Another clinician stated that:

“I firmly advocate for culturally tailored dietary tools. Take Awadu, for instance; it's not even accounted for in any existing dietary assessment tool. Additionally, we must give due consideration to culturally specific food groups in our dietary assessments” (female, 46 years, clinician).

3.4.4.3. Challenges in assessing dietary habits

Almost half of the healthcare professionals (48.6%) expressed obstacles in evaluating and analysing patients' food intake for hypertension risk assessment and subsequent dietary recommendations. These challenges encompass difficulties in accurately quantifying culturally specific meals, unfamiliar indigenous foods, concerns about recall bias, a lack of tailored assessment tools, and patients' limited capacity to measure specific components of their food precisely. Additionally, healthcare professionals raised issues related to patient education and motivation alongside cultural beliefs, posing additional challenges in the intake of dietary data from patients. On this noted a clinician stated that:

“In my experience, quantifying food content can be a real challenge. There are times when it's quite tricky to measure, and patients often struggle to accurately estimate the proportions of salt, fats and seasonings used in their cultural meals” (female, 45 years, clinician).

Similarly, another clinician stated that:

“I find myself unfamiliar with the specific foods that patients mention when assessing their food intake. It's an area where I feel a bit out of my depth in clinical practice” (male, 44 years, clinician).

3.4.4.4. Essential features of a dietary screening tool

The healthcare professionals highlighted essential features they would consider crucial in a dietary screening tool for effective integration into clinical practice for assessing dietary intake in the prevention and management of hypertension. Firstly, they emphasised that the tool should be culturally tailored to the specific population and contain common foods in relation to specific health conditions. Secondly, the tool should be easy and quick to use, accessible, and able to capture intake and quantify processed food consumption, such as fried food or takeaway meals, fibre, salt intake, and saturated fat intake. Lastly, the healthcare professionals emphasised the tool should consider lifestyle and cultural factors that influence food choices and noted that language barriers should be addressed:

“I believe a short dietary assessment tool should cover common food, be easy to use, short and culturally adaptable, and able to quantifiable content and consideration of portion sizes are also vital for accurate assessment” (male, 44 years, clinician).

3.4.4.5. Perceived benefits and challenges of integration of the new tool

A substantial majority, exceeding 90% of healthcare professionals, perceived the new screening tool as a relevant and valuable tool for assessing the food intake in patients and evaluating hypertension risk (**Table 3.5**). The integration of this tool into the prevention and management of hypertension has been identified by healthcare professionals as feasible (82.9%) and would not negatively impact workflow, conferring several benefits (**Table 3.7**). Nevertheless, they also recognised a spectrum of possible challenges that could be associated with its integration into clinical practice in hypertension management in Nigeria. Top on the list of perceived challenges was time constraints, especially in a busy clinic, where healthcare professionals and patients may be impatient due to limited consultation time, as illustrated in **Table 3.7**. In this regard, one healthcare professional stated:

In our busy clinic, both clinicians and patients can be quite impatient, especially during peak hours. Filling out the form might be rushed, and there's a risk that the dietary assessment could be skipped (male, 44 years, clinician).

3.4.4.6. Perceived implementation and suggestions

In addition to identifying potential challenges of integration of the new tool, healthcare professionals offered insightful suggestions to facilitate the seamless integration of the

dietary assessment tool into clinical practice. They advocated for targeted advocacy efforts, specifically directed towards the Ministry of Health and other health organisations, to secure support and endorsement for the implementation of the tool. Additionally, effective time management during consultations was deemed crucial, prompting suggestions such as condensing the questionnaire or streamlining the assessment process and creating a clear and simplified questionnaire, ensuring comprehensibility for individuals with varying levels of education. Language considerations were highlighted, with recommendations to translate the tool into Nigeria's three major languages to enhance accessibility and acceptance among patients. Some healthcare professionals also proposed developing the tool into a software application, a progressive step towards improved accessibility and usability for both healthcare professionals and patients.

“I feel a streamlined questionnaire, with clear language, is vital for everyone at different education levels and translating the tool into the three major languages in Nigeria will enhance its accessibility among the patient population” (male, 44 years, clinician).

Table 3. 7. Benefits and challenges of implementing the screening tool.

S/N	Benefits	Challenges
1	Promotes healthy lifestyles and provides education on various food types and their benefits for individuals with hypertension.	Time constraints in busy outpatient settings may lead to increased waiting times during consultations.
2	Facilitates early identification of individuals at risk of hypertension, contributing to prevention through risk factor reduction.	Lack of patient awareness about the tool's existence and availability of the tool in patient folders may not always be ensured.
3	Enables healthcare professionals to offer tailored dietary advice, aligning recommendations with each patient's specific needs and preferences.	Effectiveness relies on patients providing accurate dietary information, which may not always occur due to memory or reporting inaccuracies.
4	Supports ongoing assessment and tracking of dietary components influencing hypertension, enabling timely detection of potential concerns	Limited comprehensive research on the effects of all foods on hypertension may make it challenging to provide tailored recommendations.
5	Assures holistic care for hypertension patients, providing detailed information about meal patterns for more effective management.	Insufficient manpower may affect tool implementation. Accessibility to trained personnel knowledgeable about local foods may pose challenges.
6	Encourages adoption of lifestyle practices beneficial for hypertension management and fosters a patient-cantered approach to care.	Language barriers and patient literacy may hinder effective tool utilization, impacting its overall effectiveness.
7	Enhances speed and quality of patient care, streamlining risk assessment and progress monitoring in nutrition therapy.	Concerns about accurately measuring food, salt, and fat/oil intake, a critical factor in hypertension management.

3.5. Discussion

The present study explored the feasibility of integrating a validated dietary screening tool (Food Frequency Questionnaire) into clinical practice for dietary assessment of individuals at risk of hypertension in Nigeria. This feasibility study provides important preliminary data on the potential adoption and utilisation of a tailored 27-item food frequency questionnaire (FFQ) for dietary assessment to prevent and manage hypertension in Nigeria. The results indicate an overall positive reception of the tool among patients and healthcare professionals. The high completion rates, satisfaction, and perceived utility support the acceptability and promise of the tool.

3.5.1. Acceptability and user engagement

The high initial completion rate of 100% and 87.9% at three weeks far exceeds rates observed in similar feasibility studies involving FFQs, which typically ranged from 70-90% (Marks et al., 2006; Park et al., 2018; Subar et al., 2020). This high level of engagement indicates a strong acceptance among patients and aligns with another study with an 85% rate in a 2018 web-based FFQ validation trial (Park et al., 2018). Furthermore, the high retention rate of 88% compares favourably to prior FFQ trials, which retained 75-85% of patients enrolled in the study (Kristal et al., 1997), demonstrating a high level of acceptability of the screening tools. According to a review by Hebert et al., retention rates above 80% are considered robust for dietary assessment studies, signifying a solid commitment from the patients for the studies (Hebert et al., 1995). Therefore, the high retention rate achieved in this study favourably compares to previous feasibility studies involving FFQ, which retained 75-85% of participants (Kristal et al., 2014). These collective findings suggest a strong acceptance and compliance with the feasibility study protocol.

The average time taken to complete the trial, approximately < 8 minutes (7.37 minutes), aligns with the goal of developing an efficient tool, which is consistent with the 5-15 minutes range reported in previous studies focusing on the feasibility and validation of FFQ (Kristal et al., 1997; Dehghan et al., 2012; Illner et al., 2012; Park et al., 2018). Kristal et al. emphasised the importance of short completion times, defining them as ≤ 15 minutes in order to minimise participant burden (Kristal et al., 2014). The slight reduction from 7.42 to 7.02 minutes at the second administration suggests that patients find the process undemanding and that it can be completed more quickly once it is familiar. In many healthcare facilities across Nigeria, patients typically experience hospital waiting times ranging from 83.7 to 144 minutes with a mean pre-consultation interval of 48.7

minutes (Ajayi, 2002; Oche and Adamu, 2013; Abah V. O., 2021). Therefore, across most healthcare settings in Nigeria, the implementation of this screening tool, which requires less than 8 minutes for completion, is unlikely to disrupt clinical workflow. The overwhelmingly positive feedback from patients, with 96.6% expressing satisfaction, mirrors the result observed in FFQ feasibility studies reporting satisfaction rates ranging from 70-90% (Jackson et al., 2008). This high satisfaction indicates a positive user experience with an easily understandable, user-friendly format.

3.5.2. Clinical need and perceived utility

The consensus among healthcare professionals regarding the significance of dietary assessment in hypertension management is consistent with well-established evidence on the association between dietary factors and blood pressure (Appel et al., 1997; Sacks et al., 2001; Filippou et al., 2020; Batubo et al., 2023; Bharati et al., 2023). However, the reported infrequency of assessments in routine practice supports the need for tailored tools. Previous studies also highlight a gap between recommended lifestyle counselling and actual clinical practice implementation (Levine et al., 1979; Lianov and Johnson, 2010; Clarke and Hauser, 2016; Joseph et al., 2016). The anticipated benefits from the new screening tool, including education, early risk detection, personalised guidance, monitoring, and patient management, align with the multifaceted utility of such a tool. The study by Kristal et al. further emphasised the importance of healthcare professionals' confidence in FFQ data for effective counselling, which is a pivotal factor in clinical adoption (Kristal et al., 2014). Therefore, the positive perceptions of utility among this sample of healthcare professionals are promising. Additionally, the fact that 97.1% of healthcare professionals regarded the screening tool (FFQ) as valuable for providing individualised dietary recommendations further affirms its perceived clinical relevance.

3.5.3. Cultural appropriateness

The common view among healthcare professionals that existing dietary assessment tools or methods lack cultural specificity substantiates existing conclusions that current approaches often inadequately capture the dietary habits of ethnic minority populations (Blumenthal et al., 2010; Kruger et al., 2012; Sedgwick, 2014; Bricarello et al., 2021). The healthcare professionals emphasised the critical need to account for indigenous foods and quantify components, aligning with previous studies that demonstrated how traditional FFQs frequently misrepresent the dietary intake of ethnic minority groups (Hu et al., 1999; Goulet et al., 2004; Svetkey et al., 2004). Thus, there is an evident niche for culturally tailored tools like the FFQ that this tool will evaluate in the follow-up study.

3.5.4. Implementation considerations

Over half of healthcare professionals expressed full confidence in utilising FFQ data, a factor previously identified by Kristal et al. as facilitating implementation (Kristal et al., 2014). However, enhancement through training could promote broader confidence. Supporting healthcare professionals in applying FFQ insights may be warranted based on requests for guidance on counselling applications. While healthcare professionals acknowledged time constraints as a challenge, most believed implementation was feasible without causing significant disruption to workflow, aligning with studies demonstrating minimal time burdens associated with FFQ administration (Hu et al., 1999; Paxton et al., 2011).

Almost half of healthcare professionals foresaw no significant implementation challenges, reflecting a sense of optimism. However, some uncertainty remained regarding potential barriers related to patient factors, such as health literacy. Several reviews have highlighted the importance of user-centred design and a careful introduction, emphasising the influence of patient acceptance on the success of the FFQ (Baranowski and Willett, 2012; Illner et al., 2012; Soguel et al., 2019; Moutou et al., 2022). Thus, a participatory implementation approach that engages all stakeholders could prove beneficial for the successful integration and implementation of the FFQ into clinical practice in Nigeria (Ammerman et al., 1993; Damschroder et al., 2009; Lemon et al., 2010; Peters et al., 2013).

3.5.5. Strengths and Limitations

This study provides promising evidence supporting the FFQ as an acceptable, useful, and culturally-appropriate tool for the dietary assessment of individuals at high risk of hypertension in Nigeria in the clinical setting. This study demonstrates a comprehensive approach by employing both quantitative metrics and qualitative feedback, providing a multifaceted assessment of the feasibility of the FFQ from the perspectives of both patients and healthcare professionals. The pragmatic clinical environment enhances the applicability of the findings to the real-world context of hypertension care in Nigeria. The examination of numerous metrics provides comprehensive insights into retention, adherence, completion, relevance, acceptability, and anticipated integration barriers. Importantly, gathering user-centred feedback from healthcare professionals and patients allowed for evidence-based refinements that address their specific needs and priorities. The convergence of quantitative and qualitative findings offers complementary perspectives, enriching the overall feasibility evaluation.

Nonetheless, some limitations warrant acknowledgement. The single-centre design restricts generalizability to other Nigerian regions and clinical settings. Unlike past research, no comparative FFQ analysis occurred. Additionally, this study assessed perceived feasibility rather than actual pre-post implementation challenges. While potential barriers to integration were anticipated, the intricate details of real-world workflow integration remain underexplored. Furthermore, only perception-based, rather than objective data on clinical utility and patient outcomes, was captured. Finally, the absence of a longitudinal follow-up to assess whether acceptability endures over time is another notable limitation. However, as we move forward and expand our study size, a primary aim will be to evaluate differences in responses and feasibility among more diverse population groups across Nigeria and in other West African countries.

3.5.6. Relevance to clinical practice

The findings of this feasibility study have important implications for the potential integration of the food frequency questionnaire (FFQ) as a dietary screening tool within Nigerian clinical practice and also more broadly across West Africa. The high completion rates, coupled with positive user feedback, suggest a promising acceptance of the tool among patients and healthcare professionals. The minimal completion time aligns with the practical demands of a clinical setting. The implementation challenges and recommendations identified by the healthcare professionals offer valuable insights to guide the refinement of the FFQ and its implementation process for seamless integration into routine clinical practice in Nigeria.

Importantly, the development of the FFQ was informed by the evidence of a systematic review and meta-analysis of dietary factors associated with hypertension across West Africa (Batubo et al., 2023). Therefore, while this study focussed on the feasibility in Nigeria, the intention is to validate and evaluate the FFQ for potential use across other West African countries with shared cultural dietary patterns and lifestyles. Aspects like cultural tailoring, feasibility analysis, and user-centred design remain broadly relevant across West African settings where the lack of contextually appropriate tools poses a barrier to dietary screening and counselling. The study offers a framework and considerations that can inform the adaptation and integration of dietary screening tools across West Africa to enhance dietary risk screening and management of hypertension.

3.5.7. Conclusions

This study provides initial promising evidence to support the screening tool (FFQ) as an acceptable, useful, and culturally-appropriate dietary assessment tool for the prevention

and dietary management of hypertension in Nigeria. Patients demonstrated high engagement. Healthcare professionals in Nigeria affirmed the value of care this tool could address. While implementation considerations exist, optimism prevails. Further validation and careful introduction are warranted to facilitate optimal FFQ adoption and impact. Overall, the feasibility outcomes justify progressed research on this FFQ as a practical means to improve dietary assessment practices to prevent and control hypertension better in Nigeria.

3.6. Chapter summary

This chapter explored the feasibility and acceptability of integrating a culturally-appropriate Food Frequency Questionnaire (FFQ) dietary screening tool into clinical practice among patients and healthcare professionals in Nigeria. The main objective was to assess the feasibility and acceptability of the FFQ as a dietary screening tool for individuals at risk of hypertension in Nigeria. The FFQ was developed based on the systematic review and meta-analysis findings from study one (Chapter two). Utilising qualitative and quantitative methods, the study demonstrated: (i) high retention and adherence rates; (ii) a completion time of less than 8 minutes; (iii) high acceptable among patients and healthcare professionals; and (iv) positive attitudes towards its usefulness, clarity, and cultural appropriateness among patients and healthcare professionals. This evidence suggests the high utility of the FFQ in clinical practice for hypertension screening in Nigeria and highlights: (i) a rapid dietary assessment tool, (ii) the cultural appropriateness of the tool and (iii) the need to assess the validity and reliability of the tool in estimating dietary intake among adults in Nigeria. This validation of this culturally-appropriate rapid tool using a robust validation protocol was addressed in phase two of study two, described in the next chapter.

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Chapter four

Validity and reproducibility of a culturally-appropriate dietary screening tool in Nigerian healthcare

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4.1. Abstract

Introduction: Food frequency questionnaires (FFQ) are commonly used tools in dietary assessment but require validation. This study assessed the relative validity and reproducibility of a culturally-appropriate FFQ for estimating dietary intake among Nigerian adults in clinical settings.

Methods: The FFQ was administered to 58 patients at the Rivers State University Teaching Hospital, Nigeria, on two occasions, three weeks apart. Three repeat non-consecutive 24-hour dietary recalls (24DR) were conducted as a reference method to evaluate the validity of the FFQ. Spearman's rank correlations, Wilcoxon signed-rank tests, cross-classification agreement, intraclass correlation coefficients (ICC), and Bland-Altman analysis were performed in R to evaluate the relative validity and reproducibility.

Results: The correlation coefficient (r_s) between the FFQ and 24DR ranged from 0.20 for 'fats and oils' to 0.78 for vegetables, with an average r_s of 0.60 ($p < 0.05$). The Wilcoxon signed-rank tests indicated no significant differences in the 19 food groups queried ($p > 0.05$), except for fats and oils ($p < 0.05$). The exact agreement between FFQ and 24DR for classifying individuals into quartiles ranged from 17% for salt to 88% for processed meats and alcoholic drinks, with 90% of individuals classified into the same or neighbouring quartile. Additionally, the Bland-Altman analysis demonstrated acceptable agreement, with $> 96\%$ of observations within the acceptable limits of agreement for all food groups. For reproducibility, the ICC ranged from 0.31 for stew to 0.98 for fruit, with an average ICC of 0.77 between the FFQs delivered two weeks apart.

Conclusions: These data demonstrate good agreement between our novel culturally-appropriate FFQ and 24DR. Moreover, a robust reproducibility for quantifying intakes of food groups associated with hypertension in Nigeria. This confirms that this novel FFQ is a valid and reliable Nigerian dietary screening tool (NiDST) for assessing the intake of key food groups among Nigerian adults.

Keywords: Dietary assessment, food frequency questionnaire, Nigeria, relative validity, reproducibility, 24-hour dietary recalls

4.2. Introduction

Hypertension is a leading risk factor for cardiovascular disease (Forouzanfar et al., 2017), which annually is responsible for over 10 million deaths worldwide (GBD Risk Factors Collaborators, 2020; Saloni D et al., 2023). The highest hypertension burdens exist in low- and middle-income countries, with over 30% of adults affected in some African regions (Mills et al., 2016; Mills et al., 2020). In Nigeria specifically, hypertension prevalence has more than doubled since 1990, from 11.4% to 36.1% in 2019, with just over a quarter of hypertensive adults achieving blood pressure control (Murthy et al., 2013; Akinlua et al., 2015; Adeloye et al., 2021; World Health Organization, 2021). This escalating epidemic underscores an urgent need for improved screening, treatment, and prevention strategies.

Unhealthy dietary patterns are a predominant modifiable risk factor for hypertension globally, including in Sub-Saharan Africa (Mozaffarian et al., 2014; Oyeboode et al., 2016). Specifically, diets characterised by elevated levels of saturated fat, processed meats, and sugar-sweetened beverages have been associated with an increased risk of hypertension (GBD 2017 Diet Collaborators, 2019). Moreover, deficiencies in vital dietary components like fruits, vegetables, nuts, legumes, and omega-3 fatty acids from seafood correlate with elevated blood pressure levels (Schwingshackl et al., 2017). In our prior research, we highlighted a significant association between high consumption of diets rich in dietary salt, red meat, processed foods, fried foods, dietary fat, and alcohol and an elevated risk of hypertension with a mean overall risk increase of 1.42 not only in Nigeria but also in various West African countries (Batubo et al., 2023). The average daily sodium intake in Nigeria ranges from 9-12 grams, which exceeds the World Health Organization's (WHO's) recommended limit of 5 grams (Ojji and Nigeria Sodium Study, 2022). This highlights dietary optimisation as a crucial component of population-level and clinical hypertension prevention strategies in Nigeria.

Dietary assessment represents an essential first step for establishing the association between diet and chronic diseases and designing effective public health dietary prevention strategies against chronic conditions, including hypertension (Lee and Nieman, 2013). To ensure optimal relevance and validity, dietary assessment tools must be customised to the cultural context of the population, encompassing region-specific foods, meals, serving sizes, and eating patterns (Meybeck et al., 2015). Food frequency questionnaires (FFQs)

developed for Western populations show limited validity for immigrant groups retaining traditional diets (Goulet et al., 2004). This underscores the need for culturally adapted FFQs, especially in ethnically diverse countries like Nigeria, which has over 250 ethnic groups (Ene-Obong et al., 2013). However, culturally-appropriate rapid and validated FFQs for assessing dietary intake, particularly for hypertension, are notably lacking in Nigeria and other West African countries, impeding progress in diet-disease research and clinical support.

In this study, a robust validation protocol was employed in a clinical setting in Nigeria to assess the intake of common foods associated with the risk of hypertension. This study evaluated the agreement between a novel culturally-appropriate FFQ and the average of three repeat 24-hour dietary recalls (24DR). Through assessing reproducibility, we sought to enhance the applicability of the FFQ in hypertension management and provide crucial insights for implementing the FFQ tailored to the Nigerian population.

4.3. Materials and methods

4.3.1. Study design and setting

This was a single-centre, retrospective study utilising quantitative approaches to assess dietary intake and evaluated the agreement between the food groups intake estimated by the dietary screening tool and repeat 24-hour dietary recalls to assess the relative validity and reproducibility of a newly developed tailored dietary screening tool consisting of 27 food items that we aim to incorporate into routine clinical practice in Nigeria to identify adults at high risk of hypertension. The investigation was conducted at the Internal Medicine and Family Medicine Department outpatient clinics of Rivers State University Teaching Hospital (RSUTH) in Port Harcourt, Rivers State, Nigeria.

4.3.2. Ethics approval

The study protocol underwent review by two ethics boards. Firstly, it was submitted to the Business, Earth & Environment, Social Sciences (AREA FREC) Committee at the University of Leeds, Leeds, United Kingdom, on the 21st of March 2023. Subsequently, it was presented to the Rivers State University Teaching Hospital Research Ethics Committee in Port Harcourt, Nigeria, on March 20th, 2023. Final approvals were granted with the following reference numbers: 0484 on 28/04/2023 and RSUTH/REC/2023316 on 30/03/2023, respectively. The trial was duly registered at *clinicaltrials.gov* under the identifier NCT05973760.

4.3.3. Sample size

Previous validation studies investigating the correlation between FFQs and 24DR have demonstrated good agreement, with correlation coefficients (r_s) ranging from 0.3 to 0.7 (Willett, W., 2009; Adebamowo et al., 2017; Steinemann et al., 2017; Mertens et al., 2019). A moderate $r_s = 0.5$ is typically considered a robust indicator of correlation (Swinscow T.D.V. and Campbell M.J.). Therefore, it was used to estimate the sample size along with a statistical power of $P = 0.8$, a 95% confidence interval, and a two-tailed alpha level of 0.05 utilising the G*Power software (Faul et al., 2009). While a minimum of 29 participants was determined to be required to accommodate an anticipated dropout rate of 20% and address any potential missing or incomplete data, we set the target sample size at 50 participants (Thabane et al., 2010; Gupta et al., 2016).

4.3.4. Eligible participants

Our study enrolled adult patients visiting the Rivers State University Teaching Hospital for routine medical care between the ages of 18 and 70, including men and women who had been residing in Nigeria for at least two years at the time of the study and possessed proficiency in reading, writing, and communicating in English. The complete list of inclusion and exclusion criteria is presented in **Table 4.1**.

Table 4. 1. Participant's inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Age between 18 and 70 years	Individuals < 18 years or > 70 years of age
Men and women	Pregnant or breastfeeding women or those intending to become pregnant
Hypertensive or non-hypertensive individual	Diagnosis of other chronic diseases such as cancer, diabetes, renal failure, endocrine diseases, and previous and recent incidence of cardiovascular disease (CVD) and stroke
Individuals who have been residents in Nigeria for the past 2 years	Individuals who have been resident in Nigeria for shorter than 2 years
Ability to read, write, and communicate over the phone in English	Individuals on dietary restriction or recent changes to their diet or food
Individuals who gave their consent to participate	Individuals who did not give their consent to participate or are currently enrolled in other studies

4.3.5. Participant recruitment and informed consent

Participant recruitment occurred over four weeks in July 2023 during regular clinic visits. Eligible participants were recruited through a non-probability convenience sampling method. This process was facilitated through strategically placed recruitment posters within the hospital premises, referrals from healthcare professionals, and morning

briefing sessions at the outpatient clinics of the Internal Medicine and Family Medicine Departments of RSUTH. Patients expressing interest in the study were screened for eligibility using a structured questionnaire (**Table 4.1**). Subsequently, eligible patients were categorised into either the hypertension or non-hypertension groups based on their current hypertension status. Before participation, each participant received and reviewed a simplified version of the participant information sheet. They had the opportunity to address any queries or concerns with the study personnel, ensuring their consent to participate was voluntary and fully informed. All patients provided written informed consent before participating in the study. The study adheres to *CONSORT* guidelines for reporting clinical trials (Schulz et al., 2010).

4.3.6. Dietary assessment

4.3.6.1. Dietary screening tool (FFQ)

The dietary screening tool used in this study was a newly developed, 27-food group semi-quantitative food frequency questionnaire (FFQ). This FFQ was designed to capture the usual food intake over the past month. The initial list of commonly consumed foods was created through guidance from the Nigerian and Ghana National Nutritional Guideline on Non-Communicable Disease Prevention, Control and Management (Ministry of Health, 2012; Federal Ministry of Health, 2014) and supported by our prior systematic review and meta-analysis regarding dietary factors associated with hypertension in the West African region (Batubo et al., 2023). Designed to be completed in less than 20 minutes, the final FFQ comprised 26 questions on major food groups and an additional six questions related to salt (**Table S4.1**). These food groups encompassed various foods such as fruit, vegetable, fibre-breakfast cereals, rice and pasta, beans, yam and potatoes, fried or fast foods, whole meat, white meat, processed meat, sugary fizzy drinks and fruits, diet non-alcoholic drinks, tea and coffee, soups and stew (fatty soups, vegetable soups, draw soups, native soups, and stews), nuts and seeds, dessert and sweets, fats and oils, salt, milk and milk-based beverages (**Table S4.1**). For each food item, participants were asked about the frequency of consumption over the past month, with response options ranging from 'rarely or never,' '1-2 times/week,' '3-5 times/week,' to 'daily,' and 'more than once per day' (**Table S4.1**).

4.3.6.2. 24-hour Dietary Recalls (24DR)

Three repeat 24-hour dietary recalls (24DR) were conducted by trained nutritionists on non-consecutive days, covering two weekdays and one weekend day. This approach aimed to account for the day-to-day variation in dietary intake. Throughout the recalls,

detailed descriptions of all foods, snacks and beverages consumed in the preceding 24 hours were recorded, including cooking methods and brand names (where possible).

4.3.7. Data collection

Data collection was over four weeks in August 2023. At clinic visit 1 in week 1, the eligible consenting patients completed sociodemographic and health status questionnaires and underwent baseline assessments, including height, weight, and blood pressure measurement (**Figure 4.1**). The height and body weight were measured twice using a standard stadiometer (model number: DG2301, China), and the Body mass index (BMI) was calculated based on the measurements from the height and weight using the formula $BMI = \text{body weight in Kg} / (\text{height in metre})^2$. The participant's blood pressure was recorded twice in the non-dominant arm using an automated mercury sphygmomanometer (model number: ZK-BB68, Shenzhen, China).

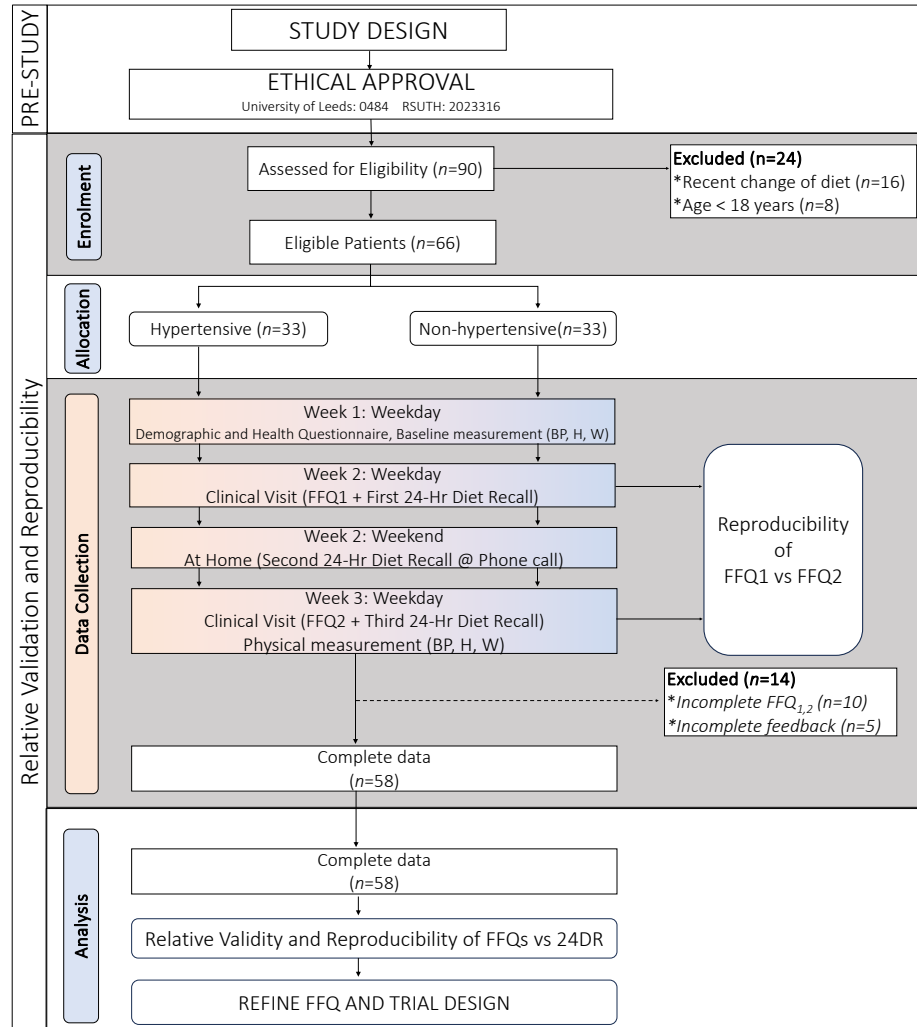


Figure 4. 1. Study design, patient recruitment, enrolment, and data collection flowchart.

FFQ1: first Food Frequency Questionnaire, FFQ2: second Food Frequency Questionnaire, 24DR1: first 24-hour dietary recall, 24DR2: second 24-hour dietary recall; 24DR3: third 24-hour dietary recall, BP: Blood pressure; H: Height; n: Number; RSUTH: Rivers State University Teaching Hospital; W: Weight.

At clinic visit 2 in week 2, eligible consenting patients completed the first self-administered dietary screening (FFQ1) tool. In conjunction with the FFQ1, the first interview-based 24DR (24DR1) was conducted to collect patient food intake data for the past 24 hours on one weekday using the multiple-pass method (Conway et al., 2004; Blanton et al., 2006; U.S. Department of Agriculture, 2021). The second 24DR (24DR2) was conducted by phone to collect the patients' food intake on a weekend day in week 2 (**Figure 4.1**). During clinic visit 3, the study patients completed the FFQ for the second time (FFQ2). The third 24DR (24DR3) was conducted on another weekday to collect food intake data for the past 24 hours. Finally, a second measurement of height, weight, and blood pressure was collected (**Figure 4.1**).

4.3.8. Participant compensation

The participants who completed all the study requirements, consisting of the two FFQs, three 24DR, and all the physical measurements (weight, height, and blood pressure), were given a token of appreciation in the form of a £5 gift. This was extended to participants as a gesture of gratitude for their participation and compensation for their valuable time. Participants were blinded to this payment until after the completion of the study, and it did not affect their compliance and decision-making.

4.3.9. Data analysis

Dietary data (i.e., frequencies of food group intakes) from the first food frequency questionnaire (FFQ1), second food frequency questionnaire (FFQ2) and the three repeat 24-hour dietary recalls (24DR) (24DR1, 24DR2 and 24DR3) for each participant were entered into a Microsoft Excel spreadsheet with quality checks. The frequencies of intakes reported in FFQ1 and FFQ2 were converted into servings/day by multiplying the average servings per week and then dividing the average by seven days according to the method by Fatihah et al (Fatihah et al., 2015). For example, 3-5 times/ week was converted ($[3+5/2] \div 7$ days) into 0.57 serving/day. The salt intake assessed by the FFQ was coded numerically as '1 for 'never or rarely', 2 for 'sometimes', 3 for 'usually' and 4 for 'always'. The food intake data from the FFQ and 24DR data were aggregated into 20 major food groups (**Table S4.2**). The mean of the FFQ was calculated by combining the data from both administrations (FFQ1 and FFQ2). Additionally, the mean for the 24DR was computed based on three non-consecutive repetitions of the 24DR. These means were used for the validity analysis.

The dietary data and their corresponding mean differences between the FFQ and 24DR were tested for normality using the Shapiro-Wilk and Kolmogorov-Smirnov tests, along

with inspection of the histogram (Massey, 1951; Shapiro and Wilk, 1965). The data were not normally distributed; therefore, non-parametric methods were used for the analysis. The results were reported as mean, median and interquartile range (IQR) for continuous data and count (*n*) and percentage (%) for categorical data. P-values <0.05 were considered statistically significant. All analyses were performed using an R computing environment (version 4.3.1) (R Core Team, 2020). The statistical analyses were performed in two phases.

In the first phase, we used multiple methods to assess the relative validity of the FFQ by evaluating the agreement between the mean of the FFQ and the mean of the 24DR. First, Spearman's rank correlation was used to quantify the strength of the agreement between intakes estimated by the FFQ with those from the 24DR. A correlation coefficient above 0.5 indicated a good correlation (Cade et al., 2002). Secondly, the Wilcoxon signed-rank test compared the difference between the mean FFQ and mean 24DR for each food group. A *p*-value > 0.05 indicated no statistically significant difference and good agreement (Rohrmann and Klein, 2003; Rey and Neuhauser, 2011). Thirdly, the cross-classification analysis was used to assess the degree of misclassification by categorising intakes (FFQ and 24DR) into quartiles by the three methods: (i) proportion of exact agreement, deviation by one quartile; (ii) proportion of adjacent agreement, indicating deviation by adjacent quartiles; and (iii) proportion of grossly misclassified participants, disagreement by three quartiles. Finally, the Bland-Altman analysis was used to assess the level of agreement and whether differences between FFQ and 24DR estimated measurements were dependent on the magnitude of measurements (Bland and Altman, 1986). The mean difference (mean FFQ–mean 24DR) was plotted against the average of the two measures ($[(\text{mean FFQ} + \text{mean 24DR})/2]$) for each food group. An acceptable level of agreement was defined as differences in means falling within the range of ± 3 standard deviations (SDs) (Savija et al., 2021). The relative differences (%) within this range were also calculated to quantify agreement.

In phase two, we assessed the reproducibility of the FFQ at two different administrations (FFQ1 vs FFQ2). The strength and association of the FFQ1 and FFQ2 were evaluated using Spearman's rank correlations. The agreement and consistency between food groups from the two FFQ administrations were assessed using intraclass correlation coefficients (ICCs). ICC values were calculated based on a single rating, absolute agreement, and 2-way mixed-effects model (Koo and Li, 2016). ICC values above 0.60 were considered evidence of good reproducibility between the two FFQ administrations (Cade et al.,

2002). The ranking agreement between the FFQ1 and FFQ2 was evaluated using the Wilcoxon signed-rank test, and a p -value >0.05 was considered to indicate a good agreement between the FFQ1 and FFQ2.

4.4. Results

4.4.1. Participant characteristics

A total of 90 patients indicated an interest in the study. Of these, 66 met the inclusion criteria and consented to participate in the study. Of the 66 eligible consenting patients, 58 completed the study protocol and their data were included in the final data analysis (**Figure 4.1**). The overall average age was 42.6 ± 11.9 years, with hypertensive participants being older, on average 46.4 ± 10.1 years, compared to non-hypertensives with a mean age of 38.7 ± 12.4 years. The majority of participants were female (69%). Over two-thirds (69%) had a university or postgraduate education. A family history of hypertension was reported by 55.2% (**Table 4.2**). A considerable proportion of participants had experienced hypertension for more than five years (41.4%), but only 55.2% reported using antihypertensive medications. Participants with hypertension, on average, appeared to be heavier (83.8kg vs 75kg), with more presenting with obesity (mean $\pm$ SD BMI: 32.1 ± 6.4 kg/m²) than those who did not have hypertension (26.9 ± 6.8 kg/m²). Similarly, participants with hypertension, on average, had higher systolic blood pressures (159.0 ± 16.9 mmHg vs 121.0 ± 11.7 mmHg) in spite of a high percentage using antihypertensive medications (**Table 4.2**).

4.4.2. Dietary intake assessment

The mean and median servings/day were similar between the two dietary assessment methods for all food groups (**Table 4.3**). The mean fold differences varied from 0.25 for fats and oils to 1.25 for yam and potatoes, indicating that, on average, the FFQ provided food groups intake estimates within 75% below to 25% above the 24DR amounts. Overall, no significant differences were observed between the food group intakes estimated by the FFQ and the 24DR ($p>0.05$).

4.4.3. Assessment of relative validity

To assess the validity of the FFQ, we evaluated the relationship between the food group intake estimated by the FFQ relative to the 24DR. The Spearman's correlation coefficients (r_s) ranged from 0.20 for fats and oils to 0.78 for vegetables, with an average correlation coefficient of 0.60 (**Table 4.4**). Although weaker positive correlation coefficients ($r_s<0.3$) were found for fat & oils, and salt, most of the food groups ($n=15$) had a correlation

coefficient ≥ 0.50 , indicating a strong positive correlation between the mean FFQ and mean 24DR ($p < 0.05$). In addition, among the 20 food groups evaluated in the FFQ, 19 food groups had no significant differences ($p > 0.05$) in the mean and median intakes compared to 24DR when a Wilcoxon signed-rank test was applied — the exception was ‘fats and oils’ ($p < 0.05$) (**Table 4.4**). Overall, the results suggest that the FFQ provides comparable rankings and intake estimates for most foods ($n=19$) compared to 24DR and shows good agreement between the dietary assessment approaches.

Table 4. 2. Sociodemographic, anthropometric, and clinical characteristics of participants

Characteristics	Overall (<i>n</i> =58)	Non-hypertensive (<i>n</i> =29)	Hypertensive (<i>n</i> =29)
Age (years), mean $\pm$ SD	42.6 $\pm$ 11.9	38.7 $\pm$ 12.4	46.4 $\pm$ 10.1
Sex, <i>n</i> (%)			
Male	18 (31.0)	9 (31.0)	9 (31.0)
Female	40 (69.0)	20 (69.0)	20 (69.0)
Education <i>n</i> (%)			
Primary	2 (3.5)	1 (3.5)	1 (3.5)
Secondary	12 (20.7)	3 (10.3)	9 (31.0)
High school	4 (6.9)	2 (6.9)	2 (6.9)
University	26 (44.8)	14 (48.3)	12 (41.4)
Postgraduate	14 (24.1)	9 (31.0)	5 (17.2)
Family history of Hypertension, <i>n</i> (%)			
Yes	32 (55.2)	19 (65.5)	13 (44.8)
Years of hypertension <i>n</i> (%)			
< 1 year	9 (31.0)	None	9 (31.0)
1-5 years	8 (27.6)	None	8 (27.6)
> 5 years	12 (41.4)	None	12 (41.4)
Antihypertensive medications use <i>n</i> (%)			
Yes	16 (55.2)	None	16 (55.2)
No	13 (44.8)	None	13 (44.8)
Height (m)	1.7 $\pm$ 0.1	1.7 $\pm$ 0.1	1.6 $\pm$ 0.1
Body weight (kg)	79.4 $\pm$ 17.2	75.0 $\pm$ 15.4	83.8 $\pm$ 18.1
Body mass index (kg/m ²)	29.5 $\pm$ 7.1	26.9 $\pm$ 6.8	32.1 $\pm$ 6.4
Blood pressure			
SBP (mmHg)	140.3 $\pm$ 23.9	121.0 $\pm$ 11.7	159.0 $\pm$ 16.9
DBP (mmHg)	87.4 $\pm$ 17.3	75.4 $\pm$ 9.7	99.3 $\pm$ 14.8

Data are presented as: n= frequency, %= percentage, mean $\pm$ SD= Standard deviation

Additionally, the percentage of participants grossly misclassified by three quartiles ranged from 0% for alcoholic drinks to 59% for salt, with an average of 11% (**Table 4.4**). For most food groups ($n=15$), over 50% of the participants were classified into the same or neighbouring quartile. Specifically, the classification of participants into the exact or adjacent quartiles ranges from 10% for dessert and sweets to 88% for processed meat and alcoholic drinks, with an average exact agreement of 53% and an adjacent agreement of 37% (**Table 4.4**). Importantly, 90% of participants were classified in the same or neighbouring quartile, indicating a good agreement between the FFQ and 24DR.

Furthermore, the Bland-Altman analysis was used to assess the level of agreement between the FFQ and 24DR (**Table S4.3**). **Figure 4.3A-F** presents the Bland-Altman plots for the three healthy food groups of the DASH diet (e.g., fruits, vegetables, and nuts and seeds) and three less healthy food groups/items identified by our recent meta-analysis of foods associated with hypertension in West African countries, including Nigeria (e.g., salt, fried/fast foods, and fats and oils) (Batubo et al., 2023; Challa HJ, January 23, 2023). The plots for the remaining food groups are provided in supplementary materials (**Figure S4.1**). Although moderate bias and wide limits of agreement (-4.18 to 03.93) were observed for fats/oils and salt food groups (**Figure 4.3D-F**), very limited bias was observed for the majority ($n=18$) of the food groups where mean differences (bias) ranged from -0.06 servings/day (meat and fried and fast foods) to 0.08 servings/day (fish) (**Figure 4.3A-4.3C and Figure S4.1**). In addition, the 95% limits of agreement (LOA) spanned 0.19 to 1.40 servings/day (upper LOA) and -1.23 to -0.20 servings/day (lower LOA) for most food groups ($n=18$), showing reasonable agreement (**Table S4.3**). A high proportion (>96%) of observations fell within the acceptable limits of agreement (± 3 standard deviation LOA) without increased differences across higher food intake ranges (**Table S4.3**). In summary, the Bland-Altman analysis and plots suggest a high level of agreement between the FFQ and 24DR for the majority of the assessed food groups ($n=18$).

Table 4. 3. Food group intake estimates from the novel Food Frequency Questionnaire (FFQ) and the 24-hour dietary recall (24DR).

Food Group (servings/day)	FFQ			24DR			Mean Fold Difference (FFQ/24DR)		
	Mean	Median	IQR	Mean	Median	IQR	Mean	95% CI	<i>p</i> -value
Fruits	0.38	0.21	0.57	0.35	0.33	0.67	1.09	0.82; 1.41	0.288
Vegetables	0.48	0.21	0.36	0.46	0.39	0.36	1.05	0.94; 1.19	0.193
Grains	0.40	0.33	0.19	0.42	0.44	0.20	0.96	0.84; 1.10	0.741
Beans and lentils	0.33	0.21	0.36	0.34	0.33	0.26	0.99	0.82; 1.12	0.723
Meat	0.55	0.50	0.30	0.61	0.50	0.29	0.90	0.80; 1.00	0.975
Processed meat	0.16	0.00	0.21	0.14	0.00	0.00	1.19	0.95; 1.59	0.069
Fish and seafoods	0.62	0.39	0.58	0.54	0.33	0.59	1.16	0.96; 1.36	0.058
Eggs	0.32	0.21	0.36	0.31	0.33	0.67	1.04	0.85; 1.28	0.365
Fried or fast food	0.23	0.21	0.37	0.29	0.33	0.33	0.80	0.62; 1.03	0.954
Yam and potatoes	0.30	0.21	0.18	0.25	0.33	0.33	1.25	0.88; 1.85	0.136
Soups	0.35	0.32	0.22	0.33	0.33	0.23	1.08	0.96; 1.20	0.096
Stew	0.45	0.39	0.36	0.42	0.33	0.34	1.09	0.92; 1.27	0.164
Nuts and seeds	0.46	0.29	0.36	0.44	0.33	0.67	1.06	0.86; 1.29	0.298
Desserts and sweets	0.19	0.00	0.21	0.21	0.00	0.33	0.96	0.60; 1.48	0.615
Soft drinks	0.22	0.13	0.24	0.19	0.17	0.33	1.15	0.85; 1.57	0.222
Alcoholic drinks	0.03	0.00	0.00	0.04	0.00	0.00	1.00	0.43; 1.57	0.787
Tea and coffee	0.39	0.21	0.47	0.34	0.33	0.67	1.15	0.89; 1.47	0.153
Milk and milk drinks	0.46	0.39	0.36	0.48	0.33	0.34	0.96	0.82; 1.11	0.739
Fats and oils	0.58	0.57	0.74	2.30	2.33	0.92	0.25	0.20; 0.31	1.000
Salt and seasonings	3.37	4.00	1.00	3.45	3.33	1.33	0.98	0.88; 1.08	0.672

FFQ: Food Frequency Questionnaire; 24DR: 24-hour dietary recalls; IQR: Interquartile range

Table 4. 4. Comparison of food group intake obtained from a semi-quantitative food frequency questionnaire (FFQ) and the 24-hour dietary recalls (24DRs).

Food Group (servings/day)	Agreement between FFQ and 24DR			Disagreement between FFQ and 24DR		
	r_s	^a p -value	^b p -value	Exact (%)	Adjacent (%)	GM ¹ (%)
Fruit	0.65	<0.001	0.748	53	33	14
Vegetables	0.78	<0.001	0.706	50	45	5
Grains	0.64	<0.001	0.042	40	53	7
Beans and lentils	0.64	<0.001	0.632	53	40	7
Meat	0.65	<0.001	0.063	50	43	7
Processed meat	0.74	<0.001	0.215	88	10	2
Fish and seafoods	0.72	<0.001	0.869	62	35	3
Eggs and egg products	0.77	<0.001	0.224	28	55	17
Fried and fast food	0.48	<0.001	0.081	52	33	15
Yam and potatoes	0.37	0.004	0.619	45	45	10
Soups	0.66	<0.001	0.361	48	45	7
Stew	0.62	<0.001	0.174	47	47	7
Nuts and seeds	0.71	<0.001	0.862	66	31	3
Desserts and sweets	0.47	<0.001	0.237	64	26	10
Soft drinks	0.65	<0.001	0.806	69	29	2
Alcoholic drinks	0.63	<0.001	0.287	88	12	0
Tea and coffee	0.55	<0.001	0.501	48	38	14
Milk & milk drinks	0.75	<0.001	0.338	67	26	7
Fats and oils	0.20	0.135	<0.001	22	59	19
Salt and seasonings	0.22	0.154	0.968	17	24	59

¹ Gross misclassification, disagreement by three quartiles, r_s : Spearman's correlation coefficient, ^a: p -value of Spearman's Rank correlation coefficients, ^b p -value: p -value for Wilcoxon signed-rank test of difference. FFQ: Food Frequency Questionnaire; 24DR: 24-hour dietary recalls

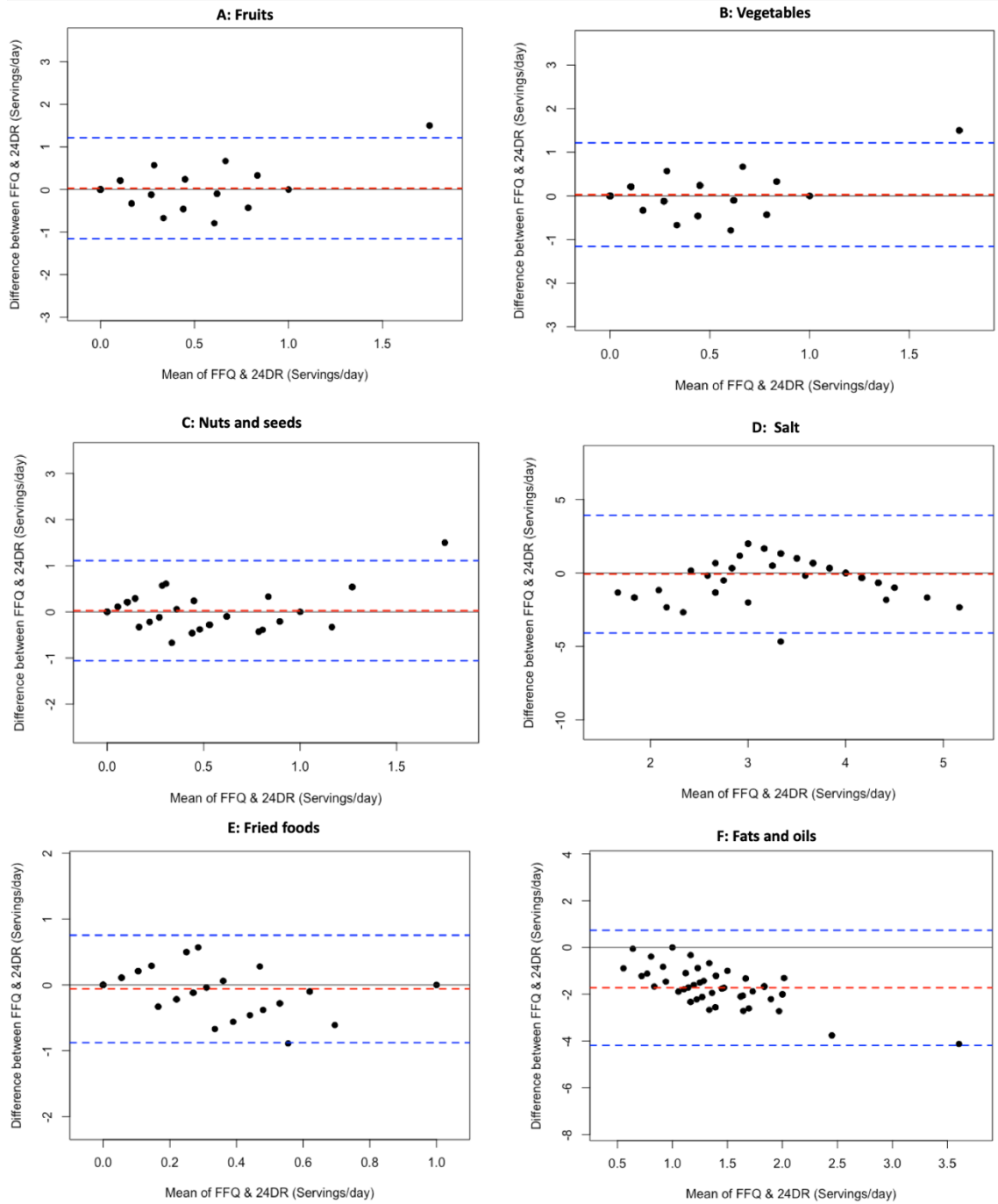


Figure 4. 2. Bland-Altman plots related to food groups identified in the DASH diet.

A: Fruit, B: Vegetables, C: Nuts and seeds and D: Salts, E: Fried and fast foods and F: Fats and oils. Differences in the serving/day of food groups derived from the mean of the three repeat 24-hour recalls (24DR) and the mean of the food frequency questionnaire (FFQ) were plotted against the corresponding mean serving/day derived from the two methods. Dashed red lines represent the mean difference (bias), and dashed blue lines show the upper and lower 95% limits of agreement (n=58).

Table 4. 5. Reproducibility on the number of food group serving/day estimated by repeated administration of a Food Frequency Questionnaire

Food Groups (Servings/day)	FFQ1			FFQ2			Reproducibility (FFQ1 and FFQ2)			
	Mean	Median	IQR	Mean	Median	IQR	r_s	* p -value	ICC	95%CI
Fruit	0.38	0.21	0.57	0.39	0.21	0.57	0.90	0.750	0.98	0.96; 0.98
Vegetables	0.49	0.21	0.36	0.46	0.21	0.36	0.84	0.154	0.92	0.88; 0.95
Grains	0.43	0.21	0.57	0.42	0.21	0.57	0.70	0.577	0.72	0.64; 0.79
Beans and lentils	0.32	0.21	0.36	0.33	0.21	0.36	0.91	0.479	0.87	0.80; 0.92
Meat	0.59	0.57	0.79	0.56	0.57	0.79	0.83	0.123	0.85	0.80; 0.90
Processed meat	0.16	0.00	0.21	0.15	0.00	0.21	0.79	0.751	0.87	0.79; 0.92
Fish and seafoods	0.65	0.39	0.79	0.58	0.39	0.79	0.79	0.166	0.80	0.68; 0.88
Eggs and egg products	0.31	0.21	0.36	0.33	0.21	0.36	0.85	0.590	0.79	0.66; 0.87
Fried and fast foods	0.26	0.21	0.48	0.22	0.21	0.21	0.76	0.203	0.73	0.59; 0.83
Yam and potatoes	0.29	0.21	0.27	0.32	0.21	0.00	0.38	0.886	0.55	0.34; 0.71
Soups	0.35	0.21	0.36	0.21	0.21	0.36	0.65	0.783	0.75	0.69; 0.80
Stew	0.45	0.39	0.36	0.46	0.21	0.36	0.53	0.867	0.31	0.06; 0.53
Nuts and seeds	0.54	0.21	0.36	0.39	0.21	0.36	0.68	0.099	0.50	0.28; 0.67
Desserts & sweets	0.19	0.00	0.21	0.19	0.00	0.21	0.55	0.746	0.45	0.21; 0.63
Soft drinks	0.23	0.00	0.21	0.21	0.00	0.21	0.87	0.290	0.92	0.89; 0.95
Alcoholic drinks	0.04	0.00	0.00	0.03	0.00	0.00	0.71	0.773	0.94	0.91; 0.97
Tea and coffee	0.38	0.21	0.36	0.39	0.21	0.57	0.73	0.944	0.73	0.58; 0.83
Milk & milk drinks	0.44	0.21	0.36	0.46	0.39	0.36	0.92	1.000	0.95	0.92; 0.97
Fats and oils	0.57	0.57	0.79	0.57	0.57	0.79	0.62	0.985	0.72	0.57; 0.82
Salt and seasonings	0.83	1.00	0.29	0.81	1.00	0.29	0.97	0.371	0.96	0.94; 0.98

*FFQ1: First Food Frequency Questionnaire administration, FFQ2: Second Food Frequency Questionnaire administration, ICC: Intraclass correlation coefficients ($p < 0.05$), CI= Confidence interval of ICC, r_s : Spearman's rank correlation coefficient, IQR: Interquartile range, * p -value for the test of the difference between FFQ1 and FFQ2 by Wilcoxon signed-rank test.*

4.4.4. Assessment of reproducibility

Assessing reproducibility between the two administrations of the FFQ, Spearman's ranked correlation coefficient ranged from 0.38 for yam and potatoes to 0.97 for salt, with an average correlation coefficient of 0.75, with most food groups (17/20) showing correlation coefficients above 0.60. All correlation coefficients were statistically significant ($p < 0.001$), reaffirming the high level of agreement between the two FFQs (**Table 4.5**). Additionally, among the 20 food groups evaluated for reproducibility, no significant differences in the mean and median intakes between the FFQ1 and FFQ2 were observed in the Wilcoxon signed-rank test for all the food groups ($p > 0.05$) (**Table 4.5**). Furthermore, the intraclass correlation coefficient (ICC) was used to evaluate the consistency and agreement between the FFQ1 and FFQ2 (**Table 4.5**). ICCs ranged from 0.31 for stew to 0.98 for fruit, with an average intraclass correlation coefficient of 0.77. The majority of food groups ($n=16$) had $ICC \geq 0.70$, which, according to the criteria of Koo and Li and Cade et al., indicates good to excellent reproducibility (**Table 4.5**) (Cade et al., 2002; Koo and Li, 2016). These findings suggest good reproducibility and consistency in individual rankings and negligible between time points for the FFQ, confirming the test-retest reliability of the FFQ across the food groups evaluated.

4.5. Discussion

This study is the first to validate a rapid culturally-appropriate Food Frequency Questionnaire (FFQ) for dietary screening of men and women for high-risk dietary behaviour associated with hypertension in a Nigerian clinic. Our aim is for the tool to be used by clinicians and patients across West Africa, with adjustment according to local diet to: (i) estimate dietary intake in routine clinical care, (ii) facilitate discussions of dietary behaviours and cardiovascular health in the clinical setting; (iii) inform personalised dietary advice for patients at risk or with hypertension; and (iv) empower its citizens to take an active role in preventing and managing hypertension. With the participation of 58 men and women, the FFQ demonstrated good validity and reproducibility in a clinical setting for estimating dietary intakes associated with hypertension in Nigeria, compared to 24DR. The validated and rapid culturally-appropriate Food Frequency Questionnaire is now called the Nigerian dietary screening tool (NiDST) for hypertension.

4.5.1. Relative validation

In all validation studies, some under- and over-estimation is expected but must be within an acceptable range. Streppel et al. evaluated the validity of an FFQ against the 24DR among 128 Dutch adults and reported overestimation in 13 of 21 foods by the FFQ

(Streppel et al., 2013). In addition, Steinemann et al. also reported overestimation in 13 of 25 foods compared to a 4-day weighed food record among 56 participants in Germany, with correlation coefficients ranging from 0.09 (soup) to 0.92 (alcohol) with 16 out of the 25 food groups having correlation coefficients <0.50 (Steinemann et al., 2017). Our FFQ demonstrated similar measures of overestimation from 4-25% and correlation coefficients between the FFQ and 24DR from 0.20 to 0.78, with the majority of the food groups ($n=15$) demonstrating moderate to strong positive correlations ($r_s>0.50$), indicating good agreement. Additionally, our study reported that 90% of participants were classified into the same or neighbouring quartiles when comparing FFQ and 24DR. The exact agreement for most food groups (17/27) was 30-88%, with an average gross misclassification of 11% across food groups. These findings are in agreement with other successful validation studies in Australia ($n=96$ adults) that reported 27-70% exact agreement and under 15% gross misclassification for most food groups (Marks et al., 2006; Wong et al., 2012).

The Bland-Altman method (Bland and Altman, 1986) was used to illustrate the agreement between the FFQ and 24DR. Although 'Fats and oils' and salt were underestimated by the FFQ, as noted in other studies, the majority of the food groups assessed in our study demonstrated minimal bias (Yun et al., 2009). Indeed, $>96\%$ of observations were within acceptable limits of agreement. This aligns with or exceeds the results of previous work, where FFQ validations study among (i) 130 men with prostate cancer reported similar small mean differences and acceptable agreements across 11 food groups; and (ii) 114 Lebanese adults with $>80\%$ agreement for the majority of the food groups (Aoun et al., 2019; Savija et al., 2021). Collectively, these results suggest that the validity of our novel FFQ meets or exceeds the levels of agreement reported by other validation studies and indicates that our tailored FFQ is well-designed for capturing the dietary habits of men and women in Nigerian populations.

4.5.2. Reproducibility

The reproducibility of a Food Frequency Questionnaire (FFQ) is an important attribute for minimising bias in estimating dietary intake with FFQ (Willett, W.C. et al., 1985). The FFQ exhibited commendable reproducibility between the two collection points (FFQ1 vs FFQ2), yielding a robust positive correlation that surpassed $r_s > 0.50$ for the majority of food groups and intraclass correlation coefficient > 0.70 for the majority of the food groups. These findings align with the results of other FFQ reproducibility studies that reported correlation coefficients between 0.32 and 0.87 and 0.65 to 0.98 and agree with current recommended standards for reproducibility between 0.5 and 0.70 (Cade et al.,

2002; Baranowski and Willett, 2012; Fallaize et al., 2014; Koo and Li, 2016; Aoun et al., 2019; Savija et al., 2021). According to these criteria, our novel FFQ demonstrated good levels of agreement between baseline and follow-up. This suggests the FFQ is well suited for accurately collecting dietary information and capturing dietary inconsistencies in Nigeria for clinicians, researchers, and public health professionals (Willett, W.C. et al., 1985; Lee et al., 1995).

4.5.3. Practical application and clinical relevance

The validity and reproducibility of our study data provide compelling evidence to further investigate the implementation and use of our FFQ as a valid Nigerian dietary screening tool (NiDST) for clinical use to screen and evaluate patient-mediated dietary risk for hypertension and can be adapted for other cardiovascular diseases. The NiDST was able to rank intakes of food groups associated with hypertension, including fruits, vegetables, grains, dairy, salt and fats and oil-based foods (soups and stew), to a similar degree of accuracy as 24-hour dietary recall, but was able to be completed in < 10 minutes (Schwingshackl et al., 2017; Batubo et al., 2023; Batubo et al., 2024). The results indicate that the NiDST can identify patients with high-risk dietary patterns who may benefit from prioritised education and support around dietary modification for blood pressure management. Integrating this rapid dietary screening tool into primary and tertiary care workflows will be a key step in enabling a systematic approach to dietary monitoring and counselling in a clinical setting for hypertension prevention and management (Batubo et al., 2024).

4.5.4. Strengths and limitations

Although the study results underline the strength and potential of the Nigerian dietary screening tool (NiDST) in a clinical setting, we openly acknowledge some limitations: (i) 24DR has inherent limitations, including possible recall biases and within-person variability in daily intake, which can attenuate validation study results (Gibson et al., 2017). However, we aimed to reduce this by having a designated professional perform all 24DR evaluations and the use of repeat recalls on non-consecutive days, including two weekdays and one weekend day, which also mitigates this intra-individual variation; (ii) the use of a non-random, convenience sample may restrict the generalizability of findings to the broader target population; however, as this tool will be used in a clinical setting we foresee this limitation as minor and inherent to the tool's primary purpose; (iii) literacy barriers among some participants required interviews instead of self-administration, which could have impacted their responses in the form of respondent bias/social

desirability; and finally (iv) testing the NiDST in a relatively small geographic area reduces the applicability of results more widely across diverse Nigerian populations, which is something we aim to address in future work.

Nonetheless, despite these limitations, this study had several important strengths: (i) the use of multiple 24DR as the reference method provided detailed participant-informed dietary intake data and allowed for day-to-day variability to be assessed, thereby strengthening the quality of the reference data; (ii) the use of multiple analytical methods permitted a comprehensive assessment of the agreement between the FFQ and the 24DR; (iii) evaluation of the reproducibility or test-retest reliability of the FFQ two weeks apart permitted the reliability and consistency of the FFQ to be estimated over time, which will offer a better measure of habitual dietary habits; and finally (iv) testing the FFQ in the patient demographic, clinical setting and cultural context of its intended use improves the applicability of the validation.

4.5.5. Conclusion

This study provides important evidence that the novel Nigerian dietary screening tool (NiDST) has good relative validity and reproducibility for ranking dietary intake of major foods and food groups in a clinical setting, compared to the average of three repeat non-consecutive 24DR. Therefore, we offer a valid and reliable NiDST that could help assess common food group intakes for the assessment and prevention of hypertension, which could empower clinicians, patients, and researchers to take an active role in preventing hypertension in Nigeria and other West African countries. Further refinements of the tool and future studies on the implementation strategies of the NiDST will improve validity for some food groups.

4.6. Chapter summary

This chapter of the PhD presented the research on phase two of study two, which aims to assess the agreement between the Food Frequency Questionnaire (FFQ) and multiple 24-hour dietary recalls for estimating dietary intake among adult patients in Nigeria within a clinical setting. The main objective of this phase was to evaluate the relative validity and reproducibility of the FFQ compared to multiple repeat 24-hour dietary recalls in assessing dietary intake among adult patients in Nigeria. This involved comparing the data obtained from the FFQ with data obtained from multiple 24-hour dietary recalls to determine the accuracy and consistency of the FFQ in estimating dietary intake. The findings demonstrated a moderate to strong agreement between the FFQ and multiple 24-hour dietary recalls, indicating that the FFQ is a valid and reproducible tool for estimating

dietary intake among adult patients in Nigeria within a clinical setting. The validated FFQ was termed the Nigerian dietary screening tool (NiDST). This suggests that the NiDST could be a practical and effective tool for assessing dietary intake in clinical practice in Nigeria. This phase two of study two builds upon the findings from study one (*Chapter two*) and phase one of study two (*Chapter three*), where the NiDST was developed and assessed for feasibility and acceptability, respectively. Further research requires simplifying the tool to support clinicians in quickly identifying individuals at risk of hypertension and stratifying them into low and high risk based on their dietary risk level to offer personalised dietary advice. This is addressed by constructing and validating a diet risk score using the NiDST as a dietary assessment tool in study three, described in the next chapter of this thesis.

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Chapter five

Evaluating Modifiable Hypertension Risk in Nigerian Adults — The Nigerian Diet Risk Score

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5.1. Abstract

Background and aims: Hypertension affects more than 1 in 3 Nigerian adults. Dietary screening tools can empower clinicians and patients to moderate hypertension risk. We derived a new score for clinical use in Nigeria to screen for modifiable hypertension risk and evaluated its association against a panel of biomarkers.

Methods: The Nigerian dietary screening tool (NiDST) was used to collect dietary intake data from participants ($n=151$) visiting the River State University Teaching Hospital, Port Harcourt, Nigeria, for routine medical care. Blood samples were collected from a subsample ($n=94$) for biomarker assessment. Multiple logistic regression was used to derive the Nigerian diet risk score for hypertension (NiDRS). Internal validation of the NiDRS was performed using measures of discrimination and calibration. Mediation analysis was used to evaluate the biomarker-mediated effects of NiDRS on hypertension. All statistical analyses were performed in R computing environment.

Results: Each incremental increase in NiDRS was associated with a 2-fold increase in odds of hypertension (OR: 2.04, 95%CI: 1.16, 3.58, $p=0.01$), with the highest score associated with >18-fold increased odds of hypertension, compared to lowest NiDRS. The score demonstrated good discrimination (ROC c-statistic 0.91, 95% CI: 0.80, 1.00) with a high sensitivity (0.85) and specificity (0.94). Additionally, mediation analysis demonstrated that total cholesterol (50%), triglycerides (47%), LDL-C (49%), VLDL-C (17%), CRP (68%), and homocysteine (71%) were mediators of the NiDRS-hypertension pathway.

Conclusion: This study is the first to test and validate a culturally-appropriate dietary risk score tailored for assessing dietary habits associated with high-risk hypertension among men and women in Nigeria. The resulting NiDRS is a valuable tool for clinicians to identify individuals at risk of hypertension and will advance community efforts in the prevention and management of hypertension in Nigeria.

Keywords: diet risk score, hypertension, clinical practice, Nigeria, biomarkers, mediation analysis

5.2. Introduction

Cardiovascular diseases account for 31% of all global deaths, including low- and middle-income countries (LMICs), the majority (80%) of which are associated with hypertension (Mozaffarian et al., 2014; Schutte et al., 2021). As of 2019, the African region reported the highest prevalence of hypertension (35.5%), with more than 1 in 4 adults (i.e., over 150 million) (Parati et al., 2022; World Health Organization, 2024). Similarly, the prevalence of hypertension among Nigerian adults was 36.1% (World Health Organization, 2024). Additionally, unlike Western countries that have reported a 6-11% decline in hypertension rates since 2010 (Conor Stewart, 2022; Zhang, M. et al., 2023), the prevalence of hypertension in West African countries has increased (Adeloye et al., 2015). In Nigeria, hypertension increased from 11.2% to 36.1% between 1990 and 2019 (Adeloye et al., 2015; World Health Organization, 2024). Consequently, a 53% proportional increase in mortality from hypertension has been observed in Nigeria (13.4 per 100,000 in 1990 to 20.5 per 100,000 in 2015 age-adjusted death rate) (GBD Causes of Death Collaborators, 2017). These data underline the urgent need for targeted prevention and management strategies.

Dietary habits, including high intakes of salt/sodium and processed meat and low intakes of vegetables, fruits, dietary fibre, and nutrients such as potassium and omega-3 fatty acids, are estimated to account for 9–17% of cases of hypertension worldwide (Mozaffarian et al., 2014; Micha et al., 2017; Batubo et al., 2023). In West Africa, the Stroke Investigation Research and Educational Network (SIREN) study in Nigeria and Ghana confirmed that diets rich in whole grains and fruit drinks were associated with lower odds of hypertension, whereas higher consumption of processed foods was associated with higher odds of hypertension (Akpa et al., 2022). Furthermore, recent meta-analyses of 31 observational studies ($n=48809$ participants) also suggest that staple foods unique to West Africa, including Nigeria, are important mediators of hypertension risk (Batubo et al., 2023). Therefore, interventions aimed at dietary habits offer a key opportunity to modify hypertension risk in West Africa.

Risk stratification tools assess the combined impact of various disease risk factors to estimate an individual's overall risk. Such tools can improve risk prediction compared to clinician assessment alone and empower patients to minimise their level of risk (Kashani et al., 2016). Framingham and INTERHEART scores are well-known cardiovascular

disease risk tools for large, diverse populations, and the DASH, xMed, and Healthy Eating Indices correlate well with hypertension (Kennedy et al., 1995; Kwan et al., 2013; Shams-White et al., 2023). However, neither is ideal for populations with unique dietary habits or cultural practices that influence hypertension risk, as observed in Nigeria (Oguoma et al., 2015; Odunaiya et al., 2021; Batubo et al., 2023). This suggests that a culturally informed dietary risk score would support clinicians and other health professionals in empowering patients in Nigeria to manage and, consequently, lower the prevalence of hypertension.

Thus, this study aimed to: (i) derive and test the utility of a dietary risk score (NiDRS) for hypertension in Nigeria and (ii) evaluate the NiDRS alongside a panel of clinical predictors and biomarkers for hypertension.

5.3. Materials and methods

5.3.1. Study design and setting

This study was a single-centre, cross-sectional study of consenting adults visiting the River State University Teaching Hospital (RSUTH) in Port Harcourt, Rivers State, Nigeria, for routine medical care. This hospital was selected as it is a centrally located referral centre for a large region, including Rivers State and the neighbouring Bayelsa, Abia and Akwa-Ibom States, with diverse patient demographics. The study protocol was reviewed and approved by both RSUTH (RSUTH/REC/2023316 on 30/03/2023) and the University of Leeds (AREA FREC #0484 on 28/04/2023) ethics committees and registered a priori at *clinicaltrials.gov* (NCT05973760). Our detailed study protocol has also been published (Batubo et al., 2024).

5.3.2. Sample size

The sample size for this study was determined based on Cohen's guidelines for multiple regression analysis, whereby f^2 values of 0.02, 0.15, and 0.35 represent small, medium, and large effect sizes, respectively (Cohen, 2013). Accordingly, a medium effect size (Cohen's f^2 value = 0.15) was used to estimate the sample size along with a statistical power of $P = 0.8$, a 95% confidence interval, and a two-tailed alpha level of 0.05 and estimated five predictors, utilising the G*Power software (Faul et al., 2009). A minimum sample size of 92 participants was calculated as sufficient to detect a medium effect size of $f^2 = 0.15$ for regression with five predictors (Green, 1991). To accommodate an anticipated dropout rate of 20% and address any potential missing or incomplete data, we set the target sample size at 120 participants (Thabane et al., 2010; Gupta et al., 2016).

5.3.3. Eligibility criteria

Our study enrolled male and female adult participants aged 18 and 70 who visited the RSUTH for routine medical care and had been residents in Nigeria for at least two years at the time of recruitment. Participants were also eligible to participate if they possessed proficiency in reading, writing, and communicating in English or were comfortable with a Pidgin-English translator. Conversely, potential participants were excluded from the study based on criteria presented in **Table 5.1**.

Table 5. 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Age between 18 and 70 years	Individuals < 18 years or > 70 years of age
Men and women	Pregnant or breastfeeding women, or those intending to become pregnant
Hypertensive or non-hypertensive individuals	Diagnosis of other chronic diseases such as cancer, diabetes, renal failure, endocrine diseases, and previous and recent incidence of cardiovascular disease (CVD) and stroke
Individuals who have been residents in Nigeria for the past 2 years	Individuals who have been resident in Nigeria for less than 2 years
Ability to read, write, and communicate over the phone in English	Individuals on dietary restrictions or with recent changes to their diet or food
Individuals who gave their consent to participate	Individuals who did not give their consent to participate or were currently enrolled in other studies

5.3.4. Participant recruitment and informed consent

Participants were recruited over three weeks in December 2023 at the Internal Medicine and Family Medicine Department outpatient clinics to ensure that a diverse and representative sample of individuals at risk of hypertension was captured. Participants were recruited using a non-probability convenience sampling method, incorporating direct and indirect approaches. Specifically, recruitment posters and recruitment fliers were strategically placed within the hospital premises, and morning briefing sessions at the outpatient clinics of the Internal Medicine and Family Medicine Departments of RSUTH aided in the direct recruitment of study participants. In addition, through healthcare professionals' information fliers, some participants were referred to the study team by healthcare professionals. All those expressing interest in the study were screened for eligibility using a structured questionnaire with the inclusion and exclusion criteria (**Table 5.1**). Those eligible were provided a Participant Information Sheet (PIS) and consent form, which they read and had the opportunity to raise any queries or concerns with the study team to ensure that their participation was both informed and voluntary. Only adults providing written informed consent could take part in the study. The

hypertension state of all participants was blinded to minimise researcher bias, and the study adhered to CONSORT guidelines for reporting clinical trials (Schulz et al., 2010).

5.3.5. Participant compensation

The participants who completed all the requirements of the study protocol, i.e., dietary assessment (FFQ), physical measurements (weight, height, and blood pressure), and blood samples, were given a token of appreciation in the form of a £20 gift. This was extended to participants as a gesture of gratitude for their participation and valuable time. Participants were blinded on this payment until after the completion of the study and did not affect the compliance and decision of the participants.

5.3.6. Clinical assessment

Participants' height, weight, waist circumference, and resting blood pressure were measured by trained clinical staff using standardised protocols. Height was measured to the nearest 0.1 cm and weight to the nearest 0.1 kg using a standard stadiometer (model number: DG2301, China). Participant's body mass index (BMI) was calculated by dividing their weight in kilograms by their height in metres squared. Waist circumference was measured to the nearest 0.1 cm at the midpoint between the bottom of the rib cage and above the top of the iliac crest. The average of three resting blood pressure measurements was obtained at the dominant arm using an automated mercury sphygmomanometer (model number: ZK-BB68, Shenzhen, China), with the participant seated comfortably for 5 minutes before measurement. Mean arterial pressure (MAP) was calculated from the average value of the systolic and diastolic blood pressure using the formula ($\text{MAP} = \text{diastolic blood pressure} + 1/3(\text{systolic blood pressure} - \text{diastolic blood pressure})$). MAP was selected as our primary outcome measure because of its performance to more accurately predict hypertension compared to systolic or diastolic blood pressure separately (Kundu et al., 2017; Kandil et al., 2023).

5.3.7. Dietary assessment

The Nigerian dietary screening tool (NiDST), a validated 25-item semi-quantitative food frequency questionnaire (FFQ) designed for a Nigerian population, was used to quantify participants' usual dietary intake over the past month (Batubo et al., 2024; Batubo et al., 2024). The tool consists of 25 questions (**Table S5.1**) on 23 food groups (fruits, vegetables, fibre-breakfast cereals, rice and pasta, eggs, nuts and seeds, fish, beans, starchy tubers, fried or fast foods, whole meat, white meat, processed meat, soft drinks, alcoholic drinks, tea and coffee, soups and stew, dessert and sweets, fats and oils, salt,

milk and milk-based beverages), with two additional questions on salt and seasonings, which have been strongly associated with hypertension in West Africa (Batubo et al., 2023). For each food group, participants reported the frequency of consumption over the past month, with response options ranging from “rarely or never”, “1-2 times/week”, “3-5 times/week”, “daily”, “1-2 times/day”, “3-4 times/day”, and “5+ times/day” (**Table S5.1**). Frequencies of intakes were converted into servings/day by multiplying the average servings per week and then dividing the average by seven (7) days according to the method by Fatihah et al. (Fatihah et al., 2015). For example, 3-5 times/ week was converted ($[3+5/2] \div 7$ days) into 0.57 serving/day.

5.3.8. Collection and analysis of biomarkers

5.3.8.1. Primary outcomes

Consenting participants visited the laboratory at Rivers State University Teaching Hospitals (RSUTH) after a 12-hour overnight fast, where a trained phlebotomist collected a 10 mL blood sample from the antecubital vein in serum separator tubes. Within two hours of collection, whole blood samples were centrifuged at 3000 rotations per minute for 10 minutes to separate serum. Aliquots of serum were prepared and immediately stored at -80°C until analysis. Low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), very low-density lipoprotein cholesterol (VLDL-C), total cholesterol (TC), triglycerides (TG), electrolytes (e.g., sodium, potassium, calcium, and magnesium), and inflammatory markers (e.g., high-sensitivity C-reactive protein (CRP) and homocysteine) were measured from serum samples in the Clinical Chemistry Laboratory at RSUTH using standard clinical and automated methods (Omunakwe et al., 2020). High-sensitivity C-reactive protein (CRP) was measured by immunoturbidimetric assay (Roberts et al., 2001), while serum homocysteine (HCY), sodium, potassium, calcium, and magnesium were measured photometrically on an A25 Biosystems analyser (BioSystems S.A., Barcelona, Spain) (BioSystems S.A, 2007). TC, TG, and HDL-C were measured enzymatically on a Cobas c 5001 analyser (Roche Diagnostics, Indianapolis, IN) (Roche Diagnostics, 2015). LDL-C and VLDL-C were calculated using the Friedewald equation (Friedewald et al., 1972). All samples were analysed in duplicate with mean values reported.

Biomarkers were selected for their association with hypertension. High levels of LDL-C, TG, CRP, and homocysteine and low levels of HDL-C are often associated with elevated risk of hypertension and cardiovascular disease events (Davey Smith et al., 2005; Zhang, Y. et al., 2019; Zhang, Z.Y. et al., 2021; Chen, S. and Cheng, 2022; Chen, X. et al., 2022;

van Apeldoorn et al., 2022; Al Hageh et al., 2023). Excessive serum sodium prompts fluid retention and elevated blood pressure, amplifying the risk of hypertension and cardiovascular events (He et al., 2005; Cole et al., 2019), whereas high levels of magnesium (Correa et al., 2021; Ferre et al., 2023) and potassium (D'Elia et al., 2011; Aburto et al., 2013) may lower blood pressure and reduce the risk of hypertension, with protective effects against arrhythmias, endothelial dysfunction and atherosclerosis. We aimed to evaluate and elucidate the roles of these dietary nutrients and serum metabolites along the diet-hypertension pathway.

5.3.8.2. Secondary outcomes

Previous studies have demonstrated that atherogenic indices derived from lipid profile parameters have an enhanced predictive capacity for cardiovascular disease (Kinosian et al., 1994). The Atherogenic Index of Plasma (AIP) and the Atherogenic Coefficient (AC) are robust predictors of atherosclerosis and coronary heart disease, especially in large arteries like the aorta, with AIP also indicating risk for peripheral artery disease (PAD) and aortic atherosclerosis (Dobiasova and Frohlich, 2001; Dobiasova, 2006; Sujatha and Kavitha, 2017). Similarly, the cardiac risk ratio (CRR) estimates the likelihood of coronary artery disease (CAD) and other ischemic heart conditions (Kinosian et al., 1994). The Castelli Risk Index I and II (CRI-I & II) integrates both atherogenic and anti-atherogenic lipid fractions to predict a spectrum of cardiovascular disease (CVD) events, encompassing CAD, stroke, and peripheral vascular disease (Sujatha and Kavitha, 2017). Lastly, the Total HDL-C Cholesterol ratio (THDL) is crucial for evaluating CAD and acute coronary syndromes, which are linked to reduced plaque formation and improved cardiovascular outcomes (Voight et al., 2012). Several atherogenic indices were calculated (as secondary outcomes) from the measured lipid profile biomarkers to further assess cardiovascular risk in our study. AIP was calculated as $\log(\text{TG}/\text{HDL-C})$ as described by Dobiasova (2004) (Dobiasova, 2006). AC was calculated as $(\text{TC} - \text{HDL-C})/\text{HDL-C}$ (Sujatha and Kavitha, 2017). The Castelli risk index I and II (CRI-I) was calculated as $\text{TC}/\text{HDL-C}$ and (CRI-II: $\text{LDL-C}/\text{HDL-C}$, respectively (Castelli, 1988; Sujatha and Kavitha, 2017), and the total HDL-C cholesterol ratio (THDL) was calculated as $\text{HDL-C}/(\text{TC} - \text{HDL-C})$ (da Luz et al., 2005).

5.3.9. Data analysis

Dietary intake data from each participant's Nigerian dietary screening tool was entered into a Microsoft Excel spreadsheet with quality control checks conducted by two independent researchers to verify accuracy. The normality of continuous variables was

assessed with a visual inspection of the histogram, with non-normal distributions confirmed using the Shapiro-Wilk (Shapiro and Wilk, 1965) or Kolmogorov-Smirnov tests (Massey, 1951). Where data were not normally distributed, non-parametric methods were used for the analysis. The results of descriptive statistics were reported as mean $\pm$ standard deviation (SD), median, and interquartile range (IQR) for continuous data and counts (*n*) and percentage (%) for categorical data. We assessed the significance of associations between variables by performing chi-squared tests for categorical data, paired student t-tests for normally distributed continuous data, and Wilcoxon-ranked signed text for non-normally distributed continuous data. The analyses of the data were stratified by hypertensive (with either a systolic blood pressure ≥ 140 or a diastolic blood pressure ≥ 90 mmHg) and non-hypertensive (with either a systolic blood pressure < 140 or a diastolic blood pressure < 90 mmHg). Additionally, we categorised the food groups into categories commonly defined as “healthy” and unhealthy” by existing dietary food scores associated with hypertension (e.g., DASH, xMED) and quantified the mean intake of all healthy foods and all unhealthy food groups between individuals with hypertension and non-hypertension.

We developed a diet risk score from the NiDST intake data using methods similar to Framingham and INTERHEART for score derivation (Sullivan et al., 2004; McGorrian et al., 2011). Briefly, participants were randomly assigned to either a derivation set (80%) or validation set (20%) stratified by hypertension status (Altman and Royston, 2000). Using the derivative set (80% data set), the association between the 23 food groups and hypertension was individually evaluated in 23 multivariable logistic regression models, adjusted for common covariates (e.g., sex, age, body mass index (BMI), and physical activity level). Correlation matrices and forward stepwise regression models were checked and used to minimise the effect of correlated food groups. Food groups were retained if they were found to be significantly associated with an increased risk of hypertension ($p < 0.05$), and their beta-coefficients (rounded to the nearest integer) were used as ‘weights’ to quantify the individual food group’s contribution to hypertension risk. We developed the dietary risk score by multiplying the weight (beta-coefficient) of each food group by the actual intake reported by each participant for that food item in the validation data set (20% data set). The score for each food group for each participant was then summed to give the total dietary risk score, which we term the Nigerian diet risk score for hypertension (NiDRS).

We used the 2/3 sample quantile to convert the total NiDRS set into the high versus low NiDRS risk category. This approach offered a balanced representation of central tendencies while minimising the impact of outliers in categorising food item intake. The NiDRS was then regressed in the validation set against measures of hypertension to evaluate its generalisability and validity. The predictive performance of the NiDRS was assessed by examining model discrimination and calibration. Discrimination was evaluated using the *c*-statistic from the receiver operating characteristic (ROC) curve analysis (Hanley and McNeil, 1982). Calibration was assessed using the Hosmer-Lemeshow goodness-of-fit test (Hosmer et al., 1997) and Brier score (Brier, 1950). Overall performance was evaluated for accuracy, precision, sensitivity, and specificity. To support clinical decisions (Hlatky et al., 2009), we evaluated the potential clinical utility of risk models by performing the decision curve analysis (DCA) to assess the net benefit (Vickers and Elkin, 2006; Vickers et al., 2016). The weighted net benefit was calculated using the formula: $\text{Prevalence} \times \text{Sensitivity} - (1 - \text{Specificity}) \times (1 - \text{Prevalence}) \times (\text{threshold} / (1 - \text{threshold}))$ (Martin et al., 2018).

We performed a mediation analysis (Jung, 2021) to better understand the roles of CVD biomarkers (mediators) in the relationship between NiDRS (exposure) and the measure of hypertension (mean arterial pressure; MAP) (outcome). Specifically, we used linear regression models to investigate biomarkers that had a significant association with both mean arterial pressure and the NiDRS using the mediation package in R (Tingley et al., 2014). We performed 1000 simulations to estimate the indirect effect (i.e., the effect of NiDRS on MAP through a biomarker), direct effect (i.e., the effect of NiDRS on MAP independent of the biomarker), and total effect (i.e., the sum of the indirect and direct pathways), along with their associated confidence intervals. The proportion mediated is the indirect effect divided by the total effect. A two-sided *p*-value < 0.05 was considered statistically significant, and all analyses were performed using R computing environment (version 4.3.1) (R Core Team, 2020).

5.4. Results

5.4.1. Participant characteristics

Exceeding recruitment targets, 165 consenting adults were enrolled in the study (**Figure 5.1**). Of these, 151 (92%) completed the study protocol (mean age = 44.4 ± 11.1 years), and their data were used for the final analysis. As expected, the hypertensive group had a significantly higher systolic, diastolic, and mean arterial pressure (MAP) compared to the non-hypertensive group (**Table 5.2**). A similar number of men and women were

recruited, but males comprised a larger proportion of the hypertensive group (59.1%) compared to the non-hypertensive group (36.5%). A family history of hypertension was reported by 22.5% of all participants. No significant differences in age, body mass index (BMI), waist circumference, physical activity, employment, education, or marital status were observed between hypertensive and non-hypertensive groups (**Table 5.2**).

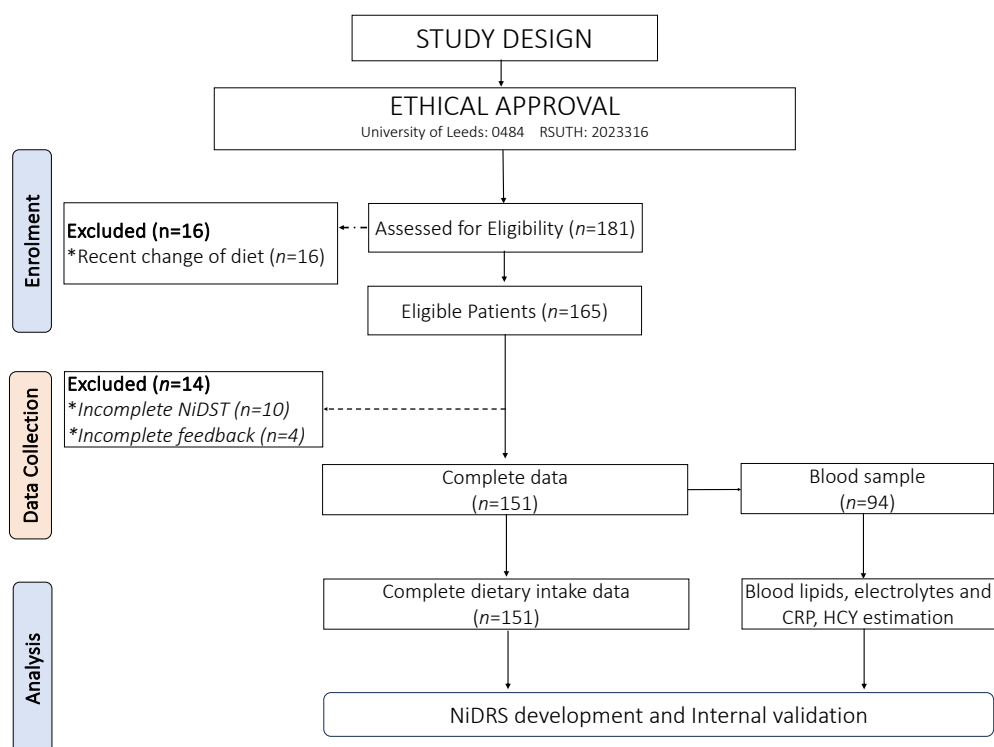


Figure 5. 1. Participant selection flowchart through completion of the Nigerian dietary screening tool (NiDST) and biomarkers estimation.

CRP: C-reactive protein, NiDRS: Nigerian diet risk score, HCY: Homocysteine; n: Number; RSUTH: Rivers State University Teaching Hospital; Blood lipids (such as triglyceride, total cholesterol, low-density lipoprotein, high-density lipoproteins, very low-density lipoprotein) and electrolytes (such as sodium, potassium, calcium, and magnesium).

5.4.2. Food intake assessment

The mean daily intakes (servings/day) of the 23 food groups within the NiDST are shown in **Table 3**. Notably, while reported intakes of the 12 food groups commonly considered “healthy foods” or “non-atherogenic foods” were similar between hypertensive and non-hypertensive participants ($p > 0.05$), hypertensive individuals reported higher intakes of 11 food groups considered “unhealthy foods” compared to non-hypertensive ($p < 0.05$). These unhealthy foods included red meat, eggs, processed meat, fried and fast foods, soup and stews, desserts and sweets, soft drinks, alcoholic drinks, and salt/seasonings (**Table 5.3 and Figure 5.2**). Interestingly, for healthy food intake, the mean intake was largely similar between groups, but the mean intake for unhealthy food groups was significantly greater in quantity by individuals in the hypertensive group (0.59 servings/day) compared to non-hypertensive adults (0.41 servings/day) ($p = 0.002$) (**Table S5.2**), supporting our

central theory that dietary behaviours differ between non-hypertensive and hypertensive individuals.

Table 5. 2. Sociodemographic and clinical characteristics of participants (n=151)

Characteristics	Overall (n=151)	Hypertensive (n=88, 58.3%)	Non-hypertensive (n=63, 41.7%)	*p-value
Sex, n (%)				0.010
Male	75 (49.7)	52 (59.1%)	23 (36.5%)	
Female	76 (50.3)	36 (40.9%)	40 (63.5%)	
Age (years)	44.4±11.1	46.0±10.2	42.1±12.2	0.098
Education, n (%)				0.472
Primary	27 (17.8)	15 (16.0)	12 (19.1)	
Secondary	62 (41.1)	40 (45.5)	22 (34.9)	
Tertiary	62(41.1)	33 (37.5)	29 (46.0)	
Marital Status, n (%)				0.072
Married	119 (78.8)	75 (85.2)	44 (69.8)	
Single	18 (11.9)	6 (6.8)	12 (19.0)	
Widowed	14 (9.3)	7 (8.0)	7 (11.1)	
Employment, n (%)				0.057
Employed	25 (16.6)	14 (15.9)	11 (17.5)	
Retired	9 (6.0)	7 (8.0)	2 (3.2)	
Self-employed	103 (68.2)	63 (71.6)	40 (63.5)	
Student	8 (5.3)	1(0.6)	7 (11.1)	
Unemployed	6 (3.9)	3 (3.4)	3 (4.8)	
Family history of HTN, n (%)	34 (22.5)	26 (29.5)	8 (12.7)	0.013
Physical activity level, n (%)				0.542
Active	23 (15.2)	12 (13.6)	11 (17.5)	
Moderately active	15 (9.9)	7 (8.0)	8 (12.7)	
Moderately inactive	41 (27.2)	27 (30.7)	14 (22.2)	
Inactive	72 (47.7)	42 (47.7)	30 (47.6)	
BMI (kg/m ²)	29.0±6.2	29.1±6.3	29.1±5.7	0.934
Waist circumference (cm)	95.4±14.5	95.5±14.6	96.0±14.2	0.740
Blood pressure (mmHg)				
Systolic blood pressure	142.5±24.2	159.4±15.7	119.0±10.0	<0.001
Diastolic blood pressure	98.0±71.5	113.0±9.8	77.1±7.2	<0.001
Mean arterial pressure	127.7±32.3	143.9±33.3	105.0±8.0	<0.001

HTN: hypertension. * $p < 0.050$ was considered as statistically significant. The results of the chi-square analysis should be interpreted with caution, as the small sub-sample sizes may not provide statistically robust conclusions.

5.4.3. Establishing food weights in Nigerian diet risk score (NiDRS) for hypertension

Multivariate logistic regression models were constructed from the derivation set (80% of study data) to assess the association between each of the 23 food group items (i.e., effect size) and hypertension risk. Eleven food groups, including red meat, processed meat, eggs, fried foods, fast foods, soups and stews, fats and oils, desserts and sweets, soft drinks, alcoholic drinks and salt and seasoning, were significantly associated with hypertension and were retained for the development of the NiDRS. Their beta-

coefficients were rounded to the nearest integer from the derivation data set (**Table 5.4**). No foods commonly considered “healthy” were found to be significantly associated with hypertension.

Table 5. 3. Daily intake of 23 food groups assessed among hypertensive and non-hypertensive adults (n=151)

Food items/groups (servings/day)	Hypertensive (n=88, 58%)			Non-hypertensive (n=63, 42%)			<i>*p-value</i>
	Mean	Median	IQR	Mean	Median	IQR	
Healthy (non-atherogenic) food groups							
Fruits	0.36	0.21	0.36	0.39	0.21	0.36	0.687
Vegetables	0.49	0.57	0.36	0.60	0.57	0.79	0.052
Rice and pasta	0.50	0.57	0.36	0.57	0.57	0.58	0.199
Wheat products	0.53	0.57	0.36	0.55	0.57	0.79	0.913
Fibre-rich cereals	0.02	0.00	0.00	0.08	0.00	0.00	0.005
Beans and lentils	0.38	0.21	0.36	0.44	0.57	0.36	0.199
Nuts and seeds	0.43	0.57	0.36	0.50	0.57	0.36	0.215
White (lean) meat	0.36	0.21	0.36	0.31	0.21	0.36	0.426
Starchy tubers	0.67	0.57	0.43	0.68	0.57	0.43	0.474
Fish and seafoods	0.60	0.57	0.79	0.79	0.57	0.43	0.155
Tea and coffee	0.43	0.57	0.68	0.35	0.21	0.57	0.167
Dairy (Milk)	0.54	0.57	0.79	0.66	0.57	0.79	0.253
Unhealthy (atherogenic) food groups							
Red meat	0.66	0.57	0.43	0.43	0.57	0.36	0.001
Processed meat	0.27	0.21	0.57	0.14	0.00	0.21	0.003
Eggs and egg products	0.40	0.21	0.36	0.23	0.21	0.00	0.001
Fried foods	0.49	0.57	0.36	0.29	0.21	0.36	<0.001
Fast foods	0.40	0.21	0.57	0.26	0.00	0.57	0.005
Soups and stews	0.83	1.00	0.43	0.68	0.57	0.43	0.027
Fats and oils	0.94	1.00	0.43	0.77	1.00	0.43	0.035
Desserts and sweets	0.32	0.21	0.57	0.14	0.21	0.21	0.001
Soft drinks	0.54	0.57	0.79	0.28	0.21	0.36	<0.001
Alcoholic drinks	0.51	0.21	1.00	0.12	0.00	0.21	<0.001
Salt and seasonings	0.92	1.00	0.43	0.71	0.57	0.43	<0.001

*p-value < 0.050 calculated by Wilcoxon signed-rank test was considered statistically significant.

5.4.4. Refinement of NiDRS for hypertension

Based on the estimated weights for each food item from the multivariable logistic regression models, we constructed the Nigerian diet risk score (NiDRS) for the validation dataset (**Table 5.5 and Table S5.3**). The food groups associated with increased odds of hypertension are presented in the first column. The reference intake categories for low and high consumption of each food group (servings/day), self-reported in the FFQ by the participants, and the specific questions to be asked are presented in the second column. Only one answer (i.e., level of frequency intake) is chosen for every question and inserted into the points awarded column. All questions must be answered for the most accurate

risk score estimation. The minimum score of the NiDRS is 0, and the maximum score is 30 for the 11 food groups positively associated with hypertension.

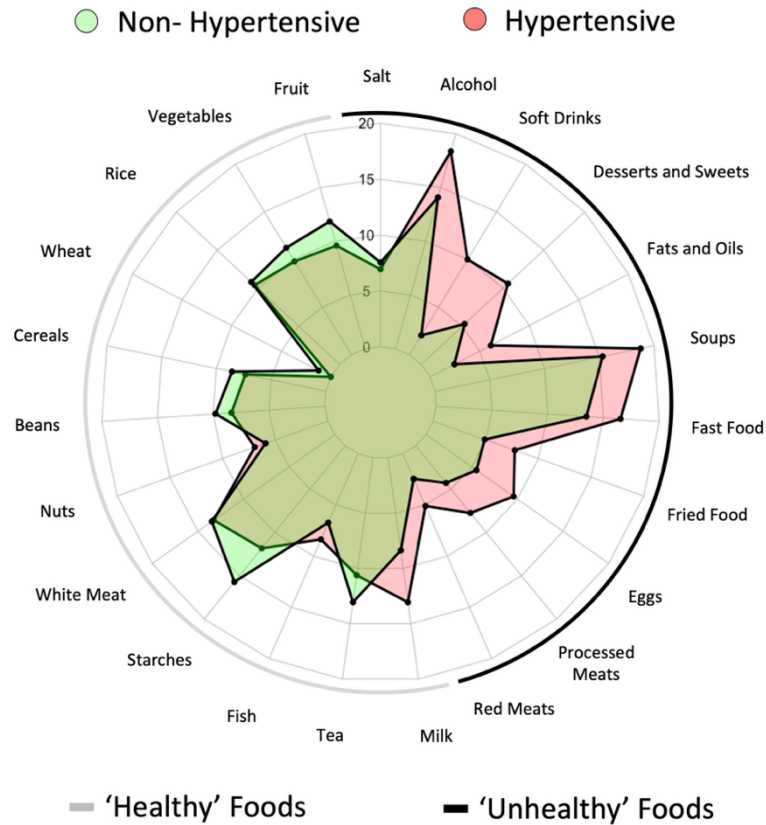


Figure 5. 2. Food group intake among adults with and without hypertension in Nigeria.

This radar plot showcases the skewed dietary intake habits of hypertensive individuals (pink) towards foods commonly considered 'unhealthy (black), compared to non-hypertensive (green) individuals with a more balanced diet of healthy (white) and unhealthy (black) foods.

5.4.5. Validation of the Nigerian diet risk score (NiDRS)

We calculated the developed Nigerian diet risk score (NiDRS) for all individuals in the validation data set ($n=30$) and regressed them against measures of hypertension. The result demonstrated a significant positive association between overall NiDRS and hypertension (OR: 2.04, 95%CI: 1.16, 3.58, $p=0.013$) (Table 5.6). This indicates that for every unit increase in the NiDRS, the odds of hypertension increased by 2.04 times. Additionally, individuals in the highest NiDRS category had a >18-fold increased odds of hypertension compared to those in the lowest category (Table 5.6). Overall, the probability of hypertension increased as the NiDRS increased in the validation data set (Figure 5.3). Checks of collinearity on the final model revealed a variance factor below 5 (IVF=1.43), indicating that collinearity was not present.

The mean NiDRS in the validation dataset was 12.4 ± 4.1 (min=6.6, max=26.3). The mean score was significantly higher ($p=0.021$) in individuals with hypertension (14.6 ± 5.0) compared to the non-hypertensive group (10.7 ± 2.4) (Table 5.6). The assessment of

NiDRS calibration (the Hosmer-Lemeshow test) suggests satisfactory model fit ($X^2=6.9$, $p=0.544$) and risk category model ($X^2=5.1$, $p=0.743$) and good calibration with a Brier score of 0.1 (**Table 5.6**), indicating that the model's predictions align well with the observed data. The discriminative ability of the NiDRS was evaluated using the ROC c -statistic, with an AUC of 92% (95%CI: 80%, 100%) and 87% (95%CI: 75, 100) for the continuous score and risk categories, respectively (**Table 5.6 and Figure 5.4**). The NiDRS demonstrated high accuracy (90%) and precision (92%), along with balanced sensitivity (85%) and a false positive fraction (1-specificity) of 6%. Additionally, as seen in **Figure 5**, the predictive model provides the greatest net benefits of identifying individuals with hypertension for the threshold probability ranging from 2 to 60% compared to the other strategies (treat all and treat none). These results collectively indicate good robustness and reliability of the NiDRS in identifying individuals at risk of hypertension.

Table 5. 4. Association between food groups and hypertension in the NiDRS derivative data set

Food items/groups (servings/day)	β (SE)	OR (95% CI)	* p -value	Weight
Healthy (non-atherogenic) food groups				
Fruits	-0.8 (0.8)	0.5 (0.1, 2.1)	0.326	-1
Vegetables	-1.0 (0.7)	0.4 (0.1, 1.3)	0.117	-1
Rice and pasta	-0.0 (0.7)	1.0 (0.2, 4.0)	0.961	0
Wheat products	0.0 (0.5)	1.0 (0.4, 2.8)	0.979	0
Fibre-rich cereals	-2.3 (1.9)	0.1 (0.0, 3.9)	0.217	-2
Beans and lentils	-0.9 (0.6)	0.4 (0.1, 1.3)	0.134	-1
Nuts and seeds	-1.0 (0.6)	0.4 (0.1, 1.3)	0.116	-1
Tea and Coffee	0.6 (0.6)	1.8 (0.6, 5.6)	0.327	1
Dairy (Milk)	-0.1 (0.2)	0.9 (0.7, 1.3)	0.643	0
Starchy tubers	-0.2 (0.5)	0.8 (0.3, 2.2)	0.701	0
Fish and seafoods	-0.7 (0.5)	0.5 (0.2, 1.2)	0.128	-1
White (lean) meat	1.1 (0.8)	2.9 (0.7, 12.7)	0.156	1
Unhealthy (atherogenic) food groups				
Eggs and egg products	2.6 (0.9)	12.9 (2.3, 71.6)	0.004	3
Red meat	2.5 (0.8)	12.2 (2.7, 54.9)	0.001	3
Processed meat	3.1 (1.1)	22.8 (2.9, 177.0)	0.003	3
Fried foods	3.7 (1.0)	41.0 (6.2, 273.8)	0.0001	4
fast foods	1.8 (0.7)	6.0 (1.6, 21.8)	0.007	2
Soups and stew	1.4 (0.7)	4.1 (1.0, 15.8)	0.042	1
Fats and oils	1.8 (0.7)	6.0 (1.7, 21.8)	0.007	2
Desserts and sweets	2.5 (1.0)	12.7 (1.9, 86.5)	0.009	3
Soft drinks	2.9 (0.8)	17.2 (3.9, 76.4)	0.0002	3
Alcoholic drinks	3.4 (0.9)	30.1 (5.1, 178.6)	0.0002	3
Salt and seasonings	3.3 (0.9)	26.5 (4.7, 150.6)	0.0002	3

Multivariable logistic regression models (adjusted for Age, BMI, physical activity levels and sex) in the derivation data set. Weight represents the value of the beta-coefficient approximated to the nearest integer. β : beta-coefficient, SE: Standard error, OR: Odds ratio, CI: Confidence interval, * $p < 0.050$ was considered as statistically significant.

Table 5. 5. The Nigerian dietary risk score (NiDRS) for hypertension

Dietary risk factors	Frequency questions (ref. intake: low and high)	Points for response	Points awarded
Eggs and egg products (such as Boiled eggs, Fried eggs, Scrambled eggs, and others)?	Never or rarely	0	
	1-2 times/week or more	3	
Red Meat (such as Beef, Sheep, Lamb, Pork, Bush meat and others)?	Less than 3-5 times/week	0	
	3-5 times/week or more	3	
Processed meat (such as Suya, Kilishi, Sausages, Nkwobi, Bacon, Corned beef, Meat pies, Gala, and others)?	Never or rarely	0	
	1-2 times/week or more	3	
Fried foods (such as Akara, Puff-puff, Pancakes, Chin-chin, Buns, Scotch egg, Chips (fried plantain, yam, and potatoes), Samosa, Fried fish, Fried chicken, Fried beef, and others)?	Less than 3-5 times/week	0	
	3-5 times/week or more	4	
Fast foods (such as Restaurant foods, Local roadside food vendors (Mama put), Shawarma, Pizza, Burgers, Fried/jollof rice, Fried chicken, Suya, Small chops, Hot dogs, Beef/chicken/fish rolls, Doughnuts, and others)	Less than 3-5 times/week	0	
	3-5 times/week or more	2	
Soups and stews (such as Egusi, Banga, or Groundnut, Vegetable, Afang, Edikaikong, Bitter leaf, Efo-Riro, Okra, Ogbono, Ewedu, Fisherman, White, Nsala soups and others), and (Palm oil stew, Vegetable oil stew, Sauces, and others)	3-5 times/week or less	0	
	Daily or more	1	
Fats and oils (such as food cooked with palm oil, vegetable oil, butter/margarine/ mayonnaise, lard, shea butter, salad cream, and others)?	3-5 times/week or less	0	
	Daily or more	2	
Desserts and sweets (Ice cream, Yoghurt, Cheese, Biscuits, Cakes, Chocolate, Sweets, and others)	Never or rarely	0	
	1-2 times/week or more	3	
Soft drinks (such as Coke, Fanta, Sprite, Pepsi, Malt, Maltina, Zobo, Tiger nut, Kunu, Smoothies, 5live, Pineapple juice, Energy drinks and others)?	Less than 3-5 times/week	0	
	3-5 times/week or more	3	
Alcoholic drinks (such as Beer, Wine, Gin, Whisky, Spirit, Liquor, Champagne, and others)	Never or rarely	0	
	1-2 times/week or more	3	
Salts and seasonings (such as Salt, Seasoning cubes (e.g., Maggi, Knorr), Sauce (e.g., Soy sauce, Suya sauce, Fish sauce, Oyster sauce), and others)	3-5 times/week or less	0	
	Daily or more	3	
Total		30	

Food groups are presented in the first column, and the specific questions to be asked in the middle column. All questions must be answered for the most accurate risk score estimate. The total minimum score is 0, and the total maximum is 30.

Table 5. 6. Internal validation of the Nigerian dietary risk score (NiDRS)

Characteristics	Validation dataset (n= 30)
NiDRS	
Sex	
Male, n (%)	13 (43.3)
Female, n (%)	17 (56.7)
Age (years), mean (SD)	48.1 (10.8)
Hypertension diagnosis	
Hypertensive, n (%)	13 (43.3)
Non-hypertensive, n (%)	17 (56.7)
Mean risk score	12.4 ±4.1 (min=6.6, max=26.3), $p=0.021$
Hypertensive	14.6±5.0
Non-hypertensive	10.7±2.4
Measures of validation (Continuous risk score)	
Odds ratio (95% CI)	2.0 (1.2, 3.6), $p=0.013$
ROC c statistic (95% CI) (%)	92 (80, 100)
Brier score	0.10
Hosmer-Lemeshow test	$\chi^2=2.8$, $p=0.945$
Accuracy (%)	90.0
Precision (%)	92.0
Sensitivity (TPF) (%)	85.0
Specificity (%)	94.0
NiDRS risk category	
High (score ≤ 11.3)	9.5±1.4 (min= 6.6, max=11.3)
Low (score > 11.3)	15.3±3.9 (min= 11.4, max=26.3)
Measures of validation (Binary risk category)	
OR (95% CI) (ref: low)	18.3 (1.3, 251.2), $p=0.030$
ROC c statistic (95% CI) (%)	87 (75, 100)
Brier score	0.15
Hosmer-Lemeshow test	$\chi^2=5.1$, $p=0.743$
Accuracy (%)	76.7
Precision (%)	75.0
Sensitivity (%)	69.2
Specificity (%)	82.4
1-specificity (%)	17.6

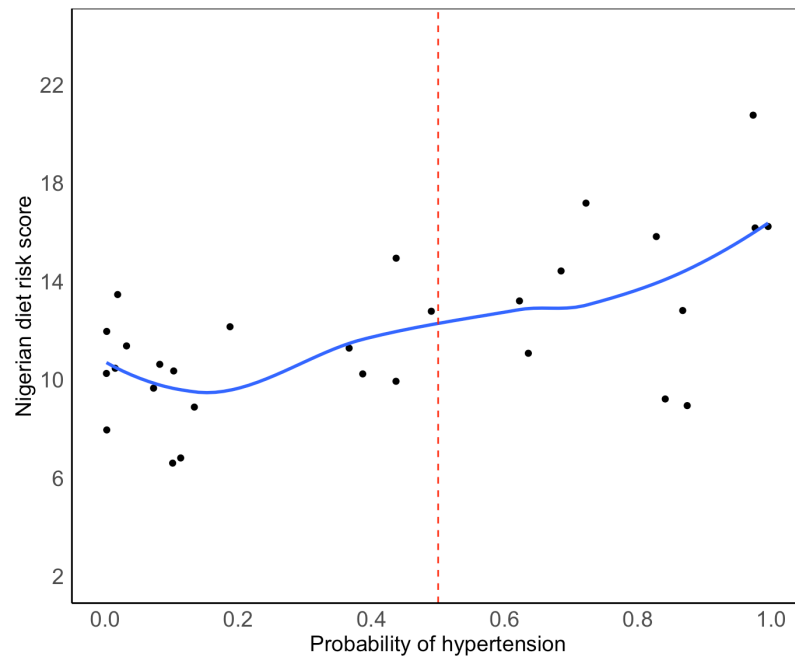


Figure 5. 3. A two-way plot of the Nigerian dietary risk score (NiDRS) and the observed probability of hypertension in the validation data set.

The red dashed line represents the threshold for hypertension status. Scores above the points of the red dashed line are associated with higher odds of hypertension risk.

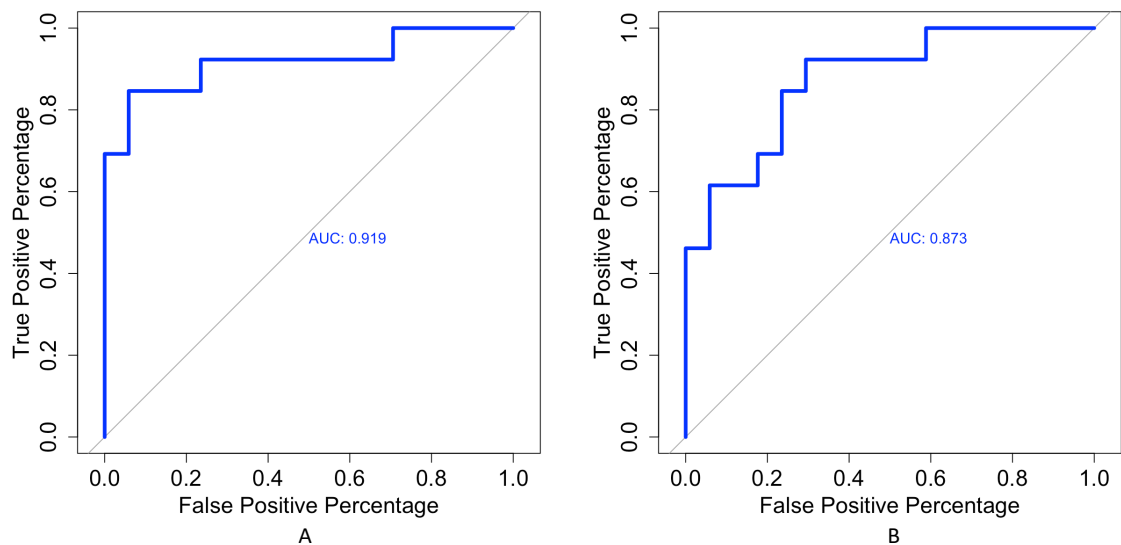


Figure 5. 4. Receiver-operating characteristic curves for the Nigerian dietary risk score (NiDRS) in the validation data set.

A: Risk score, B: Risk score category; AUC: Area under curve.

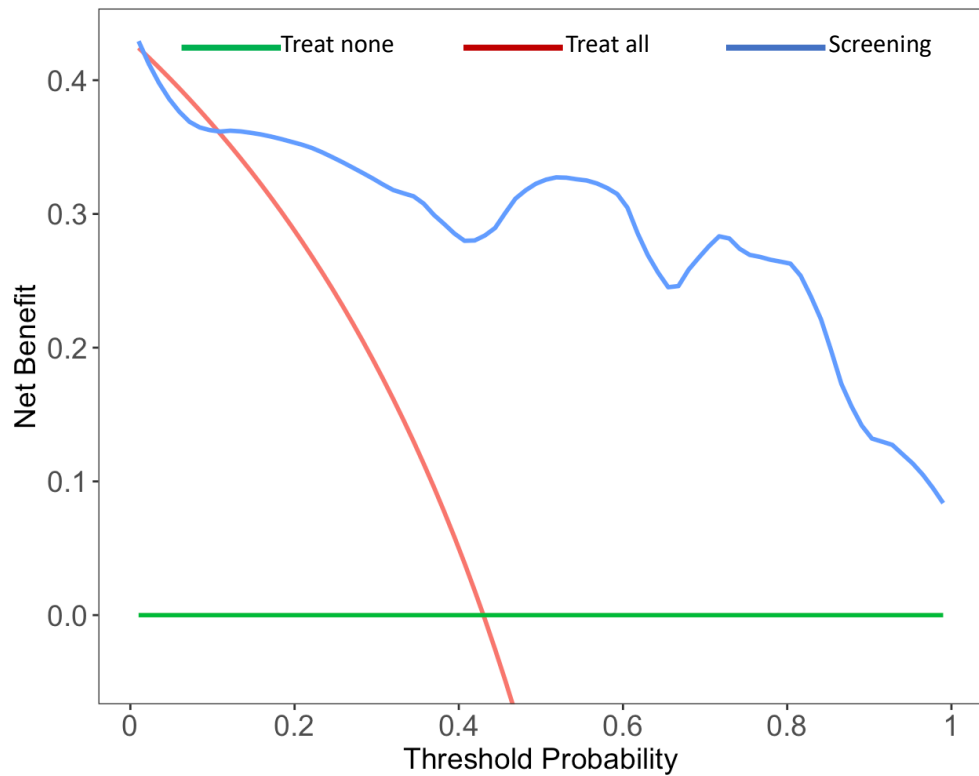


Figure 5.5. Decision curve analysis of NiDRS for prediction of hypertension risk.

Green line: Represents the strategy of no dietary screening with the Nigerian diet risk score (NiDRS). Red line: Represents the strategy of screening all patients with NiDRS. Blue line: Represents the strategy of using the NiDRS multivariable prediction model.

5.4.6. Mediation effect of biomarkers

With a validated NiDRS, the association between diet and hypertension was investigated more closely in the full cohort, where blood samples were collected from 94 eligible consenting adults to analyse blood lipids, electrolytes, and biomarkers of inflammation (**Table 5.7**). As expected, the atherogenic lipid indices, including the atherogenic index of plasma (AIP), atherogenic coefficient (AC), Castelli Risk Index-I/II (CRI-I and II), and triglyceride to high-density lipoprotein cholesterol ratio (THDL), were significantly higher ($p < 0.001$) in hypertensive participants compared to then non-hypertensive participants. This was largely driven by significant differences in blood lipids between the groups: total cholesterol, triglycerides, LDL-C, and VLDL-C were significantly higher in the hypertensive participants ($p < 0.001$) compared to non-hypertensive participants (**Table 5.7**). Inflammatory markers—C-reactive protein (CRP) and homocysteine levels were also significantly higher in the hypertensive group ($p < 0.001$) (**Table 5.7**). Renal function parameters such as creatinine, urea, and serum electrolytes (e.g., sodium, potassium, chloride, bicarbonate, and calcium) did not demonstrate any significant patterns, suggesting that both hypertensive and non-hypertensive individuals do not have renal compromise, except for magnesium ($p = 0.009$) (**Table 5.7**).

Table 5. 7. Biomarkers characteristics of a subset of the study cohort (n=94)

Biomarkers/mediators	Overall (n=94)	Hypertension (n=59)	Non-hypertension (n=35)	*p-value
Fasting lipid profile				
TC (mmol/L),	3.7±1.3	4.2±1.3	2.8±0.6	<0.001
TG (mmol/L)	1.5±0.3	1.7±0.3	1.3±0.2	<0.001
HDL-C (mmol/L)	1.4±0.2	1.5±0.2	1.5±0.2	0.823
LDL-C (mmol/L)	3.2±1.6	3.7±1.5	2.2±1.1	<0.001
VLDL-C (mmol/L)	0.7±0.2	0.7±0.1	0.6±0.1	<0.001
Atherogenic indices				
AIP	0.0±0.1	0.1±0.1	-0.1±0.1	<0.001
AC				
CRI-I	2.6±1.0	2.9±1.0	2.0±0.5	<0.001
CRI-II	2.2±1.2	2.6±1.2	1.5±0.6	<0.001
NHDL-C	2.3±1.3	2.7±1.3	1.4±0.7	<0.001
THDL-C	1.1±0.3	1.2±0.2	0.9±0.1	<0.001
C-reactive protein (mg/dL)	4.4±3.1	6.3±2.3	1.2±0.5	<0.001
Homocysteine (μmol/L)	14.5±5.5	17.8±4.0	9.0±2.2	<0.001
Serum electrolytes				
Sodium (mmol/L)	137.8±15.1	139.1±15.3	135.5±14.8	0.272
Potassium (mmol/L)	3.7±1.0	3.9±1.0	3.5±1.1	0.057
Chloride (mmol/L)	78.4±9.8	78.5±9.8	78.2±9.8	0.890
Bicarbonate (mmol/L)	24.1±3.5	25.3±4.0	24.8±2.6	0.481
Calcium (mmol/L)	2.5±0.4	2.5±0.3	2.6±0.5	0.313
Magnesium (mmol/L)	2.1±0.2	2.1±0.1	2.0±0.2	0.009
Renal function test				
Creatinine (μmol/L)	80.4±17.9	82.5±17.4	76.7±18.5	0.138
Urea (mmol/L)	3.2±0.9	3.3±0.9	3.0±0.8	0.124

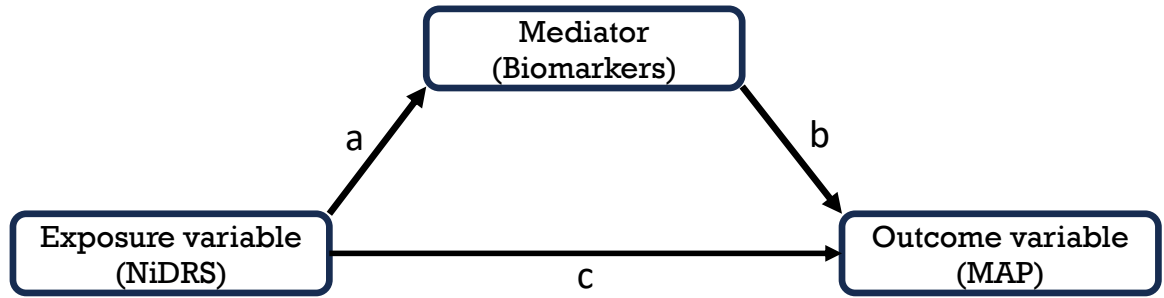
Results are presented as mean ± SD. AIP: Atherogenic Index of Plasma, CRI-I: Castelli Risk Index I, CRI-II: Castelli Risk Index II, NHDL-C: Non-HDL Cholesterol, THDL: Triglyceride to High-Density Lipoprotein Cholesterol Ratio. *p < 0.050 was considered as statistically significant.

Next, we examined the association between these biomarkers (mediators) and mean arterial pressure and Nigerian diet risk score (NiDRS). The results demonstrated that TC, TG, LDL-C, VLDL-C, CRP, HCY, and magnesium have significant positive associations with both mean arterial pressure and NiDRS ($p < 0.05$) (**Table S5.4-5**). The mediating effect of these significant biomarkers, such as blood lipids (TC, TG, LDL-C, VLDL-C), inflammatory markers (CRP and HCY), and magnesium, on the relationship between the NiDRS and mean arterial pressure (MAP) (**Figure 5.6**) was evaluated. The result indicated that TC, TG, LDL-C, CRP, and homocysteine significantly mediated the effects (indirect effect) of NiDRS on MAP in a positive direction ($p < 0.05$) (**Table 5.8 and Table S5.6**). Additionally, the proportion mediated by the biomarkers TC, TG, LDL-C, VLDL-C, CRP, and homocysteine were 50%, 47%, 49%, 17%, 68%, and 71%, respectively (**Table 5.8 and Table S5.6**). These results suggest that the effect of unhealthy foods in the NiDRS on elevated blood pressure is partly driven by its effect on blood lipids and inflammation biomarkers by 17-71%.

Table 5. 8. Biomarkers mediated effect of NiDRS on mean arterial pressure.

Mediators	Indirect effect β (95%CI)	Direct effect β (95%CI)	Total effect β (95%CI)	Proportion mediated
Fasting blood lipids				
TC (mmol/L)	0.5 (0.2, 0.9)***	0.5 (-0.1, 1.0)	1.0 (0.4, 1.5)***	0.50***
TG (mmol/L)	0.5 (0.2, 0.8)***	0.5 (-0.1, 1.0)	1.0 (0.4, 1.5)***	0.47***
LDL-C (mmol/L)	0.5 (0.1, 0.9)*	0.5 (-0.1, 1.1)	1.0 (0.5, 1.4)***	0.49*
VLDL-C (mmol/L)	0.2 (0.0, 0.4)	0.8 (0.3, 1.3)**	1.0 (0.4, 1.5)***	0.17
Inflammatory biomarkers				
CRP (mg/dL)	0.7 (0.3, 1.0)***	0.3 (-0.2, 0.8)	1.0 (0.4, 1.5)***	0.68***
Homocysteine(μ mol/L)	0.7 (0.4, 1.1)***	0.3 (-0.2, 0.7)	1.0 (0.4, 1.5)***	0.71***
Serum electrolytes				
Magnesium (mmol/L)	0.07 (-0.0, 0.2)	0.9 (0.4, 1.4)***	1.0 (0.4, 1.4)***	0.06

β : beta-coefficient; SE: Standard error; TC: Total cholesterol; TG: Triglyceride; LDL-C: Low-density lipoprotein cholesterol; VLDL-C: Very low-density lipoprotein cholesterol; CRP: C-reactive protein; HCY: Homocysteine. NiDRS: Nigeria diet risk score * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$ was considered as statistically significant.

**Figure 5. 6. Path diagram of the mediation linear regression model**

Path a: direct effects of Nigerian diet risk score (NiDRS) on biomarkers; Path b: direct effect of biomarkers on mean arterial pressure (MAP); Path c: direct effects of NiDRS on MAP.

5.5. Discussion

This study is the first to test and validate a culturally-appropriate dietary risk score tailored for assessing dietary habits associated with high-risk hypertension among men and women in Nigeria. Our aim is for the risk score to be used by clinicians, patients and researchers across Nigeria and other West African countries to: (i) facilitate discussions of dietary habits and offer personalised dietary counselling for patients at risk or with hypertension with an aim to improve cardiovascular health within clinical settings; and (ii) empower Nigerians to improve their diet and take an active role in the prevention and management of hypertension. With the participation of 151 adult men and women, we identified the 11 key food groups that significantly increased the risk of hypertension in Nigeria and then calculated and validated the Nigerian diet risk score (NiDRS) for hypertension. We also investigated the NiDRS alongside a panel of clinical predictors and markers of hypertension to report on its biological path to mediate hypertension. The

NiDRS demonstrated a remarkable ability to stratify participants by low vs high hypertension risk in Nigeria.

Our study confirmed consumption of high amounts of unhealthy food groups, including red meat, processed meat, eggs, fried foods, fast foods, fats and oils, desserts and sweets, soft drinks, alcoholic drinks and salt and seasoning, indicative of an unhealthy dietary pattern among hypertensive individuals in Nigeria. In this study population, the consumption of eggs and egg products, as well as soup and stew, was associated with increased odds of hypertension and was therefore included in the risk score. These findings may be linked to the cooking methods used, such as frying with unhealthy fats (e.g., palm oil, groundnut oil, or vegetable oil), and the addition of ingredients like salt and seasonings, which are known to increase the risk of hypertension. These unhealthy food groups were associated with an increased risk of hypertension and were therefore included in the final food group list to create the Nigerian diet risk score (NiDRS). Globally, these unhealthy food groups are commonly associated with increased cardiovascular disease risk and are commonly included in the creation of risk score tools for hypertension or cardiovascular disease in Western countries (e.g., INTERHEART score) (Kim et al., 2003; Trichopoulou et al., 2003; Fung et al., 2008; Berentzen et al., 2013; Guenther et al., 2013). The limited ability of healthier foods to discriminate between low- and high-risk individuals has been reported previously in the US and Europe (Li et al., 2016). These findings suggest that a disproportionate intake of food from animal-sourced, processed/convenience foods and alcohol are the key dietary drivers of hypertension risk in Nigeria (Batubo et al., 2023).

The NiDRS demonstrated a robust internal validity, with strong discrimination and calibration in a validation sample. An incremental increase in the NiDRS was significantly associated with 2.0 times higher odds of hypertension, while individuals scoring >11.3 (the highest risk category of the NiDRS) exhibited significantly higher odds of hypertension, i.e., an increased odds of 18.3, compared to those with a NiDRS score in the lowest risk category (score of 0-11.3). These findings are consistent with outcomes of risk scores, which either agree with or are better observed in previous studies (McGorrian et al., 2011; Elis et al., 2018; Lindbohm et al., 2021), and the validity of both the continuous and binary risk score supports its use as a dietary screening tool (Wald et al., 1999). The result suggests that the NiDRS can be an effective dietary screening tool to assess individuals at risk of hypertension in Nigeria.

Additionally, for a predictive score to have a meaningful impact on disease prediction, the area under the curve (AUC), the true-positive fraction (sensitivity), and the false-positive fraction (1-specificity) should be close to their ideal values of 1 and 0 (Pepe et al., 2004; Cook, 2008) and a positive net benefit to make an effective clinical decision (Vickers and Elkin, 2006; Halligan et al., 2015). Our findings demonstrated a notable strength of association and robust predictive performance, indicating the risk score's ability to discriminate individuals with or without hypertension, as indicated by the area under the curve (AUC) ranging from 87-92% with sensitivity ranging from 69% to 85% and a false-positive fraction (1-specificity) of 6 to 18% for the continuous and binary risk score and potential positive net benefit over a wide range of thresholds probability of dietary screening of individuals at risk of hypertension. This aligns with or exceeds the results of previous work, where the predictive performance of the INTERHEART modifiable risk score was with AUC $\geq 69\%$ (McGorrian et al., 2011), the Framingham Heart Study with AUC between 76%-79% (D'Agostino et al., 2008) and the SCORE project with AUC $\geq 71\%$ (Conroy et al., 2003). Overall, our results suggest the robustness and effectiveness of the NiDRS for the identification of individuals at risk of hypertension and support the clinical usefulness of the risk score in Nigeria.

Furthermore, our study demonstrated a robust positive association between the Nigerian diet risk score (NiDRS) with biomarkers such as total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and inflammatory markers such as C-reactive protein (CRP) and homocysteine (HCY). This association suggests that the NiDRS, reflecting on food groups considered 'unhealthy' in the Western dietary pattern, correlates with a higher risk of abnormal blood lipids such as TC, TG, and LDL-C and inflammatory biomarkers such as CRP and HCY (Fung et al., 2001; Centritto et al., 2009; Zhang, J. et al., 2016; Asadi et al., 2020; Gholizadeh et al., 2020; Koelman et al., 2022; Ushula et al., 2022). Our mediation analysis further demonstrated that TC, TG, LDL-C, CRP, and HCY significantly mediated the association between NiDRS and mean arterial pressure (MAP). Specifically, these biomarkers showed indirect effects on MAP changes, with proportions of the total effect mediated ranging from 47% to 7%. These findings confirm a major biological pathway by which diet elicits its effect on hypertension risk and posits lipid and inflammatory markers as key targets for non-dietary strategies where diet alone is inadequate.

5.5.1. Strengths and limitations

The Nigerian diet risk score (NiDRS) has several strengths. Firstly, it was constructed using a data-driven approach with clinical usefulness at the forefront and adequate adjustment for confounding factors associated with hypertension (Batubo et al., 2024). Secondly, we validated the NiDRS, with both the continuous and binary scores being positively associated with an increased risk of hypertension in this study cohort. Thirdly, the NiDRS synthesises patient-level dietary risk scores and risk categories described as binary levels of risk and has the potential to facilitate patient understanding of how their personal experiences and dietary choices modify cardiovascular disease and hypertension risk (van Steenkiste et al., 2004; McGorrian et al., 2011). Fourthly, the NiDRS demonstrated good calibration and discrimination with ROC *c*-statistic values > 0.70 and positive net benefit, indicating robust discriminating power and clinical usefulness (McGorrian et al., 2011; Martin et al., 2018). Finally, the mediation analysis and the association between NiDRS and clinical CVD outcomes further validate the NiDRS by providing biological plausibility, clinical relevance, and overall reliability, reinforcing its usefulness as a dietary screening tool for hypertension (Dragsted et al., 2018; Pico et al., 2019).

Nonetheless, the NiDRS has some limitations. Firstly, dietary intake data ascertained by the participants can be subject to recall bias; however, this was minimised by using a validated food frequency questionnaire against multiple 24-hour dietary recalls and clinical cardiovascular biomarkers. Additionally, the derivation of the NiDRS was based on case-control data rather than a prospective cohort, yet this approach allowed us to capture clinically meaningful data from individuals with hypertension while avoiding overfitting the model with too many confounding variables (Harrell et al., 1985; Steyerberg et al., 2001). Furthermore, the NiDRS was constructed using unhealthy food groups, as we observed (i) a significant difference in consumption of unhealthy foods between hypertensive and non-hypertensive groups, compared to the healthy food, (ii) unhealthy foods have a significant positive association with hypertension compared to the healthy foods and (iii) the use of unhealthy foods in the construction of risk score aligns with previous studies linking unhealthy foods consumption to hypertension and cardiovascular risks and have also incorporated such foods in risk assessment tool (McGorrian et al., 2011). Lastly, while predictive models ideally should be validated in an external sample to demonstrate their generalisability and accuracy (Altman et al.,

2009), our study did not conduct external validation; however, this is a priority we aim to address in the next phase of our research.

5.5.2. Clinical and public health relevance

The Nigerian Diet Risk Score (NiDRS) for hypertension offers healthcare professionals and researchers a culturally-appropriate and evidence-based tool to evaluate individuals at risk of hypertension and deliver personalised dietary counselling and motivational support. By leveraging the NiDRS, clinicians can proactively intervene by offering dietary guidance and recommendations unique to each patient's dietary needs and individual circumstances. This approach will foster patients' engagement and understanding of their dietary risk level and serve as a motivating factor as they observe their risk score decrease with improvements in their dietary behaviours. This approach has been recommended by the Nigerian National Strategic Plan of Action for Nutrition (Federal Ministry of Health, 2021), the American Heart Association (Smith et al., 2000; Smith et al., 2011) and the European Society of Cardiology guidelines (Graham et al., 2007). The use of the NiDRS will enhance individualised patient care and support in preventing or delaying the onset of hypertension-related complications and cardiovascular disease risk, ultimately improving clinical outcomes and quality of life for affected individuals. Additionally, the widespread adoption of the NiDRS may contribute to reducing the overall prevalence of hypertension in Nigeria and other West African nations, thereby alleviating the burden on healthcare systems, and improving population-level health outcomes (Federal Ministry of Health, 2021).

5.5.3. Conclusion

We have developed and validated a diet risk score for hypertension risk (NiDRS) tool designed to assess hypertension risk in Nigerian clinics. The NiDRS is a valuable tool to (i) provide clinicians, patients, and researchers with a practical means to identify individuals at high risk of hypertension and (ii) facilitate early intervention strategies, which will mitigate and optimise cardiovascular health management in Nigeria. As such, it represents a significant advancement in the prevention and management efforts of hypertension in Nigeria, offering a promising tool to combat the rising prevalence of hypertension and its associated complications.

5.6. Chapter summary

This chapter described the development of the Nigerian Diet Risk Score (NiDRS) aimed at assessing dietary intake linked to hypertension in Nigeria. The objectives of the study

were to: (i) derive and test the utility of a culturally-appropriate dietary risk score (NiDRS) to categorise individuals at risk of hypertension in Nigeria; and (ii) evaluate the NiDRS alongside a panel of clinical predictors and biomarkers for hypertension. The estimated dietary intake among Nigerians ($n=151$ patients) in a clinical setting using the Nigerian dietary screening tool (NiDST). The study identified 11 food groups out of 23 food groups that were significantly associated with an increased risk of hypertension. These food groups were used to construct the Nigerian diet risk score for hypertension (NiDRS). The study further demonstrated that: (i) the increase in the NiDRS is associated with a 2-fold increase in odds of hypertension; (ii) individuals in the highest score category have >18-fold increased odds of hypertension compared to the lowest NiDRS; (iii) the NiDRS have good discrimination to identify individual with low or high hypertension risk; (iv) total cholesterol, triglycerides, low-density lipoprotein, very low-density lipoprotein, c-reactive proteins, and homocysteine were mediators of the NiDRS-hypertension pathway. The findings from this study suggest that the NiDRS has the potential to support clinicians in identifying individuals at risk of hypertension and will advance community efforts in the prevention and management of hypertension in Nigeria. This chapter builds upon the Nigerian dietary screening tool developed in study two (Chapter four) by utilising the tool to assess dietary intake and inform the development of NiDRS. Future research requires the utilisation of the NiDRS by clinicians, patients and researchers across Nigeria and other West African countries to: (i) facilitate discussions of dietary habits and offer personalised dietary counselling for patients at risk or with hypertension to improve cardiovascular health within clinical settings. This is addressed by assessing the barriers to and facilitators of implementation of the Nigerian diet risk score in phase two of study three, described in the next chapter.

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Chapter six

The Nigerian dietary screening tool: A step toward improved patient-clinician communication in Nigerian hospitals: A pilot implementation study

Author original report of the study and will be submitted as: Nimisoere P. Batubo, Carolyn I. Auma, J. Bernadette Moore, and Michael A. Zulyniak. Validity and reproducibility of a culturally tailored dietary screening tool for hypertension risk in Nigerian healthcare. (Submission June 2024).

6.1. Abstract

Introduction: To offer evidence-based dietary advice for reducing diet-related disease risk in a clinical setting, dietary screening tools need to be practicable, valid, and feasible. This study aimed to evaluate: (i) the impact of the Nigerian dietary screening tool (NiDST) on patient-clinician communication and (ii) barriers and facilitators for clinicians and patients to implement the NiDST.

Methods: This study used a mixed methods approach to collect data from patients ($n=151$) and clinicians ($n=20$) from outpatient clinics at Rivers State University Teaching Hospital, Nigeria. Patients completed a validated 25-item NiDST for consultations with clinicians. Both patients and clinicians completed a modified version of the Measurement Instrument for Determinants of Innovations (MIDI) questionnaire to assess implementation determinants post-consultation. Semi-structured interviews were conducted for in-depth feedback. Qualitative data underwent thematic analysis using NVivo 14, while quantitative analysis was conducted using R.

Results: Fidelity was 91% for recruitment, 94% for completed NiDST with a mean completion time of < 6 minutes, and 97% for NiDST-reported dietary discussion with an accepted marginal increase in consultation time (< 10 mins). For clinicians, 25% reported barriers for additional nutritional knowledge and time constraints, while facilitators of NiDST implementation were its high agreement ($\geq 80\%$) for procedural clarity, completeness, and relevance and improved patient-clinician engagement and communication (90%). Among patients, over 96% reported the NiDST as quick to complete, facilitated communication with doctors, and improved their engagement, with 90.7% reporting improved understanding and reflection on food intake.

Conclusion: This study demonstrated that the NiDST has the potential to enhance patient-clinician engagement and communication in Nigerian hospitals. It highlighted

major facilitators of dietary counselling in clinical practice that overall improved dietary discussion and health outcomes.

Keywords: Dietary assessment, Nigerian dietary screening tools, hypertension, implementation, patient-clinician communication, clinical practice.

6.2. Introduction

Diet plays a crucial role in health outcomes, particularly in the prevention and management of non-communicable diseases such as diabetes, hypertension, and obesity (Gropper, 2023). In Nigeria, where the burden of these conditions is significant, the Nigerian government, alongside global health advisory groups (WHO and United Nations Assembly), reports that addressing dietary factors is paramount in the prevention of these diseases (Adesina et al., 2021).

Validated dietary screening instruments, such as a tailored food frequency questionnaire, offer standardised methods for comprehensively assessing dietary intake to inform evidence-based counselling (Vadiveloo, M. et al., 2020; Lara-Breitinger et al., 2023; Batubo et al., 2024). Despite their demonstrated utility, the adoption of these tools into frontline clinical practice has been limited, including in Nigeria, necessitating robust tool development and implementation research to facilitate its uptake. Studies have highlighted that low participant satisfaction may hinder the adoption of validated diet screening tools, which are crucial for providing personalised counselling and guiding management decisions in clinical care (Fischer et al., 2016; Ebell et al., 2018; Wang, Z. et al., 2018). In addition, healthcare professionals recognise the potential benefits of these tools but report: (i) a lack of region-specific nutrition guidance for clinicians; (ii) inadequate time to evaluate diet; (iii) already heavy clinical workload; (iv) low physician confidence; and (v) inadequate teaching materials and training (Kushner, 1995; Kolasa and Rickett, 2010; Ahmed et al., 2016; Aspary et al., 2018; Kelley et al., 2019). However, studies have shown that brief dietary training, along with the use of a rapid dietary assessment tool, can effectively mitigate these barriers and enhance integration (Vadiveloo, M. et al., 2020; Vadiveloo, M.K. et al., 2023).

The concept of patient-centred care, which emphasises collaboration between patients and healthcare professionals in decision-making, has gained global recognition (Vadiveloo, M. et al., 2020; Lichtenstein et al., 2021). Effective patient-clinician interaction is central to this approach, allowing for effective information exchange, shared decision-making, and mutual understanding of treatment goals. In Nigeria, improved and clear communication between patients and clinicians is essential for assessing dietary

habits, providing appropriate advice, and promoting healthy behavioural change (Zolnieriek and Dimatteo, 2009; Cavaco et al., 2023).

The Nigerian dietary screening tool (NiDST) is a validated culturally-appropriate food frequency questionnaire for clinical use in Nigeria (Batubo et al., 2024; Batubo et al., 2024). Our work demonstrates the NiDST to be rapid and reliable for assessing and quantifying key dietary components related to hypertension risk and management. Building upon these findings, we assess the implementation of the NiDST in a clinical setting by: (i) assessing its ability to enhance patient-clinician communication regarding dietary habits in real-world clinical settings and (ii) evaluating the perceived barriers to and facilitators of implementation into clinical practice in Nigeria.

6.3. Materials and methods

6.3.1. Study design and setting

This study employed a single-centre, mixed-methods approach, combining qualitative and quantitative methods to gather data in two workstreams — (1) patients and (2) clinicians — to enable in-depth exploration of user's views and perceptions of their experience using the NiDST and its value to inform and foster patient-clinical discussions of dietary habits and recommendations to moderate hypertension risk. The study builds on methods and recruitment processes used successfully by the research team in an earlier study (Batubo, Nimisoere P. et al., 2023; Batubo et al., 2024). The study was conducted at the Rivers State University Teaching Hospital (RSUTH) located in Port Harcourt, Nigeria. RSUTH serves as a tertiary healthcare facility, providing a range of medical services to patients across Rivers State and neighbouring regions, including Abia State, Bayelsa State, and Akwa Ibom State. The Family Medicine Department and Internal Medicine Department's outpatient clinics were the primary sites for implementing the innovation and conducting data collection. Herewith, for ease of reporting, patient participants and clinician participants will be referred to as 'patients' and 'clinicians'.

6.3.2. Ethical approval

Two ethics boards reviewed the study protocol. Firstly, it was submitted to the Business, Earth & Environment, Social Sciences (AREA FREC) Committee at the University of Leeds, Leeds, United Kingdom, on March 21, 2023. Secondly, it was presented to the Rivers State University Teaching Hospital Research Ethics Committee in Port Harcourt, Nigeria, on March 20, 2023. Final ethical approvals were granted with the following

reference numbers: 0484 on April 28, 2023, and RSUTH/REC/2023316 on March 30, 2023, respectively.

6.3.3. Sample size

The sample size was determined based on Cohen's guidelines for multiple regression analysis to detect a medium effect size ($f^2 = 0.15$) with 80% power at a 5% significance level (Cohen, 2013). We used G*Power software (Faul et al., 2009), considering a statistical power of 80%, a 95% confidence interval, and a two-tailed alpha level of 0.05 with estimated 5 predictors. A minimum sample size of 92 patient-participants was calculated. However, to account for a projected dropout rate of 20% and potential missing or incomplete data (as informed by our previous work), we aimed for a target sample size of 150 participants (Thabane et al., 2010; Gupta et al., 2016). In addition, 15 clinician-participants were deemed adequate to capture the full range of qualitative questions and enable thematic saturation based on previous research suggesting that 9-30 participants are needed to reach saturation and informational redundancy in qualitative interview studies (Guest et al., 2006; Hennink, M.M. et al., 2017; Vasileiou et al., 2018; Hennink, M. and Kaiser, 2022).

6.3.4. Participant's recruitment and informed consent

This study used a non-probability convenience sampling method to recruit participants (patients and clinicians) from the outpatient clinics at RSUTH in Nigeria. The participants for this study are adult patients and clinicians recruited during regular clinic hours at the Family Medicine Department and Internal Medicine Department outpatient clinics at RSUTH. A non-probability convenience sampling method, using both a direct and an indirect approach, was used to recruit participants over three weeks in December 2023. The patients were invited by recruitment posters within the hospital premises and through engaging with patients during their routine morning pre-consultation briefing sessions in the clinics. Additionally, clinicians were able to inform patients of the study and direct them to the study team for more information. All interested patients were screened for eligibility using the inclusion and exclusion criteria outlined in **Table 6.1** (Batubo et al., 2024). Before enrolment, each patient received a participant information sheet and had the opportunity to interface with the study team to ensure an understanding of the study protocol. Participants were also assured of: (i) their voluntary participation rights; (ii) the option to withdraw from the study at any point without giving any reasons; and (iii) the confidentiality of their information. Clinicians were recruited based on their availability and involvement in providing medical care to patients with hypertension and

cardiovascular diseases with ≥ 5 years of experience and were also assured of: (i) their voluntary participation rights; (ii) the option to withdraw from the study at any point; and (iii) the confidentiality of their information.

Table 6. 1. Inclusion and exclusion criteria for patients

Inclusion criteria	Exclusion criteria
Age between 18 and 70 years	Individuals < 18 years or > 70 years of age
Men and women	Pregnant or breastfeeding women, or those intending to become pregnant
Hypertensive or non-hypertensive individuals	Diagnosis of other chronic diseases such as cancer, diabetes, renal failure, endocrine diseases, and previous and recent incidence of cardiovascular disease (CVD) and stroke
Individuals who have been residents in Nigeria for the past 2 years	Individuals who have been resident in Nigeria for less than 2 years
Ability to read, write, and communicate over the phone in English	Individuals on dietary restrictions or with recent changes to their diet or food
Individuals who gave their consent to participate	Individuals who did not give their consent to participate or were currently enrolled in other studies

6.3.5. Innovation - The Nigerian dietary screening tool (NiDST)

The NiDST is a novel and validated 25-item dietary assessment method tailored for adults in Nigeria to assess dietary intake (Batubo et al., 2024). Briefly, the NiDST is a culturally-appropriate short food frequency questionnaire that collects patient dietary intake on 23 food groups with 2 additional questions on salt and type of milk use (**Table S5.1**) over the past month by selecting “rarely or never”, “1-2 times/week”, “3-5 times/week”, “daily”, “1-2 times/day”, “3-4 times/day”, or “5+ times/day” for each food question. Implemented as a self-administered tool, the patients can quickly complete the NiDST (mean < 8 mins) during the waiting period before their consultation (Batubo et al., 2024). Subsequently, clinicians can utilise the patient-completed NiDST in their outpatient consultation for directing dietary discussions and offering personalised advice to patients. This innovative but simple approach ensures a structured framework for dietary assessment and intervention, enhancing the effectiveness of the tool in hypertension preventive and management strategies (**Figure 6.1**).

6.3.6. Data collection

Data collection took place over five weeks from December 2023 to January 2024 and was conducted in three (3) stages: pre-implementation (1 week), implementation (3 weeks), and post-implementation (1 week).

6.3.6.1. Pre-implementation stage

During the pre-implementation stage, a structured questionnaire was used to collect data from patients and clinicians. The patients' questionnaire assessed sociodemographic information and medical history. Additionally, various physical measurements, including blood pressure, height, body weight, and waist circumference, were measured. The blood pressure was measured twice in the non-dominant arm using an automated mercury sphygmomanometer (model number: ZK-BB68, Shenzhen, China) following a standardised protocol with 5-minute intervals rest between measures. The height, weight, and waist circumference were measured twice to ensure accuracy using a standard stadiometer (model number: DG2301, China) and measuring tape. The values obtained for weight and height were subsequently used to calculate the body mass index (BMI). The clinicians' questionnaire focused on their experiences in providing care for hypertensive and cardiovascular disease patients and using dietary assessment and counselling. Furthermore, to ensure proficiency in utilising the NiDST, all eligible consenting clinicians underwent a brief training session covering its administration, interpretation, and integration.

6.3.6.2. Implementation stage

In the implementation stage, the NiDST was integrated into standard clinical procedures. Patients were provided with the NiDST to complete ahead of their outpatient consultation. Clinicians then reviewed the patient-completed NiDST with each patient as part of their outpatient consultation to foster dietary discussion and deliver personalised dietary advice. To gather patient and clinician feedback and assess their experiences with the use of NiDST, a modified version of the Measurement Instrument for Determinants of Innovations (MIDI) was used (*see 6.3.7.2. Barriers to and facilitators of implementation*) (Fleuren, M.A. et al., 2014). The MIDI was administered to each patient after their outpatient consultation, while clinicians completed the MIDI at the end of the implementation stage.

6.3.6.3. Post-implementations stage

Subsequently, the post-implementation stage commenced with semi-structured interviews with a random subset of the clinicians ($n=15$) and patients ($n=20$) to explore an in-depth understanding of their experiences with the integration of the NiDST. Separate focus group discussions were organised for clinicians ($n=10$) and patients ($n=10$) selected through a purposeful sampling approach, providing a platform for group interaction and exchange of shared experiences. These interview sessions were tailored

to accommodate the availability of all participants, with audio recordings made with their consent and later transcribed verbatim for analysis.

6.3.7. Outcome measures

6.3.7.1. Fidelity of implementation

The fidelity (adherence) of the use of the NiDST for the dietary assessment of individuals at risk of hypertension was determined by the percentage of: (i) patients recruited for the study; (ii) patients who completed the NiDST before an outpatient consultation; and (iii) NiDST discussed at outpatient consultation; and MIDI feedback provided.

6.3.7.2. Barriers to and facilitators of implementation

The Measurement Instrument for Determinants of Innovation (MIDI) supports the designing of new implementation strategies within clinical care settings (Fleuren, M. et al., 2004; Fleuren, M.A. et al., 2014). Completed by both clinicians and patients, MIDI serves to assess the barriers to and facilitators of implementing the NiDST (**Table S6.1**) (Fleuren, M.A. et al., 2014). It comprises four scales, measuring determinants for implementations related to: (i) the innovation-NiDST (5 determinants); (ii) clinicians (8 determinants); and (iii) patients (7 determinants) with answer categories ranging from “totally disagree”, “disagree”, “neutral”, “agree” and “totally agree”. Clinicians had one additional question to measure their experiences with using the NiDST in their clinical practice. Notably, we did not evaluate the “organisational” and “sociopolitical” context due to the study's main focus of assessing clinician-patient-level barriers and facilitators to implementation. In our sample, the internal consistency of this questionnaire was excellent, with a total scale of $\alpha = 0.93$, intervention scale of $\alpha = 0.92$, and user scale of $\alpha = 0.92$.

6.3.8. Data analysis

The study data from the clinicians and patients were anonymised and entered into Microsoft Excel for quality assurance purposes. Patient data was stratified into hypertensive and non-hypertensive groups. Quantitative data were analysed using an R computing environment (version 4.3.1), while qualitative data analysis was performed using NVivo software (version 14) (Lumivvero, 2020; R Core Team, 2020). Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarise the details of the sociodemographic, fidelity metrics, medical history, clinical characteristics such as blood pressure, body mass index (BMI), height, weight, waist circumference, NiDST completion time, and consultation time. Chi-square tests (for

categorical variables) and independent-sample t-tests (for quantitative variables) were performed to compare hypertension and non-hypertension groups. MIDI determinants answered by $\geq 20\%$ of clinicians and patients with “totally disagree/disagree” were considered barriers, while those answered by $\geq 80\%$ with “agree/totally agree” were considered facilitators. We considered MIDI items between these ranges not generalisable across our study population, but a larger future study may articulate their roles more clearly.

Audio recordings of interviews and focus group discussions were transcribed, checked, and anonymised and were imported into NVivo 14. They were coded by the first author (NPB) using the interview question domains (primary codes) and then for emergent themes (secondary codes) through repeated analysis of the content (Michael Quinn Patton, 2015). The reliability of coding was evaluated by a second coder (not involved in the data collection), resulting in an initial agreement of 98%, with resolution of discrepant code through discussion. Once the final coding framework was established, both coders independently indexed transcript segments to appropriate themes and subthemes using NVivo software, version 14 (Lumivivo, 2020). The qualitative data was then summarised and described narratively, utilising illustrative anonymous quotations to encapsulate participants' experiences, perspectives, and suggestions regarding the implementation of the NiDST.

6.4. Results

6.4.1. Participant characteristics

A total of 181 patients were screened for eligibility. Sixteen (16) were excluded due to a recent change of diet, while 165 satisfied the inclusion criteria and were enrolled to participate in the study after providing informed consent (with an enrolment rate of 91%) (**Figure 6.1**). The mean age of the patients was 44.4 ± 10.2 years. Hypertensive and non-hypertensive individuals did not differ by sociodemographic characteristics, body mass index, waist circumference or physical activity levels ($p > 0.05$) (Table 2). However, the proportion of men was higher among the hypertensive group (59.1%) compared to the non-hypertensive group (36.5%) ($p = 0.010$) (**Table 6.2**). As expected, hypertensive patients had significantly higher mean systolic and diastolic blood pressure and mean arterial pressure ($p < 0.001$) compared to non-hypertensive patients (**Table 6.2**). Twenty (20) clinicians who provided outpatient consultation had an average age of 42.6 ± 6.0 years and an average of 13.0 ± 4.7 years of experience. The specialities represented were family medicine (55%) and internal medicine (45%).

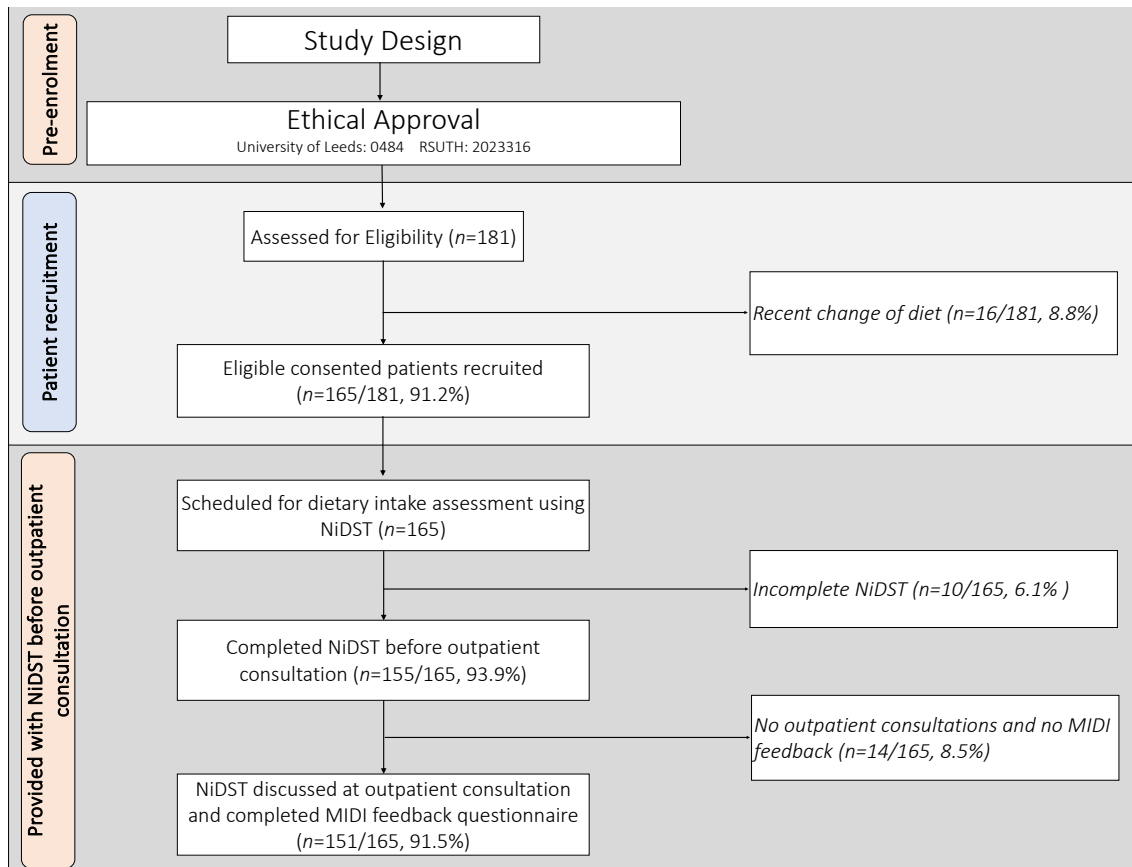


Figure 6. 1. Flowchart of patients and fidelity of the NiDST during outpatient consultations. NiDST: Nigerian dietary screening tool; MIDI: Measurement Instrument for Determinants of Innovations; n: Number; RSUTH: Rivers State University Hospital.

6.4.2. Completion and consultation time

The mean NiDST completion time was 5.5 ± 1.7 minutes, and no difference was observed between hypertensive (5.5 ± 1.6 minutes) and non-hypertensive groups (5.5 ± 1.7 minutes) ($p > 0.05$) (Table 2). Additionally, utilisation of the tool during outpatient consultation for dietary counselling increased overall consultation time by an average of 9.6 ± 1.5 minutes with no significant difference between hypertensive (9.6 ± 1.5 mins) and non-hypertensive groups (9.6 ± 1.5 mins) ($p > 0.05$) (Table 6.2). This short completion time and extra consultation time represent a manageable increase in outpatient consultation, indicating a seamless integration of the NiDST into the clinical workflow.

6.4.3. Fidelity of the use of the NiDST

As shown in Figure 6.1, the fidelity of patient recruitment for the implementation of the NiDST was 91.2%, out of which 93.9% completed the NiDST and were scheduled for outpatient consultation and dietary advice. All the completed NiDSTs were discussed during each patient outpatient consultation. However, 91.5% of the patients completed

the Measurement Instrument for Determinants of Innovations (MIDI) feedback questionnaire. This result indicates that the recruitment, screening, and consultation phases of the study were successfully implemented.

Table 6. 2. Sociodemographic and clinical characteristics of patients (n=151)

Characteristics	Overall (n=151)	Hypertensive (n=88,58%)	Non- hypertensive (n=63, 42%)	p-value
Patients (n=151)				
Sex, n (%)				0.010*
Men	75 (49.7)	52 (59.1%)	23 (36.5%)	
Women	76 (50.3)	36 (40.9%)	40 (63.5%)	
Age (years)	44.4±11.1	46.0±10.2	42.1±12.2	0.098
Education, n (%)				0.472
Primary	27 (17.8)	15 (16.0)	12 (19.1)	
Secondary	62 (41.1)	40 (45.5)	22 (34.9)	
Tertiary	62(41.1)	33 (37.5)	29 (46.0)	
Marital Status, n (%)				0.072
Divorced	3 (2.0)	2 (2.3)	1 (1.6)	
Married	119 (78.8)	75 (85.2)	44 (69.8)	
Single	18 (11.9)	6 (6.8)	12 (19.0)	
Widowed	11 (7.3)	5 (5.7)	6 (9.5)	
Employment, n (%)				0.057
Employed	25 (16.6)	14 (15.9)	11 (17.5)	
Homemaker	1 (0.6)	0 (0)	1 (1.6)	
Retired	9 (6.0)	7 (8.0)	2 (3.2)	
Self-employed	103 (68.2)	63 (71.6)	40 (63.5)	
Student	8 (5.3)	1(0.6)	7 (11.1)	
Unemployed	5 (3.3)	3 (3.4)	2 (3.2)	
Family history of HTN, n (%)	34 (22.5)	26 (29.5)	8 (12.7)	0.013
Physical activity level, n (%)				0.542
Active	23 (15.2)	12 (13.6)	11 (17.5)	
Moderately active	15 (9.9)	7 (8.0)	8 (12.7)	
Moderately inactive	41 (27.2)	27 (30.7)	14 (22.2)	
Inactive	72 (47.7)	42 (47.7)	30 (47.6)	
BMI (kg/m ²)	29.0±6.2	29.1±6.3	29.1±5.7	0.934
Waist circumference (cm)	95.4±14.5	95.49±14.6	96.0±14.2	0.740
Blood pressure (mmHg)				
Systolic blood pressure	142.5±24.2	159.4±15.7	119.0±10.0	<0.001**
Diastolic blood pressure	98.0±71.5	113.0±9.8	77.1±7.2	<0.001**
Mean arterial pressure (mmHg)	127.7±32.3	143.9±33.3	105.0±8.0	<0.001**
NiDST completion time (minutes)	5.5±1.7	5.5±1.6	5.5±1.7	0.905
NiDST consultation time (minute)	9.6±1.5	9.6±1.5	9.6±1.5	0.920
Clinicians (n=20)				
	Overall	Men (n=6)	Women (n=14)	p-value
Age (years)	42.6±6.0	43.2±6.0	42.3±6.2	0.771
Years of experience	13.0±4.7	11.2±2.0	13.7±5.4	0.279
Specialty				<0.001**
Internal Medicine n (%)	9 (45)	5 (25)	4 (20)	
Family Medicine n (%)	11 (55)	1 (5)	10 (50)	

HTN: hypertension; NiDST: Nigerian diet screening tool. *p < 0.050 was considered as statistically significant.

6.4.4. Barriers to and facilitators of implementation of the NiDST

The clinician-reported factors related to the use of the NiDST to assess patient dietary intake and inform dietary advice in routine clinic visits are presented in **Table 6.3** and **Figure 6.2**.

Table 6. 3. Determinants for the use of the NiDST by clinicians (n= 20)

MIDI scale and determinants	Disagree/ totally disagree (%)	Neutral (%)	Agree/ totally agree (%)
Nigerian Dietary Screening Tool			
Procedural clarity: Activities for the use of the NiDST were clearly described	0	0	100
Completeness: The food list in the NiDST is comprehensive	0	0	100
Complexity: NiDST is not complex for me to use	0	0	100
Compatibility: Compatible with workflows	15	0	85
Relevance for patient: Intervention is relevant for my patients	0	0	100
Clinicians			
Personal benefits: I think using the NiDST will help me to assess patient dietary intake	0	10	90
Personal communication: NiDST help me to improve my engagement and communication with patients	0	0	100
Outcomes expectations: I think using the NiDST will support me to offer dietary advice to patients	0	5	95
Professional obligation: I feel it is my responsibility to use the NiDST to assess dietary intake and offer dietary advice to patients routinely	0	5	95
Patient satisfaction: Patients will be satisfied when using the tool with their dietary intake	0	0	100
Patient cooperation: Patient will generally cooperate when using the tool having their dietary intake	0	0	100
Nutritional knowledge: I have enough knowledge to use and interpret the dietary assessment tool as intended	25	0	75
Time available: I have enough time to assess patient dietary intake and offer dietary counselling	25	0	75

MIDI: Measurement Instrument for Determinants of Innovations

6.4.4.1. Clinicians perceived barriers

The most commonly clinicians-reported barriers to using the NiDST were: (i) inadequate nutritional knowledge (25% indicated not having enough knowledge to use and interpret the dietary assessment tool); and (ii) time available (25% indicated not having enough time to assess patient dietary intake and offer dietary counselling to patients) (**Table 6.3** and **Figure 6.2**). A frequently expressed concern was an additional time of ~10 minutes,

as illustrated in **Table 6.2**, is needed to offer personalised dietary advice to patients, which may not be feasible in busy clinics due to time constraints, as stated by one clinician:

“We only offer little dietary support to patients in the clinic. The number of patients we see on each clinic day is so much as such there is no time to fully assess patient food intake and provide one-on-one dietary counselling. Personally, I refer patients to see the dietician for the purpose of nutritional assessment and counselling”. (female, 28 years).

Another clinician stated that:

“In my opinion, the tool was very useful, but the challenge is the additional time needed to counsel and make recommendations to the patients because you can imagine spending 20-45 minutes with one patient in a busy clinic.” (male, 38 years)

Similarly, another clinician discussed that:

“Well, it takes me some time to go through the tool and understand the patient’s food intake before I can start discussing it with them and advise them, but I think if the tool can be made simple and training be given on how to use it, then it will be easy to apply it without taken much time”. (male, 36 years)

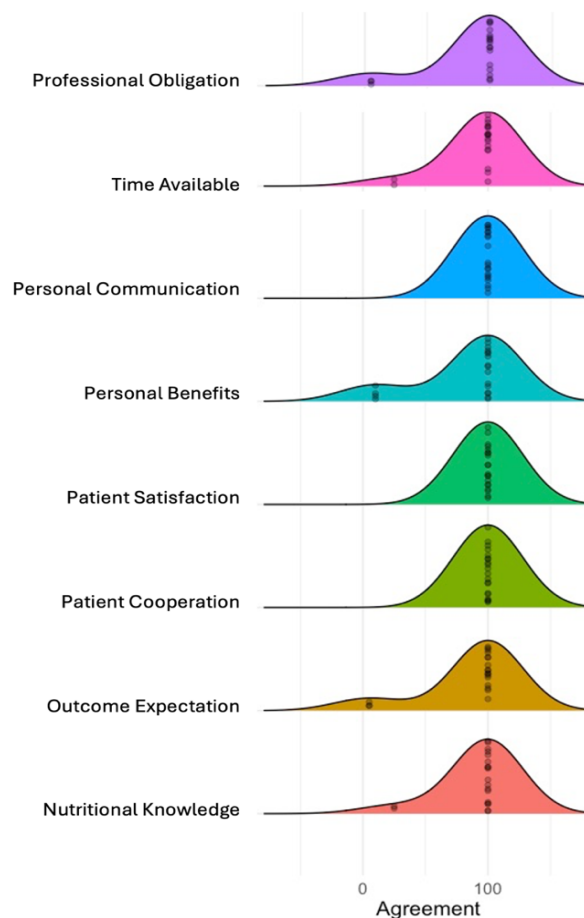


Figure 6. 2. Clinicians reported determinants of implementation using MIDI determinants. The ridgeline plot displays the distribution of agreement levels for the MIDI determinants. Each coloured ridge represents the distribution of responses for a determinant, with the width of each curve indicating the spread of agreement levels, and the peak represents the most frequent level of agreement among respondents.

6.4.4.2. Clinicians perceived facilitators

Encouragingly, despite the perception of some clinicians on these barriers, an overwhelming majority (85%) of clinicians agreed that the NiDST is compatible with their clinic routines (**Table 6.3**). The procedural clarity, completeness of the food list, and the simplicity of questions were mentioned as facilitating factors of the NiDST, with all the clinicians reporting a high level of clarity and understanding of the NiDST, as stated by a clinician:

“For me, the tool integrated well into our routine workflow and providing training for clinicians on how to use the tool, especially how to interpret the tool will provide some sort of dietary guidelines for each food group. Yeah, this can help clinicians more focused on the dietary discussion with the patient, and this can shorten the consultation time” (female, 48 years)

Furthermore, the clinicians-reported facilitators of the utilisation of the NiDST were: (i) personal benefits (where $\geq 90\%$ reported that the NiDST supported them in assessing patient dietary intake and provided better engagement and communication with patients); (ii) outcomes expectations (95% indicated that the NiDST supported them to provide guided-dietary advice to patients); (iii) professional obligation (95% expressed that dietary intake assessment and providing dietary advice to patients, as their routine task); and (iv) patient satisfaction (all clinicians indicated that patients were satisfied when using the tool with their dietary intake) (**Table 6.3 and Figure 6.2**). Overall, these findings suggest that the NiDST can support clinicians to understand patients’ dietary intake and provide personalised dietary advice to patient. In this regard, one of the clinicians remarked:

“From my experience, I’ve found that the NiDST really helps me dive into understanding my patients’ dietary habits better. It’s like having a comprehensive roadmap right in front of me during consultations. And you know what’s great? It doesn’t just stop there. Using the NiDST has actually improved my communication with patients. It’s like it bridges that gap between us, making our conversations more meaningful and productive. It’s been a game-changer for me, honestly.” (female, 42 years)

Likewise, another clinician described:

“Yeah, I saw most of the patient were satisfied because the dietary discussion was focused on their usual food intake. They were able to ask questions on the right food they eat to reduce their risk of hypertension. Like, there was this one patient who mentioned how surprised to know that excess use of Maggi can worsen hypertension. They were like, ‘I use plenty Maggi when cooking my stews and soups.’” (female, 36 years)

6.4.4.3. Patients perceived facilitators

Table 4 and **Figure 3** present the patient-reported facilitators related to using NiDST to assess their dietary intake and support clinicians in providing dietary advice during routine clinic visits. Firstly, a significant proportion of the patients ($\geq 96\%$) were satisfied with the format, contents and time used to complete the NiDST (**Table 6.4** and **Figure 6.3**), with a completion time of ~6 minutes, as illustrated in **Table 6.2**.

"[It] was very straightforward and easy to fill out. The instructions at the top clearly explained what was needed, and the arrangement with the columns was simple to understand." (female, 45 years, >5 years hypertensive).

Table 6. 4. Determinants for the use of the NiDST by patients (n= 151)

MIDI scale and items	Disagree/ totally disagree (%)	Neutral (%)	Agree/ totally agree (%)
Personal benefits: The tool was quick to complete within one clinical visit.	2.0	2.0	96.0
Personal communication: Help me in communication with doctor	0.0	0.7	99.3
Patient engagement: NiDST Help me discuss with doctors	0.0	1.3	98.7
Outcome expectations: Help me understand and reflect on my food intake	0.7	8.6	90.7
Awareness of content: The frequency response options allow me to accurately report my usual food intake.	0.0	4.0	96.0
Time available: The time taken to complete the NiDST was acceptable to me.	0.0	0.7	99.3
Patient satisfaction: I am satisfied with using the tool and consultation	1.3	2.7	96.0

MIDI: Measurement instrument for determinants of innovations

Another patient stated:

"I was able to complete the questionnaire in just a few minutes while waiting to see my doctor. It didn't feel long or burdensome at all. The length and time needed fit perfectly into the normal clinic visit." (male, 61 years, non-hypertensive)

Secondly, the majority of the patients ($\geq 96\%$) found the NiDST to be beneficial to them as it: (i) was supportive for clinicians to have an in-depth understanding of their dietary intake (98.7%); (ii) improved their engagement and communication with clinicians on dietary discussion (99%); and (iii) increases self-awareness of their food intake (91%) (**Table 6.4**). Lastly, 96% of patients expressed satisfaction with both using the screening tool and the consultation process (**Table 6.4** and **Figure 6.3**). On this note, a patient stated that:

"Filling the form and discussing with my doctor made me more aware of how often I eat food prepared by mama put and red meats each week. It was an eye-opening,

and this will motivate me to improve my diet. For me, I will complete the form next time I come to the hospital" (male, 47 years, 1 year hypertensive)

Another patient indicated an improved dietary counselling session offered to him and stated:

"I think the use of the complete form really helps my doctor to understand the food I usually eat. I was really happy to hear the doctor telling me to reduce some food that I eat because it can contribute to my BP not being controlled." (female, 56 years > 5 years hypertensive)

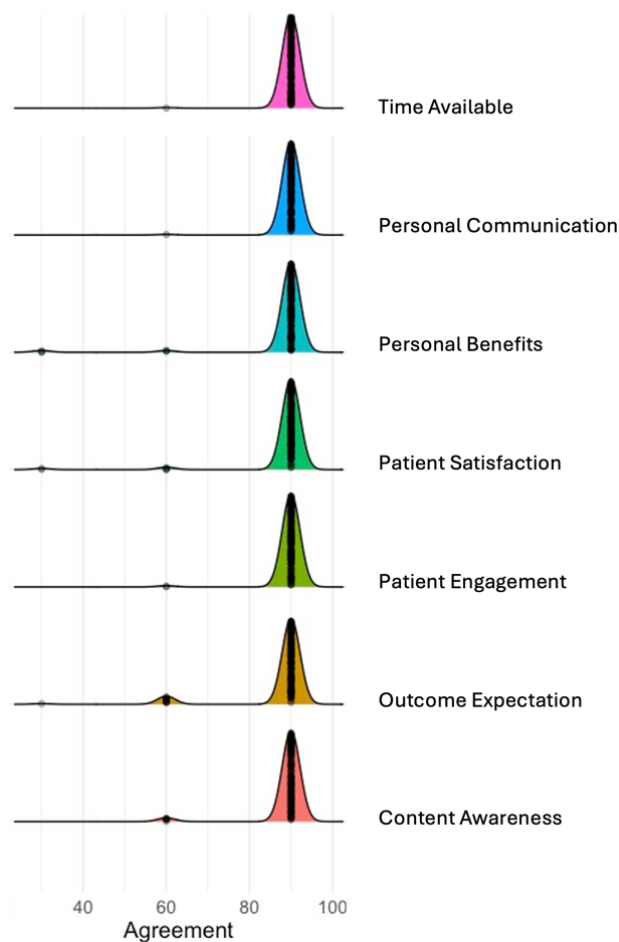


Figure 6. 3. Patients reported determinants of implementation using MIDI determinants. The ridgeline plot displays the distribution of agreement levels for the MIDI determinants. Each coloured ridge represents the distribution of responses for a determinant, with the width of each curve indicating the spread of agreement levels, and the peak represents the most frequent level of agreement among respondents.

6.5. Discussion

The present study explored the implementation of a culturally-appropriate Nigerian dietary screening tool (NiDST) into outpatient clinic workflow to assess dietary intake in adults with or without hypertension with the aim of evaluating: (i) the impact of patient-clinician interaction on dietary advice; and (ii) clinicians' and patients' perceived barriers

and facilitators for implementation in a Nigerian hospital. The findings demonstrate that the implementation of the NiDST has > 90% fidelity (adherence) for patient recruitment, dietary intake assessment and outpatient consultation. These findings suggest overall satisfaction, engagement, and compliance with the implementation protocol of the NiDST. This was comparable with previous studies on patient-reported outcomes (PROs) among adult cancer and heart failure population studies, where average PRO completion rates varied from 60% to 85% (Haverman et al., 2013; Smith et al., 2016; Schepers et al., 2017; Gallagher et al., 2019). The majority of the patients using the NiDST reported the tool was clear, complete, easy to use, and has clinical value as it helps to assess their food intake and supports their clinicians in providing helpful dietary advice. The short completion time (<6 minutes) and accepted marginal increase in consultation time (< 10 minutes) suggest that the tool can be seamlessly integrated into clinic workflow without significant disruptions and that supplementary dietary material (e.g., pamphlet) for clinicians to support their patients could reduce its impact on consultation times and facilitate its usability and value.

The NiDST effectively addresses the challenges of limited time, increased workload, and busy clinics by providing a user-friendly, time-efficient tool for assessing patients' dietary intake, evidenced by the short patient completion times and clinical counselling time. Despite the marginal increase in consultation time, clinicians acknowledged that the NiDST streamlined the dietary assessment process, allowing for more focused dietary discussions during clinic visits. Additionally, patients reported feeling more engaged in dietary discussions and expressed a greater understanding of their dietary needs and risks of hypertension. Importantly, the NiDST facilitated personalised dietary advice tailored to their needs. These findings highlight the transformative potential of the NiDST in promoting patient-clinician communication, enhancing patient engagement in dietary discussions, and fostering healthy behaviour change for hypertension management.

6.5.1. Patient-clinician communications

Patient-clinician communication plays a crucial role in effective healthcare delivery, especially in chronic disease management such as hypertension (Epstein RM and Street RL, 2007). When augmented by patient-reported outcome measures such as patient-reported dietary intake, it can significantly enhance the quality of care and promote positive patient outcomes (Weldring and Smith, 2013). For instance, a survey study among 2398 participants from 11 counties in southeast Minnesota with incident heart failure, with a mean follow-up of 1.3 years, reported that patients with good and excellent

patient-centred communication experienced lower risks of death with a hazard ratio of 0.70 (95%CI: 0.51, 0.97), compared with patients with fair or poor patient-centred communication (Fabbri et al., 2020). Our study demonstrated that the NiDST enhanced patient-clinician communication by providing focus-guided dietary discussion based on patients' reported dietary intake provided by NiDST, enabling clinicians to tailor recommendations according to individual needs (Wilkinson et al., 2012; Kaye et al., 2014). Clinicians reported a positive effect that the NiDST guided the focus of dietary consultation and increased engagement with patients, leading to improved communication quality. This finding aligns with previous studies that reported that the use of patient-reported outcomes during consultation guides the focus of the consultation, supports patients' active engagement, improves communication, and positive outcomes (Chen et al., 2013; Kotronoulas et al., 2014; Mejdahl et al., 2020). Overall, the findings indicated that using patient-reported outcome measures like the NiDST improved patient engagement and promoted patient-clinician communication.

6.5.2. Benefits and satisfactions

The perceived benefits of the NiDST for patients and clinicians in assessing dietary intake and providing dietary advice are noteworthy. Clinicians recognised the NiDST's ability to provide insights into patients' food intake and facilitated tailored dietary recommendations. Similarly, patients noted that the use of the NiDST-guided discussion increased their self-awareness of their food intake and empowered them to take control of their dietary habits and make informed positive dietary changes (Haverman et al., 2013). These findings underscore the significant role of effective communication in fostering dietary behavioural change and improvement of patient outcomes, aligning with the significance of patient-reported outcome measures reported by previous studies (Chen et al., 2013; Haverman et al., 2013; Kotronoulas et al., 2014; Mejdahl et al., 2020).

6.5.3. Barriers to and facilitators to implementations

To gain insight into factors associated with the implementation of the NiDST, the primary barriers for clinicians were additional time added to consultations (particularly on busy clinic days) and variability in nutritional knowledge in interpreting dietary data. These findings were consistent with studies that assess the barriers to adopting tools into clinical practice (Wang, T. et al., 2023; Rodrigues et al., 2024). Conversely, facilitators of implementation included the user-friendly design, relevance, compatibility with routine workflow, its ease of integration into clinical routine visits, the succinctness of the NiDST questionnaire, short completion time on the use of the NiDST, and the overall favourable

reception from patients and clinicians (Vadiveloo, M. et al., 2020; Vadiveloo, M.K. et al., 2023). These findings are consistent with previous studies on the integration of electronic patient-reported outcomes and suggest that providing additional training and nutritional resources for clinicians, sign-posting clinicians to dietician referrals in difficult cases, and leveraging facilitators are important to enhance the implementation, including the NiDST (Haverman et al., 2013; Schepers et al., 2017; Palacholla et al., 2019).

6.5.4. Practical application and clinical relevance

Given the rising prevalence of hypertension (Adeloye et al., 2021) and associated dietary risk factors in Nigeria (Batubo, N. P. et al., 2023), the seamless integration of the Nigerian dietary screening tool (NiDST) into clinical workflows supports its practicality and feasibility for widespread adoption. The practical applications of the findings of the pilot implementation study of the NiDST are multifaceted. Firstly, the study demonstrated that the NiDST could effectively integrate into clinical practice to assess dietary intake among individuals, both with and without hypertension, suggesting clinicians and other healthcare professionals can use the NiDST for dietary assessment and counselling during patient outpatient consultations, particularly in the context of chronic disease management. Secondly, the high adherence rate, acceptability, and overall satisfaction among patients indicate that the NiDST was well-received and can be seamlessly integrated into clinical workflows without causing significant disruptions. This suggests that implementing the NiDST into healthcare settings is feasible and can be adopted without imposing an additional burden on healthcare professionals or patients. Thirdly, the perceived benefits reported by both patients and clinicians, such as improved communication, increased self-awareness regarding dietary habits, and empowerment to make positive dietary changes, highlight the potential of the NiDST to facilitate meaningful patient-clinician interactions and promote patient engagement in their own healthcare. Overall, the pilot implementation study of the NiDST demonstrates its practical utility in enhancing dietary assessment and counselling in clinical practice, with potential implications for improving patient-clinician communication and patient outcomes, particularly in chronic disease management such as hypertension.

6.5.5. Strengths and Limitations

This study used a mixed-methods approach, integrating quantitative and qualitative inputs from patients and clinicians to understand facilitators and barriers to the implementation of the NiDST. By considering both patients' and clinicians' perceptions, the study offers a comprehensive understanding of the fidelity of implementation of the NiDST in

addition to the barriers to and facilitators for implementation into routine outpatient consultation in a clinical setting in Nigeria. In short, this single-centre pre-implementation study is an important step to: (i) design and plan for the actual nationwide implementation of the NiDST across the Nigerian clinical settings; (ii) plan and address the barriers identified in this study, including suggestions; and (iii) contribute to further improving and strengthening the value and acceptability of the NiDST.

Nonetheless, there were some limitations. Firstly, this study did not evaluate the role of organisations and socio-political context in this implementation phase because it is a pilot study, and the aim was to understand patients' and clinicians' perceptions of the tool. However, the evidence from this study will be used to plan for a more robust future nationwide implementation study across Nigerian clinical settings. Secondly, the findings may lack generalizability beyond the Nigerian context, as cultural and healthcare system differences could influence the acceptability and integration of the NiDST in other settings. Lastly, the lack of long-term follow-up in the study means that it may not capture the sustained effectiveness or sustainability of integrating the NiDST into clinical practice, highlighting the need for a study of longer duration and wider distribution to provide more insights into the NiDST continued utility and impact over time.

6.5.6. Conclusion

This pilot implementation study, supported by significant patient and clinician-reported facilitators, demonstrated the potential of the Nigerian dietary screening tool (NiDST) to enhance patient-clinician engagement and communication and improve patient outcomes. Additionally, the study provided promising evidence of the feasibility of implementation across Nigerian hospitals. This study lays the groundwork for further research aimed at optimising the NiDST and its implementation across clinical settings in Nigeria.

6.6. Chapter summary

This chapter explores the feasibility of implementing the Nigerian dietary screening tool (NiDST) in a single clinic setting in Nigeria. The primary objective was to evaluate the impact of using the Nigerian dietary screening tool (NiDST) in patient-clinician communication and the barriers to and facilitators of implementation in a single clinical setting in Nigeria using the Measurement Instrument for Determinants of Innovations (MIDI). The findings were promising, evidenced by: (i) the high fidelity of the implementation; (ii) short NiDST completion time and acceptable marginal increase consultation time; and (iii) improvement in patient-clinician communications. The barriers to implementation reported were time constraints and inadequate nutritional

knowledge to interpret dietary data. However, in addition to the improvement in patient-clinician communication, several facilitators of implementations were reported, such as user-friendly design, relevance, compatibility, and the benefits associated with using the NiDST. Overall, this pilot implementation study suggests that the use of NiDST has the potential to improve patient-clinician communication in dietary discussion and is feasible to implement in clinical settings in Nigeria. These findings will lay the foundation for a Nationwide implementation across clinical settings in Nigeria.

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Chapter seven

General discussion, future research, and conclusion

The narrative literature review illustrates an epidemiological transition in Nigeria, highlighted by a steady rise in the prevalence of hypertension, contributing to an increasing risk of cardiovascular disease (CVD) (Adeloye et al., 2021; Chukwu and Dogbe, 2023). This rise in hypertension and cardiovascular burden has been partly attributed to changes in diet that include high consumption of salt, ultra-processed foods, refined sugar and unhealthy fat, and low consumption of fruits, vegetables, whole grains, and fibre (Dong et al., 2022; Vaduganathan et al., 2022; Zhang, B. et al., 2023; Petrikova et al., 2023). Globally, government and healthcare bodies (e.g., WHO and United Nation Assembly) have synergised efforts to develop dietary and lifestyle guidelines and recommendations to address the public health concern of non-communicable diseases. For instance, in 2014, the Nigerian Government outlined the National Nutritional Guidelines to combat non-communicable diseases (NCDs) (Federal Ministry of Health, 2014). Despite these guidelines, most clinicians and other healthcare professionals, including in Nigeria, do not routinely assess patients' dietary risk nor counsel patients on their dietary intake in outpatient clinics due to inadequate time, inadequate advanced nutritional knowledge, and lack of culturally-appropriate dietary assessment tools (Kushner, 1995; Kolasa and Rickett, 2010; Ahmed et al., 2016; Aspary et al., 2018). However, as highlighted in Chapter one, brief nutritional training and the use of validated rapid dietary screening tools can mitigate these barriers and contribute to the preventive effort against diet-related diseases, including hypertension (Vadiveloo, M. et al., 2020; Vadiveloo, M.K. et al., 2023). To this end, this PhD developed a validated culturally-appropriate dietary screening tool and a diet risk score for hypertension that is rapid and feasible to administer and usable by clinicians, patients, and researchers with the goals of: (i) facilitating dietary discussions; (ii) providing personalised dietary advice tailored to individual patient needs; and (iii) empowering patients to improve their diet and take an active role in the prevention and management of hypertension in Nigeria.

7.1. PhD research findings

The aim and objectives of this PhD, as highlighted in **section 1.15**, were achieved through a mixed-methods design involving qualitative and quantitative approaches:

1. A systematic review and meta-analysis that synthesised previous evidence on the association between dietary factors and hypertension in West African countries. This led to the development of the initial 27-item Food Frequency Questionnaire

(FFQ) to assess the dietary intake of individuals at risk of hypertension in Nigeria (*Chapter two*).

2. A feasibility and acceptability clinical trial was then conducted to assess end users' (e.g., patients and healthcare professionals) perspective on the FFQ food list and format, usability of the FFQ, and integration of the FFQ into routine clinical practice for dietary screening. The findings from this study informed the refining of the initial FFQ to a rapid/brief, culturally-appropriate 27-item FFQ (*Chapter three*).
3. The refined 27-item culturally-appropriate 27-item dietary assessment tool (FFQ) was then validated against three repeat 24-hour dietary recalls and assessed for reproducibility of the FFQ. The findings from this study further refined the tool and informed the subsequent development of a valid and reliable rapid culturally-appropriate 25-item Food Frequency Questionnaire called the 'Nigerian Dietary Screening Tool' (NiDST) (*Chapter four*).
4. Next, a cross-sectional study was conducted using the NiDST to assess dietary intake among adult patients and evaluate the association between dietary factors and hypertension risk in Nigeria. The goal was to simplify the NiDST for clinicians to quickly identify and stratify individuals at risk of hypertension in outpatient clinics. The findings from this trial led to the development of a validated diet risk score called the 'Nigeria Diet Risk Score' (NiDRS) (*Chapter five*).
5. Finally, a qualitative single-centre pilot implementation study was conducted to assess the perceptions and experiences of both patients and clinicians on the utility of the NiDST in real-time clinical practice to evaluate its impact on patient-clinician discussion of dietary behaviour and barriers to and facilitators of implementation of the NiDST (*Chapter six*).

Chapters two to six provided detailed discussions regarding the main findings for each study component. The aim of **Chapter seven** (*General discussion, future research, and conclusion*) is to present the findings from all studies into a coherent thesis to address the research questions, objectives, and overall aims of this PhD (*section 1.15*) and, therefore, highlights the overall contributions of this work to the existing knowledge on dietary assessment strategies and hypertension prevention in Nigeria. Finally, this chapter brings together the strengths and limitations of the thesis, recommendations for policy and practice and presents future research.

7.1.1. Research objective 1

To conduct a systematic review and meta-analysis to synthesise the evidence on the association between dietary factors and hypertension in Nigeria and other West African countries.

In study one, a systematic review and meta-analysis synthesised existing evidence of dietary factors associated with hypertension risk in West African countries, including Nigeria (*see Chapter two*). The findings indicated that among 31 observational studies with 48,809 participants and 12,223 cases of hypertension, a high intake of fruit and vegetables was associated with decreased odds of hypertension (OR=0.80, 95% CI: 0.72, 0.89, $p < 0.0001$, $I^2 = 0\%$). The absence of heterogeneity in this analysis may suggest a relatively consistent association across West African countries. However, the protective effects of fruits and vegetables were found to be less pronounced in older adults. The study further identified numerous unhealthy food groups that significantly increased the odds of hypertension in previously published work: junk foods, red meat, dietary fats, dietary salt, and alcohol. For instance, high intake of red meat was associated with a 51% increased odds of hypertension (OR=1.51; 95% CI: 1.04, 2.18; $p = 0.03$, $I^2 = 27\%$) compared to low red meat intake, and high salt intake with an increased likelihood of hypertension by 25% compared to low salt intake (OR= 1.25; 95% CI: 1.12, 1.40; $p < 0.0001$, $I^2 = 30\%$). There was low heterogeneity in these meta-analyses, and the examined confounders did not significantly modify the observed association.

Moreover, high consumption of ‘junk foods’ was associated with 41% increased odds of hypertension (OR=1.41; 95% CI: 1.19, 1.67; $p < 0.0001$, $I^2 = 0\%$) compared to low consumption. Additionally, high dietary fat consumption was significantly associated with an increased likelihood of hypertension (OR=1.76; 95% CI: 1.44, 2.14; $p < 0.0001$, $I^2 = 0\%$) and high intake of alcohol, > two drinks per day for men and > one drink per day for women, was linked with 17% increased odds of hypertension (OR= 1.17, 95% CI: 1.03, 1.32; $p = 0.013$, $I^2 = 0\%$) compared to abstainers. The absence of heterogeneity, publication bias, and a lack of moderating effects of age, BMI, or study location on the association of these food groups in these meta-analyses indicates the robustness of these findings, unaffected by variations in study design, population demographics, or other potential sources of variability and indicated the consistency of association of these dietary factors across West African countries, including Nigeria.

These findings from the systematic review and meta-analysis, along with evidence from the Nigerian and Ghana National Nutritional Guidelines for Non-communicable

Diseases, informed the development of a 27-item Food Frequency Questionnaire (FFQ) dietary assessment tool, later referred to as the Nigerian Dietary Screening Tool (NiDST), to estimate dietary intake in individuals at risk of hypertension in clinical settings in Nigeria and other West African countries.

7.1.2. Research objective 2

To evaluate the feasibility and acceptability of integrating a culturally-appropriate FFQ dietary screening tool into clinical practice among patients and healthcare professionals in Nigeria.

Study two, which fulfilled research objective 2, was conducted in Phase one of this PhD (*see Chapter three*). The findings from the study indicated a robust completion rate for the 27-item FFQ, with 100% completion at the initial visit and 87.9% after three weeks. The average FFQ completion time was 7.37 ± 2.28 minutes, with a retention and adherence rate of 87.9%. Most patients (96.6%) overwhelmingly endorsed the tool's clarity, cultural appropriateness, and ease of use, with 96.6% expressing satisfaction in the use of the tool. Notably, 96.6% thought it provided a comprehensive assessment of their dietary intake, although 6.9% highlighted missing food items such as unripe plantain, corn flour, Tofu (soybeans), and Ukwa (breadfruit), while 96.6% of patients indicated that they believed that the FFQ would support healthcare professionals to provide personalised dietary support to patients.

The qualitative feedback from healthcare professionals ($n=35$) confirmed that dietary assessment was key in hypertension management. Despite this recognition, only a minority (11.4%) reported conducting regular dietary assessments, with few (2.9%) indicating the availability of culturally-appropriate tools in Nigeria. While most (77.2%) expressed confidence in using dietary assessment tools, 51.4% encountered challenges in dietary data analyses. However, with the introduction of the new FFQ (NiDST), the majority highlighted clarity (97.1%), relevance (94.3%), and value (97.1%) for estimating dietary intake and believed that the tool could support individualised dietary recommendations. The majority of the healthcare professionals (82.9%) express optimism about seamlessly integrating the FFQ into routine clinical practice without potential workflow disruptions, and 94.3% could foresee successful implementation in Nigeria.

Overall, the findings provided promising evidence supporting the use of the FFQ as: (i) a useful and acceptable tool; (ii) a culturally-appropriate tool; (iii) rapid or quick and feasible to administer and integrate into clinic workflow for dietary assessment in

hypertension screening; and (iv) the provision of personalised dietary advice to patients in clinical settings in Nigeria. These findings informed the refinement of the FFQ (NiDST) and for subsequent validation studies in clinical settings in Nigeria.

7.1.3. Research objective 3

To assess the agreement between the Food Frequency Questionnaire and multiple 24-hour dietary recalls to determine its relative validity and reproducibility in estimating dietary intake among adult patients in Nigeria in a clinical setting.

Study two fulfilled research objective 3 and was conducted in Phase Two of this PhD (*see Chapter four*). First, the 27-item Food Frequency Questionnaire (FFQ) was regrouped into 20 food groups based on food groups with similar physiological effects. The 20 food groups were evaluated for relative validity and reproducibility. The findings indicated no significant differences in the mean and median daily intake of the food groups estimated between the FFQ and 24-hour dietary recall (24DR) when a Wilcoxon signed-rank test was applied — the only exception being ‘fats and oils’ ($p < 0.05$). The mean fold differences ranged from 0.25 to 1.25 across different food groups. Moreover, the percentage of participants grossly misclassified by 3 quartiles ranged from 0% for alcoholic drinks to 59% for salt, with an average of 11%. The exact or adjacent quartiles ranged from 10% for dessert and sweets to 88% for processed meat and alcoholic drinks, with an average exact agreement of 53% and an adjacent agreement of 37%. Importantly, 90% of participants were classified in the same or neighbouring quartile, indicating a good agreement between the FFQ and 24DR in ranking individuals’ dietary intake.

The Spearman’s rank correlation coefficients ranged from 0.20 for fats and oils to 0.78 for vegetables, with an overall average correlation coefficient of 0.60. The majority of the food groups ($n=15$) had a correlation coefficient ≥ 0.50 . The Bland-Altman analysis illustrated minimal bias for most food groups, with over 96% of observations falling within acceptable limits of agreement. Regarding reproducibility, Spearman’s correlation coefficients ranged from 0.38 for yam and potatoes to 0.97 for salt, with an average correlation coefficient of 0.75. Most food groups ($n=17$) demonstrated strong positive correlation coefficients above 0.60. Furthermore, the intraclass correlation coefficient (ICC) ranged from 0.31 for stew to 0.98 for fruit, with an average intraclass correlation coefficient of 0.77. Most food groups ($n=17$) had $ICC \geq 0.70$, indicating good to excellent reproducibility.

Overall, the findings confirmed the relative validity and reproducibility of the Food Frequency Questionnaire (FFQ) — NiDST. Findings from this study informed the further

refinement of the FFQ, leading to the valid and reliable culturally-appropriate 25-item FFQ referred to as the Nigeria Dietary Screening Tool (NiDST). The NiDST was then used in study three to estimate dietary intake among patients in clinical setting in Nigeria with the goal of simplifying the tool to support its clinical use and reduced the completion.

7.1.4. Research objective 4

To derive a Nigerian diet risk score (NiDRS) for hypertension in Nigeria to facilitate clinical use and patient assessment and underscore key areas for dietary improvement.

Study three, which fulfilled research objective 4, was fulfilled in study three conducted in this PhD (*see Chapter five*). This study derived and validated a culturally-appropriate Nigerian diet risk score (NiDRS) to assess the dietary risk level of individuals with or without hypertension. Dietary intake was determined using the Nigerian dietary screening tool (NiDST). The findings demonstrated that there was no significant difference in the mean daily consumption of healthy food groups (e.g., fruits, vegetables, rice and pasta, wheat products, fibre-rich cereals, beans and lentils, nuts and seeds, tea and coffee, dairy (milk), starchy tubers, fish and seafood, and white (lean) meat)) between hypertensive and non-hypertensive individuals (all $p>0.05$). However, hypertensive individuals significantly consumed higher amounts of unhealthy food groups (e.g., red meat, eggs, processed meat, fried and fast foods, soup and stews, desserts and sweets, soft drinks, alcoholic drinks, salt and seasonings) compared to non-hypertensive individuals (all $p<0.05$), when a Wilcoxon signed-rank test was applied. Furthermore, 11 unhealthy food groups (out of 23 food groups) were identified to significantly increase the odds of hypertension, which was retained and used for the creation of the Nigerian Diet Risk Score (NiDRS). The created NiDRS (with a minimum score of 0 and a maximum score of 30) demonstrated a significant positive association with hypertension risk with increased odds of hypertension (OR: 2.04, 95%CI: 1.16, 3.58, $p=0.013$). Additionally, individuals in the highest NiDRS category (score >11.3) had >18 -fold increased odds of hypertension (OR: 18.27, 95%CI: 1.33, 251.21, $p=0.030$) compared to those in the lowest category (≤ 11.3).

Furthermore, the NiDRS demonstrated a good predictive ability with a: (i) good model fit with a Hosmer-Lemeshow test of $\chi^2=6.931$, $p=0.544$); (ii) satisfactory calibration with a Brier score of 0.1; (iii) high discriminative ability with Receiver Operating Characteristic - Area Under the Curve of 92% (95%CI: 80, 100%) along with high accuracy (90%) and precision (92%); and (iv) positive net benefits of identifying

individuals with hypertension for the threshold probability ranging from 2 to 60% compared to the other screening strategies (treat all and treat none). In addition to the predictive ability of the NiDRS, analysis of blood samples from a subset of patients ($n=94$) demonstrated a significant increase in atherogenic indices in hypertensive individuals compared to non-hypertensive individuals ($p<0.05$), such as atherogenic index of plasma (AIP), atherogenic coefficient (AC), Castelli Risk Index-I (CRI-I), Castelli Risk Index-II (CRI-II), and triglyceride to high-density lipoprotein cholesterol ratio (THDL), and inflammatory biomarkers, such as C-reactive protein (CRP) and homocysteine. This increase was largely driven by the significant elevation of serum total cholesterol, triglycerides, low-density lipoprotein, very low-density lipoprotein, C-reactive protein, and homocysteine, which were significantly higher in the hypertensive participants compared to non-hypertensive participants ($p<0.001$). Moreover, the total cholesterol, triglycerides, low-density lipoprotein, very low-density lipoprotein, C-reactive protein, and homocysteine had significant positive associations with both mean arterial pressure and NiDRS ($p<0.001$). In addition, these biomarkers significantly mediated the effects (indirect effect) of NiDRS on mean arterial pressure in a positive direction ($p<0.05$), with the proportion mediated by the biomarkers standing at 50%, 47%, 49%, 17%, 68%, and 71%, respectively.

Overall, the Nigerian Diet Risk Score for hypertension: (i) is a valid risk assessment tool; (ii) has the ability to stratify individuals into high and low hypertension risk based on their dietary intake; (iii) the effect of the NiDRS on hypertension is partially mediated by some biomarkers (e.g., TC, TG, LDL-C, VLDL-C, CRP, and homocysteine); and (iv) has a net positive benefit in making informed clinical decision.

7.1.5. Research objective 5

To evaluate the impact of using the Nigerian dietary screening tool (NiDST) and Nigerian diet risk score (NiDRS) on patient-clinician communication and the barriers to and facilitators of implementation in clinical setting in Nigeria.

Research objective 5 was achieved in study four of this PhD (*see Chapter six*). The findings indicated that the fidelity of patient recruitment was 91% and 94% for patients who completed NiDST/NiDRS before outpatient consultation with <6 minutes completion time, while 91% of the patients completed the Measurement Instrument for Determinants of Innovations (MIDI) feedback questionnaire post-outpatient consultation with NiDST/NiDRS-reported dietary intake with an accepted marginal increase in consultation time (< 10 minutes). Patients did not report any barriers to the

implementation of the NiDST. However, clinician-reported barriers were additional nutritional knowledge, and time constraints for dietary discussion, as reported by 25% of clinicians, but suggested that the inclusion of dietary guidelines for each food group (e.g., pamphlet) could shorten the additional consultation time. The facilitators of implementation reported among clinicians were: (i) high agreement ($\geq 85\%$) on the procedural clarity, completeness, and relevance of the NiDST; (ii) improved patient-clinician engagement and communication (100%); and (iii) support clinicians in dietary discussion ($>90\%$). While among patients, the facilitators were: (i). NiDST was clear, comprehensive and quick to complete (96%); (ii) facilitated communication with doctors and improved their engagement (99%); (iii) self-reflection on food intake (91%); and (iv) acceptable completion time (99%).

Overall, the findings from this pilot implementation study, on the whole, indicated that the Nigerian Dietary Screening Tool (NiDST) and Nigerian Diet Risk Score (NiDRS) have the potential to enhance patient-clinician engagement and communication and improve patient outcomes across Nigerian hospitals. These findings are supported by the patient-clinician-reported facilitators and will lay the groundwork for nationwide implementation across clinical settings in Nigeria in future work.

7.2. General discussion

This PhD aimed to support Nigerian clinicians and other healthcare professionals to assess dietary intake among individuals at risk or with hypertension, improve dietary discussion, and offer personalised dietary advice to patients in Nigeria. The findings from this PhD suggested that most Nigerians with hypertension consumed higher amounts of unhealthy food groups compared to non-hypertensive individuals, which significantly increases their risk of hypertension. Furthermore, dietary intake data from this PhD led to the creation of: (i) a validated and reliable rapid culturally-appropriate 25-item Nigerian dietary screening tool (NiDST); and (ii) the 11-item Nigeria diet risk score for hypertension (NiDRS).

7.2.1. Unhealthy foods and hypertension

The findings of the positive association between unhealthy food groups (such as dietary fats and oils, red meat, ‘junk foods’, dietary salt, and alcohol) and hypertension risk observed from the systematic review and meta-analysis conducted in study one of this PhD (*Chapter 2*) were confirmed in study three (*Chapter 5*) of this PhD as also highlighted in section 7.1.4. This indicates that hypertensive individuals consumed more unhealthy food groups compared to non-hypertensive individuals and increased their odds

of hypertension in Nigeria. However, this PhD research did not find significant differences in the consumption of healthy food groups between hypertensive and non-hypertensive individuals, suggesting that overall, individuals with hypertension exhibit poor dietary behaviour compared to non-hypertensive individuals in Nigeria. This finding aligns with a similar study conducted outside Sub-Saharan Africa in Iran by Akbarpour et al. (2019) among 8244 participants, which reported that consumption of unhealthy foods consisting of food groups such as sugar-sweetened beverages, salt, and fast foods was higher in adult individuals with hypertension with 44% increased odds of hypertension (OR=1.44; 95%CI: 1.11, 1.88) (Akbarpour et al., 2019).

Furthermore, the findings from study three (**Chapter 5**) demonstrated that these unhealthy food groups, highlighted in section 7.1.4, were not only consumed in higher amounts amongst hypertensive individuals but were associated with an increased risk of hypertension. This finding aligns with studies previously conducted in Africa and beyond Africa, indicating a consistent positive association between unhealthy food consumption and hypertension risk. For instance, several meta-analyses have reported the association between unhealthy food groups and hypertension. Firstly, a meta-analysis of six prospective cohort studies involving 312,156 participants found that high consumption of sugar and artificially sweetened beverages increased the risk of hypertension by 13%, compared to the low intake category (RR=1.13, 95%CI: 1.10, 1.16) (Qin et al., 2020). Secondly, another meta-analysis of eight cohort studies among 222,544 participants demonstrated that high consumption of fried food is associated with a 20% increased risk of hypertension (RR=1.20, 95%CI: 1.05, 1.38) (Qin et al., 2022). Thirdly, Zhang and Zhang meta-analysed 11 prospective cohort studies with 351,819 participants and reported that a high intake of red meat increased the risk of hypertension by 22%, compared to the lowest intake category (RR=1.22, 95%CI: 1.11, 1.35) (Zhang, Y. and Zhang, 2018). Fourthly, a meta-analysis of 18 studies among 138,916 participants of low and middle-income countries found a 7-42% increased hypertension risk among individuals with high salt intake, particularly amongst rural (RR=1.07, 95%CI: 1.04, 1.10) and urban (RR=1.42, 95%CI: 1.19, 1.69) populations in low and middle-income countries (Subasinghe et al., 2016). Similarly, a meta-analysis conducted in China with 23 studies among 30,565 participants found an almost 4-fold increase in the odds of hypertension with daily consumption of salt (OR=3.94, 95%CI: 3.03, 5.13) (Zhang, Y. et al., 2021). Lastly, a meta-analysis conducted by Roerecke et al. (2018) involving 20 studies among 361,254 participants highlighted that intake of more than two alcoholic drinks per day was associated with a 42-51% risk of hypertension risk in both men

(RR=1.51, 95%CI: 1.30, 1.76) and women (RR=1.42, 95%CI: 1.22, 1.66) compared to abstainers (Roerecke et al., 2018).

In addition to these meta-analyses, previous prospective cohort studies also indicated an up to 12-15% elevated risk of hypertension among 28,100 adult US women consuming high amounts of saturated (RR=1.12, 95%CI: 1.05, 1.20) and trans fats (RR=1.15, 95%CI: 1.08, 1.22) (Wang, L. et al., 2010). Similarly, another cohort study conducted among 1,086 Chinese adults demonstrated that a high fat intake was associated with 40% increased odds of hypertension (OR=1.40, 95%CI: 1.12, 1.75) compared with low-intake individuals (Yuan et al., 2020). Overall, the findings from this PhD affirm that high consumption of these unhealthy food groups increases the risk of hypertension and contributes to the pathogenesis and progression of hypertension among adults in Nigeria.

7.2.2. Biochemical evidence of unhealthy foods induced hypertension

The link between unhealthy food groups and hypertension is supported by biochemical evidence implicating certain unhealthy foods, such as red and processed meat, salt, ultra-processed foods, and alcohol, contributing to the development of hypertension through various biochemical and physiological pathways (Stamler et al., 1996; Wang, L. et al., 2010; Bhardwaj et al., 2011; Grillo et al., 2019; Qin et al., 2020; Qin et al., 2022). The digestion or metabolism of these foods often produces high concentrations of cholesterol and cholesterol products, sodium, oxidative by-products, and inflammatory biomarkers in the blood, contributing to the development of hypertension by: (i) promoting the accumulation of blood LDL-cholesterol and triglycerides plaques; (ii) increasing plasma sodium level; and (iii) inducing oxidative stress and inflammation through heightened levels of reactive oxygen species (ROS) and pro-inflammatory cytokines such as interleukin-17 and tumour necrosis factor (Stamler et al., 1986; Vogel et al., 1997; Light et al., 1999; Jennings et al., 2004; Wang, Y. et al., 2014). In addition to these food groups, alcohol stimulates renin release, leading to angiotensin-II production and aldosterone secretion, which enhances vasoconstriction, sodium retention, and water reabsorption (Oparil et al., 2003; Puddey et al., 2019). Furthermore, alcohol metabolism generates ROS and reactive nitrogen species (RNS), which cause oxidative damage to the endothelium and vascular smooth muscle (Tsuji et al., 1992; Husain et al., 2011). These factors or mediators, individually or collectively, cause sodium and water retention, endothelial dysfunction and impaired vascular function, sympathetic nerve dysregulation, and atheroma formation, leading to the increase of extracellular fluid volume (e.g., plasma volume), vasoconstriction and increased vascular resistance, increasing blood pressure

over time (Girardin et al., 1980; Guyton, 1991; Tsuji et al., 1992; Husain et al., 2011; Elijovich et al., 2016; Kurtz et al., 2017; Grillo et al., 2019; Marketou et al., 2019; O'Donnell et al., 2020).

7.2.3. Acceptability of the Nigerian dietary screening tool (NiDST)

Building upon the findings from study one, the 27-item Food Frequency Questionnaire, which is the Nigerian dietary screening tool (NiDST) for hypertension, was developed. The feasibility and acceptability of the NiDST were assessed to evaluate its cultural appropriateness, clinical relevance, effectiveness, and adoption among the end-users (e.g., patients and healthcare professionals) in real-world clinical settings (Cade et al., 2002; Subar et al., 2015; Subar et al., 2020). This is to ensure that: (i) the tool can deliver the right data; (ii) it is evidence-based; and (iii) it is feasible to administer and integrate into clinical settings in Nigeria (Vadiveloo, M. et al., 2020; Vadiveloo, M.K. et al., 2023). Involving stakeholders in the development process ensured that the NiDST accurately captured diets or foods specific to the Nigerian population to improve its acceptability as a dietary assessment tool (Teufel, 1997; Subar et al., 2015; Vadiveloo, M. et al., 2020). The findings demonstrated a positive reception of the initial 27-item NiDST among patients and healthcare professionals in Nigeria. The high retention and adherence rates, acceptable completion rates and time (<8 minutes), satisfaction levels, and perceived utility support the acceptability of the tool. These findings align with previous FFQ feasibility studies reporting similar high engagement, retention, and satisfaction rates (Hebert et al., 1995; Kristal et al., 2014). The efficient completion time of under 8 minutes is consistent with recommended timeframes of < 15 minutes from previous clinical studies (Cade et al., 2002; Kristal et al., 2014; Bailey, 2021). This timeframe suggests that the NiDST is a rapid tool and can be completed during the waiting time at the outpatient clinic, and the integration is unlikely to disrupt clinical workflows in Nigerian healthcare settings, with most patient waiting times in Nigerian hospitals ranging from 84 to 144 minutes and a mean pre-consultation interval of 48.7 minutes (Ajayi, 2002; Oche and Adamu, 2013; Abah V. O., 2021).

Furthermore, the NiDST supported healthcare professionals in assessing dietary intake, facilitating personalised dietary advice, and empowering them to manage hypertension actively. In so doing, the tool addresses the identified need for routine dietary assessment in clinical settings in Nigeria. The NiDST was found to be culturally-appropriate for dietary intake assessment for individuals with or without hypertension, as indicated by both patients and healthcare professionals, an important attribute of an assessment tool

developed for a specific population (Teufel, 1997; Kristal et al., 2014). The positive perceptions of utility and clinical relevance among healthcare professionals support the potential for successful implementation. Notably, the study highlighted the need for culturally-appropriate tools, as existing non-regional tools often inadequately capture the dietary habits of ethnic minority populations (Kristal et al., 2014). Overall, the positive reception, relevance, acceptability, and effectiveness of the NiDST from both patients and healthcare professionals demonstrated the need for the NiDST. It laid a strong foundation for further validation and implementation in subsequent phases of this PhD research.

7.2.4. Validation of the Nigerian dietary screening tool

Validation of a new tool or method is important to assess its accuracy and reliability in estimating what it was intended to measure by comparing it to a reference method or gold standard (Cade et al., 2002; Rutishauser, 2005; Gibson, 2022). The findings from the validation of the Nigerian dietary screening tool (NiDST) demonstrated good validity, with an average correlation coefficient (r_s) of 0.60 compared to the 24-hour dietary recalls (24DR) with correlation coefficients ranging from 0.20 to 0.78 and most of the food groups ($n=15$) demonstrating correlations coefficients >0.50 , indicating good agreement (Cade et al., 2002; Rutishauser, 2005). The observed under- or over-estimation by the FFQ (NiDST) was within an acceptable range and was not significantly different from the estimated intake of the 24DR, suggesting a good agreement. This finding was consistent with findings from previous validation studies. For instance, Streppel et al. evaluated the validity of an FFQ against the 24DR among 128 Dutch adults and reported overestimation in 13 of 21 food groups by the FFQ (Streppel et al., 2013).

Furthermore, the agreement between the NiDST and 24DR was satisfactory, with 90% of participants classified into the same or neighbouring quartiles with an average gross misclassification of 11%. This finding aligns with successful validation studies in Australia that reported 27-70% exact agreement and under 15% gross misclassification (Ambrosini et al., 2003; Marks et al., 2006; Wong et al., 2012). In addition to the agreement between the NiDST and 24DR, the Bland-Altman analysis revealed minimal bias for most food groups ($n=19$), with over 96% of observations within acceptable limits of agreement, aligning with or exceeding the results of previous work, having $<90\%$ agreement for the majority of the food groups as reported in some FFQ validation studies (Aoun et al., 2019; Savija et al., 2021). Moreover, the NiDST exhibited commendable performance, with robust positive correlations for reliability surpassing $r_s > 0.60$ for most assessed food groups ($n=17$ out of 20 food groups) and intraclass correlation coefficients

(ICC) > 0.70 for most food groups ($n=16$). These findings align with the recommended standards for reproducibility (Cade et al., 2002; Baranowski and Willett, 2012; Koo and Li, 2016) and are consistent with the results of other FFQ reproducibility studies (Fallaize et al., 2014; Aoun et al., 2019; Savija et al., 2021). The acceptable levels of agreement between baseline and follow-up assessments suggest that the NiDST is well-suited for accurately estimating dietary intake and capturing dietary inconsistencies among Nigerians (Willett, W.C. et al., 1985; Lee et al., 1995).

Overall, the strong validity and reliability of the NiDST laid a solid foundation for developing a diet risk score for hypertension in the subsequent phase of this PhD research. The NiDST was used to collect dietary intake data among patients in Nigeria and informed the derivation and validation of the Nigeria diet risk score (NiDRS) for hypertension.

7.2.5. Nigerian diet risk score for hypertension

This PhD successfully developed and validated the 11-item Nigerian diet risk score (NiDRS) from the dietary intake assessed using the Nigerian dietary screening tool among 151 patients in Nigeria. The NiDRS is a rapid, culturally-appropriate tool for assessing dietary intake associated with hypertension risk and stratifying individuals at risk of hypertension into high or low hypertension risk categories in Nigeria. The NiDRS included unhealthy food groups that were significantly positively associated with hypertension in the multiple multivariate regression models. The inclusion of unhealthy food groups in the scoring system aligns with well-established studies where consumption of these food groups has been found to be associated with cardiovascular disease risk, as reported in various studies from Western countries and included in risk scoring (Conroy et al., 2003; Kim et al., 2003; Trichopoulou et al., 2003; D'Agostino et al., 2008; Fung et al., 2008; Berentzen et al., 2013; Guenther et al., 2013; Elis et al., 2018). The NiDRS demonstrated robust internal validity, with strong discrimination, calibration, and positive net benefit for making informed clinical decisions. This suggests that the NiDRS is a reliable and valid tool for predicting hypertension risk, at the same time, it is effective in stratifying hypertension risk levels among individuals. These findings are consistent with those from previous risk score studies (Wald et al., 1999; McGorrian et al., 2011; Elis et al., 2018; Lindbohm et al., 2021). For instance, the discriminatory power of NiDRS to identify individuals at risk of hypertension, meet or exceed the performance of established risk scores such as the INTERHEART modifiable risk score (McGorrian et al., 2011), the

Framingham Heart Study (D'Agostino et al., 2008), and the SCORE project (Conroy et al., 2003).

Furthermore, to understand the pathway through which the NiDRS impacts hypertension, the association between the NiDRS and biomarkers of hypertension was evaluated. Interestingly, the NiDRS has a significantly positive association with biomarkers such as total cholesterol, triglycerides, LDL cholesterol, very low-density lipoprotein cholesterol, C-reactive protein, and homocysteine, which is consistent with previous studies that assess the role of biomarkers and diet on cardiovascular diseases, including hypertension (Fung et al., 2001; Centritto et al., 2009; Zhang, J. et al., 2016; Asadi et al., 2020; Gholizadeh et al., 2020; Koelman et al., 2022; Ushula et al., 2022). Similarly, these biomarkers significantly mediated the association between NiDRS and mean arterial pressure in a positive direction by 17-71%. These results suggest that the effect of unhealthy foods on elevated blood pressure is partly driven by its effect on blood lipids and inflammation biomarkers. These findings align with the biological or biochemical pathways through which diet influences hypertension risk, as discussed in *sections 1.6 and 7.2.2*. The NiDRS offers a culturally-appropriate and effective method of assessing dietary intake, enabling early identification of individuals at risk of hypertension and offering early dietary intervention (Hankin and Wilkens, 1994). The tool aims to empower Nigerians to take proactive measures in modifying their diets and making informed lifestyle changes to mitigate their hypertension risk (Bonaccio et al., 2013; Liese et al., 2015). Additionally, the NiDRS will serve as a robust and user-friendly tool for clinicians and other healthcare professionals to routinely screen and stratify patients at risk of hypertension, facilitating personalised dietary counselling and targeted interventions for high-risk individuals (Force et al., 2017; Patnode et al., 2017; Force et al., 2020).

Overall, the NiDRS and NiDST represent a significant advancement in dietary assessment and risk stratification for hypertension in Nigeria. It will form a clinical decision support for clinicians and other healthcare professionals to assess patients' dietary intake, identify potential modifiable risks associated with hypertension, and offer recommendations or interventions based on the results. These tools could also empower patients to take proactive measures to address their dietary behaviours and support the mitigating effort to prevent hypertension in Nigeria and globally.

7.2.6. Feasibility of implementation of the Nigerian dietary screening tool

Evidence has shown that clinical barriers such as low end-user satisfaction and time constraints can hinder the adoption of screening tools in clinical practice (Fischer et al.,

2016; Ebell et al., 2018; Wang, Z. et al., 2018; Vadiveloo, M. et al., 2020). Therefore, understanding the fidelity of implementation will strengthen the tool for seamless integration into the clinical practice. The findings from the pilot implementation of the Nigerian dietary screening tool highlight several critical aspects of its implementation in clinical practice. Firstly, the tool was completed in less than six minutes, and dietary discussion was offered to patients in < 10 minutes. This suggests that the tool can integrate well within the clinic workflow without disruption, aligning with findings from previous studies and recommendations of completion time <15 minutes (Kristal et al., 2014; Vadiveloo, M. et al., 2020). Secondly, the high adherence and completion rates (>90%) of the implementation of NiDST exceed or in comparison with previous implementation studies on patient-reported outcomes (PROs) among adult cancer and heart failure population studies, where average fidelity values (adherence rates) varied from 60% to 85% (Haverman et al., 2013; Smith et al., 2016; Schepers et al., 2017; Gallagher et al., 2019). Thirdly, studies have reported that communication with healthcare professionals influences decision-making, psychosocial adjustment, treatment adherence, and care satisfaction (Blanch-Hartigan et al., 2016). In addition, effective communication increases individual satisfaction and adherence to treatment protocol and improves the quality of life (Fellowes et al., 2003; Blanch-Hartigan et al., 2016). In this regard, all clinicians and 99% of patients affirmed that patient-NiDST-reported findings improved their communication and engagement in the dietary discussion. These findings align with previously reported studies that demonstrated that using patient-reported outcome measures and feedback results by clinicians can improve pain management, patient-clinician communication, detection, control and management of symptoms, increase the utilisation of supportive care, and increase patient engagement and involvement in the care process (Chen et al., 2013; Etkind et al., 2015; Howell et al., 2015; Yang et al., 2018; Licqurish et al., 2019).

Furthermore, other clinicians reported facilitators to the implementation of the NiDST, such as: (i) high agreement on procedural clarity, completeness, and relevance of the NiDST; (ii) support clinicians in dietary discussion; (iii) increased self-reflection and sensitivity to changes in dietary intake by patients; and (iv) overall end-user (patient and clinicians) satisfaction of the NiDST highlight promising evidence of the feasibility of implementation of the NiDST in clinical practice in Nigeria hospitals. Overall, clinicians and patients rated the tool as rapid to administer, improved patient-clinician communication and engagement, ease of use, clinically relevant and practically feasible to implement in Nigerian clinical settings.

7.3. Strengths and Limitations of the PhD research

The strengths and limitations of each study are discussed at the end of their respective chapters, specifically in sections 2.5.4, 3.5.5., 4.5.4, 5.5.1, and 6.5.5. This section summarises the strengths and limitations observed across the entire PhD research and the individual studies.

7.3.1. Strengths of the PhD research

The strengths of this PhD research are multifaceted, encompassing its rigorous methodology, hands-on design and management of a clinical study, innovative dietary screening and risk score tool development, and potential impact on clinical practice and public health. Firstly, The novelty of this PhD lies in the fact that it is the first study of its kind to develop and validate a culturally-appropriate Nigerian dietary screening tool (NiDST) and Nigerian Diet Risk Score (NiDRS) aimed at: (i) assessing dietary intake among Nigerians; (ii) stratifying individuals into high and low hypertension risk; and (iii) guide dietary discussion to offer personalised dietary advice to patients in Nigeria. Secondly, the PhD research commenced with a systematic review and meta-analysis, the first study of its kind to synthesise the association between dietary factors and hypertension risk in West Africa. This foundational study provided the necessary evidence-base to undertake subsequent studies of this PhD. These studies ensured that the Nigerian dietary screening tool (NiDST and NiDRS) was grounded in comprehensive, up-to-date, and culturally-relevant evidence, which is a significant strength of this PhD research.

Moreover, the refinement of the NiDST was informed by qualitative insights obtained from patients and healthcare professionals in Nigeria in phase two of study two (see *Chapter 3*). This participatory approach ensured the tool was culturally-appropriate and resonated effectively with the Nigerian population. Incorporating end-user's perspectives in the tool development process enhanced its acceptability and usability, addressing potential barriers to its implementation in clinical settings (Teufel, 1997; Cade et al., 2002). In addition to the development and validation of the NiDST, the PhD research introduced another novel contribution in the form of the Nigerian diet risk score (NiDRS). This innovative tool was designed to simplify the NiDST in order to stratify individuals based on their dietary intake and assess their risk of hypertension. The creation and validation of the NiDRS provided a new avenue for personalised risk assessment, facilitating targeted dietary interventions and promoting early preventive strategies. Lastly, the potential impact of this PhD research extends beyond academic circles to

clinical practice and public health. The validated NiDST and NiDRS offer rapid practical solutions for assessing dietary intake, supporting healthcare professionals in effective dietary discussions, and providing personalised advice to patients (Vadiveloo, M. et al., 2020). Moreover, these tools can contribute to public health preventive efforts by identifying individuals at risk of hypertension and guiding interventions to mitigate this rising trend.

7.3.2. Limitations of the PhD research

Despite these significant contributions to dietary assessment and hypertension management from this PhD research, several limitations are acknowledged. These limitations pertain to the methodology employed, the research scope, and the generalizability of the findings. One of the limitations lies in the reliance on observational studies within the meta-analysis, which limits the establishment of cause-and-effect relationships between dietary factors and hypertension. Additionally, using non-standardised assessment methods (such as non-validated or published structured questionnaires) in some included studies may introduce potential biases, affecting the accuracy of dietary data. Furthermore, the small number of studies and limited variation in moderators (e.g., age, BMI, and study location) may impede the effective uncovering of associations. Secondly, this research relies on the methodological approach adopted. Although a mixed-methods design was utilised, combining both qualitative and quantitative methods, the sequential nature of the studies may have restricted the integration of these methods (Montiel-Overall, 2007; Creswell, 2009). The initial qualitative phase, which aimed to refine the dietary screening tool based on patient and healthcare professional feedback, was followed by a quantitative validation phase. While this sequential approach allowed for an in-depth understanding and subsequent validation of the tool, it may have limited the concurrent triangulation of data, potentially overlooking nuanced interactions between dietary factors and hypertension (O’Cathain et al., 2010).

Thirdly, the reliance on self-reported dietary intake data, particularly the Food Frequency Questionnaires (FFQs) and 24-hour dietary recalls (24DRs) to estimate dietary intake, has been criticised for their reliance on participants' ability to recall and accurately report dietary habits over an extended period. This may lead to dietary intake recall bias, social desirability and misreporting of food consumption, which may impact the reliability and validity of the dietary screening tool (Thompson and Subar, 2013; Subar et al., 2015). To address this issue, the repeated administration of the FFQ at two different time points was

employed in this PhD. Additionally, relying on a single day's intake may not accurately represent an individual's usual dietary patterns, as intake can vary day-to-day (Thompson and Subar, 2013; Subar et al., 2020). To address this, three administrations of the 24DR on non-consecutive days including weekdays and weekends were employed to minimise day-to-day variability (Gibson, 2022).

Moreover, using biomarkers as a complementary approach in the validation of NiDRS helps minimise the systematic bias associated with FFQ (Cade et al., 2002; Shim et al., 2014; Subar et al., 2015). Furthermore, FFQs often use predefined food lists, which may not capture all foods consumed by individuals, leading to misclassification of dietary intake (Cade et al., 2002; Willett, W., 2013). To mitigate this, in this PhD, the food list was created based on evidence from the systematic review and meta-analysis of study one (*Chapter 2*) and the 2014 Nigerian and Ghana National Nutritional Guidelines for Non-communicable Diseases, along with input from end-users such as patients and healthcare professionals to refine the FFQ and maximise relevance (*Chapter 3*). Moreover, 24DRs require skilled interviewers or trained personnel to administer and accurately interpret the data. In this PhD, trained personnel conducted the interview-based 24-hour dietary recall in data collection and interpretation (Thompson and Subar, 2013; Subar et al., 2020).

Lastly, the single-centre design of the PhD research may limit its scope to the Nigerian population, focusing on dietary factors and hypertension within this demographic. While this approach provided valuable insights tailored to the Nigerian context, it may limit the generalizability of the findings to broader populations with different dietary behaviours and cultural contexts (Morse, 2015). The culturally-appropriate NiDST and NiDRS developed in this research require adaptation to suit diverse populations, necessitating further validation studies in different cultural and geographical settings. Additionally, the sample size of 58 participants in study two may be perceived as a limitation. However, a statistical power analysis done in this PhD using correlation coefficients as the primary outcome measure with desired power of 80% and significance level of 0.05 indicated that it was sufficient to achieve significance. The derivation of the NiDRS relied on case-control data rather than a prospective cohort. This approach allowed for capturing clinically relevant information while avoiding overfitting the model with too many confounding variables (Harrell et al., 1985; Steyerberg et al., 2001). Nonetheless, external validation in an independent sample is important to ensure the model's reliability and applicability across populations (Altman et al., 2009). Although this PhD study did not conduct external validation, it remains a priority for future research phases.

7.4. Implications for practice, public health, and policy

The implications of this PhD to clinical practice, public health, and policy of each study and phases of this PhD are thoroughly outlined in sections 2.5.3, 3.8.1, 4.9.1, 5.8.1, and 6.5.1. This section summarises the overarching implications of the entire PhD research, as well as those of the individual studies in clinical practice, public health, and policy.

7.4.1. Implications for practice

The findings from this PhD research build on existing knowledge on estimating dietary intake in individuals at risk or with diet-related diseases, which, in the case of this PhD, is diet-hypertension. Aside from developing a culturally-appropriate rapid Nigerian dietary screening tool (NiDST) and Nigerian diet risk score (NiDRS), findings also affirm that: (i) the consumption of unhealthy foods among hypertensive individuals remains high in Nigeria; and (ii) unhealthy foods are contributing to the increasing prevalence of hypertension in the study population. Firstly, integrating the validated NiDST and NiDRS into clinical practice offers clinicians and other members of the healthcare team a reliable tool for assessing dietary intake among patients at risk of hypertension. The accuracy and cultural relevance of the NiDST ensure that dietary assessments are clinically meaningful and resonate with patients, potentially improving compliance and engagement in dietary intervention outcomes (Chen et al., 2013; Kotronoulas et al., 2014; Mejdahl et al., 2020). Secondly, NiDRS developed in this study provides a stratified approach to identifying individuals at higher risk of hypertension based on their dietary intake. This stratification allows for targeted interventions, enabling healthcare providers to offer personalised dietary advice and support. Such tailored interventions are crucial in cardiovascular disease management, including hypertension, where individualised approaches often yield better outcomes compared to generic advice (Celis-Morales et al., 2015; Ordovas et al., 2018).

Moreover, the successful implementation of tools in clinical settings can enhance patient communication, engagement, education, and empowerment. The use of tool-guided dietary discussion has the potential to facilitate more effective communication between healthcare professionals and patients, thereby enhancing trust and rapport, which are essential for successful clinical outcomes (Chen et al., 2013; Kotronoulas et al., 2014; Mejdahl et al., 2020). In addition to facilitating patient-healthcare professionals' communication, the tools have the potential to: (i) provide patients with insights into their dietary intake and associated hypertension risks and can serve as motivational catalysts for behaviour change; and (ii) empower patients with knowledge and actionable insights,

which is fundamental in fostering self-management skills, a cornerstone in chronic disease management (Mackey et al., 2016). Furthermore, the potential for future adaptations and validations of the developed tools in different cultural and geographical contexts offers an avenue for broader applicability. As global healthcare systems grapple with the rising burden of hypertension and related complications, the need for effective, scalable, and culturally sensitive dietary assessment tools becomes paramount. The success of this research sets a precedent for similar endeavours in other populations, potentially catalysing advancements in hypertension management globally (World Health Organization, 2020).

Lastly, the findings from this PhD directly benefit the individuals, i.e., those at risk of or living with hypertension and other related non-communicable diseases (NCDs), by empowering them to take proactive steps in managing their health through informed dietary choices. Through routine dietary assessment and personalised dietary advice facilitated by these tools, individuals can gain access to tailored interventions that address their specific dietary needs and risk factors so that they can make informed choices about their food intake, health and well-being and contribute to the preventive efforts to mitigate hypertension and other CVDs in Nigeria (Sohl et al., 2016).

7.4.2. Implications for public health

The insights garnered from this PhD research hold profound implications for public health strategies, particularly in addressing the escalating prevalence of hypertension and associated dietary risks within the Nigerian population.

First and foremost, the dietary screening tool and diet risk score (DRS) provide public health agencies with robust instruments to assess dietary habits and associated hypertension risks at a population level. These tools can be integrated into national health surveys, allowing for comprehensive dietary assessments that inform targeted interventions and policy development, including in Nigeria (Zapka and Lemon, 2004). Furthermore, the stratified approach offered by the NiDRS can enable public health officials to identify high-risk populations more efficiently and offer tailored public health campaigns and promotions designed to address specific community needs and facilitate greater community buy-in and participation, thereby maximising the impact of interventions (Kumar and Preetha, 2012; Frieden, 2014). Additionally, a multi-sectoral approach to disease prevention and management, including hypertension, can be realised through collaboration efforts between healthcare professionals, public health agencies,

and community stakeholders. Therefore, implementation of the tool in the clinical and community can improve the collaborative efforts that are essential for addressing the multifaceted nature of hypertension, which is influenced by a myriad of socio-economic, environmental, and behavioural factors (Shahzad et al., 2019; Boch et al., 2022).

7.4.3. Implications for policy

The findings from this PhD hold significant implications for informing policy decisions and guiding clinical and public health practices to address the burden of hypertension and related non-communicable diseases (NCDs). By incorporating the NiDST and the NiDRS into existing healthcare frameworks, policymakers can strengthen preventive measures and promote early detection and management of hypertension in Nigeria, thereby reducing the overall disease burden and associated healthcare costs. One of the key implications of this PhD for policy development lies in recognition of the importance of integrating routine dietary assessment and counselling into outpatient consultation guidelines and national health policies in Nigeria. By acknowledging the role of medical nutrition education in hypertension prevention and management, policymakers can prioritise the inclusion of validated, rapid, culturally-appropriate dietary screening tools, particularly the NiDST and NiDRS, as standard components of primary healthcare services in Nigeria, as part of outpatient consultation. This can be achieved through the formulation of guidelines to encourage healthcare professionals to routinely assess patients' dietary intake and provide personalised dietary advice based on the findings from tools such as the NiDST and NiDRS. By institutionalising dietary assessment protocols, policymakers and practitioners can facilitate the delivery of targeted interventions and support services to individuals at risk of or living with hypertension, thereby improving overall health outcomes and reducing the burden on healthcare systems (Boch et al., 2022).

Moreover, the findings from this PhD research underscore the importance of multidisciplinary collaboration and integration across clinical and public health, medical nutrition education, and agricultural sectors. By fostering partnerships between healthcare professionals, patients, policymakers, community stakeholders, and public health agencies, policymakers can harness the combined expertise and resources to formulate comprehensive, tailored strategies for hypertension prevention and management using the NiDST/NiDRS in Nigeria (Boch et al., 2022). These collaborative methods can ease the implementation of community-based interventions (such as the NiDST and NiDRS), educational programs, and policy initiatives aimed at promoting healthier dietary

behaviours and reducing hypertension prevalence at the population level (Holcomb et al., 2022). In addition, by engaging stakeholders across different sectors, policymakers can ensure the alignment of policies and programs with community needs and priorities, fostering a supportive environment for sustainable health promotion efforts, including Nigeria (O'Loughlin et al., 2021; Holcomb et al., 2022).

7.5. Future research

Although several significant findings have emerged from this thesis, questions remain that should be addressed in future studies. This PhD holds considerable promise for shaping future directions in clinical practice, public health interventions, research advancements, healthcare professional training, and community engagement efforts to combat hypertension and other non-communicable diseases (NCDs). One notable avenue for future exploration is to further refine the Nigerian dietary screening (NiDST) and the Nigerian diet risk score (NiDRS) to address the additional consultation time required by utilising the tools during dietary discussion to improve its efficiency. Secondly, in order to improve the generalisability of the findings, the external validity of the tools would be assessed in different regions of Nigeria to ensure broad applicability. Lastly, conducting a nationwide implementation of the developed NiDST/NiDRS across various clinical settings and communities can provide valuable insights into the feasibility, acceptability, and effectiveness of these tools in diverse populations and healthcare settings. In addition, extending these efforts to other West African countries could contribute to a regional approach to combating hypertension and other NCDs, fostering collaboration and knowledge sharing among neighbouring nations.

Furthermore, future research initiatives should aim to engage policymakers, government and non-government agencies, and other relevant stakeholders to facilitate the integration of these dietary assessment tools into clinical practice and public health strategies. Advocacy efforts can underscore the importance of incorporating nutrition assessment and intervention into existing healthcare systems and policies, ensuring sustained support and funding for implementation efforts. Collaborative partnerships between academia, healthcare institutions, governmental bodies, and non-governmental organisations (NGOs) will drive policy changes and foster a conducive environment for adopting evidence-based dietary interventions, such as the NiDST and NiDRS (Rajabi et al., 2021).

7.6. General conclusion

The findings from this PhD significantly contribute to the field of clinical practice and public health nutrition, specifically in the context of dietary assessment, hypertension

prevention and management in Nigeria. This PhD research addresses critical gaps in existing dietary assessment practices and healthcare delivery systems through a multifaceted approach encompassing systematic review and meta-analysis, development and validation of dietary screening tools, and feasibility and implementation studies. First, this PhD found that dietary factors specific to the West African population, including Nigeria, such as healthy or unhealthy foods, are either inversely or positively associated with hypertension, and hypertensive individuals consumed more unhealthy foods than non-hypertensive individuals, which significantly increased their risk of hypertension. Secondly, these findings underscore the importance of culturally-appropriate dietary assessment tools in accurately capturing dietary intake patterns and facilitating personalised dietary advice tailored to the needs of individuals at risk of or living with hypertension. By leveraging evidence-based strategies and incorporating stakeholder input, including patients and healthcare professionals, the developed Nigerian dietary screening tool (NiDST) and the Nigerian Diet Risk Score (NiDRS) for hypertension demonstrate robust validity, reliability, acceptability, and integration into clinical settings. This innovative risk assessment framework represents a transformative milestone in hypertension management within the Nigerian healthcare system.

Furthermore, the significance of the NiDST and NiDRS transcends their role as a mere risk assessment tool; instead, they embody a paradigm shift towards proactive and preventive healthcare practices in Nigeria. By providing clinicians with actionable insights into patients' dietary behaviour and associated hypertension risk, the NiDST and NiDRS can catalyse personalised and evidence-based dietary interventions tailored to individual needs. Moreover, its integration into routine clinical practice holds the promise of fostering a culture of preventive healthcare, emphasising early detection and intervention rather than reactionary management of hypertension. Additionally, the NiDST and NiDRS will serve as a catalyst for broader public health initiatives to promote dietary awareness and foster healthy lifestyle behaviours within Nigerian communities. By raising awareness about the nexus between dietary habits and hypertension risk, the NiDST and NiDRS will empower individuals to make informed food choices and adopt healthier lifestyles, thereby fortifying the foundation for long-term hypertension prevention and management efforts in Nigeria. Overall, the utilisation of these tools, along with dietary counselling and behavioural changes, these tools have the potential to improve poor dietary habits, reduce hypertension prevalence and improve overall cardiovascular health in Nigeria.

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Appendices

Appendix A: Ethical approvals

Appendix A.1: Ethical approval for the study two

Dear Nimisoere Batubo,

0484 - Dietary Assessment and Prevention of Hypertension in Nigeria

NB: All approvals/comments are subject to compliance with current University of Leeds and UK Government advice regarding the Covid-19 pandemic.

I am pleased to inform you that the above research ethics application has been reviewed by the Business, Earth & Environment, Social Sciences (AREA FREC) Committee and on behalf of the Chair, I can confirm a favourable ethical opinion based on the documentation received at date of this email.

Please retain this email as evidence of approval in your study file.

Please notify the committee if you intend to make any amendments to the original research as submitted and approved to date. This includes recruitment methodology: all changes must receive ethical approval prior to implementation. Please see <https://ris.leeds.ac.uk/research-ethics-and-integrity/applying-for-an-amendment/> or contact the Research Ethics Administrator for further information () if required.

Ethics approval does not infer you have the right of access to any member of staff or student or documents and the premises of the University of Leeds. Nor does it imply any right of access to the premises of any other organisation, including clinical areas. The committee takes no responsibility for you gaining access to staff, students and/or premises prior to, during or following your research activities.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, risk assessments and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited.

It is our policy to remind everyone that it is your responsibility to comply with Health and Safety, Data Protection and any other legal and/or professional guidelines there may be.

I hope the study goes well.

Best wishes

Taylor Haworth, Research Ethics Administrator, Secretariat

On behalf of Dr Judith Hanks, AREA FREC, Chair

Appendix A.2: Ethical approval for field data collection for study two and three

RIVERS STATE UNIVERSITY TEACHING HOSPITAL
P M B 5064, Port Harcourt, Nigeria

CHIEF MEDICAL DIRECTOR
DR. FRIDAY E. AARON JP
MBBS, MBA, MPA, FWACS (ORTHO), FAOI, FICS, FIHIMN, FCAI, MNIM

DEPUTY CHIEF MEDICAL DIRECTOR
DR. A. DAN-JUMBO
MBBS, FWACP



CHAIRMAN OF BOARD
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DIRECTOR OF ADMINISTRATION
O. A. CHUKUIGWE
B.Sc., M.Sc.

+234 815 149 1555 Info@rsuth.ng, www.rsuth.ng, RSUTH_PH

RIVERS STATE UNIVERSITY TEACHING HOSPITAL HEALTH RESEARCH ETHICS COMMITTEE
NHREC///21/03/2022

NOTICE OF ETHICAL APPROVAL

30TH March, 2023.

RE : Dietary Assessment and Prevention of Hypertension in Nigeria.

REC Number: RSUTH/ REC/ 2023316
Principal Investigator: Dr. Nimisoere Batubo

Address: Nutritional Epidemiology Group School of Food Science
And Nutrition, Faculty of Environment.
University of Leeds, Leeds, Uk

With reference to your letter dated 20th March, 2023 requesting ethical approval for the above titled research.

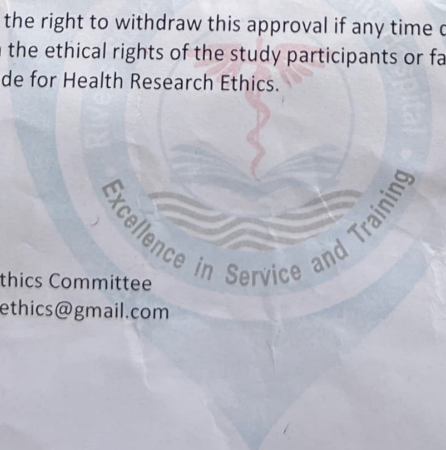
We write to inform you that the research described in the submitted protocol and collected materials have been critically reviewed and given **full approval** by the RSUTH Research Ethics Committee

This approval dates from **04/04/23 to 04/04/2024**. Note that no participant accrual or activity related to this research may be conducted outside of the dates.

The RSUTH REC reserves the right to withdraw this approval if any time during the conduct of the study you infringe on the ethical rights of the study participants or fail to comply with the tenets of the National Code for Health Research Ethics.



Mary Okuku
Secretary
RSUTH Health Research Ethics Committee
E-mail: research.researchethics@gmail.com



Excellence in Service and Training

Appendix A.3: Ethical approval for amendment for study three and four

Dear Nimisoere Batubo

Your research ethics application reference: 0976

Amendment reference number: BESS+ FREC 2023-0976-1111 976 24/11/2023

Your research project: Amendment-Dietary Assessment and Prevention of Hypertension in Nigeria

I am pleased to inform you that the above amendment application has been reviewed by the Business, Environment, Social Sciences BESS+ FREC Faculty Research Ethics Committee (FREC) for [Committee Name] which has issued a favourable ethical opinion based on the application submitted. **Please retain this email in your project file as it is evidence of the Committee's approval.**

Matters you should note:

- Ethics approval does not infer you have the right of access to any member of staff or student or documents and the premises of the University of Leeds. Nor does it imply any right of access to the premises of any other organisation, including clinical areas. The Committee takes no responsibility for you gaining access to staff, students and/or premises prior to, during or following your research activities.
- It is your responsibility to comply with all relevant Health and Safety, Data Protection and other legal and professional requirements and guidelines.
- You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, risk assessments and other documents relating to the research project. This should be kept in your project file.
- Audits are undertaken on approved ethics applications. Your project could be chosen for such an audit. You should therefore ensure your project files are kept up to date and readily available for audit purposes. You will be given a two week notice period if your project is selected.
- Please always include the above research ethics application reference and Amendment request reference in any correspondence with the Research Ethics team.

If you need to make amendments to the original research project as submitted, you are expected to seek approval from the Committee before taking any further action. Changes could include (but are not limited to) the project end date, project design or recruitment methodology, or study documentation. Please see <https://ris.leeds.ac.uk/research-ethics-and-integrity/applying-for-an-amendment/> or contact the Research Ethics team for further information at EthicsEnquiries@leeds.ac.uk.

I hope your research project continues to go well.

Best wishes,

Ms Taylor Haworth, Research Ethics Administrator, Secretariat

On behalf of Dr Judith Hanks, Chair, BESS+ FREC

Appendix B: Consent forms

Appendix B.1: Consent form for study two

School of Food Science and Nutrition and Faculty of Environment



Participant's Consent Form

Title: Dietary Assessment and Prevention of Hypertension Risk in Nigeria

University of Leeds ethical approval number: **AREA FREC 2023-0484-572**

RSUTH Research Ethics Committee approval number: **RSUTH/REC/2023316**

Add your
initials next
to the
statement if
you agree

I confirm that I have read and understand the information sheet dated 18/03/2023 explaining the above research project, and I have had the opportunity to ask questions about the project.

I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline.

Telephone number: +44 7946254090, +234 8068856935
Email: fsnpb@leeds.ac.uk, nimisoere.batubo@ust.edu.ng.

If you choose to withdraw, the already collected data will be deleted or destroyed.

I understand that members of the research team may have access to my responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research. I understand that my responses will be kept strictly confidential.

I understand that the data collected from me may be stored and used in relevant future research in an anonymised form

I understand that relevant sections of the data collected during the study, may be looked at by individuals from the University of Leeds or from regulatory authorities where it is relevant to my taking part in this research. [If applicable]

I agree to take part in the above research project and will inform the lead researcher should my contact details change.

I am happy to complete the relevant questionnaires and physiological measures.

Name of participant	
Participant's signature	
Date	
Name of lead researcher [or person taking consent]	
Signature	
Date	

Appendix B.2: Consent form for study three and four

School of Food Science and Nutrition and Faculty of Environment



Participant's Consent Form

Title: Dietary Assessment and Prevention of Hypertension Risk in Nigeria

University of Leeds ethical approval number: **BESS+ FREC 2023-0976-1111 976**

RSUTH Research Ethics Committee approval number: **RSUTH/REC/2023316**

Add your
initials next to
the statement
if you agree

1	I confirm that I have read and understand the information sheet dated 24/11/2023 explaining the above research project, and I have had the opportunity to ask questions about the project.	
2	I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I not wish to answer any particular question or questions, I am free to decline. If you choose to withdraw, the already collected data can also be deleted or destroyed at your request.	
3	I understand that members of the research team may have access to my responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research. I understand that my responses will be kept strictly confidential.	
4	I understand that the data collected from me may be stored and used in relevant future research in an anonymised form	
5	I understand that relevant sections of the data collected during the study, may be looked at by individuals from the University of Leeds or from regulatory authorities where it is relevant to my taking part in this research. [If applicable]	
6	I agree to take part in the above research project and will inform the lead researcher should my contact details change.	
7	I have read and understand the risks involved with routine blood collection and give my consent to take my blood sample for blood electrolytes and blood lipids analysis.	
8	I am happy to complete the relevant questionnaires, physiological measures, and blood sample collection for blood electrolytes and blood lipid analysis.	

Name of participant

Date

Signature

Name of lead researcher
[or person taking consent]

Date*

Signature*

*To be signed and dated in the presence of the participant.

Appendix C: Participant information sheet

Appendix C.1: Participant information sheet for Study two

University of Leeds ethical approval number: **AREA FREC 2023-0484-572**

RSUTH Research Ethics Committee approval number: **RSUTH/REC/2023316**

The title of the research project: Dietary Assessment and Prevention of Hypertension in Nigeria

Invitation paragraph: You are invited to participate in a research project titled "Dietary Assessment and Prevention of Hypertension in Nigeria." Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. If there is anything that needs to be clarified or if you would like more information, ask. Take your time to decide if you would like to take part.'

What is the purpose of the project: Hypertension (i.e., high blood pressure) is a major global public health concern and a major modifiable risk factor for cardiovascular diseases (CVD), premature death, stroke, chronic kidney disease, and dementia. Globally, around 1/3 of all women and men (~1.3 billion adults) in the world have hypertension, but in low- and middle-income countries, including Africa, it can affect almost 50% of adults. Also, while the number of people with hypertension in the UK, the US, and China has gone down over the past decade, in Nigeria and other West African reporting, it has increased by ~15%.

We know that hypertension is linked to unhealthy diets and lack of physical activity. For this reason, Nigeria and other West African countries outlined national nutritional guidelines to combat hypertension. However, without nutritional tools to evaluate their patients' diet, clinicians have struggled to (i) discuss and prescribe healthy eating with their patients and (ii) make a real change in eating habits and hypertension. To address this, the project aims to design a nutritional assessment tool to improve the level of nutritional support and guidance available to Nigerian clinicians so they can provide personalised nutritional guidance to patients to combat hypertension.

The estimated duration of the project is 12 months. The project will be divided into 2 phases. Phase 1, will investigate the feasibility of the FFQ and its agreement with 24-hour dietary recalls while Phase 2, will assess the acceptability of the FFQ and assess the association between the FFQ score and hypertension. Each phase is estimated to last six (6) months (from recruitment to data analysis). Your participation in the study will involve completing a food frequency questionnaire (FFQ) and three 24-hour dietary recall questionnaires and being asked to provide your thoughts and feedback on the FFQ (i.e., a maximum of 3 times/visits) and having your physiological measures (blood pressure, height, and weight) collected in phase 1. We will use the results of the feasibility and acceptability study to refine the FFQ and prepare for a larger study in the future.

Why have I been chosen: We have chosen you to participate in this study because your perspective and experiences will be valuable in helping us to develop a better understanding of dietary patterns and habits in Nigeria. Also, because of your socio-demographic characteristics, such as age, gender, socioeconomic status, and lifestyle factors. We are hoping to recruit about 50 participants for phases 1, and 2 of the project. Your participation will help us gather important information that will contribute to

developing practical nutritional assessment tools for the prevention of hypertension in Nigeria.

You are excluded from taking part: If you have a history of chronic diseases such as cardiovascular diseases (heart diseases), stroke, chronic kidney diseases, or pregnant or breastfeeding women, you do not need to take part in this study. Children below 18 years and adults above 70 years are also excluded from this study. Additionally, individuals who have made significant changes to their diet in the past six months or are currently following specific dietary restrictions will also be excluded from this study.

Do I have to take part: As a participant in this research study, you have the right to choose whether or not you wish to participate. Your participation in the research project is completely voluntary, and you can withdraw at any time without consequences. Before you decide to participate, it is important to understand what the study involves, your role as a participant, and the potential risks and benefits of participation. You should also ask any questions and ensure you are comfortable with the information in the informed consent form. If you choose to participate, you must remember that you have the right to change your mind at any time and withdraw from the study without any negative consequences. If you have any questions or concerns about your participation, it is essential to discuss them with the research staff or the principal investigator.

What do I have to do/ What will happen to me if I take part: You will be asked to complete a 10-15-minute Food Frequency Questionnaire (FFQ) that asks about your dietary habits and how often you consume different foods and beverages, as well as a questionnaire that asks about your lifestyle habits and demographic characteristics. Your blood pressure, height, and weight may also be measured. This process was designed to be completed in less than 30 mins.

What are the possible disadvantages and risks of taking part: Participating in the study will require some time to complete the questionnaires. If you feel uncomfortable or embarrassed discussing certain aspects of your dietary habits, you are not obligated to answer them and can stop anytime. All information you provide in the study is confidential.

What are the possible benefits of taking part: Increased self-awareness: Completing the Food Frequency Questionnaire (FFQ) may help you become more aware of your own dietary habits and provide you with a better understanding of the foods and beverages you consume on a regular basis.

Contribution to scientific research: Your participation in the study will contribute to our understanding of the dietary habits of adults living in Nigeria and its link with hypertension.

Improved health outcomes: The information gathered in the study will help in the development of validated clinical nutritional assessment tools for dietary assessment in Nigeria and the prevention of hypertension.

Personal satisfaction: Participating in the study may provide a sense of personal satisfaction and pride in contributing to scientific research and improving public health outcomes.

Where will the study be located: The study will take place at the Rivers State University Teaching Hospital (RSUTH), 8 Harley Street, Old GRA, Port Harcourt, Rivers State, Nigeria.

Use, dissemination, and storage of research data:

Use of research data: The research data collected in this study will be used to develop and validate a clinically usable Food Frequency Questionnaire (FFQ) for the assessment of dietary habits and the prevention of hypertension in Nigeria.

Dissemination of research data: Anonymised results from the study may be disseminated through academic journals, conferences, and other publications. The researcher or principal investigator will ensure that all data and findings are reported in a manner that protects the confidentiality and privacy of the participants.

Storage of research data: The research data collected in this study will be anonymised and stored securely (256 encryption) at the University of Leeds in accordance with local and international data protection regulations. Access to the data will be limited to authorised personnel involved in the study. All data will be stored securely at the University of Leeds, adhering to the Data Protection Act.

What will happen to my personal information?

Confidentiality: Your personal information will be kept confidential and stored securely in accordance with the University of Leeds (256-bit encryption), which will only be accessible by the PI in adherence to the Data Protection Act.

Data storage: The personal information collected in this study will be stored securely for a maximum of 5 years after the completion of the study. After this point, all data will be destroyed.

What will happen to the results of the research project: All the contact information we collect about you during the research will be kept strictly confidential and stored separately from the research data. Research data will be anonymised using a random number generator so that researchers will not be able to link you with your data, and you cannot be identified in reports or publications.

The results of the study will be published in academic journals and presented at conferences to share the findings with the scientific community.

What type of information will be sought from me, and why is the collection of this information relevant to achieving the research project's objectives?

Demographic information: This will include basic information such as your age, gender, and occupation.

Dietary information: You will be asked to provide information on the types and amounts of foods you consume, including frequency, portion size, method of cooking, and mode of preparation.

Lifestyle information: You will be asked to provide information on your physical activity levels, smoking habits, and alcohol consumption.

Will participants be able to withdraw from the study, and how can I remove my data once collected?

You can withdraw from the study at any time and have your data removed from any unpublished research. You can request the removal of your data at any point by contacting the principal investigator directly and providing the necessary information to identify your data. Withdrawal from the study will have no impact on your care at the hospital.

Gift inducement: You will receive a £5 gift after the completion of the project.

Who is organising/ funding the research?

Tertiary Education Trust Fund (TETFund). N0 6 Zambezi Crescent, Off Aguiyi Ironsi Street, Maitama, Abuja, FCT Nigeria

Contact for further information.

Name: Nimisoere Batubo (BSc, MBBS, MSc)

Address: University of Leeds

Telephone number: +44 7946254090, +234 806 885 6935

Email: fsnpb@leeds.ac.uk, nimisoere.batubo@ust.edu.ng.

Conclusion: We extend our sincerest thanks for taking the time to read this information sheet. Your participation in this study is greatly appreciated. Your contribution will help us better understand the relationship between dietary habits and the risk of hypertension in Nigeria. We understand that participating in a research study requires time and effort, and we are grateful for your willingness to participate in this important project. Finally, a copy of the information sheet and, if appropriate, a signed consent form will be made available for the participant to keep.

Appendix C.2: Participant information sheet for Study three and four

University of Leeds ethical approval number: **AREA FREC 2023-0484-572**

RSUTH Research Ethics Committee approval number: **RSUTH/REC/2023316**

The title of the research project: Dietary Assessment and Prevention of Hypertension in Nigeria

Invitation paragraph: You are invited to participate in a research project titled "Dietary Assessment and Prevention of Hypertension in Nigeria". Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. If there is anything that needs to be clarified or if you would like more information, ask. Take your time to decide if you would like to take part.

What is the purpose of the project: Hypertension (i.e., high blood pressure) is a major global public health concern and a major modifiable risk factor for cardiovascular diseases (CVD), premature death, stroke, chronic kidney disease, and dementia. Globally, around 1/3 of all women and men (~1.3 billion adults) in the world have hypertension, but in low- and middle-income countries, including Africa, it can affect almost 50% of adults. Also, while the number of people with hypertension in the UK, the US, and China has gone down over the past decade, in Nigeria and other West African reporting, it has increased by ~15%. We know that hypertension is linked to unhealthy diets and lack of physical activity. For this reason, Nigeria and other West African countries outlined national nutritional guidelines to combat hypertension. However, without nutritional tools to evaluate their patients' diet, clinicians have struggled to (i) discuss and prescribe healthy eating with their patients and (ii) make a real change in eating habits and

hypertension. To address this, the project aims to design a nutritional assessment tool to improve the level of nutritional support and guidance available to Nigerian clinicians so they can provide personalised nutritional guidance to patients to combat hypertension.

The estimated duration of the project is 12 months. The project will be divided into 2 phases. Phase 1 will investigate the feasibility of the food frequency questionnaire (FFQ) and its agreement with 24-hour dietary recalls, while Phase 2, will assess the acceptability of the FFQ and assess the association between the FFQ score and hypertension. While your commitment to the study can be completed in 1 month (Phase 1) or even 1 day (Phase 2), each of the study phases is estimated to last six (6) months (from recruitment to data analysis). For Phase 1: Your participation will involve completing a FFQ and three 24-hour dietary recall questionnaires and being asked to provide your thoughts and feedback on the FFQ (i.e., a maximum of 3 times/visits) and having your physiological measures (blood pressure, height, and weight) collected in phase 1. We will use the results of the feasibility and acceptability study to refine the FFQ and prepare for a larger study in the future. For Phase 2: in a single clinic visit/time, we will ask you to complete the refined FFQ and provide your thoughts and feedback before collecting your physiological measures (blood pressure, height, weight, and waist circumference) and a blood sample (2.5mls) to analyse your blood electrolytes and blood lipids. The analysis of blood will help us to understand the link between diet and blood pressure, blood lipids and electrolytes more clearly.

Why have I been chosen: We have asked you to participate in this study because your perspective and experiences will be valuable in helping us to develop a better understanding of dietary patterns and habits in Nigeria. Also, because of your socio-demographic characteristics, such as age, gender, socioeconomic status, and lifestyle factors. We are hoping to recruit about 50 participants for phases 1 and 2 of the projects. Your participation will help us gather important information that will contribute to developing practical nutritional assessment tools for the prevention of hypertension in Nigeria.

You are excluded from taking part: If you have a history of chronic diseases such as cardiovascular diseases (heart diseases), stroke, chronic kidney diseases, or pregnant or breastfeeding women, you do not need to take part in this study. Children below 18 years and adults above 70 years are also excluded from this study. Additionally, individuals who have made significant changes to their diet in the past six months or are currently following specific dietary restrictions will also be excluded from this study.

Do I have to take part: You have the right to choose whether or not you wish to participate and in which parts. Your participation in the research project is completely voluntary, and you can withdraw at any time without consequences. Before you decide to participate, it is important to understand what the study involves, your role as a participant, and the potential risks and benefits of participation. You should also ask any questions and ensure you are comfortable with the information in the informed consent form. If you choose to participate, you must remember that you have the right to change your mind at any time and withdraw from the study without any negative consequences. If you have any questions or concerns about your participation, it is essential to discuss them with the research staff or the principal investigator.

What do I have to do? / What will happen to me if I take part: You will be asked to complete a 10-15-minute Food Frequency Questionnaire (FFQ) that asks about your dietary habits and how often you consume different foods and beverages, as well as a

questionnaire that asks about your lifestyle habits and demographic characteristics. Your blood pressure, height, weight, and waist circumference will be measured. This process was designed to be completed in less than 30 minutes.

Blood Samples: If you consent, a trained phlebotomist from the hospital will collect one-time blood samples (2.5 mL) for the study during your routine clinic visits and at the time of your monthly blood collection for routine check-ups in the Hospital laboratory (Rivers State University Teaching Hospital). With this, we will look at blood electrolytes and blood lipids and hypertension.

What are the possible disadvantages and risks of taking part?

Participating in the study will require some time to complete the questionnaires. If you feel uncomfortable or embarrassed discussing certain aspects of your dietary habits, you are not obligated to answer them and can stop anytime. All information you provide in the study is confidential.

The collection of blood samples will take place at the same time as your routine blood collection and will be performed by qualified clinical staff (phlebotomist). As with all blood collections, discomfort will be minimised by good technique. The phlebotomist will have sufficient experience as he/she is a member of the Rivers State University Teaching Hospital staff.

What are the possible benefits of taking part?

Increased self-awareness: Completing the Food Frequency Questionnaire (FFQ) may help you become more aware of your own dietary habits and provide you with a better understanding of the foods and beverages you consume on a regular basis.

Contribution to scientific research: Your participation in the study will contribute to our understanding of the dietary habits of adults living in Nigeria and its link with hypertension.

Improved health outcomes: The information gathered in the study will help in the development of validated clinical nutritional assessment tools for dietary assessment in Nigeria and the prevention of hypertension.

Personal satisfaction: Participating in the study may provide a sense of personal satisfaction and pride in contributing to scientific research and improving public health outcomes.

What if something goes wrong: We foresee no or minimal risks because blood is collected as standard care and precaution by an experienced and satisfied phlebotomist. However, if you are unhappy about any part of the study, you are encouraged to discuss this with the research team. In addition, because we are in a hospital, you will receive the highest quality of care to minimise any risks.

What will happen to my blood samples: Blood samples will be labelled with your unique study number, stored in freezers at your local hospital and analysed in the Rivers State University Teaching Hospital laboratory. Analysis of the samples for blood electrolytes and blood lipids will be undertaken. Only the principal researcher directly involved in the study will have access to the samples. Any remaining blood samples and the sample bottles after the analysis will be destroyed.

Where will the study be located: The study will take place at the Rivers State University Teaching Hospital (RSUTH), 8 Harley Street, Old GRA, Port Harcourt, Rivers State, Nigeria.

Use, dissemination, and storage of research data.

Use of research data: The research data collected in this study will be used to develop and validate a clinically usable Food Frequency Questionnaire (FFQ) for the assessment of dietary habits and the prevention of hypertension in Nigeria.

Blood: Prior to blood analyses, your sample will be anonymised to ensure that it cannot be connected to you by anyone outside of the primary research team (NB and MZ). The result from your blood sample analysis will be stored on an encrypted USB drive and copied to an encrypted cloud storage (i.e., University of Leeds), and analysed at the University of Leeds (UK). After copying to OneDrive, the USB key will be wiped. At Leeds, we will investigate the link between specific foods consumed in Nigeria and how their connection with blood electrolytes, lipids, and blood pressure. All analyses and reports will be written using anonymised IDs to ensure that your personal results cannot be linked to you.

Dissemination of research data: Anonymised results from the study may be disseminated through academic journals, conferences, and other publications. The researcher or principal investigator will ensure that all data and findings are reported in a manner that protects the confidentiality and privacy of the participants.

Storage of research data: The research data collected in this study will be anonymised and stored securely (256 encryption) on the University of Leeds OneDrive in accordance with local and international data protection regulations. Access to the data will be limited to authorised personnel involved in the study. All data will be stored securely at the University of Leeds, adhering to the Data Protection Act.

What will happen to my personal information?

Confidentiality: Your personal information will be kept confidential and stored securely in accordance with the University of Leeds (256-bit encryption), which will only be accessible by the principal investigator in adherence to the Data Protection Act, 2018.

Data storage: The personal information collected in this study will be stored securely for a maximum of 5 years after the completion of the study. After this point, all data will be destroyed.

What will happen to the results of the research project: All the contact information and personal identifiers we collect about you during the research will be kept strictly confidential, encrypted, and stored in a separate password-protected location on OneDrive. Research data will be anonymised using a random number generator so that researchers will not be able to identify you and you cannot be identified in reports or publications. The results of the study will be published in academic journals and presented at conferences to share the findings with the scientific community.

What type of information will be sought from me, and why is the collection of this information relevant to achieving the research project's objectives?

Demographic information: This will include basic information such as your age, gender, and occupation.

Dietary information: You will be asked to provide information on the types and amounts of foods you consume, including frequency, portion size, method of cooking, and mode of preparation.

Lifestyle information: You will be asked to provide information on your physical activity levels, smoking habits, and alcohol consumption.

Will participants be able to withdraw from the study, and how can I remove my data once collected?

You can withdraw from the study at any time and have your data removed from any unpublished research. You can request the removal of your data at any point by contacting the principal investigator directly and providing the necessary information to identify your data. Withdrawal from the study will have no impact on your care at the hospital.

Gift for participation: You will receive a token of £15 cash appreciation as a gesture of gratitude for your participation and compensation for your valuable time.

Compensation for support staff: You will receive a token of £20 cash of appreciation for the support provided by clinicians, phlebotomists, and other support staff during the data collection process.

Who is organising/ funding the research?

Tertiary Education Trust Fund (TETFund). N0 6 Zambezi Crescent, Off Aguiyi Ironsi Street, Maitama, Abuja, FCT Nigeria

Contact me for further information.

Principal investigator

Name: Nimisoere Batubo (BSc, MB.BS, MSc)

Address: University of Leeds

Telephone number: +44 7946254090, +234 806 885 6935

Email: fsnpb@leeds.ac.uk, nimisoere.batubo@ust.edu.ng.

Primary Supervisor

Name: Dr Michael Zulyniak, Ph.D., FHEA

Address: EC Stoner Building, University of Leeds, Woodhouse Lane, LS2 9JT

Email: m.a.zulyniak@leeds.ac.uk

Telephone: +44 (0)113 343 0685

Conclusion

We extend our sincerest thanks for taking the time to read this information sheet. Your participation in this study is greatly appreciated. Your contribution will help us better understand the relationship between dietary habits and the risk of hypertension in Nigeria. We understand that participating in a research study requires time and effort, and we are grateful for your willingness to participate in this important project. Finally, a copy of the information sheet and, if appropriate, a signed consent form will be made available for the participant to keep.

Appendix D: Participant eligibility screening form

Screening for Eligibility



Participant Information		
Date of recording: D M Y		
Study Participant ID number:		
Study Participant Name:		
Email:		
Phone:		
Eligibility Criteria		
S/N	Questions	Response
1	Are you above the age of 18? (Circle all that apply)	Yes ☐ No ☐
2	Do you have any of these conditions? Diabetes, Kidney disease, heart disease	Yes ☐ No ☐
3	Have you been diagnosed with hypertension or high blood pressure?	Yes ☐ No ☐
4	Are you currently taking medications for hypertension?	Yes ☐ No ☐
5	Are you currently pregnant or breastfeeding?	Yes ☐ No ☐
6	Are you willing to complete a dietary assessment question in the questionnaire	Yes ☐ No ☐
7	Are you able to understand and provide informed consent for participating in the study?	Yes ☐ No ☐
8	Have you made any recent changes to your diet in the past six months?	Yes ☐ No ☐
9	Do you have any specific dietary restrictions or guidelines you follow?	Yes ☐ No ☐ If yes, please specify the nature of the dietary changes (e.g., increased fruit and vegetable intake, reduced sodium intake):
Eligibility		

Thank you for accepting to participate.

Appendix E: Participation information form

Appendix E.1 Patient information form

Short Form Food Frequency Questionnaire
Patient's Participation Information Sheet



Thank you for your interest in participating in this study.

This study aims to test the feasibility and validate a **short dietary assessment tool** to obtain information on the food intake of Nigerians to improve their hypertension risk. This tool is intended for future use by clinicians, patients, and researchers across Nigeria to assess patient's dietary habits and risk of hypertension and offer personalized dietary advice and support the prevention and management of hypertension in Nigeria. All questions are voluntary, and you are not obliged to answer questions you are uncertain or uncomfortable with.

This questionnaire consists of three sections:

1. Sociodemographic and Health Status: This section will ask you questions regarding your personal information, such as age, gender, and health status. Please provide accurate and honest answers to help us understand your background.
2. Dietary Intake Information: This section will ask questions related to the types of food you eat. Your responses will assist us in assessing your dietary habits for research purposes.
3. Feedback: This section will ask you to provide any comments, concerns, or suggestions you may have regarding the questionnaire. Your feedback is valuable to us and will help improve the quality of the dietary assessment tool.

You can fill out the questionnaire by placing a **"tick"** or **"circle"** in the box next to your answer. If you are unsure about any answer, give the best answer you can.

The study is organized by researchers in the School of Food Science and Nutrition, University of Leeds, Leeds, United Kingdom, and a summary of the main findings may be requested by contacting the lead researcher.

- All responses will be kept strictly confidential and anonymised.
- The questionnaire is voluntary, and you can request to withdraw at any time.
- Please read the detailed participant information sheet and consent form attached before proceeding.

Please check that you have answered every question to the best of your ability. Then return the questionnaire to one of the **research team members**.

If you require further information or have any questions about your participation, please do not hesitate to contact Dr Nimisoere Batubo (fsnpb@leeds.ac.uk, nimisoere.batubo@ust.edu.ng).

Please remember to sign and return the consent form with this survey.

Please select 'agree' if you have read and understood the information above and would like to continue.

Agree ☐

Disagree ☐

Appendix E.2 Healthcare professional information form

Short Form Food Frequency Questionnaire Clinicians Participation Information Sheet



Thank you for your interest in participating in this study.

This study aims to test the feasibility and validate a **short dietary assessment tool** to obtain information on the food intake of Nigerians to improve their hypertension risk. This tool will be ready to use by clinicians, patients, and researchers across Nigeria to assess patient's dietary habits and risk of hypertension and offer personalised dietary advice to patients to improve patient outcomes and in the prevention and management of hypertension in Nigeria.

This questionnaire consists of three sections:

1. Sociodemographic and Health Status: This section will ask you questions regarding your personal information, such as age, gender, and health status. Please provide accurate and honest answers to help us understand your background.
2. Dietary Intake Information: This section will ask questions related to the types of food you eat. Your responses will assist us in assessing your dietary habits for research purposes.
3. Feedback: This section will ask you to provide any comments, concerns, or suggestions you may have regarding the questionnaire. Your feedback is valuable to us and will help improve the quality of the dietary assessment tool.

****As a healthcare professional, you are not expected to complete section 1 just review it and offer your thoughts in sections 2 and 3.**

Your valuable input will contribute to our understanding of dietary assessment practices, dietary assessment tools and the relevance and implementation of short dietary assessment tools (< 10 minutes) for hypertension prevention and management in clinical care.

You can fill out the questionnaire by placing a **"tick"** in the box next to your answer **(in sections 2 and 3)**

The study is organised by researchers in the School of Food Science and Nutrition, University of Leeds, Leeds, United Kingdom, and a summary of the main findings may be requested by contacting the lead researcher.

- All responses will be kept strictly confidential and anonymised.
- The questionnaire is voluntary, and you can request to withdraw at any time.
- Please read the detailed participant information sheet and consent form attached before proceeding.

Please check that you have answered every question to the best of your ability. Then, return the questionnaire to one of the **research team members**.

If you require further information or have any questions about your participation, please do not hesitate to contact Dr Nimisoere Batubo (fsnpb@leeds.ac.uk, nimisoere.batubo@ust.edu.ng).

Please remember to sign and return the consent form with this survey.

Please select 'agree' if you have read and understood the information above, and on the Participant Information Sheet provided to you and would like to continue.

Agree	☐
Disagree	☐

Appendix F: Patient sociodemographic and health status questionnaire

Date of recording: D M Y

Study Participant ID number:

Email:

Phone:

Section 1: Sociodemographic and Health Status

Demographic information		
S/N	Questions	Response
1	What is your gender (sex)	Male ☐ Female ☐ Others ☐
2	What is your age?	Years Date of birth (dd/mm/yyyy)
3	What is your height	meters cm
4	What is your weight?	Kilograms
	What is your waist circumference?	meters cm
5	What is your blood pressure reading?	Systolic: mmHg Diastolic: mmHg
6	What is the highest level of education you have completed?	No formal schooling ☐ Primary school ☐ Secondary school ☐ Tertiary ☐
7	What is your marital status?	Single ☐ Married ☐ Divorced/Separated ☐ Widowed ☐
8	Which best describes your main work status over the past 12 months?	Employed ☐ Self-employed ☐ Unemployed ☐ Student ☐ Retired ☐ Homemaker ☐
9	In the past month, how often did you do at least 30 minutes of moderate physical activity (like brisk walking, jogging, cycling, swimming, etc.)	Rarely or Never ☐ 1-2 days/week ☐ 3-4 days/week ☐ 5-7 days/week ☐
Health status information		
	Questions	Response
10	Do you have a history of hypertension (high blood pressure)? (Please circle one)	Yes ☐ No ☐
11	How long have you been diagnosed with hypertension?	Less than 1 year ☐ 1-5 years ☐ More than 5 years ☐ Don't know ☐
12	Do you have a close family (parent, brother, or sister) diagnosed with hypertension?	Yes ☐ No ☐
13	If yes in question 12, which of your family members was diagnosed with hypertension?	Mother ☐ Father ☐ Brother ☐ Sister ☐
14	Are you currently taking any medications for hypertension?	Yes ☐ No ☐

Appendix G: Participant feedback questionnaire

Appendix G.1: Patient feedback questionnaire for phase one of study two

Short Form Food Frequency Questionnaire



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This section will ask you to provide any comments, concerns, or suggestions you may have regarding the questionnaire. Your feedback is valuable to us and will help improve the quality of the dietary assessment tool.

Section 3: Patient's Feedback				
S/N	Feedback question	Response		
1	The food item in the FFQ was comprehensive and included my regular food and drinks.	Strongly Disagree ☐	Disagree ☐	Neutral ☐
		Agree ☐	Strongly Agree ☐	
2	The FFQ questions and instructions were clear, easy to understand and follow.	Strongly Disagree ☐	Disagree ☐	Neutral ☐
		Agree ☐	Strongly Agree ☐	
3	The frequency response options allow me to accurately report my usual food intake.	Strongly Disagree ☐	Disagree ☐	Neutral ☐
		Agree ☐	Strongly Agree ☐	
4	The FFQ was appropriate in length, quick and easy to complete within one clinical visit.	Strongly Disagree ☐	Disagree ☐	Neutral ☐
		Agree ☐	Strongly Agree ☐	
5	The time taken to complete the FFQ was acceptable to me.	Strongly Disagree ☐	Disagree ☐	Neutral ☐
		Agree ☐	Strongly Agree ☐	
6	Completing the FFQ helped me reflect on my food intake habits related to high blood pressure.	Strongly Disagree ☐	Disagree ☐	Neutral ☐
		Agree ☐	Strongly Agree ☐	
7	The FFQ could be a useful tool for doctors and nurses in providing dietary support to patients.	Strongly Disagree ☐	Disagree ☐	Neutral ☐
		Agree ☐	Strongly Agree ☐	
8	The FFQ can fit well into your clinical visit and workflow.	Strongly Disagree ☐	Disagree ☐	Neutral ☐
		Agree ☐	Strongly Agree ☐	
9	I would be willing to complete the FFQ again in the future.	Strongly Disagree ☐	Disagree ☐	Neutral ☐
		Agree ☐	Strongly Agree ☐	
10	Overall, I am satisfied with the FFQ as a dietary screening tool.	Strongly Disagree ☐	Disagree ☐	Neutral ☐
		Agree ☐	Strongly Agree ☐	

Thank you for taking the time to complete the questionnaire.

Appendix G.2: Healthcare professional feedback questionnaire for study two



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Short Form Food Frequency Questionnaire

This section will ask you to provide any comments, concerns, or suggestions you may have regarding the questionnaire. Your feedback is valuable to us and will help improve the quality of the dietary assessment tool.

Section 3: Clinician Feedback		
S/N	Feedback question	Response
1	In your experience, how important is a dietary assessment of food intake for the effective dietary management and prevention of hypertension in clinical practice?	Very important ☐ Important ☐ Neutral ☐ Not important ☐ Not sure ☐
2	How frequently do you assess patients' detailed dietary food intake as part of clinical care (hypertension)?	Daily ☐ Weekly ☐ Monthly ☐ Occasionally ☐ Never ☐
3	How confident are you in your ability to interpret and utilise the data generated by the new dietary assessment tool to guide your clinical decision-making in hypertension care?	Very confident ☐ Confident ☐ Neutral ☐ Not confident ☐ Not sure ☐
4	Are there any existing dietary assessment tools for the assessment of food intake that are culturally specific to Nigerians for the prevention and management of chronic diseases? What methods or tools do you use for the dietary assessment?	Yes, culturally specific tools are available. ☐ Yes, but not culturally specific. ☐ No, there are no specific tools. ☐ Not sure ☐
5	Do you believe that the current dietary assessment tools/ methods used in your practice adequately capture culturally specific patients' dietary habits and provide actionable insights for hypertension prevention and management?	Yes, current methods are sufficient. ☐ No, some aspects are lacking. ☐ Not sure ☐ If not, what aspects are lacking?
6	Have you encountered challenges in assessing and analysing patients' food intake to determine their risks of hypertension and providing dietary recommendations for patients?	Yes ☐ No ☐ If yes, please elaborate on the difficulties you have faced.
7	Based on your understanding of the dietary assessment tool, how relevant do you perceive it to be in identifying and addressing dietary factors contributing to hypertension in your patients?	Highly relevant ☐ Relevant ☐ Neutral ☐ Irrelevant ☐ Not sure ☐
8	From a clinical perspective, how valuable would the information obtained from the dietary assessment tool be in tailoring individualised dietary recommendations for patients with hypertension?	Very valuable ☐ Valuable ☐ Neutral ☐ Not valuable ☐ Not sure ☐
9	Have you received formally education or training regarding the link between diet and hypertension?	Yes ☐ No ☐
10	What features would you consider essential in a short dietary assessment tool for effective integration into clinical practice to assess dietary intake for the prevention and management of hypertension?	Feature 1:..... Feature 2:..... Feature 3:..... Others:.....
11	Based on your clinical experience, do you think this short dietary assessment tool (< 10 minutes) can be used to assess patient food intake and hypertension risk in clinical practice?	Yes ☐ No ☐ Not sure ☐



Short Form Food Frequency Questionnaire

This section will ask you to provide any comments, concerns, or suggestions you may have regarding the questionnaire. Your feedback is valuable to us and will help improve the quality of the dietary assessment tool.

Section 3: Clinician Feedback		
S/N	Feedback question	Response
12	How feasible do you perceive the integration of this short (< 10 minutes) dietary assessment tool into your current workflow and patient consultations?	Highly feasible ☐ Feasible ☐ Neutral ☐ Not feasible ☐ Not sure ☐
Are there any logistical or practical considerations that you anticipate?		
13	Considering the time constraints during patient consultations, do you believe that the implementation of this short dietary assessment tool would be feasible without significantly impacting the workflow?	Yes ☐ No ☐ Not sure ☐
14	In your opinion, what are the potential benefits and limitations of implementing this short dietary assessment tool in clinical care for hypertension prevention and management?	Benefits: Limitations:
15	Have you used any other dietary assessment tools or interventions in your practice for managing hypertension?	Yes, other tools used are: ☐ No, I have not used any other tools ☐ If so, how do you compare their effectiveness and feasibility with the proposed new tool?
16	Do you have any additional comments, concerns, or suggestions regarding the implementation of a dietary assessment tool for hypertension prevention and management?	
17	Can you foresee any potential challenges or barriers in integrating the dietary assessment tool into routine clinical care?	Yes ☐ No ☐ Not sure ☐ If yes, what strategies or support would be necessary to overcome these challenges?
18	Were the questions easy to understand and complete?	Yes ☐ No ☐
19	Were there any questions that were unclear or difficult to answer?	Yes ☐ No ☐ If YES, please give the reason:
20	Overall, how likely do you think the implementation of the dietary assessment tool would offer personalized dietary advice to patients to improve patient outcomes and in the prevention and management of hypertension in Nigeria?	Very likely ☐ Likely ☐ Neutral ☐ Unlikely ☐ Very unlikely ☐
21	Is there more feedback	

Thank you for taking the time to complete the questionnaire.

Appendix G.3: Patient and Clinician feedback questionnaire for study four

Pilot implementation study of the Nigerian dietary screening tool

This section will ask you to provide any comments, concerns, or suggestions you may have regarding the questionnaire. Your feedback is valuable to us and will help improve the quality of the dietary assessment tool.

You can fill out the questionnaire by placing a “tick” in the box next to your answer based on the response scale.

Measurement Instrument for Determinants of Innovation (MIDI) Feedback Questionnaire for						
S/N	Determinants	Response scale				
		Totally disagree	Disagree	Neutral	Agree	Totally agree
Section 1: Determinant associated with the innovation-Nigerian dietary screening tool (NiDST)						
1	Procedural clarity: The NiDST clearly describes the activities I should perform and in which order					
2	Completeness: The food list in the NiDST is comprehensive					
3	Complexity: The NiDST is too complex for me to use. The questions were not clear or easy to understand					
4	Compatibility: The NiDST is a good match for how I used to work (i.e., compatible with my workflows)					
5	Relevance for patient: I think the NiDST is relevant for my patients					
Section 2: Determinants associated with the clinicians						
1	Personal benefits: I think the NiDST supported me to assess patient dietary intake					
2	Personal communication: I think using the NiDST improved my engagement and communication with patients					
3	Outcome expectation: I think using the patient-reported NiDST supported me to offer dietary advice to patients					
4	Professional obligation: I feel it is my responsibility to use the NiDST to assess dietary intake and offer dietary advice to patients routinely					
5	Patient satisfaction: Patients will generally be satisfied if I use their completed NiDST for their dietary discussion					
6	Patient cooperation: Patient will generally cooperate if I use their completed NiDST in dietary discussion					
7	Nutritional knowledge: I have enough knowledge to use and interpret the NiDST as intended					
8	Time available: I have enough time to use the completed NiDST for dietary discussion in outpatient clinic					
Section 3: Determinants associated with the patients						
1	Complexity: The NiDST is too complex for me to complete. The questions were clear or easy to understand					
2	Personal benefit: I think the NiDST help me to understand and reflect on my food intake					
3	Patient engagement: I think the NiDST help me discuss with doctors about my food					
4	Outcome expectations: I think the NiDST Help me discuss with doctors					
5	Awareness of content: I think food list and frequency response options allow me to accurately report my usual food intake					
6	Time available: The time taken to complete the NiDST was acceptable to me during waiting for my consultation					
7	Patient satisfaction: I am satisfied with using the NiDST during outpatient consultation					
8	Personal communication: I think using the NiDST improved my communication with doctor during outpatient consultation					

Thank you for participating in this study.

Appendix H: Recruitment materials

Study 2: Assessment of adult food intake in Nigeria

This study has been reviewed and approved by the University of Leeds ethical committee (AREA FREC 2023-0484-572) and RSUTH Research Ethics Committee (RSUTH/REC/2023316)

You are invited to participate.....

This is what you will do:

1. Fill out a short form that will ask you about the food you usually eat weekly for the past 1 month.
2. Your Blood pressure, height and weight will also be measured.

If you are interested to participate in the research, then contact the team leader:

Name: Dr Batubo

Phone: 09139193514

Email: nimisoere.batubo@ust.edu.ng
fsnpb@leeds.ac.uk

Are you eligible?

- 18 years or older
- Man or woman
- Not pregnant or breastfeeding
- You do not have heart, or Kidney diseases, Stroke, diabetes, Cancer
- You are hypertensive or not
- You have not changed your diet

Venue:

Rivers State University Teaching Hospital (RSUTH),
Port Harcourt,
Rivers State, Nigeria.

You will receive £5 as a token of appreciation for completing all the required activities

Nutritional Epidemiology Group, School of Food and Nutrition

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Study 3: Dietary Assessment of food intake in Nigeria	
Aims This study aims to evaluate the feasibility and validate a short dietary assessment tool to obtain information on the food intake of Nigerians to improve their risk of hypertension. This tool will be ready to use by clinicians, patients, and researchers across Nigeria to assess patient's dietary habits and risk of hypertension and offer personalized dietary advice to patients to improve patient outcomes and in the prevention and management of hypertension in Nigeria.	Eligibility You will be a perfect candidate if you..... • 18 years or older • Man or woman • Not pregnant or breastfeeding • You do not have heart, or Kidney diseases, Stroke, diabetes, Cancer • You are hypertensive or not • You have not changed your diet
Methods A pre-designed paper-form questionnaire will be used to collect participant's information on: 1. Sociodemographic and Health Status : 2. Dietary Intake Information: 3. Provide Feedback on the dietary assessment tool Participants will be asked to: • Fill out a short dietary assessment questionnaire that will eat weekly for the past 1 month, at 3 different visits, and • their Blood pressure, height and weight will also be measured.	Location All sections of the study will be in: • Rivers State University Teaching Hospital, 8-9 Harley Street, Old GRA, Port Harcourt, Rivers State, Nigeria. Contact If you are unsure if you meet the requirements, call or email a member of the study team: • Dr Nimisoere Batubo • Phone: 09139193514 • Email: fsnpb@leeds.ac.uk, nimisoere.batubo@ust.edu.ng
Participants will receive £20 as a token of appreciation on completing all required activities	

Nutritional Epidemiology Group, School of Food and Nutrition

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Appendix I: Supplementary materials for chapter two

Table S2.1: Search strategy used in PubMed database.

PICO Framework	Concept	Search terms
P- West African nations	1	"Africa, Western"[Mesh] OR "West Africa" OR Benin OR "Burkina Faso" OR "Cape Verde" OR "Cote d'Ivoire" OR "Ivory coast" OR Gambia OR Ghana OR Guinea OR Guinea-Bissau OR Liberia OR Mali OR Mauritania OR Niger OR Nigeria OR Senegal OR Sierra Leone OR Togo OR Cameroon
I – High dietary exposure	2	((("Diet"[Mesh]) OR "Nutrients"[Mesh]) OR "Food"[Mesh] OR Diet* OR nutrition OR nutrient* OR "food habit*" OR "eating habit*" OR lifestyle OR food* OR "dietary pattern*" OR "fatty food*" OR fat* OR DASH OR "Dietary approaches to stop hypertension" OR "table salt*" OR salt* OR egg* OR vegetables OR "fruit and vegetable" OR fruit* OR "healthy diet*" OR "low-fat dairy product*" OR potassium OR sodium OR meat OR starch OR carbohydrate* OR "dietary supplement*" OR sugar* OR alcohol
C- Low dietary exposure		
O- Hypertension/ high blood pressure	3	"Hypertension"[Mesh] OR hypertension OR "high blood pressure" OR "high systolic blood pressure" OR "high diastolic blood pressure" OR SBP OR DBP OR "elevated blood pressure" OR HTN

Table S2.2. Characteristics of the included studies in the meta-analysis

S/N	Ref	Study type	Study location	Mean age (years)	Number of Participants	Sex		Exposure		Hypertension		Adjusted covariates	Result (High vs low intake category) OR (95% CI)
						Male	Female	Dietary Assessment method	Estimated dietary factor	Method of assessment	Cases		
1.	Anto et al. (2020)	CS	Ghana	44	527	Nil	Nil	Structured questionnaire	Fast food	Measured	204	Age, ethnicity, and family history of hypertension	FF (2.43; 1.18-5.02)
2.		CS	Côte d'Ivoire	34	360	123	170	WHO Stepwise questionnaire	Fruit & vegetables, alcohol	measured	67	NA	FV (>5) 0.87 (0.22-3.45) Alcohol (0.82; 0.47-1.41)
3.	Sackou et al. (2019)	CS	Nigeria	42	271	86	185	Structured questionnaire	Red meat, fish	measured	62	NA	Red meat: fish [27(11): 240(51)]; 2.55(1.11-5.83)
4.		CS	Nigeria	40	417	145	272	WHO Stepwise questionnaire	Fruit & vegetables	measured	34	Age, gender, exposure to second-hand smoke and physical activity status	FV (<5) : (1.06; 1.01–1.13), (>5): 0.94(0.90–0.98)
5.	Ugwu et al. (2015)	CS	Nigeria	43	606	326	280	WHO Stepwise questionnaire	Fruit & Vegetables	measured	201	Age, gender, exposure to second-hand smoke and physical activity status	FV (low): 0.91 (0.48–1.72), (high): 1.10(0.58–2.08)
6.		CS	Ghana	50	216	NA	NA	WHO Stepwise questionnaire	Extra salt Fruit & vegetables Fast food, alcohol	measured	73	age, marital status, education status, employment status, alcohol drinking, extra salt intake, fast foods intake, and body mass index	FV (<5): 3.17 [1.05–9.55], (>5): 0.32(0.11–0.93) Salt: 1.34 [0.64–2.81] FF: (No): 0.69[0.33–1.45]- (High): (1.45(0.69–3.05) Alcohol (1.55; 0.77–3.12)
7.	Oguoma et al. (2018)	CS	Nigeria	41	476	NA	NA	Food Frequency Questionnaire (FFQ)	Fast Food	measured	208	Age, obesity, fast food, education status, MDA place of work	FF=>(3/week): 1.28(0.80 2.031)
8.		CS	Ghana	58	4675	1954	2799	WHO Stepwise questionnaire	Extra salt use	Measured	1444	sex, age, residence, educational level and hypertension prevalence	Salt: 1.11 (0.952–1.299)
9.	Olawuyi and Adeoye (2018)	CS	Benin	43	1777	695	1082	WHO Stepwise survey	Fruits and vegetables Salt intake, alcohol	Measured	584	age, sex, country, area, marital status, and previous occupation, tobacco use, BMI, physical activity, diabetes, salt consumption, alcohol consumption, fruits & vegetables	FV (>5): 0.97(0.69–1.36) Salt (1.23 (1.00–1.50) Alcohol (1.19; 0.94–1.53)
10.		CS	Nigeria	42	517	213	287	Interviewer administered questionnaire	Fruit, vegetable, nut, legume, alcohol	Measured	195	Age, sex, educational level, self-percieved health status, obesity, alcohol intake, fruit,	F (>5): 0.64 (0.32–1.27) V (>5): 0.82 (0.54–1.24)

												vegetable, nuts , legume	FV (>5): 0.77(0.54-1.09) Alcohol (2.04; 0.80-5.20)
11.	Acheampong et al. (2019)	CS	Nigeria	53	134	48	86	Questionnaire	Salt, fat, alcohol	Measured	59	Age, marital status, gender, education, family history hypertension, smoking status, alcohol consumption, physical activity, BMI, fruit and vegetable consumption, salt	Salt: 1.59 (0.79, 3.20) Fat: 1.60 (0.54, 4.75) Alcohol (1.10; 0.55-2.20)
12.		CS	Cameroon	37	571	473	98	food frequency questionnaire	Fruit & vegetable Meat (bush meat, red meat)	Measured	223	age, body mass index, rank, vigorous physical activity and total energy intake, the fruit and vegetable	FV (high): 0.82(0.20-2.19) Meat: 1.35 (0.74–2.47)
13.	Obasohan et al. (2019)	CS	Cameroon	36	700	340	360	Semi-structured questionnaire	Salt	Measured	143	Age, marital status, gender, education, family history hypertension, smoking status, alcohol consumption, physical activity, BMI, salt, hyperlipidaemia	Salt (high): 1.05 [0.52–2.07]
14.		CS	Nigeria	39	410	230	180	WHO STEPS questionnaire	Fruit, vegetable, salt intake	Measured	205	Physical activity, fruit and vegetable, current smokers, current alcohol drinkers, salt intake, obesity, diabetes, hypercholesterolemia	FV (>5): 0.15 (0.09, 0.27) Salt Never: 0.400 (0.198–0.81) Often: 2.5 (1.23-5.05)
15.	Menyanu et al. (2017)	CS	Nigeria	35	300	192	108	structured questionnaire	Snack, puff puff, fried foods	measured	144	BMI, age, smoking, meal skipping, snacking, physical activity, alcohol,	FAST: 1.35 (0.29, 1.65)
16.		CS	Nigeria	56	517	213	287	Interviewer administered questionnaire	Fruit, vegetable, nut, legume, alcohol	Measured	195	Age, sex, educational level, self-percieved health status, obesity, alcohol intake, fruit, vegetable, nuts , legume	F (>5): 0.64 (0.32–1.27) V (>5): 0.82 (0.54–1.24) FV (>5): 0.77(0.54-1.09) Alcohol (2.04; 0.80-5.20)
17.	Desormais et al. (2019)	CS	Nigeria	20	401	188	213	Interviewer method of questionnaire	Snacks, baked food products, fruits, vegetables	Measured	76	Age, sex, marital status, Socioeconomic variables of interest were occupation and monthly income, smoking, alcohol consumption, sleep duration and exercise, Meal skipping, consumption of snacks,	Snacks= 1.30 (0.08,21.98) <u>FF= 4.95 (0.66, 37.13)</u> <u>FE= 3.15 (0.61, 16.26)</u> Sugar drinks= 1.57(0.62, 3.93) Fruit=0.53(0.24, 1.17)

												fruits, vegetables and sugar- containing drinks	
18.		CS	Benin	35	717	327	390	WHO Stepwise survey	Salt Fatty food, Fruits and vegetables, alcohol	Measured	238	Sex, age, ethnicity, marital status, salt intake, fatty food consumption, physical activity, fruit and vegetable, alcohol consumption, tobacco consumption, BMI, Glucose level	High salt (1.54; 1.07 - 2.21) Fruit (<5): 1.34(0.66-2.70), (>5): 0.75(0.37-1.52) fat (2.07; 0.94 - 4.54) Alcohol (1.04; 0.83-1.30)
19.	Ayogu, R. N. B. et al. (2021)	CS	Burkina Faso (Rural)	44	3600	1773	1827	WHO Stepwise approach to Surveillance survey	Butter, lard, margarine, vegetable oil	Measured	553	Age, education, marital status, sex, family history of HBP, smoking, physical activity, fats, BMI, HDL cholesterol	High fats: 1.42 (0.89–2.27) 1.98(1.22–3.22)
20.			Togo	49	2002	907	1095	Interviewer administered questionnaire	Salt, alcohol	measured	734	Alcohol, Tobacco, salt, obesity, cola, oestrogens	High Salt: 1.4; 1.13–1.72) Alcohol (1.21; 0.97-1.51)
21.	Ofili et al. (2015)		Benin	40	540	NA	NA	questionnaire	Salt, fat Fruit & vegetable, alcohol	Measured	154	Place of residence, salt, fruit and vegetables, tobacco, physical use, physical activity, obesity, alcohol intake	F (>5): 0.83 [0.56; 1.23] Salt (3.40; 1.76-6.57) Fat (1.81; 1.17-2.81) Alcohol (2.00; 0.97-4.12)
22.		CS	Nigeria	20	488	124	219	24-hour dietary recall	Puff-puff, eggs, fruits, vegetables, Beef	Measured	145	NA	Red meat [NO-343(105); YES-81(64)] OR=2.87(1.92-4.28) Fried: NO-343(202) vs Yes-94(57): OR-1.08(0.68-1.71) FV: No-343(275), Yes-94(80) (Low): 1.41(0.76-2.65), (High)-0.71(0.38-1.32)
23.	Nkondjock and Bizome (2010)	CS	Ghana	44	242	104	138	Structured questionnaires	Salt, fruit & vegetable, palm oil, protein (animal, fish and plant)	Measured	90	NA	Salt (High): 1.53(1.05, 2.22) Fruit: (high)= 0.66(0.52, 0.85) Veg: (high)= 0.83 (0.64, 1.08) Red meat=1.40 (0.69, 2.83) Fat: Palm oil=1.65(1.25, 2.19)
24.		CS	Ghana	46	204	80	124	Elaborate pilot-tested questionnaire	Fruit and vegetable	Measured	100	Age, sex, highest educational level, marital status, employment status, physical activity, fruits	FV (low)= 1.51(0.80-2.84) FV(inverse)= 0.66(0.35, 1.25)

												and vegetable intake, alcohol consumption, and family history of hypertension.	
25.	Pancha Mbouemboue et al. (2016)	Survey	Ghana	36	5662	NA	5662	Structured questionnaire	Salted fish	Measured	918	Marital status, age, level of education, wealth index, parity, occupation	Salt (Yes)=1.06 [0.90–1.24]
26.		Survey	Burkina Faso	44	4187	2257	1930	WHO STEPS survey tool	Fruit and vegetable	Measured	774	living environment, sex, age, marital status, education level, BMI, Physical activity, alcohol use and occupation.	FV (low) = 2.8 (1.2–6.7) FV (inverse)=0.36[0.15, 0.83]
27.	Charity E. C et al. (2021)	Survey	Nigeria	55.4,	3215	1530	1685	FFQ	Vegetables	Measured	1727	Sex, age, education, family history of CVD, ever smoked, ever used alcohol, physical inactivity, BMI, Diabetes, Dyslipidaemia	V(Nig)= 0.96(0.59, 1.57)
28.		Survey	Ghana	53.7	3214	1541	1673,	FFQ	Vegetables	Measured	1240	Sex, age, education, family history of CVD, ever smoked, ever used alcohol, physical inactivity, BMI, Diabetes, Dyslipidemia	V(Gha)= 0.97(0.77, 1.23)
29.	Oladoyinbo et al. (2020)	Survey	Burkina Faso	49.8	2097	1056	1041	FFQ	Vegetables	Measured	345	Sex, age, education, family history of CVD, ever smoked, ever used alcohol, physical inactivity, BMI, Diabetes, Dyslipidemia	V(Bur)= 1.09(0.13, 9.19)
30.		CS	Nigeria		397	108	289	Food frequency questionnaire	Meat	Measured	39	NA	0.87 (0.37, 1.96)
31.	Ayogu, R. N. B. et al. (2021)	Survey	Ghana		9367	NA	9367	Food frequency questionnaire	Salted meat	Measured	1244	Age, BMI	β = 0.06, z = 2.03, OR= 1.06 (1.00, 1.12)
	Total				48,290						12,223		

Cross-sectional studies in the meta-analysis of the association between dietary factors and hypertension in West Africa

Abbreviations: CS= Cross-sectional study; FF= Fried/fast food; FV= Fruit and vegetable, V= vegetable, β = Beta-coefficient, z =Z-score, Nig= Nigeria, Gha= Ghana, Bur= Burkina Faso, NA= Not available

Table S2.3: Quality assessment of studies included in the meta-analysis.

Study	Selection of study groups				Comparability	Outcome		Total score	Study Quality (*9)	Risk of Bias
	Representativeness of the sample (*)	Sample size (*)	Non-Response rate (*)	Ascertainment of the screening/surveillance tool (**)	Potential Confounders (**)	Assessment of Outcome (*)	Statistical test (*)			
Anto et al. (2020)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Sackou et al. (2019)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Ugwuja et al. (2015)	*	*	*	**	-	*	*	***** (7)	7	Low risk
Oguoma et al. (2018)	*	*	*	**	-	*	*	***** (9)	9	Low risk
Olawuyi and Adeoye (2018)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Acheampong et al. (2019)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Obasohan et al. (2019)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Menyanu et al. (2017)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Desormais et al. (2019)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Ofili et al. (2015)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Nkondjock and Bizome (2010)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Pancha Mbouemboue et al. (2016)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Charity E. C et al. (2021)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Oladoyinbo et al. (2020)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Ayogu et al. (2021)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Akoklannou A. H et al. (2020)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Soubéiga et al. (2017)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Soubéiga et al. (2017)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Yayehd et al. (2013)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Colette A. et al. (2020)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Shokunbi and Ukangwa (2021)	*	*	*	**		*	*	***** (7)	7	Low risk
Kingsley Boakye et al. (2019)	*	*	*	**		*	*	***** (7)	7	Low risk
Owiredu et al. (2019)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Dorgbetor et al. (2022)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Diendere et al. (2022)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Akpa et al. (2022)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Akpa et al. (2022)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Akpa et al. (2022)	*	*	*	**	**	*	*	***** (9)	9	Low risk
Makinde and Babalola (2011)	*	*	*	**		*	*	***** (7)	7	Low risk
Oyekale (2019)	*	*	*	**	**	*	*	***** (9)	9	Low risk

The Newcastle-Ottawa Scale adapted for cross-sectional studies was used to assess the quality of the included studies in the meta-analysis of the association between dietary factors and hypertension in West Africa

Table S2.4: Meta-regression results for moderators for fruits and vegetables consumption

Moderator	n	Coefficient (95% CI)	*p -Value	*I ² (%)	R ² index (%)	H ²
Bivariate meta-regression						
Mean age (years)	17	0.015 (0.001, 0.030)	0.04*	0	0	1.00
Body mass index (kg/m ²)	17	-0.037 (-0.134, 0.059)	0.45	0	0	1.00
Location (Nigeria as ref.)	17	0.051 (-0.245, 0.347)	0.74	0	0	1.00
Multivariate meta-regression						
Test of moderators	17	QM (df = 3) = 1.0	0.80	0	0	1.00
Mean age (years)	17	0.015 (-0.016, 0.046)	0.33			
Body mass index (kg/m ²)	17	-0.033 (-0.195, 0.129)	0.67			
location (Nigeria as ref.)	17	-0.081 (-0.690, 0.528)	0.79			

Moderating effects of mean age, study location, and BMI on the association between fruit and vegetable consumption and hypertension in West Africa.

*Abbreviations: CI: Confidence interval, H²: Unaccounted variability/ sampling variability, I²: Residual heterogeneity/unaccounted variability, n- Number of studies, OR-Odds ratio, R²: Amount of heterogeneity accounted for. *I², and *p-Value related to the test of moderators. * Significant at 0.05*

Table S2.5: Meta-regression results for moderators for junk food consumption

Moderator	n	Coefficient (95% CI)	p Value	I ² (%) *	R ² index (%)	H ²
Bivariate meta-regression						
Mean age (years)	6	0.001 (-0.031, 0.033)	0.96	2	0	1.00
Body mass index (kg/m ²)	6	0.043 (-0.048, 0.134)	0.35	0	0	1.00
Location (Nigeria as ref.)	6	0.329 (-0.220, 0.877)	0.24	0	0	1.00
Multivariate meta-regression						
Test of moderators	6	QM (df = 3) = 0.96	0.74	0	0	1.00
Mean age (years)	6	-0.039 (-0.116, 0.039)	0.33			
Body mass index (kg/m ²)	6	0.077 (-0.342, 0.495)	0.72			
location (Nigeria as ref.)	6	0.400 (-1.573, 2.374)	0.69			

Moderating effects of mean age, study location, and BMI on the association between junk food consumption and hypertension in West Africa.

*Abbreviations: CI: Confidence interval, H²: Unaccounted variability/ sampling variability, I²: Residual heterogeneity/unaccounted variability, n- Number of studies, OR-Odds ratio, R²: Amount of heterogeneity accounted for. *I², and *p-Value related to the test of moderators. * Significant at 0.05.*

Table S2.6: Meta-regression results of moderators for red meat consumption

Moderator	n	Coefficient (95% CI)	p Value	I ² (%) *	R ² index (%)	H ²
Bivariate meta-regression						
Mean age (years)	4	0.059 (-0.038, 0.156)	0.23	16	51	1.18
Body mass index (kg/m ²)	4	-0.062 (-0.394, 0.271)	0.77	48	0	1.92
Location (Nigeria as ref.)	4	-0.711 (-1.438, 0.015)	0.05	0	100	1.00
Multivariate meta-regression						
Test of moderators		QM (df = 3) = 2.04	0.56	0	0	1.00
Mean age (years)	4	-0.000 (-0.070, 0.070)	0.99			
Body mass index (kg/m ²)	4	0.060 (-0.411, 0.531)	0.80			
location (Nigeria as ref.)	4	-0.843 (-2.168, 0.481)	0.21			

Moderating effects of mean age, study location, and BMI on the association between red meat consumption and hypertension in West Africa.

*moderating effects of mean age, study location, and BMI on the association between red meat consumption and hypertension in West Africa Abbreviations: CI: Confidence interval, H²: Unaccounted variability/ sampling variability, I²: Residual heterogeneity/unaccounted variability, n- Number of studies, OR-Odds ratio, R²: Amount of heterogeneity accounted for. *I², and *p-Value related to the test of moderators. * Significant at 0.05*

Table S2.7: Meta-regression results of moderators for dietary fat consumption

Moderator	n	Coefficient (95% CI)	p Value	I ² (%) *	R ² index (%)	H ²
Bivariate meta-regression						
Mean age (years)	5	-0.015 (-0.077, 0.048)	0.64	0	0	1.00
Body mass index (kg/m ²)	5	0.016 (-0.057, 0.088)	0.67	0	0	1.00
Location (Nigeria as ref.)	5	0.096 (-1.001, 1.193)	0.86	0	0	1.00
Multivariate meta-regression						
Test of moderators		QM (df = 3) = 0.16	0.98	0	0	1.00
Mean age (years)	5	-0.029 (-0.193, 0.136)	0.74			
Body mass index (kg/m ²)	5	0.027 (-0.142, 0.193)	0.76			
location (Nigeria as ref.)	5	-0.226 (-2.703, 2.252)	0.56			

Moderating effects of mean age, study location, and BMI on the association between dietary fat consumption and hypertension in West Africa.

*Abbreviations: CI: Confidence interval, H²: Unaccounted variability/ sampling variability, I²: Residual heterogeneity/unaccounted variability, n- Number of studies, OR-Odds ratio, R²: Amount of heterogeneity accounted for. *I², and *p-Value related to the test of moderators. * Significant at 0.05.*

Table S2.8: Meta-regression results of moderators for dietary salt consumption

Moderator	n	Coefficient (95% CI)	*p Value	*I ² (%)	R ² index (%)	H ²
Bivariate meta-regression						
Mean age (years)	10	-0.004 (-0.019, 0.012)	0.63	36	0	1.58
Body mass index (kg/m ²)	10	0.022 (-0.027, 0.072)	0.38	28	4	1.38
Location (Nigeria as ref.)	10	-0.468 (-1.015, 0.079)	0.09	19	52	1.23
Multivariate meta-regression						
Test of moderators	10	QM (df = 3) = 1.25	0.74	0	0	1.00
Mean age (years)	10	-0.006 (-0.036, 0.025)	0.72			
Body mass index (kg/m ²)	10	0.018 (-0.091, 0.127)	0.74			
location (Nigeria as ref.)	10	-0.470 (-1.370, 0.430)	0.31			

Moderating effects of mean age, study location, and BMI on the association between dietary salt consumption and hypertension in West Africa.

*Abbreviations: CI: Confidence interval, H²: Unaccounted variability/ sampling variability, I²: Residual heterogeneity/unaccounted variability, n- Number of studies, OR-Odds ratio, R²: Amount of heterogeneity accounted for. *I², and *p-Value related to the test of moderators. * Significant at 0.05.*

Table S2.9: Meta-regression results of moderators for alcohol consumption.

Moderator	n	Coefficient (95% CI)	p Value	I ² (%) *	R ² index (%)	H ²
Bivariate meta-regression						
Mean age (years)	8	0.017 (-1.653, 0.576)	1.22	0	0	1.00
Body mass index (kg/m ²)	8	0.000 (-0.050, 0.050)	0.99	10	0	1.12
Location (Nigeria as ref.)	8	-0.167 (-0.741, 0.407)	0.57	6	0	1.07
Multivariate meta-regression						
Test of moderators		QM (df = 3) = 0.30	0.96	0	0	1.00
Mean age (years)	8	0.012 (-0.053, 0.076)	0.72			
Body mass index (kg/m ²)	8	-0.008 (-0.124, 0.108)	0.89			
location (Nigeria as ref.)	8	-0.102 (-1.152, 0.949)	0.85			

Moderating effects of mean age, study location, and BMI on the association between alcohol consumption and hypertension in West Africa.

*Abbreviations: CI: Confidence interval, H²: Unaccounted variability/ sampling variability, I²: Residual heterogeneity/unaccounted variability, n- Number of studies, OR-Odds ratio, R²: Amount of heterogeneity accounted for. *I², and *p-Value related to the test of moderators. * Significant at 0.05.*

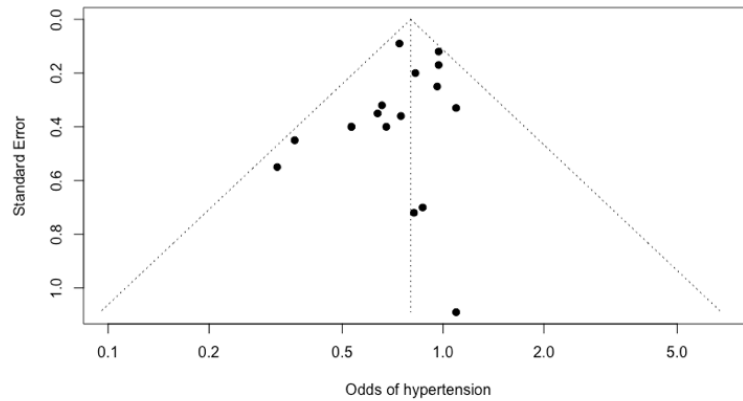


Figure S2.1: Funnel plot that reported on fruits and vegetables consumption.

The funnel plot illustrates the publication bias of the association between fruit and vegetable consumption and hypertension in West Africa from 17 studies. Odds ratio on the x-axis vs standard error on the y-axis. No publication bias was demonstrated by the funnel plot, Egger's regression test ($p = 0.18$), and rank correlation test ($p = 0.17$) in the meta-analysis.

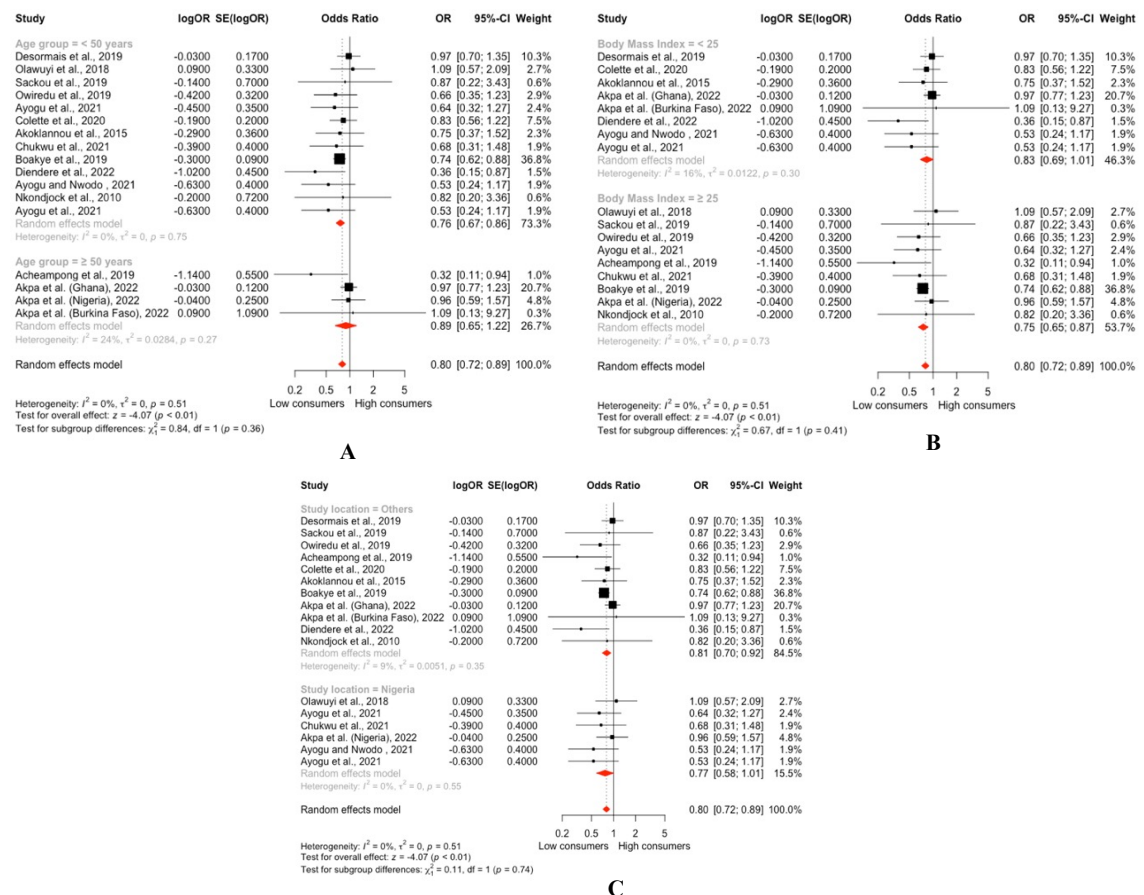


Figure S2.2. Forest plot of subgroup analysis of moderators of fruit and vegetable consumption.

Forest plot illustrating the moderating effect of (A) mean age, (B) BMI, and study location (C) on the association between fruit and vegetable consumption and hypertension in West Africa. The result in (A) suggests that mean age significantly moderates the effect size and shows a stronger association in individuals < 50 years than those ≥ 50 years old. No significant moderating effect was observed for BMI and study location in (B) and (C), respectively. CI: Confidence interval, logOR: Treatment effect, OR: Odds ratio, SE (logOR): Standard error.

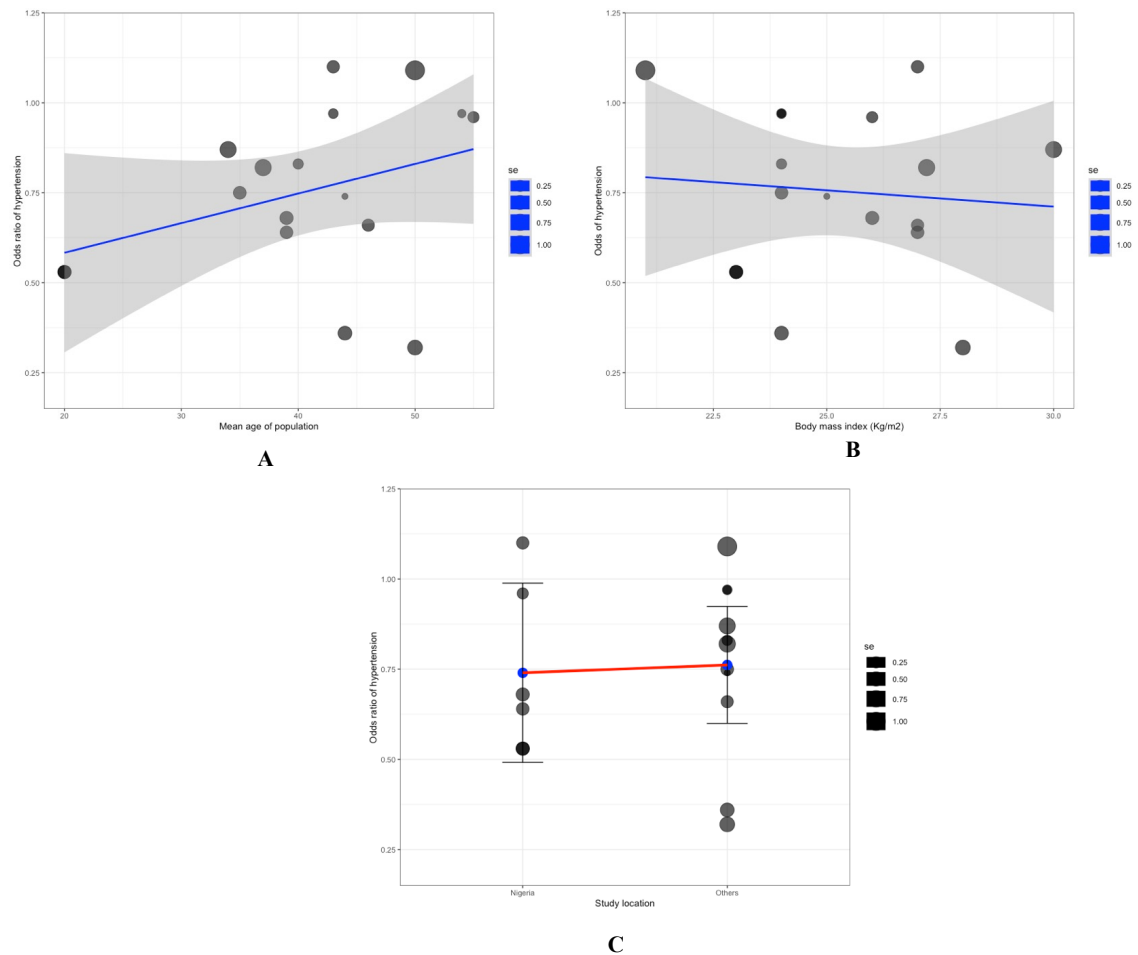


Figure S2.3. Bubble plot that reported on fruit and vegetable consumption.

The bubble plot illustrates the relationship of moderating effects of (A) mean age, (B) body mass index (BMI), and (C) study location on the association between fruit & vegetable consumption and hypertension in West Africa from 17 studies. The bubble plot in (A), (B), and (C) suggests that there is no significant moderating effect of the mean age, BMI, and study location on the relationship between fruit consumption and hypertension.

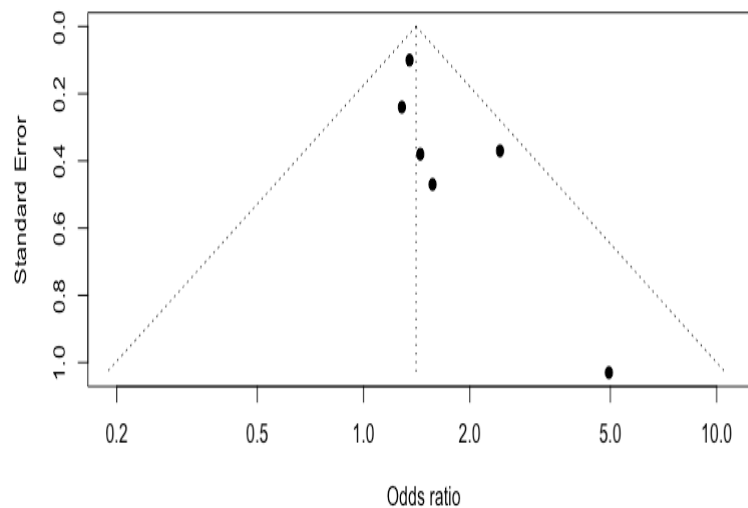


Figure S2.4. Funnel plots that reported on junk food consumption.

Odds ratio (x-axis) vs standard error (y-axis). No publication bias was demonstrated by the funnel plot, Egger's regression test ($p = 0.26$), and rank correlation test ($p = 0.06$) in the meta-analysis of 5 studies.

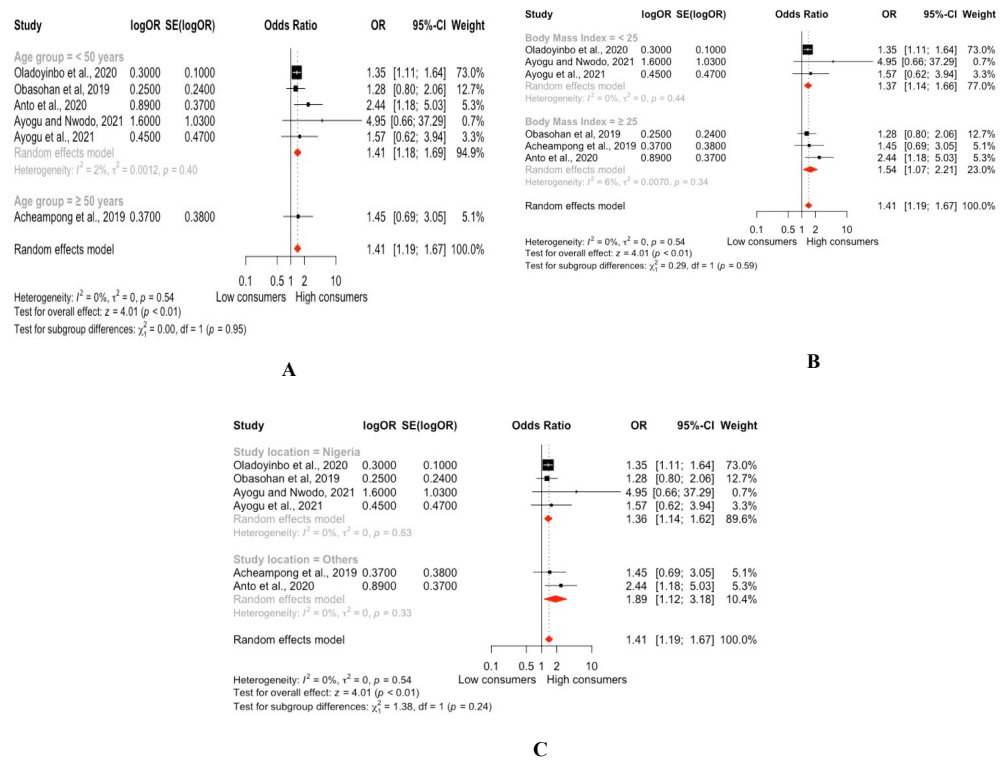


Figure S2.5. Forest plot of subgroup analysis of the moderators of junk food consumptions.

No significant moderating effect was observed for mean age, BMI, and study location in (A), (B), and (C) on the effect size, respectively. CI: Confidence interval, logOR: Treatment effect, OR: Odds ratio, SE (logOR): Standard error.

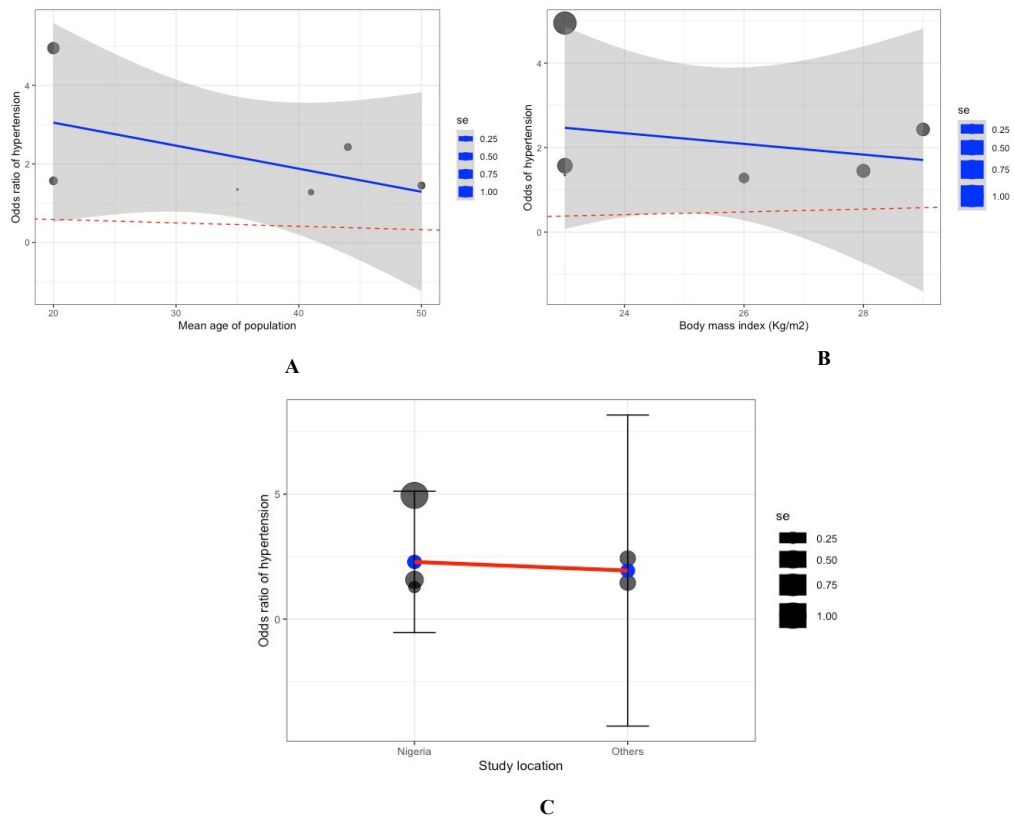


Figure S2.6. Bubble plot that reported on junk food consumption.

The bubble plot illustrates the relationship of moderating effects of (A) mean age, (B) body mass index (BMI), and (C) study location on the association between junk food consumption and hypertension in West Africa from 6 studies. The bubble plot in (A), (B), and (C) suggests that there is no significant moderating effect of mean age, BMI, and study location on the relationship between fruit consumption and hypertension.

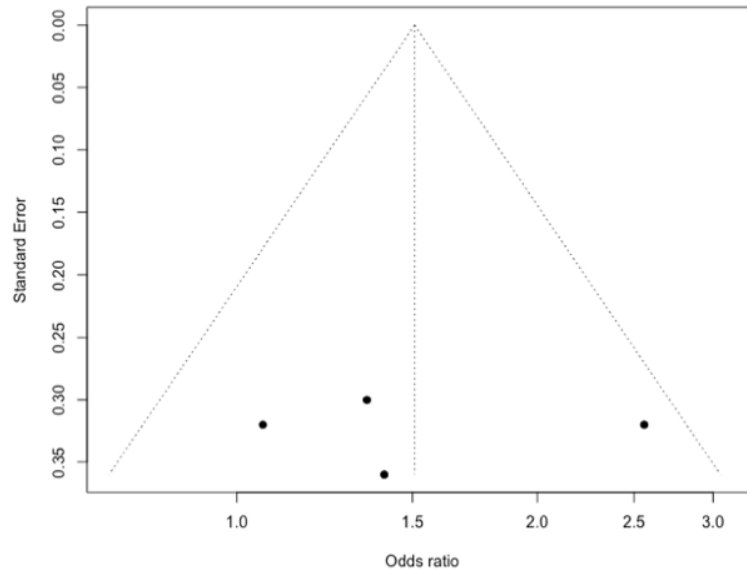


Figure S2.7. Funnel plots that reported on red meat consumption.

Odds ratio (x-axis) vs standard error (y-axis). No publication bias was indicated by the funnel plot, Egger's regression test ($p = 1.00$), and rank correlation test ($p = 0.72$) in the meta-analysis of 4 studies.

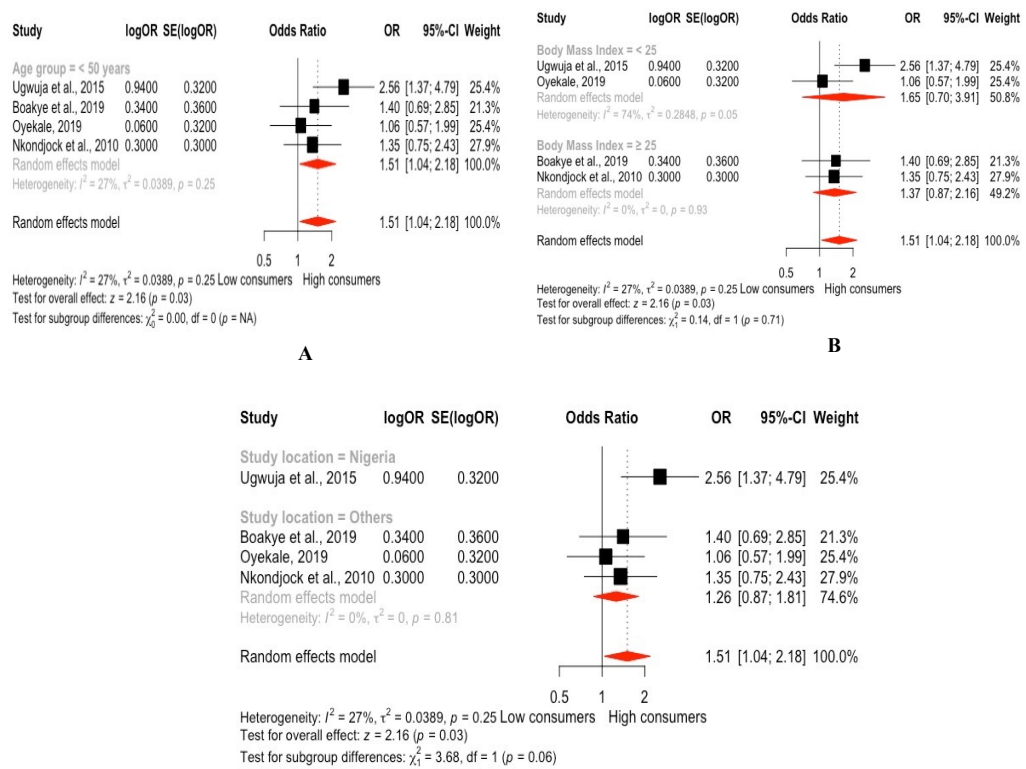


Figure S2.8. Forest plot of subgroup analysis of the moderators of red meat.

No significant moderating effect was observed for mean age, BMI, and study location in figures (A), (B), and (C), respectively. CI: Confidence interval, logOR: Treatment effect, OR: Odds ratio, SE (logOR): Standard error.

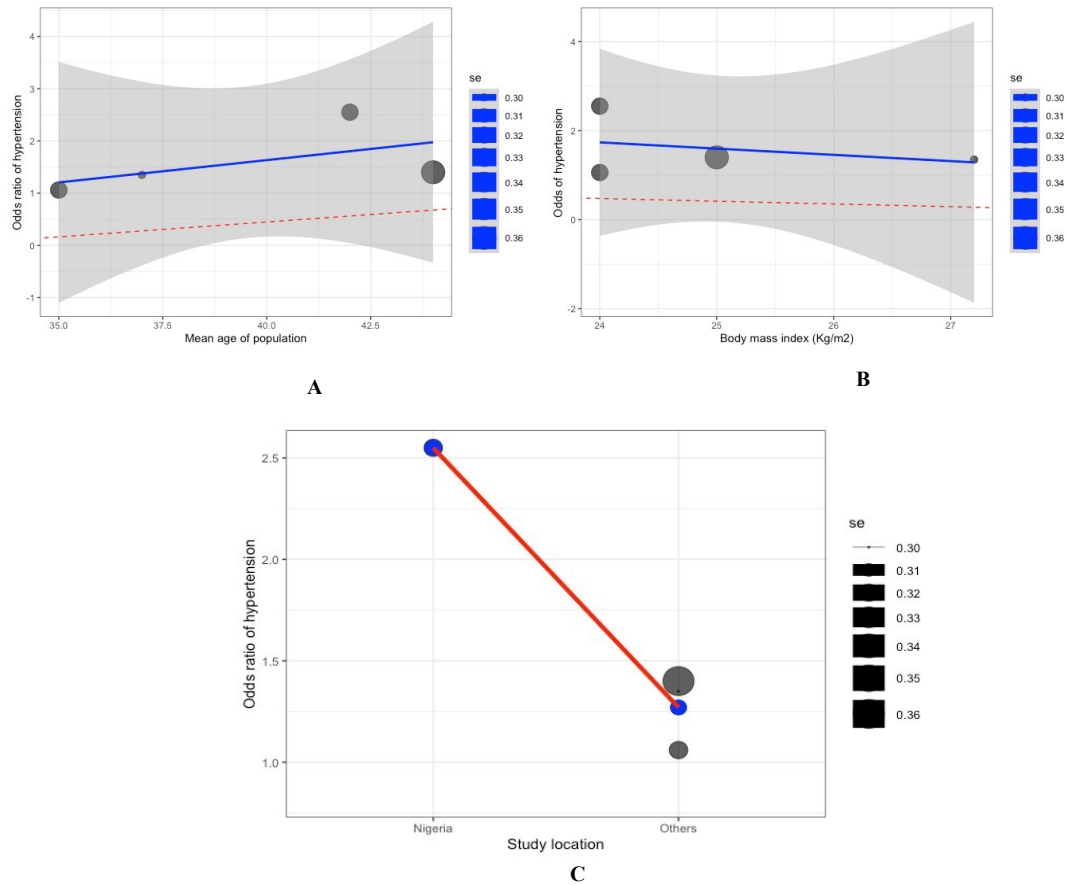


Figure S2.9. Bubble plot that reported on red meat consumption.

The bubble plot illustrates the relationship of moderating effects of (A) mean age, (B) body mass index (BMI), and (C) study location on the association between red meat consumption and hypertension in West Africa from 4 studies. No moderating effect of the mean age, BMI, and study location on the relationship between red meat consumption and hypertension was observed.

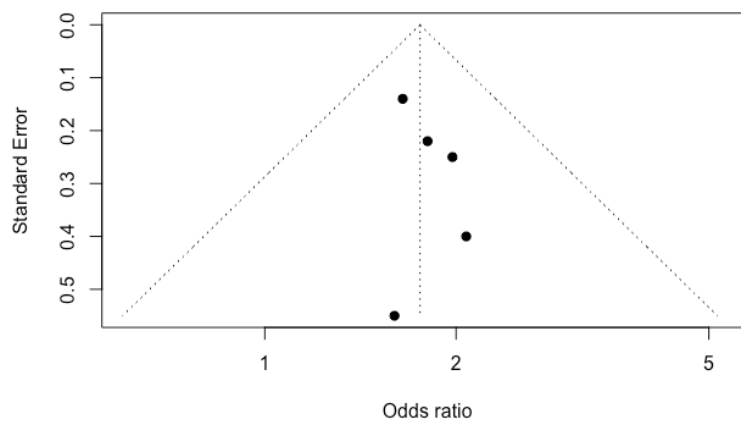


Figure S2.10. Funnel plots that reported on dietary fat consumption.

Odds ratio (x-axis) vs standard error (y-axis). No publication bias was demonstrated by the funnel plot, Egger's regression test ($p = 0.89$), and Begg's test ($p = 0.48$) in the meta-analysis of 5 studies.

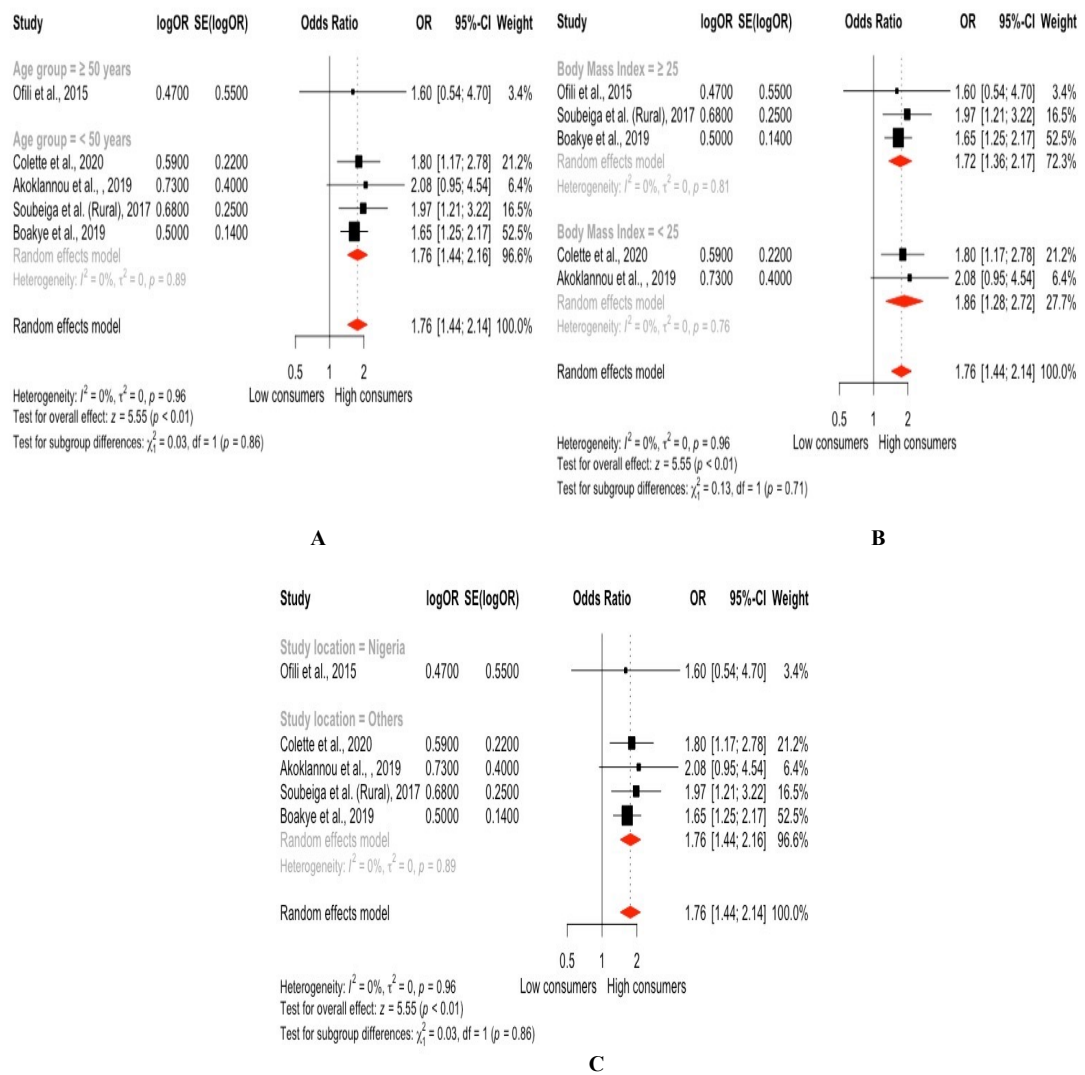


Figure S2.11. Forest plot of Subgroup analysis of the moderators of dietary fat consumption.

No significant moderating effect was observed for mean age, BMI, and study location in figures (A), (B), and (C) on the effect size, respectively. CI: Confidence interval, logOR: Treatment effect, OR: Odds ratio, SE (logOR): Standard error.

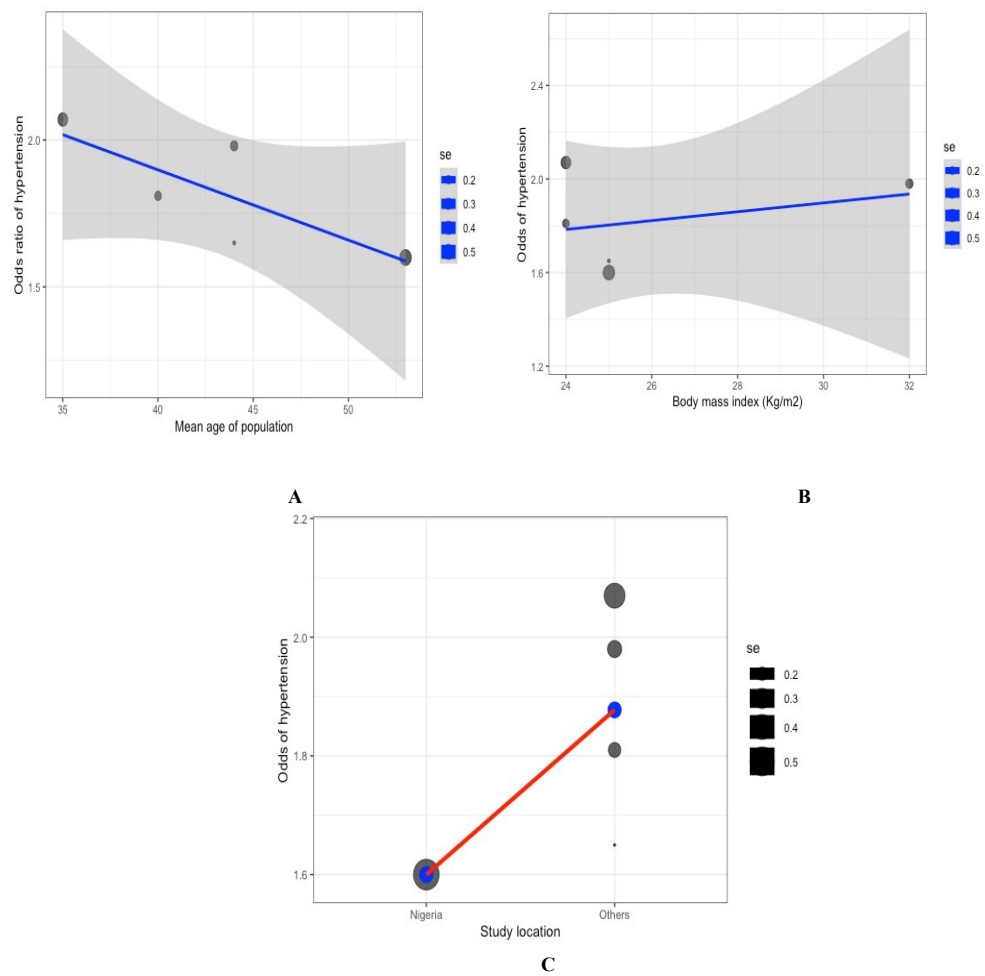


Figure S2.12. Bubble plot that reported on dietary fat consumption.

The bubble plot illustrates the relationship of moderating effects of (A) mean age, (B) body mass index (BMI), and (C) study location on the association between dietary fat consumption and hypertension in West Africa from 5 studies. The bubble plot in (A), (B), and (C) suggests that there is no significant moderating effect of the mean age, BMI, and study location on the relationship between dietary fat consumption and hypertension.

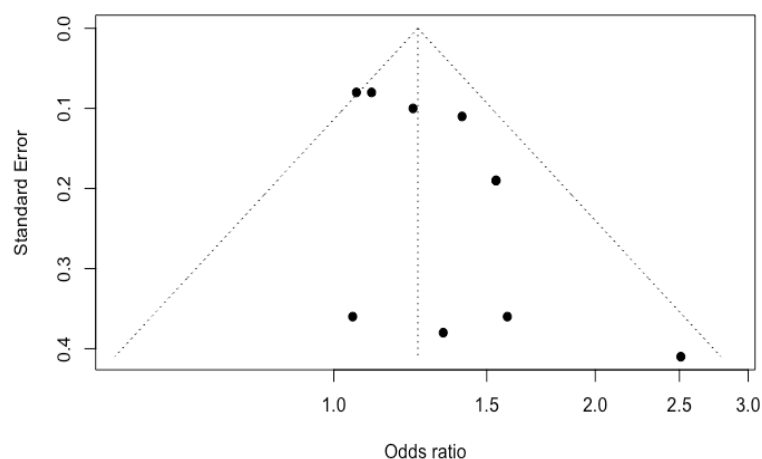


Figure S2.13. Funnel plot that reported on dietary salt consumption.

Odds ratio (x-axis) vs standard error (y-axis). No publication bias was demonstrated by the funnel plot, Egger's regression test ($p = 0.31$), and rank correlation test ($p = 0.05$) in the meta-analysis of 10 studies.

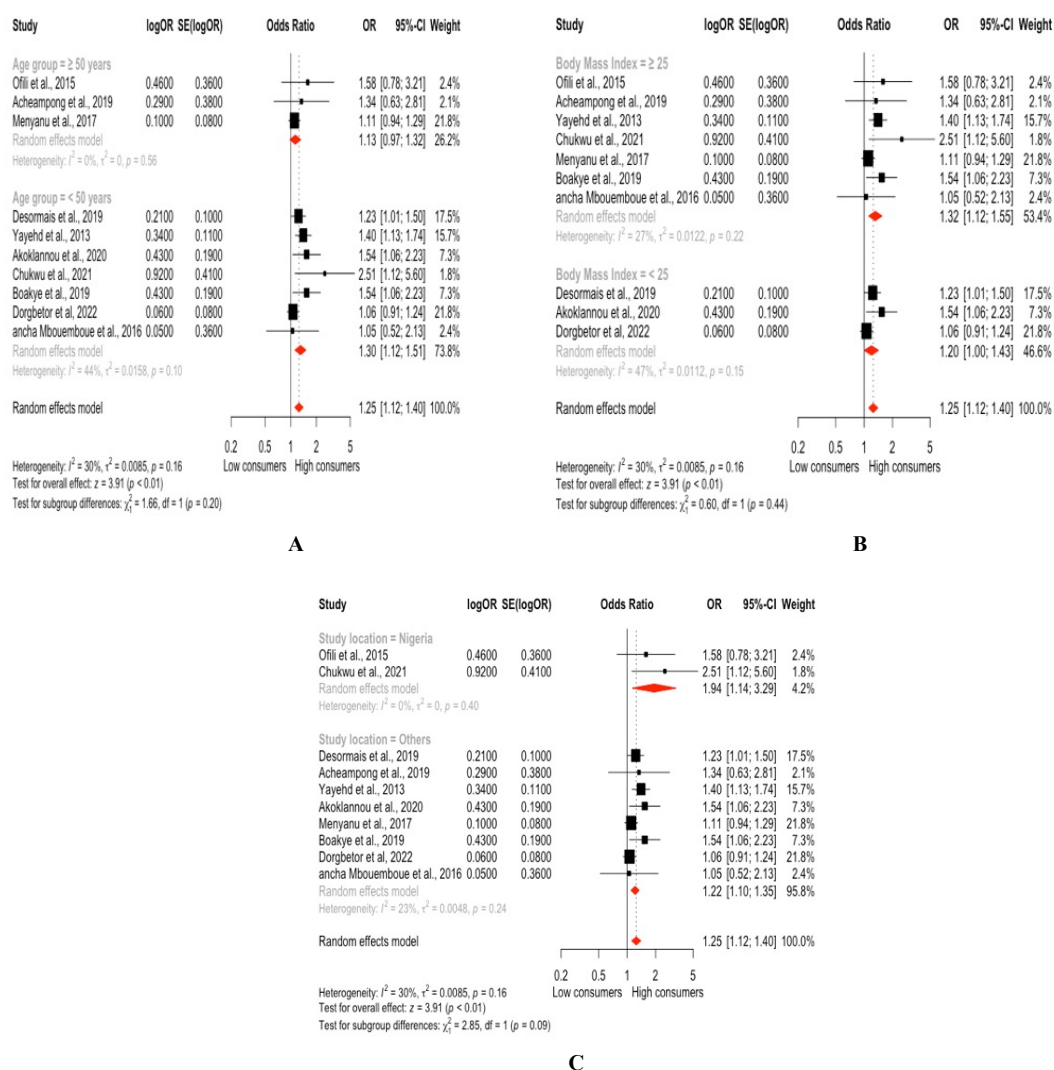


Figure S2.14. Forest plot of subgroup analysis of the moderators of dietary salt consumption.

No significant moderating effect was observed for mean age, BMI, and study location in (A), (B), and (C) on the effect size, respectively. CI: Confidence interval, logOR: Treatment effect, OR: Odds ratio, SE (logOR): Standard error.

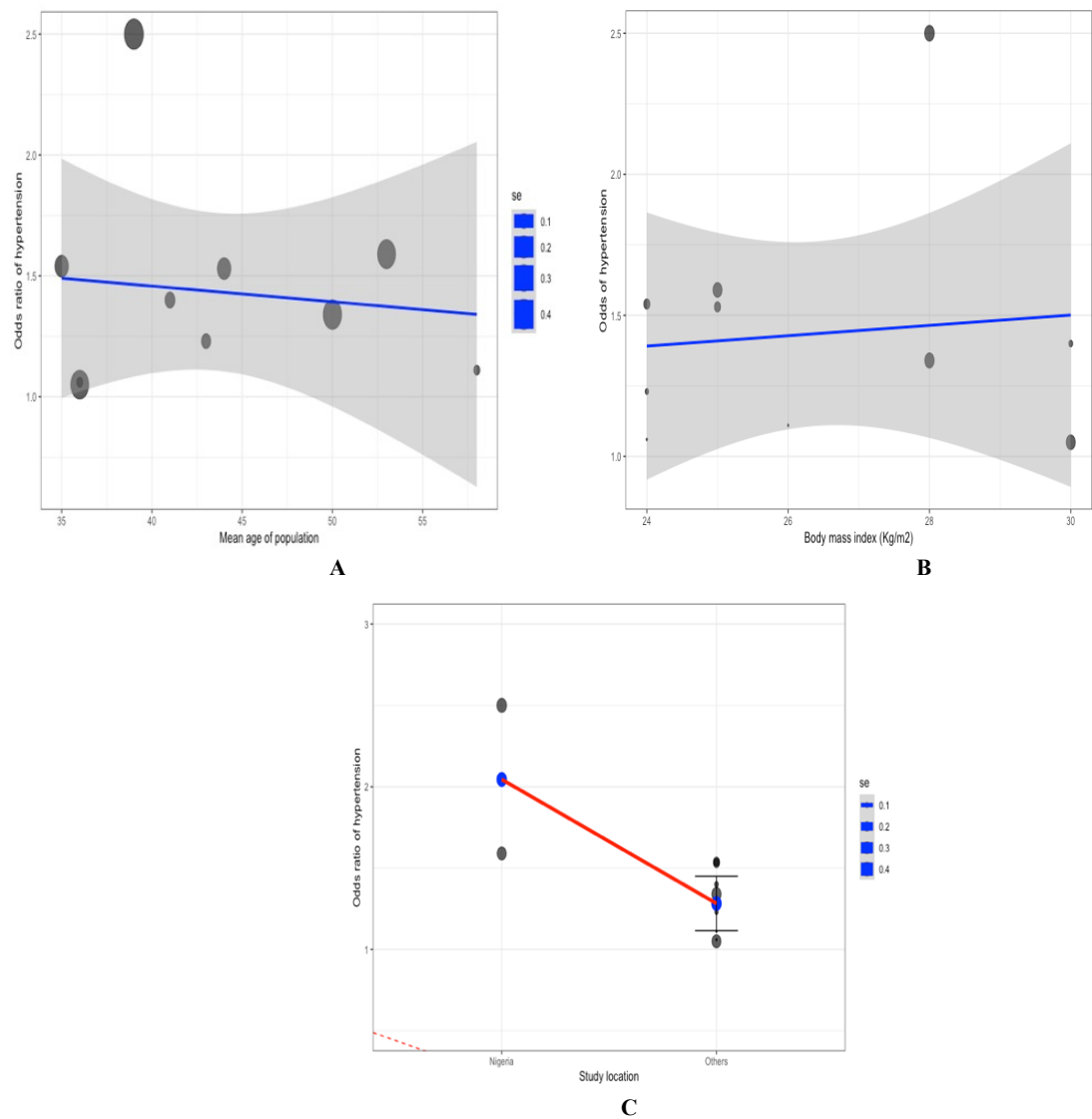


Figure S2.15. Bubble plot that reported on dietary salt consumption.

The bubble plot illustrates the relationship of moderating effects of (A) mean age, (B) body mass index (BMI), and (C) study location on the association between dietary salt consumption and hypertension in West Africa from 10 studies. The bubble plot in (A), (B), and (C) suggests that there is no significant moderating effect of mean age, BMI, and study location on the relationship between fruit consumption and hypertension.

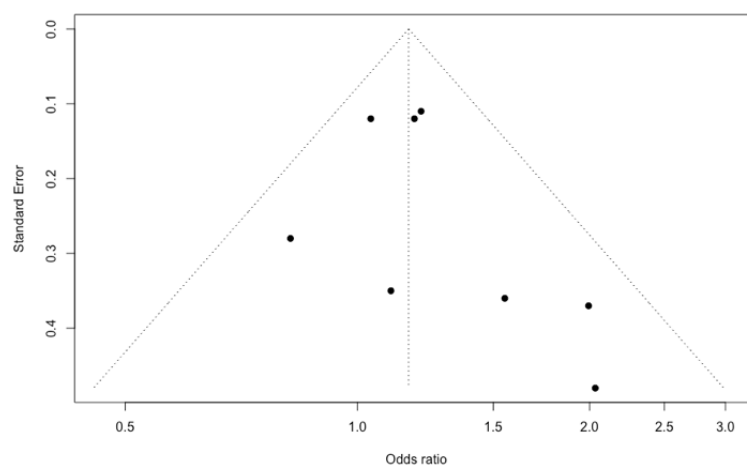


Figure S2.16. Funnel plots that reported on alcohol consumption

Odds ratio (x-axis) vs standard error (y-axis). No publication bias was demonstrated by the funnel plot, Egger's regression test ($p = 0.46$), and Begg's test ($p = 0.17$) in the meta-analysis of 8 studies.

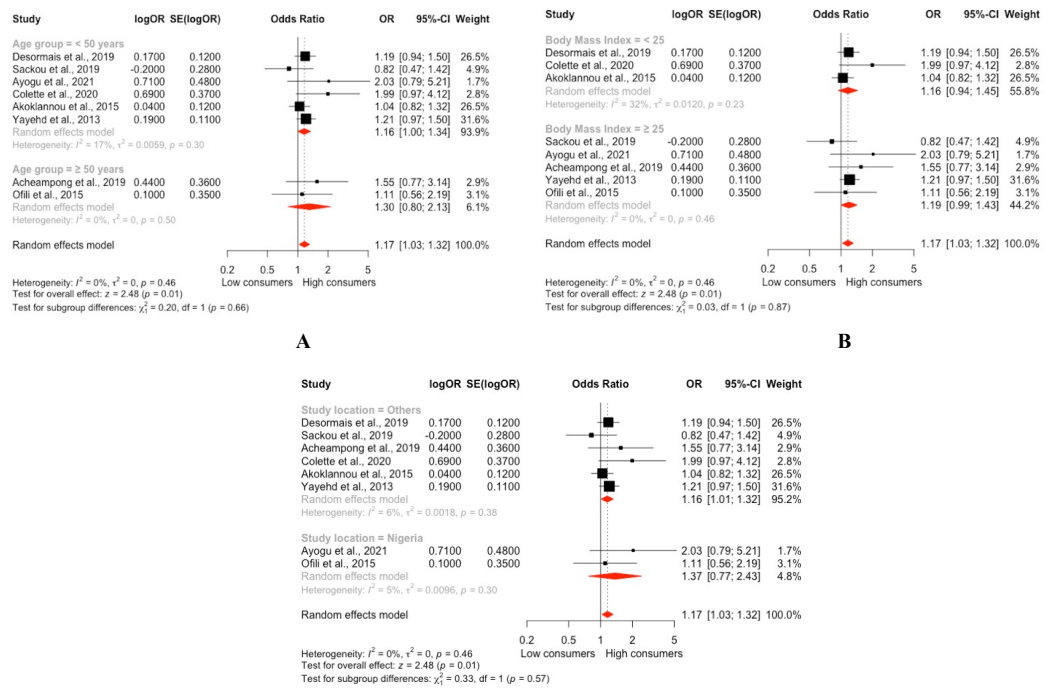


Figure S2.17. Forest plot of subgroup analyses of the moderators of alcohol consumption.

No significant moderating effect was observed for mean age, BMI, and study location in (A), (B), and (C) on the effect size, respectively. CI: Confidence interval, logOR: Treatment effect, OR: Odds ratio, SE (logOR): Standard error.

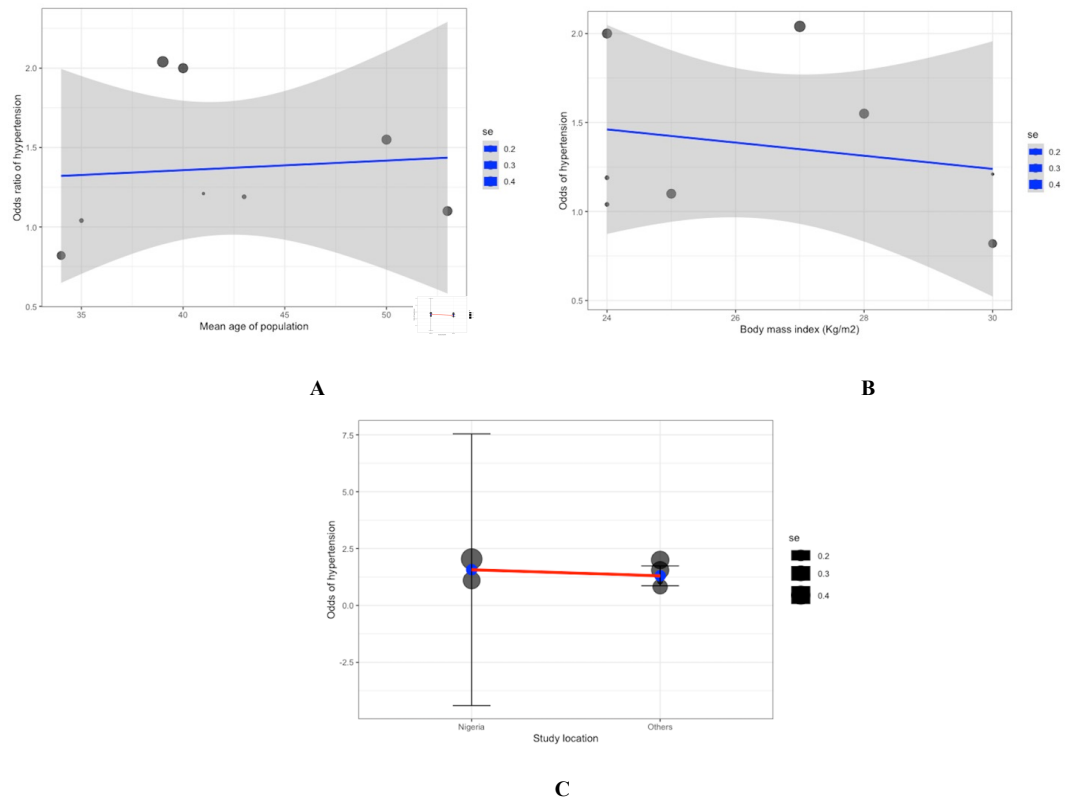


Figure S2.18. Bubble plot that reported on alcohol consumption.

The bubble plot illustrates the relationship of moderating effects of (A) mean age, (B) body mass index (BMI), and (C) study location on the association between alcohol consumption and hypertension in West Africa from 5 studies. The bubble plot in (A), (B), and (C) suggests that there is no significant moderating effect of the mean age, BMI, and study location on the relationship between alcohol consumption and hypertension.



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Time started: :

Section 2: Dietary intake information						
S/N	Food group/item	Frequency				
		More than once/ day	Daily	3-5 times a week	1-2 times a week	Never/ Rarely
1	Fruit (such as Cherry, Mango, Oranges, Pineapples, Pawpaw, Bananas, Guavas, Avocado (peas), Grapefruit, Tangerines, Soursoy, Butter pear, and others)?	☐	☐	☐	☐	☐
2	Vegetables and Corn (maize) (such as Tomatoes, Water leaves, Cabbage, Carrots, Cucumber, Watermelon, Garden eggs, Eggplant, Broccoli, Corn, and others)?	☐	☐	☐	☐	☐
3	Rice and Pasta (such as White rice, Spaghetti, Macaroni, and Noodles)?	☐	☐	☐	☐	☐
4	Wheat products (such as Semolina and wheat bread, white bread, brown bread)?	☐	☐	☐	☐	☐
5	Fibre-rich breakfast cereals (such as Cornflakes, Golden morn, Weetabix, Fruit 'n Fibre, and others)?	☐	☐	☐	☐	☐
6	Beans (such as Boiled beans, porridge beans)?	☐	☐	☐	☐	☐
7	Whole Meat (such as Cow meat, Beef, Lamb, Pork, Bush meat and others)?	☐	☐	☐	☐	☐
8	White Meat (such as Chicken, Turkey, and others)?	☐	☐	☐	☐	☐
9	Processed Meats (such as Suya, Kilishi, Sausages, bacon, corned beef, meat pies, burgers, Gala, and others)?	☐	☐	☐	☐	☐
10	Fish (unbattered) or Whole fish?	☐	☐	☐	☐	☐
11	Eggs (such as Boiled eggs, fried eggs, and scrambled eggs)?	☐	☐	☐	☐	☐
12	Fried or fast (takeaway) foods (such as Fried rice, Jollof rice, Akara, Puff-puff, Pancakes, Chin-chin, Buns, Chips (plantain, yam, and potatoes), Shawarma, Pizza, Moin-moin, fried fish, fried chicken)?	☐	☐	☐	☐	☐
13	Potatoes and Yam (such as Boiled yam, Amala, pounded yam, porridge yam, boiled potatoes)?	☐	☐	☐	☐	☐
14	Fatty soups (such as Egusi (melon) soup, Banga soup or groundnut soup and others) and Swallow (Fufu, Garri, and Eba)?	☐	☐	☐	☐	☐
15	Vegetable soups (such as Afang soup, Edikaikong soup, Bitter leaf soup, Efo Riro and others) and Swallow (Fufu, Garri, and Eba)?	☐	☐	☐	☐	☐
16	Draw soups (such as Okra soup, Ogbono soup, Ewedu soup and others) and Swallow (Fufu, Garri, and Eba)?	☐	☐	☐	☐	☐
17	Native soup (such as Fisherman soup, white soup, Nsala soup and others) and Swallow (Fufu, Garri, and Eba)?	☐	☐	☐	☐	☐
18	Stew (sauce) (such as Palm oil stew, vegetable oil stew and others)?	☐	☐	☐	☐	☐
19	Nuts/seeds (such as Groundnut, peanut, coconut, and others)?	☐	☐	☐	☐	☐
20	Dessert and sweets (Ice cream, yoghurt, cheese, sweet biscuits, cakes, chocolate, sweets, and others)?	☐	☐	☐	☐	☐



Short Form Food Frequency Questionnaire

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21	Fat and Oils (such as Palm oil, Vegetable oil, Groundnut oil, Coconut oil, butter, lard, mayonnaise/salad cream, margarine)?	☐	☐	☐	☐	☐
22	Fizzy (Soft) drinks and fruit juices (such as Coke, Fanta, sprite, Pepsi, Betas Malt, Guinness Malt, Maltina, Zobo, Tiger nut, Kunu, 5live, Pineapple juice and others)?	☐	☐	☐	☐	☐
23	Diet Non-alcoholic fizzy drinks (such as Diet Coke, diet Fanta, diet sprite, energy drink and others)?	☐	☐	☐	☐	☐
24	Alcoholic drinks (such as Beer, wine, gin, whisky, spirit, and others)?	☐	☐	☐	☐	☐
25	Tea and Coffee (such as Green tea, Lipton, Nescafe and others)?	☐	☐	☐	☐	☐
26	Milk or milk-based beverages (such as Peak, Three Crowns, Dano, Cowbell, Loya Milk, Coast, Hollandia, Nunu, Milo, Ovaltine, Chocomilo, Nesquik, Nutri-C, Viju Milk Drink, and others)?	☐	☐	☐	☐	☐
27.	Dietary salt	Frequency				
		Never/ Rarely	Sometimes	Usually	Always	Don't know
	Do you add salt to food while cooking including seasoning cubes (such as Salt, Seasoning (e.g., Maggi, Knorr), Sauce (e.g., Soy sauce, Suya sauce, Fish sauce, Oyster sauce), and others)	☐	☐	☐	☐	☐
	How often is salt, salty seasoning or a salty sauce (Such as Salt, Seasoning (e.g., Maggi, Knorr), Sauce (e.g., Soy sauce, Suya sauce, Fish sauce, Oyster sauce), and others) added to your household's cooking or preparing foods?	☐	☐	☐	☐	☐
	Do you add salt to any food while eating?	☐	☐	☐	☐	☐
	How often do you eat meals prepared outside of your home? (e.g., Restaurants, fast-food establishments, local roadside food vendors (Mama put))	☐	☐	☐	☐	☐
	How often do you check food labels for Salt content when purchasing packaged foods?	☐	☐	☐	☐	☐
	How much salt or salty sauce do you think you consume? (Such as Salt, Seasoning (e.g., Maggi, Knorr), Sauce (e.g., Soy sauce, Suya sauce, Fish sauce, Oyster sauce), and others)	Very low ☐ Low ☐ Moderate ☐ High ☐ Very high ☐ Don't know ☐				

What milk do you usually use or drink, such as in hot & cold drinks or on cereal? (Including tea, coffee, hot milk, milkshakes, or cereal)

Whole / full-fat milk	☐	Semi-skimmed milk	☐
Skimmed milk	☐	Rarely/never use milk	☐

Other (please write its name)

Other foods: Are there other foods and beverages you have eaten more than once a week in the past month?

Yes ☐ No ☐ (If yes, please list below)

Please tick how often you eat at least ONE portion of the following foods & drinks (Please only put one tick, but answer EVERY line)

S/N	Food group/item	Usual Serving	Frequency				
			More than once/ day	Daily	3-5 times a week	1-2 times a week	Never/ Rarely
1			☐	☐	☐	☐	☐
2			☐	☐	☐	☐	☐
3			☐	☐	☐	☐	☐

Time finished: ☐☐ : ☐☐

Thank you for taking the time to complete the questionnaire.

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Appendix K: Supplementary materials for Chapter four

Table S4.2. Categorisations of food groups in the food frequency questionnaire (FFQ)

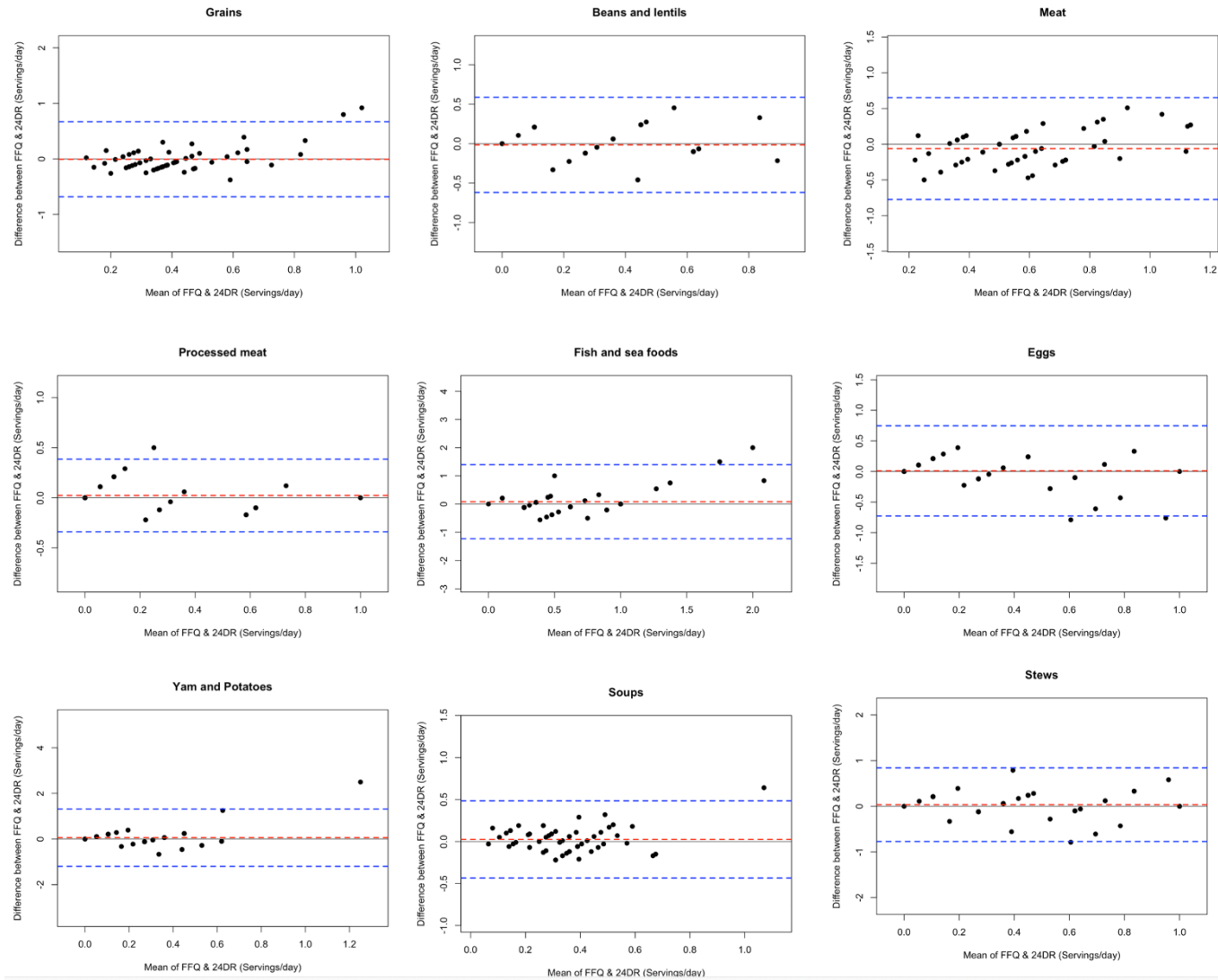
S/N	Food group	List of Food items
1	Fruit	Fruit (q1)
2	Vegetable	Vegetables and Corn (maize) (q2)
3	Grains	Rice and Pasta (q3), Wheat products (q4), Fibre-rich breakfast cereals (q5),
4	Beans	Beans (q6)
5	Meat	Whole Meat (q7), White Meat (q7)
6	Processed meat	Processed Meats (q8)
7	Fish and seafoods	Fish (unbattered) or Whole fish (q10)
8	Eggs	Eggs (q11)
9	Fried or fast food	Fried or fast (takeaway) foods (q12)
10	Yam & potatoes	Potatoes and Yam (q13)
11	Soups	Fatty soups (14), Vegetable soups (q15), Draw soups (q16), Native soup (q17),
12	Stew	Stew (sauce) (q18)
13	Nuts & seeds	Nuts/seeds (q19)
14	Dessert and sweets	Ice cream, yoghurt, cheese, sweet, biscuits, cakes, chocolate, and others (q20)
15	Soft drinks	Fizzy (Soft) drinks and fruit juices (q22), Diet Non-alcoholic fizzy drinks (q23)
16	Alcoholic drinks	Alcoholic drinks (q24)
17	Tea and coffee	Tea and Coffee (q25)
18	Milk and milk drinks	Milk or milk-based beverages (q26)
19	Fats and oils	Fat and Oils (q21)
20	Salt and seasonings	Dietary salt (q27)

The food groups in Table S3.1 was further categorised into 20 food groups based on food groups that have similar physiological and biochemical effects.

Table S4.3. Bland-Altman analysis between the food frequency questionnaire and 24-hour dietary recalls.

Food groups (servings/day)	Bias	Upper LOA	Lower LOA	% within LOA
Fruit	0.03	1.21	-1.16	97
Vegetables	0.02	0.66	-0.62	100
Grains	-0.03	0.46	-0.52	100
Beans and lentils	-0.02	0.58	-0.62	100
Meat	-0.06	0.65	-0.77	100
Processed meat	0.02	0.38	-0.34	98
Fish	0.08	1.40	-1.23	97
Eggs	0.01	0.75	-0.73	97
Fried or fast food	-0.06	0.76	-0.88	98
Yam and potatoes	0.06	1.21	-1.20	98
Soups	0.02	0.48	-0.43	98
Stew	0.03	0.84	-0.77	100
Nuts and seeds	0.02	1.11	-1.06	98
Desserts and sweets	-0.01	1.01	-1.03	97
Soft drinks	0.03	0.87	-0.81	98
Alcoholic drinks	-0.00	0.19	-0.20	97
Tea and coffee	0.05	1.16	-1.06	97
Milk and milk drinks	-0.02	0.76	-0.82	98
Fats and oils	-1.73	0.73	-4.18	84
Salt and seasonings	-0.08	3.93	-4.08	98

Bias: Mean difference between FFQ and 24DR, LOA: limits of agreement, %: percent



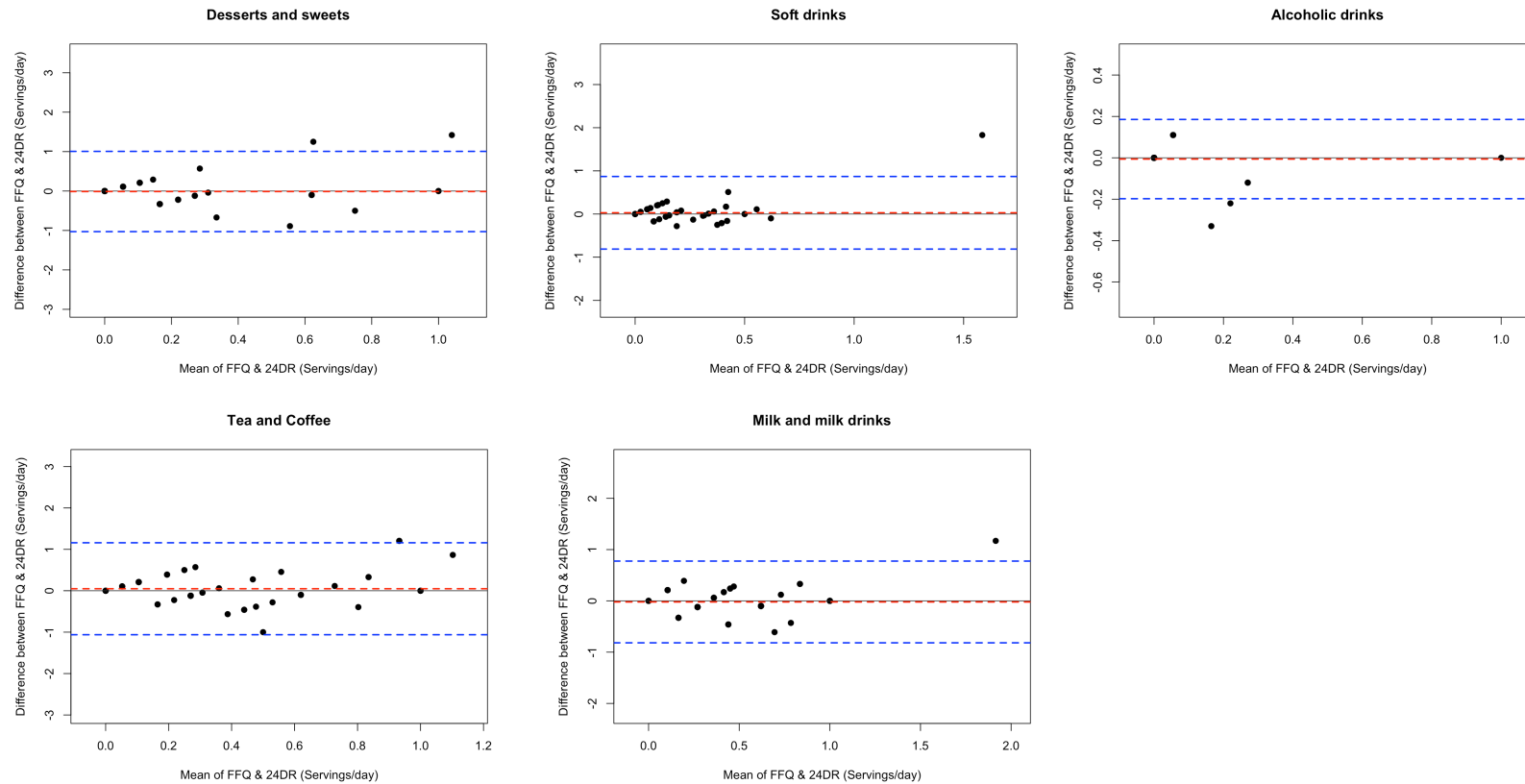


Figure S4.1. Bland-Altman plots related to food groups.

Dashed red lines represent the mean difference, and dashed blue lines show the lower and upper 95% limits of agreement ($n=58$). 24DR: 24-hour dietary recall; FFQ: Food frequency questionnaire.

Appendix L: Supplementary materials for Chapter five

Table S5.1. 25-item Food Frequency Questionnaire (NiDST)

How often do you eat or drink the following foods & drinks in a ‘typical’ week over the past month or so? Do not be concerned if some food/snacks or drinks you eat or drink are not mentioned.

Section 2: Dietary intake information								
S/N	Food group/item	Frequency						
		Never or Rarely	1-2 times/ week	3-5 times/ week	Daily	1-2 times/ day	3-4 times/ day	5+ Times/ day
1	Fruit (such as Mango, Oranges, Pineapples, Pawpaw, Bananas, Guavas, Avocado (peas), Grapefruit, Tangerines, Soursop, Butter pear, watermelon, Cherry, and others)?	☐	☐	☐	☐	☐	☐	☐
2	Vegetables (such as Cabbage, Carrots, Cucumber, Garden eggs, Eggplant, Broccoli, Corn, Cooked vegetables (e.g. Tomatoes, onions, peppers, bitter leaf, okazi, spinach, pumpkin, ogu), Canned vegetables, and others)?	☐	☐	☐	☐	☐	☐	☐
3	Rice, Millet, and Pasta (such as Rice, Maise, Millet, Sorghum, Spaghetti, Macaroni, Instant noodles, and others)?	☐	☐	☐	☐	☐	☐	☐
4	Wheat products (such as Bread, Oat, Semolina, Fonio, Wheat flour)?	☐	☐	☐	☐	☐	☐	☐
5	Fibre-rich breakfast cereals (such as Cornflakes, GoldenMorn, Weetabix, Fruit 'n Fiber, and others)?	☐	☐	☐	☐	☐	☐	☐
6	Beans, and lentils (such as Black-eyed peas, Brown beans, Cowpeas, Boiled beans, Moin-moin, and others)?	☐	☐	☐	☐	☐	☐	☐
7	Nuts and Seeds (such as Groundnut, Coconut, Melon seeds, Sesame seeds, cashews, and others)?	☐	☐	☐	☐	☐	☐	☐
8	Red Meat (such as Beef, Sheep, Lamb, Pork, Bush meat and others)?	☐	☐	☐	☐	☐	☐	☐
9	White Meat (such as Chicken, Turkey, Cow head, Cowskin (Kpomo), and others)?	☐	☐	☐	☐	☐	☐	☐
10	Processed Meats (such as Suya, Kilishi, Sausages, Nkwobi, Bacon, Corned beef, Meat pies, Gala, and others)?	☐	☐	☐	☐	☐	☐	☐
11	Eggs and egg products (such as Boiled eggs, Fried eggs, Scrambled eggs, and others)?	☐	☐	☐	☐	☐	☐	☐
12	Fish and seafood (such as Tilapia, Catfish, Mackerel, Shrimp, Stockfish, Smoked fish, and others)?	☐	☐	☐	☐	☐	☐	☐
13	Fried foods (such as Akara, Puff-puff, Pancakes, Chin-chin, Buns, scotch egg, Chips (fried plantain, yam, and potatoes), Samosa, Fried fish, Fried chicken, Fried beef, and others)?	☐	☐	☐	☐	☐	☐	☐
14	Fast (takeaway) foods? (e.g., Restaurants foods, local roadside food vendors (Mama put), Shawarma, Pizza, Burgers, fried/jollof rice, fried chicken, Suya, Small chops, Hot dog, Beef/chicken/fish rolls, Doughnuts, and others)	☐	☐	☐	☐	☐	☐	☐
15	Starchy tubers (such as Yam, Cassava, Plantain, Cocoyam, Potatoes, and others)?	☐	☐	☐	☐	☐	☐	☐
16	Soups and Stew (sauce) (such as Egusi, Banga, or groundnut, vegetable, Afang, Edikaikong, Bitter leaf, Efo-Riro, Okra, Ogbono, Ewedu, Fisherman, white, Nsala soups and others), and (palm oil stew, vegetable oil stew, sauces, and others)?	☐	☐	☐	☐	☐	☐	☐
17	Fats and Oils (such as food cooked with palm oil, vegetable oil, butter/margarine/ mayonnaise, Lard, shea butter, salad cream, and others)?	☐	☐	☐	☐	☐	☐	☐
18	Dessert and sweets (Ice cream, yoghurt, cheese, Biscuits, cakes, chocolate, sweets, and others)?	☐	☐	☐	☐	☐	☐	☐
19	Fizzy (Soft) drinks and fruit juices (such as Coke, Fanta, Sprite, Pepsi, Malt, Maltina, Zobo, Tiger nut, Kunu, smoothies, 5live, Pineapple juice, energy drinks and others)?	☐	☐	☐	☐	☐	☐	☐
20	Alcoholic drinks (such as Beer, wine, gin, whisky, spirit, liquor, champagne, and others)?	☐	☐	☐	☐	☐	☐	☐
21	Tea and Coffee (such as green tea, black tea, Herbal tea, Lipton, Nescafe, and others)?	☐	☐	☐	☐	☐	☐	☐
22	Dairy- Milk or milk-based beverages (such as Peak, Three Crowns, Dano, Cowbell, Loya Milk, Coast, Fura da nonon, Hollandia, Nunu, Kunun zaki, Milo, Ovaltine, Chocomilo, Nesquik, Nutri-C, Viju Milk, smoothies, and others)?	☐	☐	☐	☐	☐	☐	☐
23	Seasonings (such as Salt, Seasoning cubes (e.g., Maggi, Knorr), Sauce (e.g., Soy sauce, Suya sauce, Fish sauce, Oyster sauce), and others)	☐	☐	☐	☐	☐	☐	☐
24	Salt use How often do you add extra salt to your food at the table when eating?	Never or rarely ☐		Sometimes ☐				Always ☐
25	What type of milk do you usually drinks?	Skim milk ☐	Low-fat milk ☐		Whole milk ☐			

Table S5.2. Average daily mean intake (servings/day) of unhealthy and healthy foods in the study cohort (n=151)

Food Category (servings/day)	Food groups (n)	Non-hypertensive (n=63, 41.7%)			Hypertensive (n=88), 58.3%			*p-value
		Mean	Median	IQR	Mean	Median	IQR	
Healthy foods	12	0.46	0.47	0.24	0.42	0.43	0.13	0.195
Unhealthy food	11	0.41	0.29	0.48	0.59	0.54	0.31	0.002

*p-value < 0.050 calculated by Wilcoxon-signed rank test was considered statistically significant.

Table S5.3. Association food group (servings/day) and hypertension based on intake level

Food groups	Intake level	β	SE	OR	95% CI	p-value	Weight
Red meat	High vs low	2.50	0.77	12.22	2.72, 54.85	0.001	3
Processed meat	High vs low	3.12	1.05	22.74	2.92, 176.97	0.003	3
Egg and eggs products	High vs low	2.56	0.88	12.88	2.32, 71.62	0.004	3
Fried foods	High vs low	3.72	0.97	41.05	6.16, 273.76	<0.001	4
Fast foods	High vs low	1.70	0.76	5.46	1.23, 24.12	0.025	2
Soups and stews	High vs low	1.41	0.69	4.08	1.05, 15.80	0.041	1
Fats and oils	High vs low	1.79	0.66	5.96	1.64, 21.75	0.006	2
Desserts and sweets	High vs low	2.54	0.98	12.71	1.87, 86.51	0.009	3
Soft drinks	High vs low	2.85	0.76	17.21	3.88, 76.36	<0.001	3
Alcoholic drinks	High vs low	3.41	0.91	30.11	5.08, 178.58	<0.001	3
Salts and seasonings	High vs low	3.28	0.89	26.49	4.66, 150.64	<0.001	3

Multivariable logistic regression in the derivation data set with hypertension status as the dependent variable and the dietary risk factors as independent variables. Food items with $p < 0.05$ were presented. The model was adjusted for Age, sex, BMI, and physical activity level.

β : beta-coefficient, SE: Standard error; OR: Odds ratio, CL: Confidence interval

Table S5.4. Association between mediators and Nigerian diet risk score (NiDRS) for hypertension

Biomarkers/Mediators	B (SE)	95%CI	p-value
FASTING BLOOD LIPIDS			
TC (mmol/L)	0.141 (0.026)	1.093, 1.212	<0.001
TG (mmol/L)	0.037 (0.007)	1.023, 1.052	<0.001
LDL-C (mmol/L)	0.190 (0.031)	1.138, 1.286	<0.001
VLDL-C (mmol/L)	0.007 (0.003)	1.001, 1.014	0.024
HDL-C (mmol/L)	0.002 (0.004)	0.994, 1.010	0.640
INFLAMMATORY BIOMARKERS			
CRP (mg/dL)	0.340 (0.065)	1.236, 1.597	<0.001
Homocysteine(μ mol/L)	0.620 (0.117)	1.478, 2.338	<0.001
SERUM ELECTROLYTES			
Magnesium(mmol/L)	0.008 (0.004)	1.001, 1.016	0.038
Sodium (mmol/L)	0.603 (0.334)	0.947, 3.528	0.076
Potassium (mmol/L)	0.026 (0.024)	0.979, 1.076	0.282
Calcium (mmol/L)	-0.003 (0.009)	0.979, 1.015	0.736
RENAL FUNCTION TEST			
Creatinine (μ mol/L)	0.127 (0.442)	0.477, 2.701	0.775
Urea (mmol/L)	0.002 (0.021)	0.962, 1.045	0.916

β : beta-coefficient; SE: Standard error; TC: Total cholesterol; TG: Triglyceride; HDL-C: High-density lipoprotein cholesterol; LDL-C: Low-density lipoprotein cholesterol; VLDL-C: Very low-density lipoprotein cholesterol; CRP: C-reactive protein. * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$ was considered as statistically significant.

Table S5.5. Association between biomarkers/mediators and the mean arterial blood pressure.

Biomarkers/Mediators	B (SE)	95%CI	p-value
FASTING BLOOD LIPIDS			
TC (mmol/L)	4.96 (1.09)	0.12, 8.45	<0.001
TG (mmol/L)	18.62 (4.00)	0.00, 2551.39	<0.001
LDL-C (mmol/L)	3.76 (0.90)	0.17, 5.84	<0.001
VLDL-C (mmol/L)	37.78 (10.35)	0.00, 6.49 x 10⁸	0.0005
HDL-C (mmol/L)	-10.52 (8.89)	0.00, 3.72 x 10 ⁷	0.240
INFLAMMATORY BIOMARKERS			
CRP (mg/dL)	2.60 (0.40)	0.45, 2.21	<0.001
Homocysteine(μmol/L)	1.55 (0.22)	0.66, 1.53	<0.001
SERUM ELECTROLYTES			
Magnesium(mmol/L)	17.34 (9.11)	0.00, 5.73 x 10 ⁷	0.060
Sodium (mmol/L)	0.17 (0.11)	0.81, 1.23	0.111
Potassium (mmol/L)	2.76 (1.49)	0.054, 18.507	0.067
Calcium (mmol/L)	-3.61 (3.91)	0.00, 2115.44	0.357
RENAL FUNCTION TEST			
Creatinine (μmol/L)	0.14 (0.08)	0.85, 1.18	0.099
Urea (mmol/L)	3.75 (1.70)	0.04, 28.07	0.030

β: beta-coefficient; SE: Standard error; TC: Total cholesterol; TG: Triglyceride; HDL-C: High-density lipoprotein cholesterol; LDL-C: Low-density lipoprotein cholesterol; VLDL-C: Very low-density lipoprotein cholesterol; CRP: C-reactive protein. **p*<0.05, ***p*<0.01, and ****p*<0.001 was considered as statistically significant.

Table S5.6. Biomarkers mediated effect of NiDRS on mean arterial pressure.

Mediators	Indirect effect β (95%CI)	Direct effect β (95%CI)	Total effect β (95%CI)	PM
FASTING BLOOD LIPIDS				
TC (mmol/L)	0.49 (0.19, 0.85)***	0.48 (-0.10, 1.03)	0.96 (0.42, 1.48)***	0.50***
TG (mmol/L)	0.46 (0.18, 0.82)***	0.49 (-0.12, 0.99)	0.95 (0.40, 1.45)***	0.47***
LDL-c (mmol/L)	0.47 (0.13, 0.85)*	0.50 (-0.05, 1.09)	0.97 (0.48, 1.42)***	0.49*
VLDL-c (mmol/L)	0.16 (0.00, 0.40)	0.78 (0.32, 1.29)**	0.95 (0.44, 1.48)***	0.17
HDL-c (mmol/L)	0.03 (-0.05, 0.15)	0.92 (0.42, 1.44)**	0.94 (0.45, 1.44)**	0.02
INFLAMMATORY BIOMARKERS				
CRP (mg/dL)	0.66 (0.34, 1.03)***	0.31 (-0.17, 0.82)	0.97 (0.44, 1.47)***	0.68***
Homocysteine(μmol/L)	0.69 (0.37, 1.06)***	0.27 (-0.22, 0.73)	0.96 (0.43, 1.49)***	0.71***
SERUM ELECTROLYTES				
Magnesium(mmol/L)	0.07 (-0.04, 0.24)	0.89 (0.39, 1.38)***	0.97 (0.46, 1.43)***	0.06
Sodium (mmol/L)	0.05 (-0.05, 0.20)	0.91 (0.36, 1.45)**	0.96 (0.41, 1.50)***	0.04
Potassium (mmol/L)	0.06 (-0.04, 0.20)	0.90 (0.38, 1.41)***	0.96 (0.43, 1.47)***	0.05
Calcium (mmol/L)	0.01 (-0.06, 0.10)	0.96 (0.46, 1.48)***	0.97 (0.47, 1.50)***	0.01
RENAL FUNCTION TEST				
Creatinine (μmol/L)	-0.02 (-0.15, 0.10)	0.97 (0.47, 1.49)***	0.96 (0.44, 1.47)***	-0.01
Urea (mmol/L)	0.01 (-0.15, 0.16)	0.96 (0.45, 1.49)***	0.97 (0.44, 1.54)***	0.01

PM: Proportion mediated; *β*: beta-coefficient; SE: Standard error; TC: Total cholesterol; TG: Triglyceride; HDL-C: High-density lipoprotein cholesterol; LDL-C: Low-density lipoprotein cholesterol; VLDL-C: Very low-density lipoprotein cholesterol; CRP: C-reactive protein. NiDRS: Nigeria diet risk score. **p*<0.05, ***p*<0.01, and ****p*<0.001 was considered as statistically significant.

Appendix M: Supplementary materials for Chapter six

Table S6.1. Measurement Instrument for Determinants of Innovation (MIDI) feedback questionnaire

Pilot implementation study of the Nigerian dietary screening tool

This section will ask you to provide any comments, concerns, or suggestions you may have regarding the questionnaire. Your feedback is valuable to us and will help improve the quality of the dietary assessment tool.

You can fill out the questionnaire by placing a “tick” in the box next to your answer based on the response scale.

Measurement Instrument for Determinants of Innovation (MIDI) Feedback Questionnaire for						
S/N	Determinants	Response scale				
		Totally disagree	Disagree	Neutral	Agree	Totally agree
Section 1: Determinant associated with the innovation-Nigerian dietary screening tool (NiDST)						
1	Procedural clarity: The NiDST clearly describes the activities I should perform and in which order					
2	Completeness: The food list in the NiDST is comprehensive					
3	Complexity: The NiDST is too complex for me to use. The questions were not clear or easy to understand					
4	Compatibility: The NiDST is a good match for how I used to work (i.e., compatible with my workflows)					
5	Relevance for patient: I think the NiDST is relevant for my patients					
Section 2: Determinants associated with the clinicians						
1	Personal benefits: I think the NiDST supported me to assess patient dietary intake					
2	Personal communication: I think using the NiDST improved my engagement and communication with patients					
3	Outcome expectation: I think using the patient-reported NiDST supported me to offer dietary advice to patients					
4	Professional obligation: I feel it is my responsibility to use the NiDST to assess dietary intake and offer dietary advice to patients routinely					
5	Patient satisfaction: Patients will generally be satisfied if I use their completed NiDST for their dietary discussion					
6	Patient cooperation: Patient will generally cooperate if I use their completed NiDST in dietary discussion					
7	Nutritional knowledge: I have enough knowledge to use and interpret the NiDST as intended					
8	Time available: I have enough time to use the completed NiDST for dietary discussion in outpatient clinic					
Section 3: Determinants associated with the patients						
1	Complexity: The NiDST is too complex for me to complete. The questions were clear or easy to understand					
2	Personal benefit: I think the NiDST help me to understand and reflect on my food intake					
3	Patient engagement: I think the NiDST help me discuss with doctors about my food					
4	Outcome expectations: I think the NiDST Help me discuss with doctors					
5	Awareness of content: I think food list and frequency response options allow me to accurately report my usual food intake					
6	Time available: The time taken to complete the NiDST was acceptable to me during waiting for my consultation					
7	Patient satisfaction: I am satisfied with using the NiDST during outpatient consultation					
8	Personal communication: I think using the NiDST improved my communication with doctor during outpatient consultation					

Thank you for participating in this study.

Table S6.2. Qualitative analysis codebook for patients and clinicians.

Name	Description	Files	References	Selected Quotes
Patients' qualitative analysis codebook				
Patient-clinician communication	The NiDST improves patient engagement and enables focused dietary discussions with clinicians.	6	8	<i>"Filling the form and discussing with my doctor made me more aware of how often I eat food prepared by mama put and red meats each week. It was eye-opening, and this will motivate me to improve my diet." (male patient, 47 years, 1 year hypertensive)</i>
Perceived benefits	Patients perceive the NiDST as beneficial in increasing their self-awareness of dietary habits and empowering them to make positive dietary changes.	9	12	<i>"I think the use of the complete form really helps my doctor to understand the food I usually eat. I was really happy to hear the doctor telling me to reduce some food that I eat because I can contribute to my BP not being controlled." (female patient, 56 years, > 5 years hypertensive)</i>
Facilitators of implementation	The NiDST's user-friendly design, clarity, and brief nature facilitated its implementation and acceptance among patients.	15	18	<i>"The food frequency questionnaire was very straightforward and easy to fill out. The instructions at the top clearly explained what was needed, and the arrangement with the columns was simple to understand." (female patient, 45 years, > 5 years hypertensive)</i>

Clinicians' qualitative analysis codebook

Name	Description	Files	References	Selected Quotes
Patient-clinician communication	The NiDST enhances patient-clinician communication and enables clinicians to have more focused dietary discussions with patients.	8	10	<i>"For me, the tool integrated well into our routine workflow and training clinicians on how to use the tool, especially how to interpret and provide some sort of dietary guidelines for each food group, can help clinicians more focused on the dietary discussion with the patient and this can shorten the consultation time" (female clinician, 48 years)</i>
Perceived benefits	Clinicians perceive the NiDST as beneficial in understanding patients' dietary habits and providing tailored dietary recommendations.	10	12	<i>"From my experience, I've found that the NiDST really helps me dive into understanding my patients' dietary habits better. It's like having a comprehensive roadmap right in front of me during consultations." (female clinician, 42 years)</i>
Barriers to implementation	Time constraints during busy clinic days can hinder the effective utilization of the NiDST.	5	6	<i>"In my opinion, the tool was very useful, but the challenge is the additional time needed to provide dietary counselling and recommendation to the patients because you can imagine spending 20-45 minutes with one patient in a busy clinic." (male clinician, 38 years)</i>
Facilitators of implementation	Training on the application of the NiDST facilitated its implementation and enabled clinicians to provide dietary counseling.	8	9	<i>"For me, the training I received on the dietary assessment and interpretation of the tool before the study really helped me to counsel patients after they have completed the screening tool." (female clinician, 28 years)</i>