Are oral health conditions associated with children’s school performance and school attendance in the Kingdom of Bahrain?

A Life course approach

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Dedication

To my mother, the pure and innocent soul, who taught me that believing in Allah, good intention, and hard work is the key to success.

COVID-19 statement

“It was the best of times; it was the worst of times” (Dickens, 1949). A cliché? I do not think so. Not after most of us has experienced in the past months.

It was the summer holiday of 2019, and things could have never been better. I am at home with my family, just finished a brilliant year one of my PhD. My mother responded well to chemotherapy, and her lymphoma is gone. I started collecting data from schools and children. I was there for day one when the pupils came back to begin a new academic year. The children’s smiles and anticipations were so refreshing. The job was done, and I headed back to the United Kingdom (UK) to start my year two, planning to revisit the children by the following autumn.

My husband was supposed to join my three children and me in the UK for the Christmas holidays. That was my last sense of normality. A health professional by himself, my husband withheld his plan as the news of mysterious disease started to grow up like a snowball. By February 2020, Covid-19 cases were confirmed in Bahrain. Soon, my mother was admitted to a hospital with difficulty breathing. I wanted to go back home and see her, but travel restrictions were in place at that time meant that I should quarantine for two weeks. By February the 23rd, she was in ICU isolation with an unknown infection, and by February the 26th, 2020, we lost her. I was 20 days late and could not say goodbye.

On March the 11th, 2020, WHO declared Covid-19 a pandemic. Bahrain entered a draconian lockdown, followed by the UK. The hospitals became hotspots for contracting the disease, and people tried to avoid them. My father had chest pain, and because of fears and restrictions in accessing the hospital, he developed a severe heart attack. The risk of losing him too was so eminent, but surgical interventions kept his heart going. He also started developing dry gangrene in his diabetic feet, and a lengthy journey of lifestyle, non-surgical and surgical management just managed to save his feet.

Education was severely hit by this pandemic. As in many other countries, a shift to online learning swiftly replaced conventional education in the UK. My children and I had to adapt to this e-learning. As a teacher by profession, I find this one of the hardest things. The value of face-to-face learning can never be overestimated. With much appreciation for my supervisors' and tutors' efforts, I have always missed the traditional interaction. However, my children enjoyed being at home and online studying. Nevertheless, this has put lots of pressure on me to manage a total of nine sessions per day for all my 4-, 9- and 10-years old children, instantly helping them to do their homework and posting them online.

As schools in Bahrain implemented online tutoring, and even if the kids went back to school in the 2020-2021 academic year (which they did not till now), It was clear that the impact of Covid-19 on children's school outcomes would have proven more influential than the measured variables in the study. Soon I realised that I would not be able to conduct the proposed longitudinal design for my research. This was morally devastating for me, as I was so eager to have it done. Disappointment aside, I promptly amended the study design to get the best of the data I collected. To do that, I had to apply for changes in the ministry of education in Bahrain and the University of Sheffield, get their approvals, and gather children's school performance through the parents via a phone application and their school attendance via school registers.

Back to the UK in 2020 and through 2021 with two more lockdowns and further travel restrictions meant my children and I could not see our beloved family as much as we would like to. The constraints challenged our mental health to the limits. I also applied to extend my study duration, resulting in more strain on my financial resources.

Ultimately, reading and writing about life course puts enormous pressure on me as a mother living away from my family with three children and doing a PhD degree at this pandemic time. I am aware such an event might leave its scars not only in everyday lives, but it can leave a long-lasting one. However, I am very proud of how I managed to go through it, even publishing a paper during this time (Appendix 1). Summing up my experience, for myself, I will say, “It is a far, far better thing that I do than I have ever done” and for my mother, I hope “it is a far, far better rest that you go to than you have ever known” (Dickens, 1949).

Abstract

Background: The link between oral health conditions (OHCs) and school performance and attendance remain unclear among Middle Eastern children. The association has been studied extensively in the Western region; however, several concerns have been raised regarding the reliability and validity of measures, low quality of studies, inadequate inclusion of potential confounders, and the lack of a conceptual framework. These limitations have meant that, to date, there has been no detailed understanding of the association or of the key social, clinical, behavioural and parental factors which may impact the association.

Aim: To examine the association between OHCs and children's school performance and school attendance at Grade 2 in Muharraq city in the Kingdom of Bahrain (KoB) using Heilmann et al.'s (2015) life course framework for oral health (OH).

Objectives: To (1) describe the prevalence of OHCs among 7-8 years old schoolchildren of the good, rated schools in the city of Muharraq; (2) analyse the social, biological, behavioural, and parental pathways that link early and current life exposures with children's current OHCs by testing the critical, and the accumulation life course models with consideration of social determinants of OH; (3) examine the association between OHCs and school performance and school attendance among schoolchildren including the direct and indirect (mediated) pathways; (4) explore the early and current life course social, biological, behavioural and parental factors associated with children's school outcomes in addition to OHCs.

Design: A time-ordered-cross-sectional study was conducted with 466 schoolchildren aged 7-8 years and their parents from Muharraq city in KoB. Data were collected through parents' self-administered questionnaires, children's face-face interviews, and dental clinical examinations. Outcome variables, including school performance and school attendance data, were obtained from the parents and school records. The data were analysed using confirmatory factor analysis and structural equation modelling (SEM).

Results: Dental caries, the consequence of dental caries (PUFA/pufa), and enamel developmental defects (EDD) prevalence were 93.4%, 25.7%, and 17.2%, respectively. The findings from the SEM showed that children born in families with high SES were less likely to suffer from dentine dental caries (β= -0.248) and more likely to earn high school performance (β= 0.136) at 7-8 years of age in Muharraq. From the current life course of children, the dental plaque was associated significantly and directly with enamel caries (β= 0.094), dentine caries (β= 0.364), treated teeth (filled or extracted because of dental caries) (β= 0.121), and indirectly associated with dental pain (β= 0.057). Further, dentine dental caries was associated significantly and directly with low school performance (β= -0.155). At the same time, the dental plaque was indirectly associated with low school performance via dental caries (β = −0.044). Conversely, treated teeth were associated directly with high school performance (β= 0.100). Besides OHCs, parents' early and current SES were significantly and indirectly associated with children's school performance via parental characteristics (β= 0.457). Notably, none of the OHCs, biological, SES, behavioural, or parental conditions was related to school attendance in children.

Conclusion: The life course approach was adequate to examine the role of OHCs on children’s school performance and attendance. Birth and current (7-8-year-olds) social factors were significant predictors of poor OH and poor school performance. Dental caries was associated with poor school performance but not with school attendance. Treated dental caries was associated with good school performance.

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I owe many thanks to schools, pupils and families, whom this work was conducted, for their effective and wholehearted involvement.

I also had the great pleasure of working with many volunteers whose professionalism and enthusiasm in conducting the fieldwork was unparalleled.

I extend my sincere gratitude to my father and my late mother, who, despite their illiteracy, have relentlessly endorsed my academic interests since my school days and their prayers and blessing were always my comfort zone.

My special thanks go to the people who witness this journey step by step, my husband and our three boys. Thank you for being my life's cornerstones.

Finally, Sheffield, the university, the place, and the people, I am deeply indebted to the kindness, the inclusiveness and the warmness that my family and I were shown.

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List of Abbreviations

Aberdeen Maternity Neonatal Databank	AMND
Adjusted Goodness-of-Fit Index	AGFI
Assessment of Multiple Systematic Reviews	AMSTAR
Attentive Deficit Hyperactivity Disorder	ADHD
Bahrain Ministry of Education	BMOE
Bahraini Dinar	BD
Bias-corrected	BC
Birth SES	BSES
Bleeding on Probing	BOP
British Association for The Study Of Community Dentistry	BASCD
Caries Assessment Spectrum and Treatment	CAST
Caries Management by Risk Assessment	CAMBRA
Child Oral Impact on Daily Performance	C-OIDP
Child Perception Questionnaire	CPQ8-10
Children’s Dental Health Survey in the UK	CDHS-UK
Community Periodontal Index	CPI
Comparative Fit Index	CFI
Confirmatory Factor Analysis	CFA
Cooperation Countries	CC
Current SES	CSES
Dental Aesthetic Index	DAI
Deoxyribonucleic Acid	DNA
Direct Acyclic Graphs	DAG
Directorate of Government Schools	DGS
Dunedin Multidisciplinary Health and Developmental Study	DMHDS
Early Childhood Caries	ECC
Early Childhood Protein-Energy Malnutrition	EC-PEM
Early Longitudinal Study in Kindergarten Cohort	ECLS-K
Economic Development Board	EDB
Economic Freedom Index	EFI
Education & Training Quality Authority	BQA
Education Quality and Qualification Assurance	QQA
Enamel Developmental Defects	EDD
Fédération Dentaire Internationale	FDI
Focusing Resources on Effective School Health	FRESH
Fragile Families and Child Wellbeing Study	FFCWS

Goodness of Fit	GOF
Grey Matter Density	GMD
Gross Domestic Product	GDP
Government employee	GE
Gulf Cooperation Council	GCC
High Development Status	HDS
Human Development Index	HDI
Index of Orthodontic Treatment Need	IOTN
Infant Feeding Survey	IFD
Informed Consent	IC
Intelligent Quotient	IQ
Interclass Correlation Coefficients	ICC
International Caries Detection and Assessment System	ICDAS
International Federation of Gynaecology and Obstetrics	IFGO
Ischemic Heart Disease	IHD
Joanna Briggs Institute	JBI
Kingdom of Bahrain	KoB
Life Course Health Development	LCHD
Low Birth Weight	LBW
Maternal Chronic Health Conditions	MCHCs
Maximum Likelihood	ML
Ministry of Education	MOE
Ministry of Health	MOH
Missing Completely at Random	MCAR
Modification Indices	MI
Molar Incisor Hypomineralization	MIH
Mouth Wash	MW
National Health Regulatory Authority	NHRA
National Immunisation Survey	NIS
National Institute for Health and Care Excellence	NICE
National Survey of Children's Health	NSCH
Non-Communicable Diseases	NCD
Oral Health	OH
Oral Health Conditions	OHCS
Oral Health Education	OHE
Oral Health Impact Profile	OHIP
Oral Health Practises	OHPs
Oral Health-Related Quality of Life	OHRQoL
Oral Hygiene Index Simplified	OHI-S

Oral Impacts on Daily Performance	OIDP
Paediatric Dental Service	PDS
Paediatric Oral Health-Related Quality of Life	POQL
Parental–Caregivers Perceptions Questionnaire	P-CPQ
Parenting Style Dimension Questionnaire	PSDQ
Preterm Birth	PB
Programme for International Student Assessment	PISA
Prostaglandin E	PGE
Public Health England	PHE
Pulpal Involvement, Ulceration, Fistula and Abscess	PUFA
Quality and Qualification Assurance	QQA
Quality of Life	QoL
Randomised Controlled Trial	RCT
Root-Mean-Squared Error of Approximation	RMSEA
Scale of Oral Health Outcome for 5-Year-Old Children	SOHO-5
Socioeconomic Status	SES
Specific Learning Disability	SPLD
Standardised Root Mean Residual	SRMR
Statistical Package for The Social Sciences	SPSS
Streptococcus Mutans	SM (S. mutans)
Structural Equation Modelling	SEM
Structural Model	SM
The Centre for Disease Control	CDC
Traumatic Dental Injury	TDI
UK Children's Dental Health Survey	UK -CDHS
United Nations Development Programme	UNDP
United Nations Educational, Scientific and Cultural Organization	UNESCO
United Nations International Children's Emergency Fund	UNICEF
United Nations Programme On HIV/AIDS	UNAIDS
United States Dollar	USD
University of Bahrain	UOB
Value Added Tax	VAT
Very Low Birth Weight	VLBW
United Arab of Emirates	UAE
United Kingdom	UK
World Health Organization	WHO

Chapter 1. Introduction

Despite a greater understanding of the aetiology and causes of OHCs, the global burdens of OHCs have continued (Peres et al., 2019). Moreover, it is estimated that these conditions have been exacerbated, especially in low-income countries (Kassebaum et al., 2017). Over 3.5 billion individuals worldwide suffer from OHCs, with untreated dental caries being the most significant public health problem (Watt et al., 2019). The concerns are even more severe across low-income countries where the prevalence of OHCs is increasing (Peres et al., 2019).

It should be mentioned that OHCs cause pain infection and impair people's quality of life, especially among the disadvantaged population (Martins et al., 2016). The impacts of OHCs may influence children’s school outcomes, such as school performance and school attendance (de Paula and Mialhe, 2013). Such distress, especially in a child’s early life, could irreversibly impact their current and later life course by restricting their education and future career (Banerjee, 2016). Thus, although attempts have been made to close the global gap in social inequality by investing in education and improving the health and OH of the population (Dornan and Woodhead, 2015), OHCs remain a significant health problem that might have a detrimental impact when fighting inequality. It has been suggested that promoting OH contributes positively overall to human development, including an individual’s cognitive development (Dornan and Woodhead, 2015), by relieving the disease, and together with the economic and social burdens that OHCs cause (Watt et al., 2019).

A comprehensive framework to investigate health-related outcomes, named “life course”, was developed and used in oral epidemiology (Halfon et al., 2018). The life course approach provides a theoretical framework to evaluate how social inequalities and socially patterned exposures during the life span may affect health later. The framework examines the early life social, biological, behavioural and psychosocial exposures that may influence health through independent, cumulative and subsequent effects (Ben-Shlomo and Kuh, 2002, Kuh et al., 2004). The life course approach emphasises that children's early life social circumstances are essential for later development throughout the stages of development (Barker, 2001).

Through the life course approach lens, common risk and protective factors related to OH and education development could be highlighted. Accordingly, it would facilitate our recognition of the nature of the association and its' pathways which might be pertinent to improving OH and educational attainment. Therefore, this study examined the association of OHCs with children's school performance and attendance at Grade 2 in the city of Muharraq at KoB using Heilmann et al.'s (2015) life course framework for OH.

This thesis is structured as follows:

Chapter 1: Introduction

Chapter 2: Literature review, which outlines all of the relevant literature for the PhD study with the following objectives:

- Describe the emergence of the life course approach
- Outline the influence of early life circumstances on the development of adult's chronic diseases
- Identify the common concepts and principles of the life course approach
- Explain Ben-Shlomo and Kuh's (2002) life course models
- Describe the key stages of the life course affecting human development

- Review the application of the life course approach in oral health research
- Explain the association between life course factors and the development of dental caries in children
- Assess the available evidence on the association of OHCs with school performance and school attendance
- Provide an overview of the factors related to children's school performance and school attendance
- Explain the study's life course theoretical framework
- Describe the rationale of the study

Chapter 3: Methods which includes a description of the study design, ethical approvals, population, sample size, data collection and analysis

Chapter 4: Results including the descriptive statistics for all the clinical, demographic, study variables, alongside the findings from the structural equation modelling, which tested the life course framework

Chapter 5: Discussion of the findings, including the strengths and limitations of the study

Chapter 6: Conclusions and recommendations for research and practice

Chapter 7: References

Chapter 8: Appendices

1.2 Aim

To examine the association of OHCs with children's school performance and attendance at Grade 2 in the city of Muharraq at KoB using Heilmann et al.'s (2015) life course framework for OH.

1.3 Objectives

1. To describe the prevalence of OHCs among 7-8 years old schoolchildren of the good, rated schools in the city of Muharraq.

2. To analyse the social, biological, behavioural, and parental pathways that link early and current life exposures with children's current OHCs by testing the critical, and the accumulation life course models with consideration of social determinants of OH

3. To examine the association between OHCs and school performance and school attendance among schoolchildren, including the direct and indirect (mediated) pathways.

4. To explore the early and current life course social, biological, behavioural and parental factors associated with children's school outcomes in addition to OHCs.

Chapter 2. Literature review

This chapter is presented in seven sections. Section 1 is an introduction to the life course approach. Section 2 reviews the application of life course in relation to oral health. Section 3 explains the association between life course factors and the development of dental caries in children. Section 4 assesses the available evidence on the association of OHCs with school performance and school attendance. Section 5 provides an overview of the factors related to children's school performance and attendance other than OH. Section 6 explains the study's life course theoretical framework, and Section 7 describes the rationale of the PhD study.

2.1 Introduction to life course approach

This introductory section on the life course approach addresses five objectives. First, it describes the origin and emergence of the life course approach. Second, it outlines the influence of early life circumstances on the development of chronic conditions in adulthood. Third, it identifies the common concepts and principles of the life course approach. Fourth, it explains Ben-Shlomo and Kuh's (2002) life course models. Fifth, it describes the key stages of the life course affecting human development.

2.1.1 Emergence of the life course approach

The life course approach has been used across several disciplines over the last 40 years by exploring how people's lives, transitions, environment, and social change shapes the individual's life from birth to death (Elder et al., 2003).

Early applications of the life course can be traced from 1918-1920 in the social sciences. William Thomas, a pioneer researcher in sociology, advocated the importance of longitudinal studies of life history in 1920 using data recorded throughout life. He proposed studying many types of individuals concerning their experiences in different times and circumstances, and following them up in the future, with continuous documentation of their experiences. Through his book titled: *The Polish Peasant in Europe and America* (1918-1920), co-authored with Florian Znaniecki, a Polish immigrant from Chicago, they emphasised the importance of an individual's social network, believing that it was a vital factor regarding social change. He argued that Polish society shaped their culture and social networks rather than the policies found in the United States (US). The book was unique and considered a 'society scandal' at that time (Elder et al., 1985).

In the 1950s, Wright Mills proposed the study of the life course in behavioural science with the intention to explore the societal pathway of people's lives, particularly in their historical place and time. However, there was scant information concerning how people spent their lives from childhood to adulthood; neither the pathways of impacts on their course of development and ageing nor the importance of historical or geographical settings were acknowledged. Furthermore, World War II and the social and financial consequences concealed life course research for a time (Kuh et al., 2004). Consequently, Mill's proposal did not come to light at that time. Likewise, the thoughts of William Thomas began to be implemented in sociology in the 1960s by Elder and Clausen (Halfon et al., 2018). Subsequently, his initial thoughts became the imperative driver of life course and longitudinal research in most current disciplines, including sociology and medicine (Elder et al., 1985).

2.1.2 Early life circumstances and chronic diseases in adulthood

The epidemic of coronary heart disease and lung cancer raised concerns regarding the aetiological factors of specific chronic conditions as possible reasons for the incremental rates of these diseases in the inter-war period. Increasing attention was placed on the influence of social and lifestyle factors on adults' health (Kuh and Ben-Shlomo, 2004). However, the failure of the lifestyle model to explain the underlying causes of chronic conditions or clarify the social and geographical health disparities stimulated some investigators to explore the contributions of early life exposures to the development of chronic health conditions (Kuh et al., 2004).

The assumption that an individual's early life circumstances may influence an adult's health status and mortality was not new. It was the main view of public health in Britain during the Boer War in the first forty years of the 20th century and substantially influenced early social reforms to enhance maternal and child health care (Gilbert, 1993).

Thus, the first attempt to link environmental factors during early life to diseases during adulthood was raised by ecological investigations using official mortality statistics, which showed geographical associations between past mortality rates and current adult mortality rates rather than cohort analysis (Kuh et al., 2004).

In 1977, Forsdahl provided the first evidence relating early life factors to susceptibility to disease during adulthood. He explored the association between living standards using the infant mortality index and mortality rates from ischemic heart disease in Norwegians. Geographic area was associated with infant mortality and current adult mortality rates among those born in the same year. It was observed that high infant mortality in the same cohort exhibited high mortality rates during middle age. In conclusion, living in a poor environment during childhood followed by wealth was associated with high mortality rates of ischemic heart disease later in life (Forsdahl, 1977). Furthermore, the observations hypothesised that the weakest infants died during infancy, whilst the healthy ones survived. However, unfavourable living circumstances in early life carried lifelong susceptibility to diseases that increased the likelihood of acquiring other risk behaviours during their life, suggesting the accumulation of risks over the life course (Forsdahl, 1977).

Studies from the UK also replicated Fordahl's findings (Barker and Osmond, 1986, Barker and Osmond, 1987). The studies by Barker and Osmond (1986) revealed a significant geographical relation between ischaemic heart disease mortality rates in 1968-1978 and neonatal and postnatal mortality in 1921-1925 and between, stroke mortality rates in 1968-1978, and maternal mortality rates in 1911-1914 (Barker and Osmond, 1987). Other demography researchers adopted the same ecological approach to explore whether early life exposures were related to high death rates later in life in Sweden (Fridlizius, 1989), Italy (Bengtsson and Lindström, 2000), US (Caselli, 1990), and Japan (Okubo, 1981).

In addition, others discovered a reverse relation between adult height and different causes of mortality rates from cardiovascular and respiratory diseases. The causes were attributed to earlier life circumstances since height is a natural process determined in childhood and adolescence (Kuh et al., 2004). A cohort study in Finland argued that mortality rates from coronary heart disease, myocardial infarction, and IHD related to small height in adulthood were influenced by childhood malnutrition or hereditary factors (Notkola et al., 1985). Similar results were observed in the UK by the Whitehall study (Marmot et al., 1984) and in Norway (Waaler, 1984).

However, the above studies have been criticised as they failed to separate poverty in early life from the one through life (Elford et al., 1992). Similarly, the geographic association between past death rates and present adult death rates logically depicted persistence in the geographic distribution of poverty (Ben-Shlomo and Kuh, 2002). To overcome these flaws, Barker and colleagues adopted a retrospective study design to examine the pathways between early life circumstances and adults' chronic conditions. They recruited men and women in middle age whose birth records were available in three areas in England (Hertfordshire, Preston and Sheffield). Data from the Hertfordshire study, involving 16,000 individuals born between 1911-1930, revealed that low weight at one year of age was associated with high mortality rates from IHD in adulthood (Barker and Osmond, 1986).

Moreover, Barker and Osmond (1986) discussed the pathways between prenatal and postnatal exposures and IHD later in life. Their research findings highlighted the role of several mediators, including plasma cholesterol concentration, high blood pressure, diabetes and glucose tolerance, body fat and fibrinogen concentration in plasma. Research in Sweden (Leon et al., 1998), Finland (Eriksson et al., 2001), the US (Rich-Edwards et al., 1997), and India (Stein et al., 1996) confirmed those findings.

Barker (1990) illustrated the cornerstone of 'biological programming' or the 'Foetal Origins' hypothesis, through which he argued that deprivation and undernutrition during the prenatal and postnatal period (critical period) were the principal reasons behind the development of coronary heart diseases later in life (Barker and Osmond, 1986). The hypothesis suggested that environmental factors can interact with the body's cells, genes and tissue growth, resulting in permanent health impacts later in life.

Roseboom et al. (2001) supported Barker's hypothesis from their study on the impacts of the Dutch Famine during the gestational period on the development of chronic conditions in later life. A cohort study conducted in the Netherlands involving 2,414 participants born between 1943 and 1947 demonstrated that people who experienced the famine during the first and mid-trimesters of gestation were at greater risk of having diabetes, hypertension, and obesity than those who experienced the famine in the third trimester of gestation. Hoek et al. (1998) observed a high rate of schizophrenia among people exposed to famine during gestation. Other studies also investigated the effect of famine during the gestation period on chronic conditions. However, they did not find such an association in Finland (Kannisto et al., 1997) and Leningrad (Stanner et al., 1997).

Nonetheless, Barker's hypothesis has been criticised. Paneth and Susser (1995) argued that Barker's hypothesis was too broadly defined and vague. They argued that proposing nutritional intake during gestation affected disease risk in adulthood permitted investigators to examine the influence of several nutritional measures on any diseases. Specifically, such a hypothesis can generate 'Type-I' errors (Paneth and Susser, 1995). Pedhazur (1991) criticised Barker's hypothesis for being difficult to replicate, which is considered crucial in scientific theory because the hypothesis was a general formulation. However, further modifications to the original hypothesis have addressed several of these criticisms, including explaining the hypothesis concerning specific diseases and replication in animal models (Barker, 2001).

Barker's hypothesis has also been criticised for evaluating the association between birth's anthropometric measures and health status in adulthood without adjustment for relevant confounders (Susser and Levin, 1999). Some later investigations have controlled for possible confounders and confirmed the initial findings (Barker, 2001, Huxley et al., 2007). Further, a meta-analysis suggested the occurrence of publication bias concerning the inverse association between birthweight and high blood pressure (Schluchter, 2003). However, the re-evaluation of the data with control for the estimated bias determined that the association weakened but remained significant (Skogen and Overland, 2012).

Moreover, incomplete sample, attrition on follow-up, and missing records were significant criticisms of the initial studies of Barker's hypothesis since the health records of forty- to fifty-year-old people were used to analyse the association between early life circumstances and chronic health conditions (Susser and Levin, 1999). Despite initial debate in this area, further studies with high follow-up rates, using appropriate research designs and controlling for confounders confirmed the correlation between social deprivation in early life and chronic health conditions (Kuh et al., 2004). Eighty studies revealed a significant association between low birth weight and high blood pressure (Huxley et al., 2000), whereas thirty-eight investigations showed the link between low birth weight and insulin resistance (Hales et al., 1991).

2.1.3 The concepts and the principles of the life course approach

Many researchers have defined life course as a concept, while others consider it a theoretical framework. As a concept, a life course can be defined as "a sequence of socially defined events and roles that the individual enacts over time" (Giele and Elder, 1998, p. 22). Thus, the concept of life course suggests age-differentiated social events discrete from the life span and life-cycle concepts (Elder et al., 1985). Life span is the length of an individual's life rather than age-related social events (Baltes, 1987). Conversely, a life cycle is related to life's event stages or the transformation from one generation to the next in a population (Elder et al., 1985).

However, Elder's recent writings on this subject defined life course as a theoretical framework focused on studying human lives, development and ageing (Elder, 1998).

Thus, five principles were derived from the social and behavioural sciences research using the life course as a framework.

The first principle relates to historical time and location. As research started to study family and individual life pathways, it has been observed that people born in different years confronted different historical events with different life opportunities. Thus, historical time and geographic location may produce cohort effects when social transition impacts one cohort differently from the following cohorts (Elder, 1985). For example, Elder's (1974) longitudinal study Children of the Great Depression found that the influence of family hardship on the life course of the Berkeley cohort (1928-1929) who were born or were young during the time of the economic depression was more extreme than the Oakland cohort (1920-1921) who were older or at late teenage years.

The second principle of the life course is timing. Developmental antecedents, events, the effect of transitions, and behaviours patterns fluctuate depending on their timing in the individual's life (George, 1993). The same events may influence people differently depending on when they happen in the life course and developmental stage (Elder et al., 2003). Lee and Ryff (2016) concluded that women who entered parenthood early, particularly teenagers, were more likely to have heart problems, economic difficulties, depression, and a higher risk for smoking and obesity; indicating that life transitions should occur within a specific period so that human development is compatible with those changes. The transition is a different life event within a person's trajectory, whereas the trajectory is a lifelong pathway with temporal sequences of development within a social institution like family or education (Elder et al., 1985). The transition can be stable or change over time and varies between individuals according to economic, environmental and social factors (Halfon et al., 2018). Thus, the life course intends to explain the societal pathways of these transitions and trajectories.

The third principle is social networks. Life course acknowledges that lives are connected and lived interdependently via social networks. Social and individual experiences are connected via the family and its shared interrelationships (Elder, 1998). Elder's (1974) study of children issued during the Great Depression revealed that parents' financial pressures resulted in depression and marital conflicts, negatively affecting their children's ability to nurture. Consequently, their children experienced many emotional, academic, and behavioural problems. Therefore, this emphasizes that one person's life changes can affect the lives of other family members.

The fourth hallmark of the life course is human agency. In life course, people are active agents in their own development (Featherman, 1981). Individuals may influence their own life course through the decisions they encounter and their choices within the contexts of history and social circumstances (Elder, 1998). These choices, however, are highly determined by the available opportunities faced during the life course. Furstenberg et al. (2000) claimed that the environment does not passively draw people to individual choices; they can still have control and discover alternatives. They illustrated that by analysing urban families who lived in disadvantaged environments with limited resources, poverty, and violence. However, despite such adversities, they could raise their children away from this by considering other environments like churches and youth clubs.

The last tenet concerning life course is ageing. Human development defines ageing as an everlasting process that does not stop at eighteen (Baltes, 1987). In effect, transitions from childhood can shape an individual’s life forty to fifty years later (George, 1993). Thus, studying lives over a long period is essential to understand the impact of the interplay between social changes and human development.

2.1.4 Conceptual models in life course epidemiology

In epidemiology, Kuh et al. (2004, p. 1) defined life course as “the study of long-term biological, behavioural and psychosocial processes that link adult health and disease risk to physical or social exposures acting during gestation, childhood, adolescence, earlier in adult life, or across generations”. This definition stemmed from Barker’s hypothesis and the lifestyle approach (Kuh et al., 2004). The life course approach acknowledges the interrelationship between biological and social risk processes as determinants of health rather than separating them. Its aim is to investigate the early and later life exposures together to recognise risk and protective factors across the life course. It suggests that several biological and social factors may act independently and cumulatively throughout life to influence adult health (Kuh et al., 2003).

Considering the different determinants of health, the significance of timing and duration of those factors might affect health in various ways. Thus, Ben-Shlomo and Kuh (2002) proposed several life course models to explore the links between exposures throughout the life course and health outcomes later in life. The following section explains the well-established life course models in health, including critical period, accumulation of risk and the chain of risk models.

2.1.4.1 Critical period model

The critical period model acknowledges that health discrepancies observed in a different social group are due to exposures during a critical development period. Such exposures may include social deprivation, malnutrition, smoking, or other risk factors. The timing of exposure to environmental variables plays an essential role in influencing health outcomes (Kuh et al., 2004). Moreover, this model considers the intrauterine period and childhood as critical or sensitive periods for developing diseases throughout life.

Ben-Shlomo and Kuh (2002) differentiated between the critical and sensitive periods. They defined the critical period as “the limited time window in which an exposure can have adverse or protective effects on development and subsequent disease outcome”. In contrast, the sensitive period is “the time period when an exposure has a stronger effect on development and subsequent disease risk than it would at other times” (Ben-Shlomo and Kuh, 2002, p. 288). The critical model proposed by David Barker is also known as the ‘programming’ or ‘latency model’. The model suggested that inadequate diet during the gestational period was critical, potentially leading to physical alteration to some of the body’s organs or structure, producing irreversible or permanent deviation in later life (Barker, 1990). The latency model correlates exposure at one stage in the life course with the possibility of health outcomes in later life regardless of transitional events in life (Hertzman and Power, 2003).

2.1.4.2 Critical period model with later effect modifier

The critical period model with a later effect modifier is a modified version of the critical period model that presumed that physiological or psychosocial risks in later life might increase the influence of exposure via a critical period of development (Kuh et al., 2004). For example, it was suggested that the associations of high blood pressure, coronary heart disease, and insulin resistance with low birth weight were higher among obese adolescence or adulthood (Lynch and Smith, 2005).

2.1.4.3 Accumulation of risk model/cumulative model

The accumulation model hypothesises that health conditions in later life result from the accumulation of risks throughout the life course regardless of their timing (Ben-Shlomo and Kuh, 2002). This model explores the role of risk accumulation during the life course on health outcomes, considering the number of risks, exposure duration, and interactions between them.

Accordingly, risk factors can be independent (Figure 1a) or clustered (Figure 1b) in socially predicted ways. For instance, disadvantaged pregnant women were more likely to deliver a child with low birth weight, grow up in a poor environment, be exposed to passive smoke, have inadequate nourishment, and experience poor educational attainment (Ben-Shlomo and Kuh, 2002). The risk may accumulate differently in a birth cohort, specific cohort or when a generation was exposed to disadvantaged situations in a specific period, resulting in undesirable health outcomes in the entire cohort. It could be an incident-based event such as the Dutch Famine or a sudden social and economic change like the 'baby boom' generation (Smith, 2007).

The cumulative risk model may follow a dose-response association since the extent of accumulated damage increases if the amount, length and severity of exposures increases. Additionally, the ageing process limits the ability to cope with the harmful effects of exposures (Kuh et al., 2003).

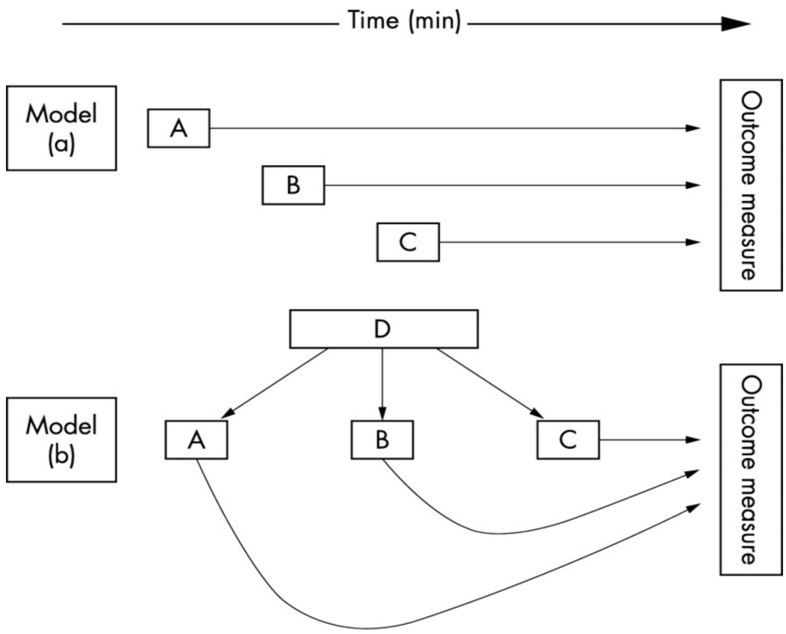


Figure 1. Life course causal model, accumulation of risks: (a) dependant risk; (b) accumulation. (Ben-Shlomo and Kuh, 2002)

2.1.4.4 Chain of risk model

The chain of risk model designates a sequence of linked factors that contribute to impaired function and increase disease risk because one factor introduces the next one and then another (Ben-Shlomo and Kuh, 2002). Each risk factor in the chain can increase the subsequent risk and have an independent ‘additive effect’ on the latter function or health outcomes (Figure 2c). Alternatively, ‘trigger effect’ defines a chain of risk where only the final exposure in the chain impacts health outcomes (Figure 2d). For instance, unemployment cause’s financial problems, which may result in losing one’s house. Besides, family conflicts can lead to abuse and neglect, resulting in psychosocial stress and subsequently poor health-related behaviours like alcohol addiction, inadequate diet, and ultimately chronic health conditions (Ben-Shlomo and Kuh, 2002).

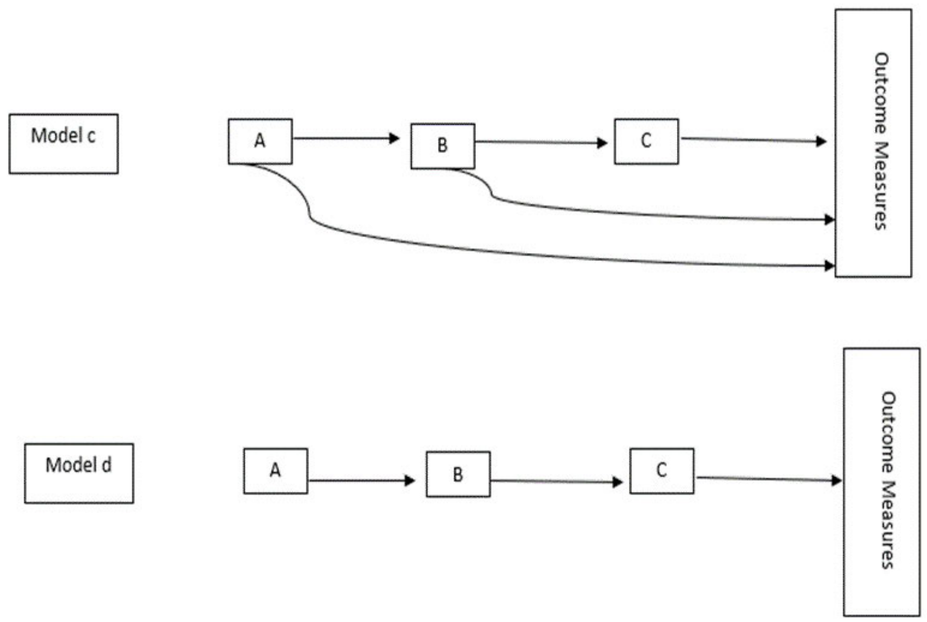


Figure 2. Chain of risk models with (c) additive effect; (d) trigger effect. (Ben-Shlomo and Kuh, 2002)

2.1.5 Key stages of the life course affecting health

Understanding the key stages of peoples' lives relevant to their health is required within the life course approach. This section highlights the key stages of human development from pregnancy to adulthood.

2.1.5.1 Pregnancy period

Barker's hypothesis raises awareness regarding the factors associated with foetal growth and patterns, including maternal and perinatal health roles on later health outcomes (Kuh et al., 2004). Those factors include malnutrition, smoking and alcohol, chronic health conditions, and age during pregnancy.

Unfavourable conditions like malnutrition during gestation can produce epigenetic changes to the foetus's development, increasing the risk of diseases in later life

(Barker, 1998, Halfon et al., 2018). Epigenetics was defined as the "changes to an individual's genetic code that can alter gene expression without changing the DNA sequence passed from one cell generation to the next" (Waddington, 2012). Maternal nutritional status is considered a vital determinant of fetal growth before, during and after pregnancy. The International Federation of Gynaecology and Obstetrics (IFGO) suggested that nutrition during the prenatal period is a steppingstone for maternal and child health development. In turn, this adds better health outcomes to the next generation, assuming a healthy lifestyle before conception (Hanson et al., 2015).

Poor SES can result in malnutrition, undesirable pregnancy outcomes, and less optimum foetal and child development (Inskip et al., 2009). For instance, the lack of folate during pregnancy can change the epigenetic status of the foetus (Aisling et al., 2016), resulting in LBW (McGee et al., 2018). Conversely, a systematic review reported a two-fold rise in folate consumption linked with a 2% gain in newborn's weight (Fekete et al., 2012). Micronutrient deficiency during pregnancy, like vitamin B12, was linked to LBW and risk of diabetes in later life (Yajnik et al., 2008). Inadequate iron and calcium intake has been associated with maternal death, while maternal anaemia through pregnancy has been associated with LBW (Black et al., 2013).

Social disadvantages were also linked with unhealthy lifestyles during pregnancy, including smoking, high sugar consumption and alcohol misuse (McGovern, 2013). Maternal smoking can reduce thirty grams of the baby weight at birth, while non-smoking can increase the baby weight by 180 grams (Durmuş et al., 2011). Overall, smoking during pregnancy accounted for 40% of infant mortality in the UK (Department of Health - UK, 2007). Alcohol consumption has also been linked to risk factors associated with congenital anomalies like heart defects (Liu et al., 2015). Both smoking and alcohol consumption have been significantly correlated with miscarriage, preterm delivery and LBW (Stephenson et al., 2011).

Other maternal related factors correlated with fetal growth impairment during pregnancy is maternal chronic health conditions (MCHCs), such as gestational diabetes, obesity, hypertension and kidney diseases. Gestational diabetes can cause epigenetic changes that increase the risk of premature delivery, LBW and type 2 diabetes in adulthood (Darnton-Hill et al., 2004). High maternal insulin levels during pregnancy might also increase the insulin level in offspring, which can continue during childhood (Dabelea et al., 2000). Evidence has illustrated that obesity during pregnancy could cause epigenetic changes in the mother and the foetus, increasing the risk of obesity during childhood (Yuanyuan, 2018). Likewise, maternal hypertension and renal diseases have also been linked to developmental programming and, therefore, intrauterine growth impairment, LBW and preterm birth, hypertension in later life and low nephron numbers (Luyckx et al., 2017).

Whether young or old, maternal age during pregnancy is another cause of concern (McCall et al., 2015). Population's analysis in Europe from 1950 to 2010 using data from the Aberdeen Maternity Neonatal Databank (AMND) confirmed that although teenage pregnancy rates had reduced, in the period mentioned above, deprived areas still sustained higher rates of teenage pregnancies (McCall et al., 2015). Teenage pregnancy is connected with many adverse birth and health outcomes due to insufficient maternal physiological and psychosocial development and young women not being prepared for pregnancy (McCall et al., 2015). Besides, young women's reproductive systems' immaturity and nutritional status are in flux (Scholl et al., 1990). Likewise, Chen et al. (2007) contended that reduced foetal growth in young pregnant women resulted from nutritional competition between the growing young body of the mother and the foetus for growth. However, low SES status can be attributed to many unhealthy behaviours in young people like smoking, alcohol misuse and inadequate diet, which might influence adverse birth outcomes independently (Smith and Pell, 2001). Also, evidence has revealed that advanced maternal age was associated with various adverse pregnancy outcomes, including LBW, preterm delivery, foetal death, and high caesarean section rates (Blomberg et al., 2014).

A recent cohort study completed in Saudi Arabia compared pregnancy outcomes between young and older women in a sample of 14,514 women (Fayed et al., 2017). The study found that younger women (age < 20 years) were more likely to be educated than those aged 40 years or older. The former group were also more likely to have a vaginal delivery and preterm birth. Pregnant women at higher ages were less likely to be educated and more likely to have childbirth by caesarean section, have gestational diabetes and preterm delivery than those younger than 20 years (Fayed et al., 2017).

2.1.5.2 Infancy period

Children acquire essential developmental skills according to their physical, social, and emotional development during infancy and early childhood. This should involve healthy eating styles and activities, besides developing self-regulation skills, language, and cognitive and learning skills (Jacob et al., 2017).

Infancy is defined as the period from birth until eighteen months, while toddlers span from eighteen months to three years of age (Erikson, 1980). According to Erikson, infancy is when a child develops trust and hope. Children during this period require care and visual and sensible attention from parents. A lack of those attributes can result in low self-esteem, and a sense of insecurity, besides the risk of developing temper tantrums and a stubborn attitude or antisocial behaviour (Erikson, 1980). Children start to gain body control during the toddler stage and develop independent skills. Successful completion of this stage can enhance self-esteem in children, while the opposite can cause an unstable personality (Erikson, 1980).

One of the main predictors of adequate physiological and psychosocial development during this period is breastfeeding. The World Health Organization (WHO) classified breastfeeding as exclusive breastfeeding when the infant is fed with breast milk only until six months of age or predominant breastfeeding when other liquids or solid foods are also used fed to the infant besides breast milk. The WHO and United Nations International Children's Emergency Fund (UNICEF) recommend that breastfeeding should commence during the first hour after birth, and exclusive breastfeeding should be the only source of food during the first six months and continue until two years of age or more (Walters et al., 2016). Breastfeeding can enhance a newborn's sense of security by establishing a solid bond between the infant and the mother (Bai et al., 2009). Breastfeeding can be a protective factor for infants and mothers against undesirable health outcomes. Evidence regarding breastfeeding and child's health has revealed that breastfeeding decreases the likelihood of ear infections, gastroenteritis, respiratory infection, dermatitis and sudden infant death. It can also reduce the risk of asthma, obesity, diabetes type 1 and diabetes type 2 in early childhood. Furthermore, breastfeeding may protect the mother against maternal breast cancer and ovarian cancer (Chowdhury et al., 2015). However, the same study concluded that formula-feeding practices could increase ear infections by 100%.

Although breastfeeding is considered one of the oldest and least expensive ways to feed a newborn baby, different factors influence breastfeeding practices and breastfeeding duration. These factors can include the mother's age, ethnicity, education level, occupation, type of delivery, night feeding, social support and use of contraceptives (Meedya et al., 2010).

Data from the UK Infant Feeding Survey (IFD) in 2005 indicated that ethnicity and SES significantly predicted breastfeeding practices and duration. The survey concluded that Asian, African and Chinese women were more likely to engage in breastfeeding practices than Caucasian women. African women had the highest prevalence of exclusive breastfeeding and a longer duration of breastfeeding (until nine months of age). Moreover, mothers over thirty years exhibited the highest prevalence of exclusive breastfeeding than younger ones. Similarly, the higher the years of education, the higher the breastfeeding practices and duration (Meedya et al., 2010).

Social support can positively influence the initiation and continuation of breastfeeding. A prospective cohort study involving 1,069 Australian women has shown that social support and encouragement from their partners positively influenced women's breastfeeding initiation while at the hospital and its continuation afterwards (Scott et al., 2001). It is worth noting that professional support for working women also reinforced breastfeeding practices and duration (Trivedi, 2018).

Breastfeeding is a maternal behaviour that also can be influenced by religious practices and cultural norms. For example, in Islam, women are encouraged to breastfeed until the child is two-years-old by a biological mother or a lactating woman if the former cannot provide it. This possibly explains the high prevalence of breastfeeding until six months (98%) among Muslim countries (Anggraeni et al., 2020). The decision to discontinue breastfeeding should be made by couples considering practical reasons (Anggraeni et al., 2020).

Cultural norms can also enforce or inhibit breastfeeding practices. For instance, in India and some areas of Turkey, women believe that colostrum is a harmful and dirty material. Therefore, breast milk is thrown away rather than given to the infant. In Lebanon, ordinary people believe that abdominal cramps women experience is transmitted to the infant when the child is breastfed. In Egypt, there is a common belief that breastfeeding in public can expose the mother and infant to an evil eye, whereas in Kenya, breastfeeding is encouraged but only after ritual cleaning (Osman et al., 2009).

2.1.5.3 Early childhood

Early childhood is from 3 to 6 years old (Erikson, 1980). Children during this period are also susceptible to environmental or economic disadvantages in developing diseases. At this age, children begin to follow their parents' behaviours, who are their role models. Adequate care can increase a child's self-initiative. Nonetheless, children may experience self-guilt and weak personalities (Erikson, 1980).

It has been suggested that childhood is a critical period since exposure might have an enduring influence in later life. A cohort study in Ireland assessed the impact of improvements in public health services, such as water and sanitation, on children's health after World War II. They found that upward social mobility during childhood dramatically decreased mortality and disability in adulthood (Delaney et al., 2011). Another longitudinal study conducted in poor villages in Guatemala ascertained a significant association between health conditions during early childhood, including diarrhoea, pulmonary diseases, anorexia and other infectious diseases, besides adulthood heart disease and type 2 diabetes, and low SES circumstances (Margolis, 2008).

Interventions targeting this age group may prevent many chronic health conditions, including sedentary lifestyles and obesity in adulthood (Mark et al., 2017). The Canadian Society for Exercise for Physiology suggested that children aged 1-4 years should have at least three hours of physical activity spread out over the week to achieve positive health outcomes like musculoskeletal, motor, adiposity, psychosocial and cognitive skills (Mark et al., 2017).

2.1.5.4 Middle childhood

Middle childhood referring to 6-12 years-old children, is considered one of the foremost critical periods in childhood development, as manifested by the eruption of the first permanent molars and androgen released by the adrenal gland (Bogin, 1997). The period is characterised by slow body growth, rapid brain development, increased muscle mass gain and adiposity of fat, with sex features in the body structure becoming distinct (Halfon et al., 2018).

The stage is manifested by increased perceptual and motor skills and problem-solving and reasoning skills. However, the most distinct features happen in the domain of self-regulation: they become much more capable of resisting undesirable behaviour, preserving constant attention, creating and following plans (Weisner, 1996). School plays an integral role in skills and knowledge acquisition and psychological development during this period due to social interactions with peers and school faculties. During middle childhood, children develop friendships outside the family environment, build their self-competence, and reduce feelings of inferiority (Erikson, 1980).

The adrenarche at this stage plays a role as a developmental switch (regulator) that enable adaptive plasticity (Halfon et al., 2018). West-Eberhard (2003) defined a switch as “a regulatory mechanism that activates at a specific point in development, collects input from the external environment or the state of the organism, and shifts the individual along alternative pathways, ultimately resulting in the development of alternative phenotypes”. In contrast, plasticity is an organism’s capacity to adjust its phenotype as a reaction to environmental stimuli (West-Eberhard, 2003). For instant, a switch may determine the acquisition of aggressive behaviour; thus, living in a broken family environment might trigger aggression, while a stable family environment entrains the development of a low level of aggression (Del Giudice et al., 2009). Concerning health, the middle childhood period appears as a switching period for further growth and metabolic functions that may leave enduring influences on health, like the risk of obesity and type 2 diabetes (Hochberg, 2010). Thus, it has been argued that metabolic changes in middle childhood reflect both the effect of the early environment and the stimulation of new genetic factors (Halfon et al., 2018). Consistent with this, Day et al. (2015) found a significant association between genetic and puberty timing, diabetes type 2 and heart disease.

2.1.5.5 Adolescence

Adolescence is the continuous period marked by rapid brain growth and hormonal changes, accompanied by physical, emotional and psychological changes (Patton and Viner, 2007). The WHO (2014) defined adolescence as the age group between ten and nineteen years old and the transition period from childhood to adulthood. Erikson defined this age group as 12-18 years, corresponding to the time when a person is looking for his/her identity and experiences a shift from being attached to parents to peer influence by seeking to develop independence and build their personality (Erikson, 1980). Adolescence can be a critical period affected by previous and current emotional and physiological changes that influence health and wellbeing (Patton and

Viner, 2007). Adolescence is also an exceedingly challenging period, as the individual has the physical features of an adult, but their psychological development is not yet concluded.

Blakemore et al. (2010) suggested that hormones can affect brain function. The limbic system, which controls one's appetite and desires, is established prior to the prefrontal cortex that regulates decision-making functions (Blakemore et al., 2010). Consequently, adolescence is a crucial period for adopting many risky behaviours, such as smoking and alcohol misuse, that, if not prevented, can be maintained through life (WHO, 2014). Most adult smokers start smoking before nineteen years of age (UK Parliament Department Of Health, 2010) and one in four teenagers reported alcohol consumption (Viner et al., 2015).

Psychological problems like depression and anxiety are frequently initiated by fourteen years (UK Parliament Department Of Health, 2010). If ignored, they can influence health and social life in adulthood (WHO, 2014). In addition, puberty associated with sedentary activities, such as watching TV for a long time, unhealthy snacks and responses to advertisements, especially in females, may contribute to obesity. The initiation of a sedentary lifestyle during adolescence may have future health consequences since eight out of ten obese teenagers remain obese in adulthood (UK Parliament Department Of Health, 2010).

2.1.5.6 Adulthood

Adulthood is the period from 18-64 years old. On the one hand, it is the period of love and developing commitments: engaging in healthy associations produces a happy ageing life. Conversely, failing to engage in healthy associations might result in isolation, loneliness and depression (Erikson, 1980).

During this period, most health-related risk factors from early life, childhood, and adolescence accumulate and manifest, resulting in undesirable health conditions (Kuh et al., 2004). Poor SES have a significant impact on adults' health behaviours. People with poor SES are more likely to have an inadequate diet, smoke, and a sedentary lifestyle, and consequently, are at a greater risk of chronic diseases (UK Parliament Department Of Health, 2010). Approximately half of all deaths related to chronic diseases affected adults aged seventy years or younger, and 30% affected people younger than 60 years (Jacob et al., 2017). Other risks that cause concern at age 50-69 years old are smoking, second-hand smoking, high blood pressure and insufficient intake of vitamins (Lim et al., 2012).

Further, the influence of poor SES on an adult's health can cause suicide attempts, psychological disorders, and heart disease (UK Parliament Department Of Health, 2010). Marmot et al. (1991) concluded that the lower the occupational status, the higher the probability of being exposed to risk factors for heart diseases, high blood pressure, stress and mortality.

2.2 Life course and oral health

This section aims to review the application of a life course approach in OH. It describes the main reasons for applying life course in OH research and provides an overview of Heilmann et al.'s (2015) life course framework. Subsequently, it discusses the possible factors associated with children's OH according to life course considering social and family aspects. Finally, it explains the association between life course factors and dental caries in children.

2.2.1 Oral health over the life course

The life course approach is considered applicable to OH research due to five main features (Nicolau et al., 2007). First, the main OHCs are prevalent chronic conditions; thereby, retrieving a representative cohort is practicable. Dental caries is often the most prevalent chronic condition, affecting 3.5 million people globally (Kassebaum et al., 2017). Second, OHCs are cumulative and can affect people from early childhood to adulthood (Heilmann et al., 2015). Thus, a comparison between individuals could be drawn based on disease severity and extent rather than counting all who develop the condition together (Halfon et al., 2018). Third, OHCs can be easily detected through clinical examination even when the individual fails to report them (Halfon et al., 2018). Fourth, reliable and valid measures to detect OHCs are available and affordable. Fifth, oral conditions have a significant adverse impact on quality of life and wellbeing (Martins et al., 2016). The recent review of the global burden of disease emphasised that those OHCs accounted for 16.9 million disability-adjusted life years globally (Kassebaum et al., 2017). Untreated dental caries in the primary dentition of preschool children can be the cause of pain, discomfort and infection (Wong et al., 2012). Thus, it can disturb their eating and sleeping habits and disturb children’s attention in school, eventually affecting their academic performance (Sheiham, 2006). Also, severe dental caries may adversely affect a child’s growth and development (Duijster et al., 2015). Besides the adverse impact of oral conditions on one’s everyday life, OHCs can, directly and indirectly, impact the economy. Petersen (2003) estimated that OHCs are the fourth most expensive condition to manage (direct cost) in industrialised countries. The WHO (2010) estimated the economic impact of the global burden of OHCs as US$442 billion in 2010, with direct estimated treatment costs worldwide equal to US$298 billion yearly. The indirect costs associated with loss of productivity were estimated to be US$144 billion yearly (Listl et al., 2015).

Thus, OHCs are considered a public health problem, and therefore, an investigation of oral conditions is ethically sound and can have economic consequences.

Studying OH using a life course approach provides a comprehensive explanation of risks and protective factors of OH diseases because it considers the interaction of socioeconomic, behavioural and psychosocial exposures over time (Kawachi et al., 2002). Using a Life courses approach provides a framework that conceptualises the OH and OH development process in a unified definition. OH within a life course is “the capacity to adapt to ubiquitous environmental and microbial challenges, maintaining the robustness of teeth and other structures in the mouth, and OH development refers to the pathways and trajectories of change of these assets over the life course” (Halfon et al., 2018, p. 301).

2.2.2 Early life factors and oral health in adulthood

Most of the empirical OH research that adopted the life course approach has explored the association between childhood SES and an OH in adulthood. Considering the scarcity of prospective cohort studies, most of the available evidence stemmed from three birth cohort studies: the Newcastle Thousand Families 1947 birth cohort in England, the Dunedin Multidisciplinary Health and Development Study (DMHDS) in New Zealand (1972–1973), and the Pelotas birth cohorts in Brazil (1982 and 1993) (Heilmann et al., 2015). This section briefly explains the association and the pathways between childhood SES and OH in adulthood and the impact of social mobility on OH.

2.2.2.1 Childhood SES and oral health in adulthood

Poulton et al. (2002) examined the association between childhood SES and health status, including the OHCs at 26 years, in a cohort of 1000 participants from the Dunedin study. SES of the cohort had been assessed according to the parent's occupation status recorded at birth and seven life stages (3, 5, 7, 9, 11, 13, and 15 years). At twenty-six, the adult's physical, mental and dental health was examined. The results revealed that all OHCs, such as dental caries, dental plaque, periodontal disease and bleeding status, were linked with childhood SES after adjusting for adult SES. As SES increased, the level of OHCs decreased. Similar results were also documented by Thomson et al. (2004).

These results contrast with studies that examined the relations between childhood SES and tooth retention and OHRQoL at age 50 in the Newcastle Thousand Families cohort (Pearce et al., 2004, Mason et al., 2006). To illustrate, Pearce et al. (2004), with a sample of 337, evaluated the significant risk factors during childhood and adulthood that could influence tooth retention at age 50. The difference in the number of retained teeth was mostly related to adult risk factors like SES, smoking, and alcohol consumption. After adjusting for adult SES, childhood SES predicted tooth retention among middle-aged women only, and the association was no longer statistically significant. Within the same sample, childhood SES was associated with OHRQoL among men. However, the association was mediated by adult SES (Mason et al., 2006). Despite that, the number of retained teeth in middle age was associated with OHRQoL among men and women.

2.2.2.2 Pathways between childhood SES and OH in adulthood

The previous sections indicated that childhood SES predicted OH in adulthood but without describing the pathways linking early life socioeconomic position and later OH status. The following sections highlight the findings of the potential pathways.

2.2.2.2.1 Early malnutrition

The pathways between poverty in early life and OH within the life course have been linked to malnutrition, a condition described by protein, energy, and micronutrient deficiencies (Schroeder, 2001). Most of the evidence discussed the association between early malnutrition and dental caries.

In line with the critical period, disturbing dental enamel during development may result in irreversible, visible anomalies, which provides relevant evidence on the influence of early life disadvantages on OH (Suckling, 1989). Thus, it has been suggested that early childhood malnutrition influenced dental caries via two different mechanisms: via enamel developmental defects and impairment of salivary function (Psoter et al., 2005, Caufield et al., 2012). Teeth with an enamel defect and irregular surface will favour *Streptococcus mutans* (S. mutans) accumulation increasing the risk of having dental caries (Li et al., 1994). Longitudinal evidence following Australian children from birth until 24 months showed that children with enamel hypoplasia were 4.4 times more likely to have SM than those with non-enamel hypoplasia in a disadvantaged population (Wan et al., 2003).

In parallel with that, enamel anomalies have been frequently linked with preterm and low birth weight. Such association has been studied in a systematic review that involved twenty-three studies: 19 cohort studies, two case-control studies, and two cross-sectional studies (Jacobsen et al., 2014). The result revealed a significant link between preterm birth and enamel hypoplasia based on thirteen studies. Additionally, limited studies conveyed an association between primary teeth's enamel opacities and children with low birth weight (<1500 g). Seow (2014) suggested that the primary pathway linking enamel defects and low birth weight was via mineral deficiencies caused by systematic conditions related to low birth weight, like infection, malnutrition, and renal diseases.

Another indirect marker of childhood malnutrition linked to OH status is stunted growth (Psoter et al., 2008b, Psoter et al., 2008a). Psoter et al. (2008a), in a retrospective cohort study, evaluated the effects of Early Childhood Protein-Energy Malnutrition (EC-PEM) and stunted condition on the dental exfoliation and eruption status in 498 11- to 13-year-old Haitian's adolescents. The results revealed that EC-PEM and stunting conditions in early childhood were associated with the delayed exfoliation of primary teeth and eruption of permanent teeth. Their further study (Psoter et al., 2008b) with a sample of 1017 11-19-years old found that severe EC-PEM and continuing nutritional stress, as evidenced by stunting, were linked with reduced salivary flow for a prolonged period.

In addition, deficiencies in vitamin D at the time of teeth development have also been linked with enamel hypoplasia and early childhood caries (ECC). A Canadian prospective cohort study recruited 207 expectant mothers from low SES urban areas to examine the association between prenatal vitamin D status and ECC (Schroth et al., 2014). The study concluded that children over 14 months of age with prenatal vitamin D deficiency were more likely to have enamel hypoplasia and ECC in the primary dentition. Vitamin D is essential to facilitate calcium absorption and calcification stages of the hard tissue. Thus, any Vitamin D deficit disturbs the enamel and dentine structure (Schroth et al., 2014).

2.2.2.2.2 Breastfeeding in early life

Breastfeeding is one of the critical early life factors influencing OH development. A Brazilian cohort study was conducted in 2015 at age five with 1,123 participants (Peres et al., 2015b). Using the Pelotas birth cohort's data, the study compared the impacts of exclusive breastfeeding and the predominant one on occlusion. The breastfeeding pattern was reported at birth, 3, 12 and 24 months. Children exclusively breastfed until six months displayed a 41-72% lower moderate to severe malocclusion rate than those who were never breastfed.

Additionally, Peres et al. (2015a), in a metal analysis, included forty-one studies (n = 27 023 individuals), concluded that participants who breastfed for a longer period were 60% less likely to have malocclusions in contrast to those who were breastfed for shorted time, suggesting a dose-response effect of breastfeeding on malocclusions. The reason is that the sucking and squeezing forces stimulate the lips, tongue, facial bone and muscles, which, in turn, encourage normal craniofacial development (Sánchez-Molins et al., 2010). In contrast to bottle feeding, where the nipples of the bottle are less flexible to adapt to the shape of the infant's mouth and consequently interfere with the development of oral structures, causing inadequate space for teething, malalignment, and mouth breathing (Inoue et al., 1995)

Another meta-analysis investigated 63 studies concerning the link between breastfeeding and dental caries (Tham et al., 2015). The results found that breastfeeding for up to 12 months was associated with a reduced level of dental caries, and breastfeeding beyond 12 months was associated with an increased level of dental caries. Another metanalysis recently confirmed the results (Cui et al., 2017). Nevertheless, most of these studies asserted that other confounders could interfere with such associations as the frequency of tooth brushing and cariogenic food intake. Breastfeeding is considered a protective factor against dental caries among children because of three principles. First, breast milk comprises antibodies and proteins that interfere with bacterial growth, including S. mutans. The primary sugar of breast milk is lactose, which is less metabolised by mutans than sucrose (Arnold et al., 1977). Furthermore, the bottle nipples tend to prevent access of saliva to upper central incisors, exposing them to a prolonged acidic environment compared to natural nipples (Seow, 1998).

2.2.2.2.3 Family environment

Family structure and parenting style were established as critical predictors of children's psychosocial and physical well-being, mainly in the first three years of life (Vernon-Feagans et al., 2012). However, few studies explored the pathways between these variables and OH.

In a systematic review, Kumar et al. (2016) synthesised the evidence on the association between different family characteristics and dental caries in children aged 6-12 years. Among 48 studies, the results revealed that only parents' SES was associated with children's dental caries level. The results were inconsistent regarding the associations between family structure and their' OH behaviour and children's dental caries rate.

However, Hooley et al. (2012), analysing 55 studies with children aged 1-6 years old, reported a significant association between children living with single or separated parents and poor OH. The authors claimed that parents' economic burden and stress shift their attention away from their children, placing OH as a low priority. Further, the study found that higher birth order and larger family size were associated with higher dental caries levels. This is because the large family size and high birth order can influence the emotional and economical resources available to the family.

Research supports a possible association between the different dimensions of parenting styles, child behaviour, and dental caries, but there is limited research. Baumrind (1967) divided parenting styles into three types, namely authoritarian, authoritative and permissive, based on warmth and control levels. Researchers have identified a fourth type of parenting style called rejecting-neglecting, explained by low warmth and control (Lamborn et al., 1991). One related study examined the link between the different types of parenting styles and a child's behaviour during a restorative dental visit (Aminabadi and Farahani, 2008). The study found that a caregiver's parenting style influences a child's reaction to restorative treatment. The study also suggested that permissive and authoritarian parenting styles were associated with poorer behaviour during dental treatment than authoritative ones.

Further, Howenstein et al. (2015) studied the association between parenting style, child's behaviour during the first dental visit and dental caries among 132 pairs of parents/child samples in Ohio. The study found that children with an authoritative parent (high responsiveness and high control) had a substantially favourable influence on children's OH behaviour and the lowest rate of dental caries compared to children with authoritarian and permissive parents. Further, Hooley et al. (2012) also determined that permissive parenting generally creates children with temperamental or challenging behaviour who showed higher caries rates. Authors argued that permissive style parents tend to soothe or reward their difficult children with sugary snacks. Sarit et al. (2021) also argued that children raised with permissive parenting experience a higher level of ECC because parents have less control of their children's cariogenic food.

2.2.2.2.4 Oral health-related behaviours

Socioeconomic and psychosocial pathways have been outlined to evaluate the complex associations between childhood SES and adult OH behaviours. Data from the Dunedin Multidisciplinary Health and Development Study (DMHDS) provided fundamental prospective longitudinal evidence for the possible pathways between childhood SES and OH behaviours from birth to 38 years old among 878 members (Broadbent et al., 2016). Based on structural equation modelling, the study outlined five findings. First, early SES and parental OH beliefs were associated with participants' OH beliefs at ages 15, 18, and 26. Second, positive OH beliefs in early adulthood predicted routine dental check-ups and more frequent tooth brushing at ages 26 and 32. Third, toothbrushing and dental check-ups were linked with the number of untreated dental caries and missing tooth surfaces at age 38. Fourth, high adult SES was associated with favourable OH self-care at ages 26 and 32. Finally, the number of untreated caries lesions and missing teeth was associated with OHRQoL. Consequently, OH in adulthood resulted from intergenerational factors operating since childhood life.

Further, a psychosocial pathway in terms of a sense of coherence was also proposed to explain the relation between SES and OH behaviours in adulthood (Heilmann et al., 2015). Bernabé et al. (2009) investigated the role of a sense of coherence in the association between parental SES and OH behaviours in adulthood among 5,399 Finnish adults. The study found a significant association between adults' sense of coherence and favourable OH-related behaviours like routine dental visits, frequent toothbrushing, less sugar intake, and reduced smoking habits. However, the moderating role of sense of coherence on the link between childhood SES and OH behaviours in adulthood was not supported by the study.

2.2.2.2.5 Dental services

Evidence from life course research supports the long-lasting benefits of dental care visits on OH (Thomson et al., 2010). The study used data from 932 participants from the DMHDS in New Zealand who were followed at ages 15, 18, 26 and 32 years. The results revealed that at any given age, routine dental attendees had better OH, less missing teeth due to caries, and a lower mean of DMFS. The effect was stronger among those with longer routine dental visits. By age 32, routine dental attendees had better self-report OH and fewer missing teeth and dental caries.

A retrospective study based on data from 13 European countries confirmed the association between early life routine dental visits and chewing ability at 50 years (Listl et al., 2014). The study even suggested that childhood routine dental visits predicted adulthood dental care visiting patterns.

2.2.2.3 Impact of social mobility on OH

Based on the accumulation of risk model, health outcomes could be influenced by reducing and increasing risk via upward and downward social mobility (Heilmann et al., 2015).

Peres et al. (2011) studied the effect of family income trajectories and the number of unsound teeth in a sample of 729 24-years-old from the 1982 Pelotas birth cohort data. The study obtained data regarding family income trajectories at birth, age 15 and 24 years, while the number of unsound teeth was recorded at age 24. The study results indicated that the consistently poor group had the highest level of unsound teeth. The group who experienced upward and downward mobility had more unsound teeth than those of the never poor group. Further, the study revealed a dose-response association between cumulative exposures to poverty and the number of unsound teeth, parallel with the accumulation life course model. Similar findings were also found previously by Poulton et al. (2002) and Thomson et al. (2004).

In contrast, Pearce et al. (2009) studied the association between the number of retained teeth at age 50 and OHRQoL and social mobility using the Newcastle Thousand Families cohort data. Social class data was collected for the age of 25 and 50 years. Based on constricting four SES mobility groups (stable manual, stable non-manual, upward and downward), the results revealed that maintaining functional dentition, determined if ≥ 21 natural teeth (WHO, 1992) to age 50 was only related to social mobility amongst women. In addition, women who remained in the stable-nonmanual group (high social class) were more likely to maintain functional dentition than women who were either in the stable manual group (lower class) upwardly or downwardly mobile group. However, the study did not find any link between social mobility and retained teeth for the men or between social mobility and OHRQoL in this cohort.

Further, a recent metanalysis (Celeste et al., 2021) explored the link between social mobility and tooth loss among middle-aged and older people within eighteen articles from different countries. The results confirmed that poor SES in any stage of life was significantly associated with tooth loss, supporting the accumulation model. However, the high heterogeneity of the included studies prevented the review from concluding which group (downward, upward) may be more detrimental.

2.2.3 Life course framework for oral health

Overall, the Ben-Shlomo and Kuh life course model (2002) has been the most applied framework in dental research to date. However, more recently, Heilmann et al. (2015) has proposed a life course theoretical framework for OH that combines Ben-Shlomo and Kuh's model (2002) with the social determinants of OH and their impact on risk factors of common general and OH diseases (see Figure 3).

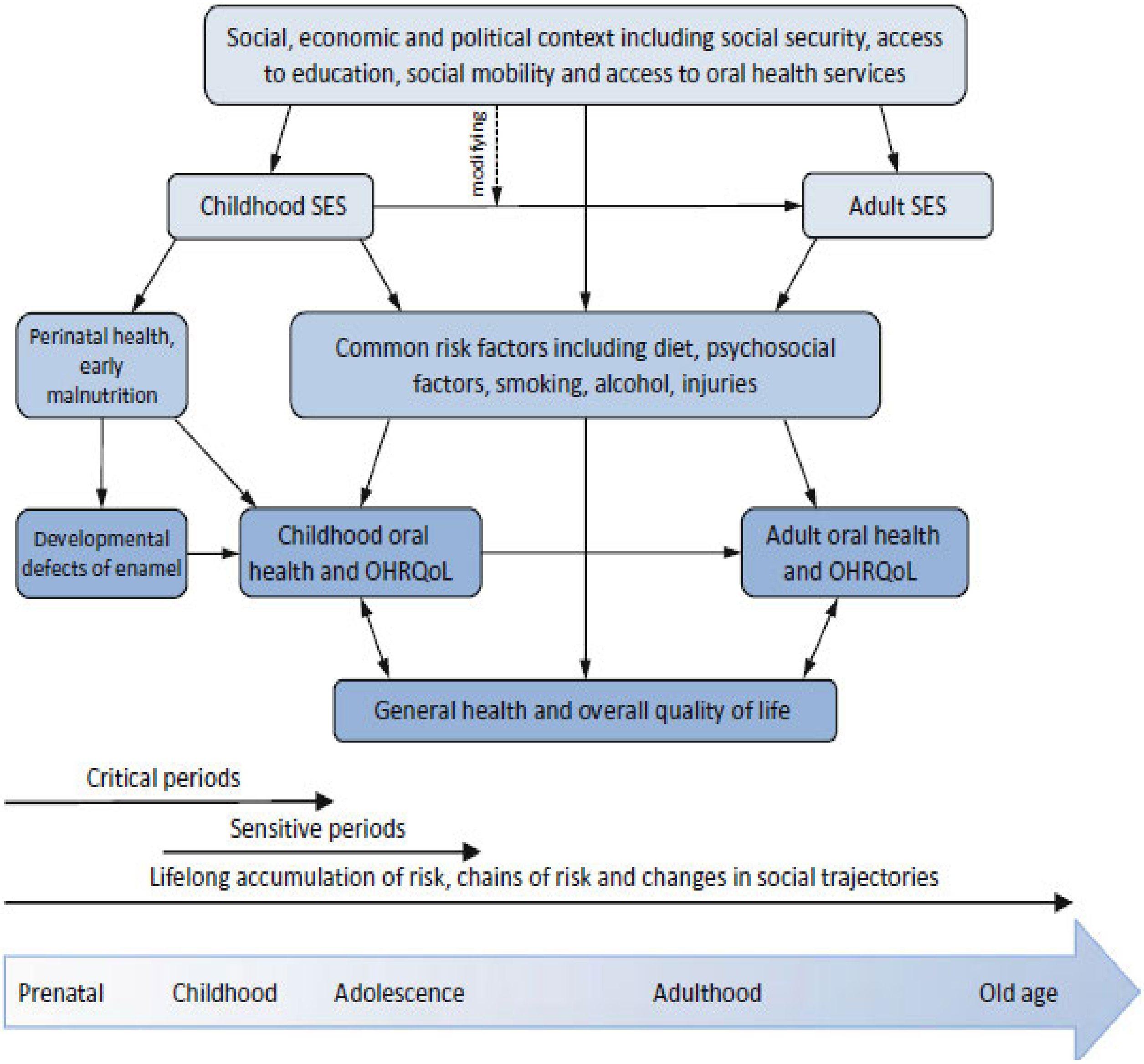


Figure 3. Life course framework for oral health (Heilmann et al. 2015)

The model underlines the role of economic, political and social factors at the societal level to shape SES (education, income) in childhood and adulthood. It assumes that childhood SES predicts adult SES considering a country's level of social mobility and the national policies and provision of education, social security, public health and healthcare. Different pathways have been proposed to explain how exposures in early life influence poor OH in adulthood. The first pathway is through the formation of enamel defects due to enamel's abnormal development within a critical time window (Psoter et al., 2005). The development of enamel occurs within a specific time. Thus, it was revealed that exposures during the enamel formation period might cause irreversible damage and become embedded in the physical structure of the dentition (Seow, 2014). Moreover, enamel defects may increase the vulnerability of dental caries due to the chain of risk model (Psoter et al., 2005).

The model assumes that childhood OH status predicts adult OH status for some reason. First, parental SES influences the child's life chances like education and income; then, adulthood SES is significantly linked to common risk factors for OHCs. Second, biofilm colonisation of the oral cavity, irreversible impairment to dental hard tissues and tooth loss in early life can directly affect OH in later life. Additionally, early exposure to psychosocial factors may increase the risk of developing diseases via biological mechanisms (allostatic load). Notwithstanding these pathways, the model also suggests that the trajectories of diseases can be changed according to social trajectories, i.e., they are not fixed and unchangeable. Finally, the model proposes an interrelationship between oral and general health and that both influence a person's quality of life.

2.3 Dental caries life course studies among children and adolescents

Recently, a systematic review has evaluated the link between exposures in early life and throughout the life course and the development of dental caries in children and adolescents (Abreu et al., 2015). The review contained eleven observational studies that predominantly employed Ben-Shlomo and Kuh's (2002) life course model. Further, six studies were found after systematic search and update for Abreu et al (2015), that published between 2012 and July 2021 (Appendix 2) (Birungi et al., 2017, Bernabé et al., 2017, Sun et al., 2017, Priyanka et al., 2019, Silva et al., 2019, Velasco et al., 2018). One more study evaluated social mobility (Peres et al., 2007). The following section briefly summarises the characteristics of these studies (Table 1) and highlights the possible factors associated with dental caries among children and adolescents within the life course approach.

Table 1. Life course studies to understanding dental caries indicators and risk factors among children and adolescents (2012-2021)

Author, city, Country	Study design	Participant's age at baseline	Participants' age at the end of the study	Initial sample size	Final Sample Size	Dental caries measures	Life course factors
Peres et al., 2003, Pelotas, Brazil	Cohort/retrospective	6 years	6 years	400	359	dmft≥1	1.< 8 years of maternal education. 2. Family income < 6-time Brazilian minimum wages at birth. 3. Not attending day-care at 6 years. 4. Sweat consumption of a minimum of one /day at 6 years.
Nicolau et al., 2003, Cianorte, Brazil	Cross-sectional	13 years	13 years	Phase I:764 Phase II:330	652 311	DMFT ≤6 low >6 high	1. Family income ≤ 5 Brazilian minimum wages. 2. Sconed or higher birth order. 3. Being a girl. 4. High level of paternal punishment. 5. non-brick house at birth. 6. Low birth weight. 7. High birth order ≥ second.
Bedos et al., 2005 Quebec-Canada	Cross-sectional	5-9 years	5-9 years	7382	6303 264 edentulous	DMFT/dmfs ≥1	1. Edentulous mother (child's primary teeth). 2. Edentulous mother (child 'permanent teeth).
Peres et al., 2005 Pelotas-Brazil	Cohort/retrospective	6 years	6 years	400	359	dmft ≤1 low ≥4 high	1. Self-employed. 2. Unemployed 3. < 8 years of parental education at childbirth. 4. Height by age deficit at 12 months 5. Not attending day-care at 6 years. 6. Sweet consumption of a minimum of one /day at 6 years. 7. Teeth brushing < once /day.
Nicolau et al., 2005 Cianorte-Brazil	Cross-sectional	13 years	13 years	652	586	DMFT ≤6 low >6 high	1. Maternal education for ≤ 8 years. 2. Residence in a rural area. 3. Being a second or later child. 4. High level of paternal punishment. 5. Height (Being a shorter individual)
Peres et al., 2007 Pelotas, Brazil	Cohort/ retrospective	15 years	15 years	888	875	(DMFT) DMFT=0, high caries DMFT>5	1. Always poor= poor DMFT pattern 2. Never were poor= better DMFT pattern. 3. Moved from poverty to non-poverty= poor DMFT pattern 4. Moved from non-poverty to poverty= poor DMFT pattern 5. Girls had fewer caries, better OHPs, and higher use of dental care.

Cinar et al., 2008b Finland-Turkey	Cross-sectional	10-12 years	10-12 years	Turkish=611 Finnish=338	Turkish=459 Finnish=155	DMFT>0	1. Lower height in Finnish pre-adolescent. 2. Lower height in Turkish pre-adolescent. 3. Turkish with lower levels of self-esteem. 4. Finnish from single-parent families. 5. Turkish with a higher number of children. 6. Finnish spending less time with mother. 7. Finnish with higher body weight.
Peres et al., 2009 Pelotas-Brazil	Cohort/prospective 6 years duration	6 years	12 years	359	339	DMFT≥1	1. Stunting at 12 months and 4 years. 2.1-3 and 4-19 DMFT at 6 years. 3. Gingival bleeding (28.1-92%) at 12 years.
Zhou et al., 2011 Xinhua-China	Cross-sectional	2 years	2 years	400	394	dmft mean	1. Maternal education < 12 Yeats. 2. Visible plaque index > 60%. 4. Streptococcus mutans
Lu et al., 2011 Hong Kong-China	Cohort/prospective 6 years duration	12 years	18 years	638	221	DMFT mean	1. DMFT at age 12 positively affected the value at 15 and 18 years old. 2. CPI at age 12 positively affected the value at 15 and 18 years old. 3. The income level at 12 years old directly affected the utilisation of dental services at 12-15 years and 15-18 years and significantly influenced the DMFT at 18 years, but not the CPI.
Zhou et al., 2012 Xinhua-China	Cohort/prospective 2 years duration	8 months	32 months	225	155	dmfs mean	1. Maternal education < 12 years. 2. Higher family monthly income at birth (≥450 USD). 3. Enamel Hypoplasia. 4. Z value of height <-2. 5. Visible plaque (≥ 20%) Presence of Streptococcus mutans.
Wong et al., 2012 Hong Kong-China	Cohort/ prospective	3-4 years	5-6 years	465	358	dmft>0	1. ≤ 9 years of parental education. 2. Using nursing bottles at 4 years. 3. First-time teeth are brushed after 12 months. 4. Snacking one or more times/day at 4 years.
Birungi et al., 2017 Uganda	Cohort/prospective 5 years duration	24 weeks	5 years	863	417 mother-child	dmft >0	1.Exclusive breastfeeding 24 weeks 2.living with both parents
Sun et al., 2017 China	Cross-sectional	5 years	5 years	12692	9722	dmft mean	1. Exclusive & predominant breastfeeding 2. Brushing at later life 3. Being a boy 4. Second or third birth order 5. >1 sibling 6. Low income 7. Primary education 8. Brushing <1 9. Sugar ≥2
Bernabé et al., 2017 Dundee-Scotland	Cohort/ prospective 4 years duration	1 year	4 years	1102	765	dmfs	1. Low birth weight 2. Smoking

Velasco et al., 2018 Bauru, Brazil	Cross-sectional	9-11 years	9-11 yeas	350	350	DMFT EDD index	1.EDD increase caries risk 2. Maternal education 3. Household income
Priyanka et al., 2019 Guntur-India	Cross-sectional	12 years	12 years	800	800	DMFT mean 0 1-3 >3	1. Government school 2. Shorter height 3. Low and medium SES
Silva et al., 2019 Australia	Cohort/prospective 6 years duration	24 gestational weeks	6 years	250 pairs	172 pairs	ICDAS Any caries Advanced caries	1.No difference in caries between types of twins. 2.Maternal obesity, non-fluorinated water, and enamel defects

2.3.1 Study design

Of the 18 studies, ten were cohort studies, and the remaining eight were cross-sectional (Table 1). Three cohort studies were designed retrospectively (Peres et al., 2003, Peres et al., 2005, Peres et al., 2007), and the remaining seven were prospective. Most of the above studies studied the association between early life social, biological, psychosocial, and behavioural factors and dental caries in children and adolescents from 0-18 years old and 2-6 years follow-up periods. In contrast, Peres et al. (2007) investigated the impacts of social mobility on dental caries among adolescents.

2.3.2 Origin of the studies

Generally, most studies were conducted in Brazil, four of which were drawn from a nested birth cohort study in Pelotas in 1993 (Peres et al., 2003, Peres et al., 2005, Peres et al., 2007, Peres et al., 2009). The other two were in the city of Cianorte in Brazil (Nicolau et al., 2005, Nicolau et al., 2003) and one in Bauru (Velasco et al. 2018). Five studies were conducted in China; two in Hong Kong (Lu et al., 2011, Wong et al., 2012), two in Xinhua (Zhou et al., 2012, Zhou et al., 2011) and one included the entire population of China (Sun et al., 2017). One study was carried out in Quebec, Canada (Bedos et al., 2005), another was conducted in both Finland and Turkey (Cinar et al., 2008b), one in Uganda (Birungi et al., 2017), one in Scotland (Bernabé et al., 2017), one in India (Priyanka et al., 2019), and one in Australia (Silva et al., 2019)

2.3.3 Participants' age

Children's ages at baseline ranged from 24 weeks (gestation) to 18-years of age. The final wave of the cohort studies involved participants of different ages based on the duration of the follow-up period (2-6 years) (Table 1).

2.3.4 Oral examination and indices

DMFT measured dentine dental caries as the primary outcome in seven studies and dmft in six studies. Two studies measured DMFT and dmft (Cinar et al., 2008b, Bedos et al., 2005). Three studies assessed dental surfaces instead of the tooth component of the DMF index (Zhou et al., 2012, Bernabé et al., 2017, Bedos et al., 2005). One study used ICDAS (Silva et al., 2019).

It is essential to state that different DMFT/dmft or DMFS/dmfs thresholds were applied in the studies. The most common was the presence or absence of dental caries in eight studies (Table 2). Three studies applied different ranges to indicate low and high levels of dental caries (Table 3), whilst the remaining five studies used the mean value of the DMF index.

Table 2. DMFT's mean threshold used in life course studies

Study	Index	The threshold of dental caries
Peres et al., 2003	dmft	≥1
Bedos et al., 2005	DMFS/dmfs	≥1
Peres et al., 2007	DMFT	≥5
Cinar et al., 2008b	DMFT	>0
Peres et al., 2009	DMFT	≥1
Wong et al., 2012	dmft	>0
Bernabé et al., 2017	dmfs	>0
Velasco et al., 2018	DMFT	>0

Table 3. DMFT's mean threshold used to assess severity of dental caries in life course studies

Study	Index	Low	High
Nicolau et al., 2003	DMFT	≤ 6	> 6
Nicolau et al., 2005	DMFT	≤ 6	> 6
Peres et al., 2005	dmft	≤1	≥4

Although the DMFT/dmft index is recommended by the WHO for OH surveys and its widely used (WHO, 1997), the adoption of the index in analytic epidemiologic studies has been extensively criticised for measuring dental caries at the cavitated stage only (dentine). In contrast, the condition is present, diagnosable and reversible before this stage (Ismail et al., 2007). Furthermore, the index does not consider the conditions of sealants, disease progression, restorations, and activity conditions. Likewise, it gives equal value to restored, missing, and untreated teeth, making it hard to assess progression or regression changes in teeth status in longitudinal studies (Pitts and Ekstrand, 2013).

2.3.5 Non-clinical data collection

Self-completed questionnaires and interviews were used to collect non-clinical information in the epidemiologic studies of the life course of dental caries (Table 4). The interviews were conducted with adolescents and their parents or with the parents only regarding younger children. Two studies employed maternal self-administered questionnaires (Bedos et al., 2005; Cinar et al., 2008b). The latter also used a self-administered questionnaire to gather children's information.

Table 4. Use of questionnaires and interviews in dental caries life course studies

Study	Child/Adolescent	Parent's data collection
Nicolau et al., 2003	Interview	Interview
Peres et al., 2003	No	Questionnaire
Peres et al., 2005	No	Questionnaire
Bedos et al., 2005	Interview	Questionnaire- maternal- Self-administered
Nicolau et al., 2005	Interview	No
Peres et al., 2007	Interview	No
Cinar et al., 2008b	Questionnaire (self-administered)	Questionnaire- maternal- Self-administered
Peres et al., 2009	Interview	No
Lu et al., 2011	Questionnaire	No
Zhou et al., 2011	No	Questionnaire
Wong et al., 2012	No	Questionnaires (both surveys)
Zhou et al., 2012	No	Questionnaire
Birungi et al., 2017	No	Interview
Sun et al., 2017	No	Questionnaire
Bernabé et al., 2017	No	Questionnaire
Velasco et al., 2018	No	Questionnaire
Priyanka et al., 2019	Interview	No
Silva et al., 2019	No	Questionnaire

Pre-existing data on dental and related information were used in some studies as baseline data of participants. For example, in the nested birth cohort study conducted in Pelotas with 1,993 participants (Peres et al., 2003, Peres et al., 2005, Peres et al., 2007, Peres et al., 2009), or in the 2001 Hong Kong OH Survey (Lu et al., 2011), National OH Survey in China 2005 (Sun et al., 2017) and the PROMISE-EBF trial in Uganda (Birungi et al., 2017). Bedos et al. (2005) used the Study on the Oral Health of Quebec Students Aged 5-6 and 7-8 Years, 1998-99 in Canada. Moreover, the OH data of Finnish pre-adolescents were recovered from Helsinki City Health Department (Cinar et al., 2008b). Bernabé et al. (2017) also used data from the birth cohort of 1993-1994. The remaining studies did not use any pre-existing information.

2.3.6 Dental caries life course factors

Among the 18 studies in Table 1, there were 73 life course factors related to dental caries arranged and analysed at different hierarchical levels. Regardless of the levels used in each study, the factors can be organized into six groups: demographics, socioeconomic characteristics at birth and at follow up, biological, psychological, OH behaviours, and OH status.

Demographic data comprised age, gender, skin colour, birthplace, mother's and father's ages, family structure, family type (single or two-parent) and the number of children. Socioeconomic variables at birth included house building material, the presence of a toilet, house tenure, piped water, car ownership and overcrowding, social class, parent's schooling, household income, parent's employment status, area of residence and the school type. At follow up, they consisted of house material, house tenure, overcrowding, presence of a toilet or piped water, car ownership, household income and parents' level of education.

Biological factors included birth order, birth weight, maternal health thru pregnancy, maternal smoking thru pregnancy, and mother's age at delivery. It also included childhood infectious diseases, feeding habits (breastfeeding, bottle feeding at night), stunting, and wasting conditions at 12 months. Additionally, it included the number of erupted teeth when the child was 12 months old, the number of times admitted to hospital, prolonged use of medication, gestational age, enamel defects, sleeping with a pacifier and shared cutlery with other children.

The psychological factors were related to family life, such as parental levels of punishment and support, mother academic involvement, and self-efficacy and self-esteem. Behavioural factors included oral hygiene practices (when started tooth brushing/ frequency of toothbrushing /help/floss/chewing gum), dental attendance pattern, fluoride use, and dietary habits (stable access to food, snacking frequency and consumption of sweets). Moreover, these variables included day-care centre attending at the age of six months and visits to a dentist. Similarly, what the child drinks regularly, the reason for the last dental visits, and visible dental plaque. Finally, certain studies considered previous dental caries experience, gingival bleeding, S. mutans and the mother's dental status (dentate or edentulous).

2.3.7 Life course models and analysis methods

Most studies utilised the critical period and the accumulation of risk models proposed by Ben-Shlomo and Kuh’s (2002) to guide the analysis of the association between life course factors and dental caries. Generally, the studies assumed that risk accumulates independently from early and throughout life and causes dental caries. However, Lu et al. (2011) presumed that social factors cause a chain of risks that eventually trigger dental caries during a child’s life. Silva et al. (2019) examined the biological programming theory (critical model).

The studies mainly relied on analysing the associations between those factors and dental caries using hierarchical regression, where variables were introduced in the analysis in a specific sequence of levels. The number of levels varied between the studies from six

(Peres et al., 2009) to three levels (Wong et al., 2012), except for Lu et al. (2011), where the chain of risk model was tested using path analysis.

2.3.8 Summary of the results of the studies

This section summarises the results of the 18 studies that explored the associations between early and current life course factors and dental caries in children and adolescents using the life course approach according to different age groups.

2.3.8.1 Age 1-5 years old

Six studies evaluated the pathways between early life circumstances and ECC development in 1-5-year-olds (Zhou et al., 2012, Zhou et al., 2011, Wong et al., 2012, Birungi et al., 2017, Sun et al., 2017, Bernabé et al., 2017).

Zhou et al. (2012) explored the risk factors of ECC in 225 children aged eight months old from a rural area of southern China. They followed the participants every six months for two years. Mothers with a low level of education (< 12 years), families with higher monthly income (≥450 USD) at childbirth, children with hypoplasia, visible plaque, low height-z value at 0-2 years old and having *S.* mutans were associated with a high level of ECC in children below the age of three years. Similar findings were also concluded in the previous research undertaken by Zhou et al. (2011) but using a cross-sectional design study. Although this study provided a comprehensive prospective longitudinal design study (Abreu et al., 2015), there was no sample size calculation. Participants were selected from the maternity and children's hospital with relatively small sample size. Additionally, the study experienced a significant drop-out (31.1%) on completion, which restricted the generalizability of the study.

Wong et al. (2012) also explored the early life risk factors associated with ECC lesions in toddlers through a prospective cohort study in Hong Kong. Three hundred and fifty-eight children were recruited between the ages of 3-4 years and were followed for two years. The study revealed that children with parents with ≤ nine years of education, night bottle-feeding at four years of age, snacking ≥ one time per day at age four, and tooth brushing initiated after 12 months were more prone to dental caries. They found that one-third of the children developed at least one new lesion over the two-year follow-up period, but only with a small increment (0.9). However, the accuracy and reliability of dental caries measures in this study are questionable because different examiners carried out the examination in 2007 and 2009.

Birungi et al. (2017) explored the impact of early social and behavioural factors in developing ECC among five-year-old children in Uganda using a prospective cohort study. The study involved 417 mother-child pairs and followed them at 24 weeks, two and five years of the child's age. The results revealed that exclusive breastfeeding and living with both parents were protective factors for ECC in 5-year-old children.

Further compelling evidence was reported by Bernabé et al. (2017), who conducted a longitudinal study to evaluate the role of early life risk factors on ECC increments over four years among 1102 infants in Scotland. The study found that children born with low birth weight and whose mothers were smokers had sharper increments of dental caries over four years. On the other hand, no association was reported between breastfeeding duration and dental caries. Interestingly, birth weight, breastfeeding, and maternal smoking were not associated with children's baseline dmfs. However, by Wave 4, low birthweight children and those with smoking mothers had 1.9 and 1.7 more tooth surfaces with caries than their better-off counterparts. Both factors placed children on a trajectory of increasing dental caries over time. This could highlight the importance of focusing on the accumulation of disease over time and explain why previous studies failed to report such a relationship when measuring caries only once in time. However, the study reported selection bias since the participants who continued in the study were healthier and wealthier than those lost to follow up, which could have affected the study's generalizability.

Using a cross-sectional study, Sun et al. (2017) assessed the link between early life factors and dental caries among 9722 pre-school children in China. Interestingly, the study ascertained that formula-fed children who brushed their teeth within the first year of life had lower dental caries than those exclusively breastfed and those who started to have their teeth brushed later in life. However, the study has some limitations as it was a secondary analysis of cross-sectional data collected in 2005. Thus, due to the nature of the study, no causal and temporal association can be implied.

2.3.8.2 Age 5-11 years old

Five studies investigated the association between early social and biological factors and dental caries among children aged 5-11 years old (Peres et al., 2003 and 2005; Bedos et al., 2005; Velasco et al., 2018; Silva et al., 2019).

Both studies undertaken by Peres et al. (2003 and 2005) were conducted retrospectively in Pelotas, Brazil, involving 400 participants aged six years. The most recent study (Peres et al., 2005) was more comprehensive as it included more variables than the previous one (Peres et al., 2003). Peres et al. (2005) found that low social class and father's low level of education (< 8 years) at the time of the childbirth, child's with stunting condition at 12 months, low frequency of toothbrushing (< once a day) and once a day consumption of sweets at six-years-old were substantial risk factors for dental caries development at the age of 6 years. Interestingly, attending daycare in Pelotas was a fundamental protective factor for developing dental caries at six years old. The authors argued that this was because of the early introduction of OH education and prevention programmes or because the daycare provided a conducive environment to acquire good OH practices (Peres et al., 2005). The study did not report any significant association between access to dental care at 4 and 6 years and dental caries.

From a different perspective, Silva et al. (2019) established a longitudinal study in Australia to evaluate the role of genetic, fetal and environmental factors on dental caries risk. The authors collected non-clinical data among 250 twin pregnancies at 24 weeks through age six when the children undertook oral examination. At follow-up, 345 children were examined for enamel developmental defects (EDD) and dental caries. The study compared the caries rate between monozygotic and dizygotic twins using concordance rate and found no difference in caries between both types of twins. The findings revealed that environmental rather than genetic factors determine the difference in dental caries, despite the biological programming hypothesis. The study concluded that factors like non-fluoridated community water, enamel defect and maternal obesity were important early life determinants of dental caries (Silva et al., 2019).

In a similar approach, Bedos et al. (2005) explored the association between maternal edentulism and dental caries in children aged 5-9 years using a cross-sectional study with a sample of 6,303 mother-child pairs in Quebec. Children with edentulous mothers were more likely to have dental caries in both deciduous and permanent teeth than those with dentate mothers. These results were independent of sociodemographic factors and OH behaviours. The authors claimed that dental caries was the main cause of maternal edentulism, which increased their children's susceptibility to dental caries. Three hypotheses explained the association: transmission of the mother's genes, the programming hypothesis while pregnant, and the transmission of OH habits and behaviour from mother to child. However, the reasons for edentulousness were not investigated, whether caries or periodontal reasons.

Velasco et al. (2018) studied the association between EDD and dental caries among 350 children aged 9-11 years in Bauru, Brazil. Children with EDD were twice as likely to develop dental caries than those without EDD. However, the possible pathways could not be identified due to the study's cross-sectional design.

2.3.8.3 Age 12-18 years old

This part outlines the findings of six studies that examined the biological, social and behavioural factors related to dental caries in permanent dentition in early life and throughout the child's life course. Peres et al. (2009) conducted a population-based cohort study in Pelotas involving 339 children followed from birth to six and 12 years old. The study identified four risk factors of dental caries at the age of twelve through regression analysis, including low maternal education at the time the child was born, height deficit at 12 months and four years of age, previous experience of dental caries in primary teeth, and gingival bleeding. The authors explained the association between dental caries in the primary and permanent teeth by means of three hypotheses. First, dental caries experienced at six years old might result from a life course's social, behavioural and feeding pattern accumulative effect. Second, the persistence of the cariogenic bacteria over the years may predispose dental caries in both dentitions. Third, it could be a combination of both of these previous explanations.

The authors argued that the association between gingival bleeding and dental caries might result from ineffective tooth brushing, influencing both caries and gingival health. It should be stated that the above findings cannot be generalised to other regions of Brazil because the area where the study was conducted (Pelotas) has a water fluoridation system in 90% of houses. This could also explain the low levels of dental caries (1.2 mean) with a low number of children with caries compared to the country (2.8 mean) (Peres et al., 2009).

While Peres et al. (2009) explored the cumulative effect of life course factors on dental caries, Lu et al. (2011) sought to explore the effect of social factors in triggering a chain of risks that might predict dental caries among 638 adolescents in Hong Kong. The study retrospectively followed participants at birth, then from 12, 15 and 18 years old. In this study, family income directly influenced dental services use, and dental services use positively predicted children’s dental caries. Nevertheless, no association was observed between education level and utilisation of dental services. The authors argued that economic rather than educational variables might be a stronger predictor of dental care utilization in Hong Kong, mainly when the government does not fund dental services and people must use costly private clinics (Lu et al., 2011). The study clearly explains that dental services were well suited for the chain of risk model despite the following limitations. First, the study did not mention whether Hong Kong has fluoridated water. Second, different examiners collected data throughout the study. Third, the follow up after six years resulted in only 50.8% of the population present, possibly resulting in attrition bias.

Family life might significantly impact individual OH development and behaviours (Castilho et al., 2013, Kumar et al., 2016). However, there is limited evidence on the pathways between family characteristics and the development of OHCs. Four cross-sectional studies examined the association between family characteristics and dental caries throughout the life course among adolescents (Nicolau et al., 2005, Cinar et al., 2008a, Priyanka et al., 2019, Nicolau et al., 2003).

Nicolau et al. (2003) conducted their study in two phases. Six hundred and fifty-two adolescents (aged 13 years) were recruited in the first phase, and 311 families were recruited in the second phase in the city of Cianorte in Brazil. There was an association between a high family SES and lower dental caries in both phases. Moreover, adolescents born with low birth weight had a higher level of parental punishment. Being the second or later birth order doubled the risk of having dental caries. In contrast, being taller had a protective effect on dental caries. This finding was confirmed by another study conducted by Nicolau et al. (2005). The study's cross-sectional design restricted the causal inference between variables. Additionally, the study relied on retrospective information, resulting in recall bias. The use of the cut-off points for low DMFT (≤ 6) and high DMFT mean (> 6) complicates the comparison with other studies.

Further evidence came from a study conducted in Turkey (N = 611) and Finland (N = 338) (Cinar et al., 2008a). The study assessed the influence of family type, the number of children, and time spent between mother and child on the association between adolescent health (height-weight), self-esteem, toothbrushing, and dental caries experience. Turkish adolescents with more than two siblings were more likely to be shorter and to have more dental caries than their counterparts. Alternatively, Finnish adolescents who lived with a single parent were less likely to spend time with their mother and more likely to have dental caries. In this study, Turkish adolescents had a higher rate of dental caries (84%) than Finnish ones (33%).

Nonetheless, it was unclear if the study attempted to compare the two communities or explored the pathways between the proposed association. Another limitation was that the anthropometric measures of the adolescents were obtained by their mothers, which may raise questions about the validity and reliability of those measures.

Finally, a cross-sectional study with 800 adolescents aged twelve studied different biological and family-related factors that might influence their risk of developing caries (Priyanka et al., 2019). The study found that children with shorter height, low and medium income, and attending governmental school were more likely to have dental caries than their counterparts. However, the study did not find family variables associated with dental caries risks, such as family structure, number of siblings, and time spent between children and their mothers. Although the study was recent and claimed to adopt a life course approach, it did not provide any life course model to support its theory and analysis.

2.3.8.4 Impacts of social mobility

Few studies explored the impact of social mobility on dental caries among children and adolescents. Most of the available evidence was measured during adulthood. However, it should be mentioned that at least two measurements are required to assess health trajectories. Likewise, at least three measurements are required to assess the pattern of these trajectories (Burton - Jeangros et al., 2015).

Notwithstanding this, analysis of the Pelotas birth cohort concerning social trajectories with adolescents (n=875) generated mixed results (Peres et al., 2007). The study investigated the impact of family SES trajectories from birth to adolescence on dental caries, tooth brushing and use of dental services at age 15. The study showed that adolescents from the always poor group had the highest caries rate had a lower frequency of tooth brushing and attending dental services than their correspondent counterparts. However, no variations were observed in dental caries and teeth brushing patterns between adolescents from upward or downward mobility groups and those who lived in poverty. Thus, the upward social improvement did not reverse the unfavourable effect of poverty in early life, and the study suggested that poverty, even in one stage of early life, is formidable enough to cause poor OH in later life.

2.3.9 Conclusion

The limitations of the lifestyle approach to preventing chronic conditions motivated the interest to examine the natural history of risk factors of diseases using the life course approach (Ben-Shlomo and Kuh, 2002).

Recently, the life course approach has been demonstrated to be suitable to study the factors related to OHCs. Studies that adopted this approach concluded that dental caries among children and adolescents result from exposures accumulated early and later in life.

Thus, Heilmann et al. (2015) developed their life course framework specifically to study the factors associated with OH by incorporating the social determinants of OH together with the critical and accumulation life course model and common risks connected to health and OH in their framework.

After highlighting possible life course factors related to dental caries, the next section summarised the impact of OHCs on children's and adolescents' school outcomes.

2.4 The impact of OHCs on school performance and attendance in children and adolescents

2.4.1 Overview

Education during early life can predict the opportunities throughout the life course (Banerjee, 2016). OHCs can impair children’s cognitive ability and hinder their academic school performance in early life (Rebelo et al., 2019), influencing their academic attainment in adult life and future career development (Dornan and Woodhead, 2015). This section summarises the available evidence on the impacts of OHCs on children’s and adolescents' school performance and attendance using an umbrella review method.

2.4.2 Aim

To summarise the available systematic reviews that explored the impacts of OHCs on school performance and school attendance among children and adolescents.

2.4.3 Study question

What is the association of clinical and self-reported OH measures with children’s and adolescents' school performance and attendance?

2.4.4 Inclusion criteria

2.4.4.1 Type of participants

The scope of the overview included children and adolescents up to 19 years of age participants.

2.4.4.2 Phenomena of interest

The phenomena of interest (outcomes) included school performance, and attendance was measured by school reports of grades and attendance, self-reported measures, such as parent's or adolescent's perceptions, or any other measure included in the systematic reviews.

2.4.4.3 Exposures

The exposures included clinical and subjective OH measures.

2.4.4.4 Context

No restriction was made in terms of country and cultural variables.

2.4.4.5 Type of studies

Any systematic review or meta-analysis of epidemiologic studies exploring the association between OH measures, school performance and school attendance in schoolchildren.

2.4.4.6 Reviews' features

The plethora of systematic reviews began in 1990 (Smith et al., 2011). Hence, the electronic databases were searched from 1990 until March 2019**,** with no language restriction. The literature search presented at the end of this section was updated to include primary studies until July 2021.

2.4.5 Search strategy

2.4.5.1 Database search and terms

The electronic search was conducted using PubMed, Education database, Scopus and Medline using the following MeSH terms and keywords: (“oral health” or “dental health”, or “oral health status” or “dental health status”, or “dental caries”) and (“academic performance” or “academic achievement” or “school performance” or “educational performance” or “educational achievement” or “educational measurement” or “lost school days” or “school absenteeism” or absenteeism or attendance) and (children or child or adolescent or adolescence) and (review or “systematic review” or “meta-analysis”).

2.4.5.2 Review Selection

The initial search was performed by the lead reviewer (SM). Screening of the titles and abstracts was conducted by two reviewers independently (SM and YA).

2.4.6 Review method

2.4.6.1 Assessment of methodological quality

The Assessment of Multiple Systematic Reviews (AMSTAR) checklist tool was used to evaluate the quality of the included systematic reviews (Shea et al., 2007) (see Appendix 3). Two reviewers independently evaluated the quality of the included systematic reviews (SM, YA). The tool comprises eleven criteria (one point each), and the final scores can range from 0 to 11. The quality of the reviews was classified as follows: high (8-11 points), medium (4-7 points) and low quality (0-3).

2.4.6.2 Data extraction and management

The identified reviews were saved in Endnote X7. The duplicated articles were deleted. The Jonna Briggs Institutes (JBI) data extraction form was employed to report the data of the included systematic reviews (see Appendix 4).

2.4.6.3 Search and quality assessment results

Figure 4 illustrates the results of the electronic database search using the PRISMA flow chart (Moher et al., 2009). The electronic search retrieved 178 articles after removing duplicates. One hundred and seventy-four articles did not meet the eligibility criteria after screening the title and abstract. The umbrella review included four systematic reviews (Ribeiro et al., 2018, de Paula and Mialhe, 2013, Ruff et al., 2019, Rebelo et al., 2019). Most of the excluded studies were not systematic or meta-analysis reviews.

According to the AMSTAR, Shea et al. (2007), de Paula and Mialhe (2013), Rebelo et al. (2019) and Ribeiro et al. (2018) were judged to be of moderate quality, while Ruff et al. (2019) was assessed as having high quality. The result is presented in Table 5 below.

Table 5. The quality assessment results of four systematic reviews using AMSTAR (Shea et al. 2007)

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Overall
de Paula & Mialhe., 2013	X	✓	✓	X	✓	✓	X	X	X	X	✓	5
Rebelo et al., 2019	✓	✓	✓	X	X	✓		X	✓	X	✓	7
Ribeiro et al., 2018	✓	✓	✓	✓	X	✓		✓	X	X	X	7
Ruff et al., 2019	X	✓	✓	✓	✓	✓		X	✓	✓	✓	8

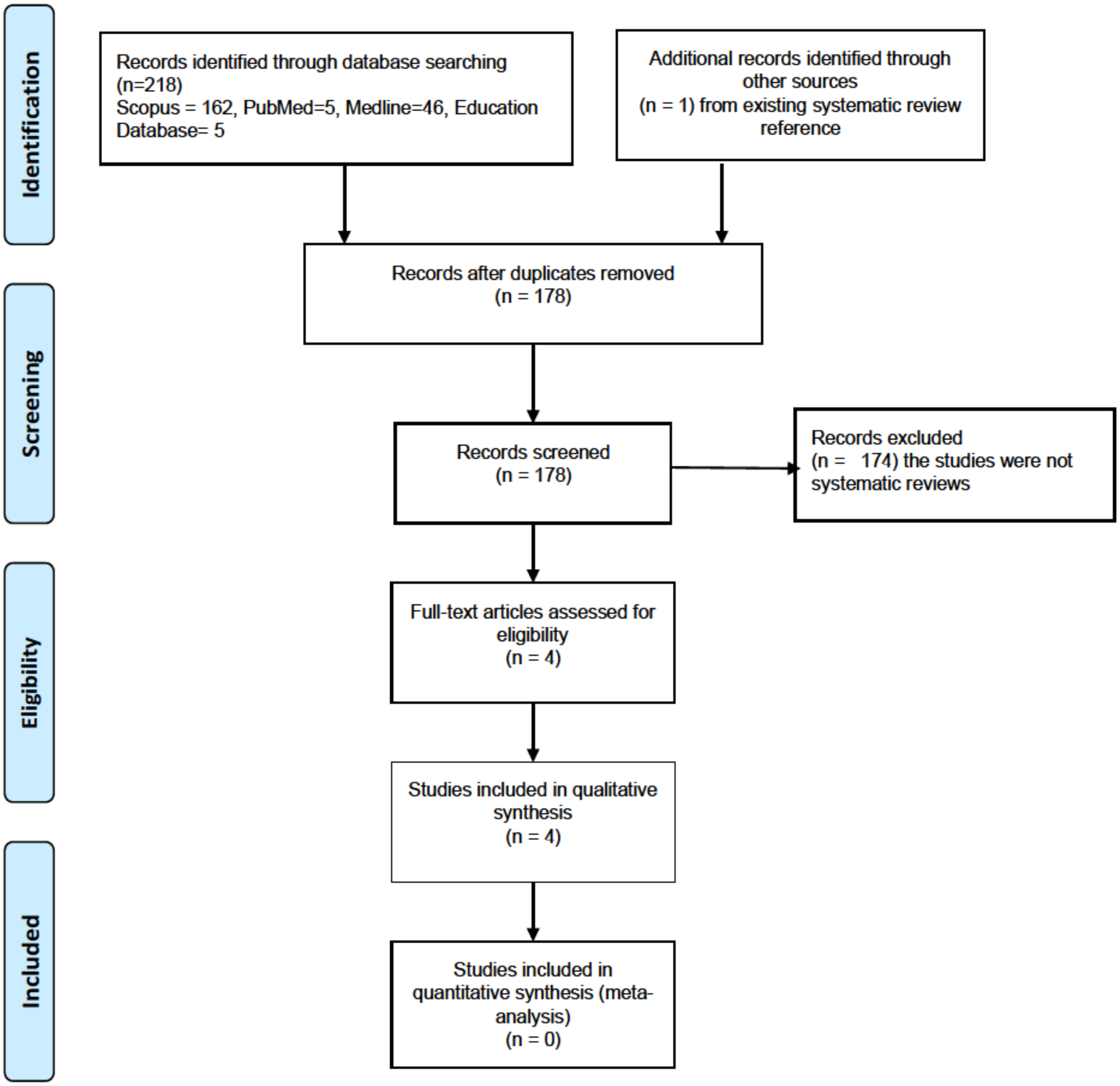


Figure 4. Prisma flow chart for identifying systematic reviews on the impacts of OHCs on school performance and attendance in children and adolescents (2019)

2.4.7 Summaries of the systematic reviews

Table 6 summarises and compares the four systematic reviews in terms of authors and country, aim, inclusion and exclusion criteria, number and type of the included studies, the use of PRISMA, risk assessment, results and the main recommendations.

2.4.7.1 Population and sample

The target population included in the systematic reviews were schoolchildren and adolescents. Across all the included studies, there were 359,912 children and adolescents aged 3-19 years. Three of the four reviews selected primary studies involving specific age groups. Ribeiro et al. (2018) included three- to nineteen-year-old students, Ruff et al. (2019) comprised students aged five to eighteen and Rebelo et al. (2019) consisted of those aged eighteen years or younger. No specific age group restrictions were identified in the review of de Paula and Mialhe (2013). Such diversity in target groups is related to the selected studies included in each systematic review.

Table 6. Summary of systematic reviews exploring the impacts of OH on school performance and attendance in children and adolescents

Author-year-Country	Aim	Inclusion criteria	Exclusion criteria	PRISMA	Risk assessment	Results	Conclusions and recommendations
de Paula & Mialhe, 2013 (Brazil) 21 studies 14 cross-sectional and 7 ecological studies	To investigate the association between OHCs and school attendance and performance in children & adolescents	(1) English language only (2) Between 1990 and 2013	(1) Other languages	No	No	The significant association found between OH and school performance and absences by	1 - Longitudinal studies 2 - Multivariate statistics to control confounders 3 - Use reliable and valid criteria
Ribeiro et al., 2018 (US-Brazil) 6 cross-sectional studies	To confirm the association between OHCs & academic performance in children and adolescents.	(1) Observational studies and clinical trials. (2) OHS with clinical examinations. (3) Academic performance by school records (4) Age range 3-19 years old. (5) No restrictions on time or language.	(1) Self-reported measures. (2) Letter, review papers, case reports and case studies	Only the flow chart	National Heart, Lung and Blood Institute	- 4 papers (high risk of bias) OHS were associated with children's academic performance - 2 papers (good quality) did not show an association unless mediated by SES.	1 - Longitudinal studies 2 - Considering confounders 3 - Valid OH measures carious lesions in different stages (e.g., PUFA or CAST). 4- Objective measures of academic performance.
Rebelo et al., 2019 (UK) 18 studies 1 cohort 1 case-control 16 cross-sectional	To explore the possible impact of OH on school performance and attendance in children and adolescents.	(1) Clinical trials and observational. (2) Aged 18 years or under. (3) Any language. (4) No publication period restrictions to May 2018.	(1) Letter, review papers, case reports and case studies	Yes + MA	- NOS for cohort studies and case-control. - Modified NOS for cross-sectional studies	Children with - ≥1 decay and poor parental perception of OH have a higher probability of poor school performance attendance	1 - Longitudinal studies. 2 - Reliable school data from school records 3 - Valid OHS measures. 4 - SES and family structure considered.
Ruff et al., 2019 (US) 14 (10 low risks and 4 high risks 1 cohort 1 case-control 12 cross-sectional)	To evaluate the association between OHS & school attendance and academic performance in children aged 5 through 18 years.	(1) Observational studies (2) Aged 5 to 18 years (3) Exposures: caries, periodontitis or gingivitis s (4) school performance and attendance (5) Jan1945 - Dec 2017	(1) Included only articles published in English.	Only flow chart + MA	The modified NOS for non-randomised studies.	Poor OH was significantly associated with increased odds of poor academic performance	1 - Design and implement targeted interventions for specific conditions. 2 - Understanding the best period in which OH immediately influences performance.

2.4.7.2 Exposures

All the systematic reviews included the broad term "oral health" followed by different terms such as status, problem or measures to refer to the exposure. The most common OHCs assessed were dental caries, included in all systematic reviews. Nevertheless, evaluation of other conditions, including oral hygiene, periodontal diseases, dental trauma, malocclusion, dental pain and self-report OH, were assessed in a few studies.

2.4.7.3 Assessment of exposures

Three systematic reviews considered primary studies that assessed exposures using clinical examination (normative needs) or perceived (reported) OH status. The latter can be either parental or self-reported OH status. It should be stated that only the review from Ribeiro et al. (2018) believed the OH information in the included studies was required based on clinical examination alone. DMFT, dmft and DMFS indices were predominantly used to assess dentine dental caries. The descriptions of these indices are provided when describing the included studies.

2.4.7.4 Outcome measure

Three systematic reviews included school performance and school attendance as the outcomes of interest, and the other review considered the former outcome only (Ribeiro et al., 2018).

2.4.7.5 Evaluation of outcome measure

School performance was assessed using either school records (i.e., school grades or marks using standard tests or teacher reports) or self-reported (i.e., questionnaire or interview assessing child's or adolescent's or parents' perception of school performance). Ribeiro et al. (2018) covered only studies that used school records to evaluate school performance. The other three systematic reviews included both school records and self-reported assessments of school performance. Similarly, school attendance was evaluated using either school records (i.e., school attendance registers) or self-reported measures (i.e., parental or self-reported information by questionnaire or interview regarding the number of missing school days due to dental problems).

2.4.7.6 Registration of protocol

Two of the four systematic reviews were registered at the Prospective International Registration of Systematic Reviews (PROSPERO). Ribeiro et al. (2018), under the reference CRD42016041587 and Rebelo et al. (2019), under the reference CRD42016036909.

2.4.7.7 Design of the included studies

The systematic reviews included observational studies. Although clinical trials were eligible for inclusion, no intervention studies were identified.

2.4.7.8 Search strategy

Ruff et al. (2019) searched for publications in three databases (PubMed, EMBASE and Google Scholar). Alternatively, Rebelo et al. (2019) examined five databases (Medline, SCOPUS, Web of Science, Science Direct, LILACS). de Paula and Mialhe (2013) and Ribeiro et al. (2018) searched four databases. The former explored Medline, ISI, Lilacs and Scielo, whilst the latter used PubMed, Lilacs, Web of Science and Scopus.

Three reviews provided keywords and a search strategy, whereas one review paper (de Paula and Mialhe, 2013) provided only the keywords. All the reviews included a search of the references lists. Two reviews included the grey literature search, specifically Ribeiro et al. (2018) and Ruff et al. (2019).

2.4.7.9 Search restrictions and justifications

Overall, some restrictions were applied regarding participants' age, language and time. All of the reviews included participants aged 19 years and younger. However, Raff et al. (2018) and Ribeiro et al. (2018) restricted the youngest age to be children aged five and three years, respectively. On the contrary, de Paula and Mialhe (2013) did not restrict the age group. Regarding language restrictions, two reviews, namely de Paula and Mialhe (2013) and Ruff et al. (2019) included only articles published in English. Other reviews did not report language restrictions. Furthermore, Ruff et al. (2019) limited their search to commence from January 1945, as this was necessary to coincide with the beginning of community water fluoridation in the US. Similarly, the studies undertaken by de Paula and Mialhe (2013) included studies published from 1990 to 2013. However, without time limitations, Ribeiro et al. (2018) and Rebelo et al. (2019) unearthed no literature prior to 1990.

2.4.7.10 Study selection and data extraction

Two reviewers selected and extracted the data of the identified studies in two systematic reviews (de Paula and Mialhe, 2013; Ribeiro et al., 2018). Three reviewers selected and extracted the data from the published paper in Rebelo et al. (2019). Data extraction was completed in duplicate in Ruff et al. (2019). However, in the latter review, it was not clear whether the selection of the studies was made in the same way.

2.4.7.11 Excluded studies

Ruff et al. (2019) excluded fifteen studies after reading the full text, and the reasons for excluding was informed in a flow chart. The fifty excluded articles that were read in full were not reported in Rebelo et al. (2019), and the justifications for exclusion were explained in a flow chart. Similarly, Ribeiro et al. (2018) excluded eight articles whose justifications were shown in the flow chart. In de Paula and Mialhe (2013) review, no such exclusion was done as all studies were read in full and included. Interestingly, four articles were excluded from the Rebelo et al. (2019) and one paper from Ruff et al. (2019), as there was no access to the full text of the manuscripts.

2.4.7.12 Characteristics of the included studies in the systematic reviews

The following details of the characteristics of all the included primary (n=39) studies in the four systematic reviews (see Appendix 5).

2.4.7.12.1 Number of the studies

Fifty-nine studies were included in the four reviews. de Paula and Mialhe (2013) included 21 papers, followed by Rebelo et al. (2019) (18 studies), Ruff et al. (2019) (14 studies) and Ribeiro et al. (2018) (6 studies). Several of these studies were found in more than one systematic review. Hence, the combined list of all the studies included in these systematic reviews after excluding duplicates was 39 articles. Only one study was included in all the reviews (Seirawan et al., 2012); another three were included in three of the four reviews (Jiang et al., 2005, Piovesan et al., 2012, de Paula et al., 2015a). Moreover, 25 primary studies appeared in one only review. Table 7 presents the combined list of the included studies according to the identified systematic reviews.

Table 7. Studies included in the four systematic reviews (Ribeiro et al., 2018, de Paula and Mialhe, 2013, Ruff et al., 2019, Rebelo et al., 2019)

	Studies included in the previous systematic reviews	de Paula & Mialhe., 2013	Rebelo et al., 2019	Ribeiro et al., 2018	Ruff et al., 2019	Total
1	Gift et al., 1992	X				1
2	Petridou et al., 1996	X			X	2
3	Milgrom et al., 1998	X				1
4	Astrøm & Okullo., 2003	X				1
5	Viviane & Sandra., 2003			X		1
6	Egri & Gunay., 2004	X				1
7	Muirhead & Marcenes., 2004	X				1
8	Sandra et al., 2005	X				1
9	Jiang et al., 2005	X	X		X	3
10	David et al., 2006	X			X	2
11	Gherunpong et al., 2006	X				1
12	Muirhead & Locker.., 2006	X				1
13	Bernabé et al., 2007	X				1
14	Bernabe et al., 2007	X				1
15	Blumenshine et al., 2008	X	X			2
16	Freire et al., 2008	X				1
17	Pau et al., 2008	X				1
18	Petersen et al., 2008	X				1
19	Pongpichit et al., 2008				X	1
20	Butani et al., 2009	X				1
21	Jürgensen & Petersen., 2009	X			X	2
22	Gradella et al., 2011		X			1
23	Jackson et al., 2011	X	X			2
24	Garg et al., 2012		X	X		2
25	Guarnizo-Herreno & Wehby., 2012		X		X	2
26	Piovesan et al., 2012		X	X	X	3
27	Seirawan et al., 2012	X	X	X	X	4
28	Krisdapong et al., 2013		X		X	2
29	Detty & Oza-Frank., 2014				X	1
30	Osman & Alsayed., 2015			X		1
31	Agaku et al., 2015		X		X	2
32	de Paula et al., 2015a		X	x	X	3
33	Nasuuna et al., 2016		X			1
34	Neves et al., 2016		X			1
35	Paula et al., 2016		X			2
36	Sameer et al., 2016		X		X	2
37	Maharani et al., 2017		X			1
38	Kaewkamnerdpong & Krisdapong., 2018		X			1
39	Naavaal & Kelekar., 2018		X			1
	Grand Total	21	18	6	14	59

2.4.7.12.2 Location of the studies

The study undertaken by Egri and Gunay (2004) gathered data from 44 developing countries. The remaining 38 studies were originated from 17 different countries. Ten studies were conducted in the US, followed by Brazil (9 studies). Four studies were conducted in Thailand, while two were conducted in China, India and Peru. The other ten studies were carried out in different countries. Table 8 illustrates the countries of the primary studies included in the previous systematic reviews. Interestingly, given the context of the present thesis, very few studies have been conducted in Middle Eastern countries.

Table 8. Country of origin of the studies included in the systematic reviews

Country	Author, year
Australia	Nasuuna et al., 2016
Brazil	Viviane & Sandra., 2003, Sandra et al., 2005, Freire et al., 2008, Gradella et al., 2011, Piovesan et al., 2012, de Paula et al., 2015a, Neves et al., 2016 and Paula et al., 2016
Canada	Muirhead & Locker., 2006
China	Jiang et al., 2005, Petersen et al., 2008
Greece	Petridou et al., 1996
India	David et al., 2006, Garg et al., 2012
Indonesia	Maharani et al., 2017
Laos	Jurgensen & Petersen., 2009
Pakistan	Pau et al., 2008
Peru	Bernabé et al., 2007, Bernabé et al., 2007
Saudi Arabia	Sameer et al., 2016
Sudan	Osman & Alsayed., 015
Thailand	Gherunpong et al., 2006, Pongpichit et al., 2008, Krisdapong et al., 2013, Kaewkamnerdpong & Krisdapong, 2018
Turkey	Egri & Gunay., 2004
Uganda	Astrom & Okull., 2003
UK	Muirhead & Marcenes., 2004
US	Gift et al., 1992, Milgrom et al., 1998, Blumenshine et al., 2008, Butani et al., 2009, Jackson et al., 2011, Guarnizo-Herreno and Wehby., 2012, Seirawan et al., 2012, Detty and Oza-Frank., 2014, Agaku et al., 2015, Naavaal & Keleka., 2018

2.4.7.12.3 Study designs

Table 9 summarises the study design of studies included in all the systematic reviews. The studies were grouped into four types: longitudinal, case-control, cross-sectional, and ecological.

Table 9. Study design of the studies included in the systematic reviews

Study design of the included studies	Number of studies	Author, year
Longitudinal studies	2	Pongpichit et al., 2008, Nasuuna et al., 2016
Cross-sectional studies	32	Petridou et al., 1996, Milgrom et al.,1998, Astrøm and Okullo., 2003, Viviane & Sandra., 2003, Sandra et al., 2005, Jiang et al., 2005, David et al., 2006, Gherunpong et al., 2006, Bernabé et al., 2007, Bernabe et al., 2007, Blumenshine et al., 2008, Freire et al., 2008, Petersen et al., 2008, Pau et al., 2008, Butani, et al., 2009, Jürgensen and Petersen., 2009, Gradella et al., 2011, Jackson et al., 2011, Garg et al., 2012, Guarnizo-Herreno and Wehby., 2012, Piovesan et al., 2012, Seirawan et al., 2012, Krisdapong et al., 2013, Detty & Oza-Frank., 2014, Osman & Alsayed., 2015, Agaku et al., 2015, de Paula et al., 2015a, Neves et al., 2016, Sameer et al., 2016, Maharani et al., 2017, Kaewkamnerdpong and Krisdapong., 2018, Naavaal and Kelekar., 2018
Case-Control study	1	Paula et al., 2016,
Ecological studies	4	Gift et al., 1992, Egri and Gunay., 2004, Muirhead and Marcenes., 2004, Muirhead and Locker., 2006
Total	39	

2.4.7.12.4 Sample size

The sample size of the included studies in the four systematic reviews varied significantly, possibly related to the difference in the study design, research resources and availability of participants. The sample size was unknown only in Egri and Gunay (2004) (Table 10). Gift et al. (1992) included the largest sample size (N=109,603), which accounts for approximately 30.5% of the total participants (N=359,912) in all the 39 included studies. Agaku et al. (2015) included 65,680 participants, comprising more than 18.3% of the total sample.

In contrast, thirty-one studies contributed less than 1% of the overall sample, with Viviane and Sandra's (2003) having the least participants (n = 101). Piovesan et al. (2012) also had a small sample size (n=281).

Table 10. Sample size and age group of the studies included in the systematic reviews

	Studies included in all systematic review	Sample size	Age group
1.	Gift et al., 1992	109.,603	≥2 years
2.	Gradella et al., 2011	765	2-4 years
3.	Seirawan et al., 2012	2.,313	2-16 years
4.	Garg et al., 2012	600	3-5 years
5.	Neves et al., 2016	836	3-5 years
6.	Viviane & Sandra., 2003	101	4 years
7.	Sandra et al., 2005	861	≥4 years
8.	Muirhead & Marcenes., 2004	1.,968	≥ 5 years
9.	Nasuuna et al., 2016	24.,678	4-7 years
10.	Milgrom et al., 1998	828	5-11 years
11.	Osman & Alsayed., 2015	385	5-15 years
12.	Naavaal and Kelekar., 2018	3.,833	5-17 years
13.	Butani et al., 2009	416	6-10 years
14.	Maharani et al., 2017	984	6-7, 10-11 years
15.	Agaku et al., 2015	65.,680	6-17 years
16.	Guarnizo-Herreno & Wehby., 2012	46.,750	6-17 years
17.	Detty & Oza-Frank., 2014	16.,022	8 years
18.	Muirhead & Locker., 2006	59.,266	8-11 years
19.	Paula et al., 2016	1.,149	8-19 years
20.	Pongpichit et al., 2008	1.,211	9-13 years
21.	Bernabé et al., 2007	903	11-12 years
22.	Bernabe et al., 2007	805	11-12 years
23.	Gherunpong et al., 2006	1.,226	11-12 years
24.	Jürgensen & Petersen., 2009	621	11-13 years
25.	Jiang et al., 2005	2.,662	11, 13 and 15 years
26.	Petersen et al., 2008	2.,662	11,13, and 15 years
27.	David et al., 2006	838	≥12 years
28.	Pau et al., 2008	500	≥12 years
29.	de Paula et al., 2015a	515	12 years
30.	Egri & Gunay., 2004	--	12 years
31.	Kaewkamnerdpong & Krisdapong., 2018	925	12 years
32.	Piovesan et al., 2012	281	12 years
33.	Krisdapong et al., 2013	1.,063	12-15 years
34.	Petridou et al., 1996	360	12-17 years
35.	Astrøm & Okullo., 2003	1.,146	13-19 years
36.	Freire et al., 2008	761	≥15 years
37.	Sameer et al., 2016	480	16-18 years
38.	Blumenshine et al., 2008	2.,871	≤<17 years
39.	Jackson et al., 2011	1.,782	≤<18 years
	Total	359,912	

2.4.7.12.5 Participants' ages

Three articles included the lowest children's age (two years old) (Gradella et al., 2011, Seirawan et al., 2012, Gift et al., 1992). However, the former study did not have any children at this age, and the latter excluded those aged 2-5 years from the analysis due to the lack of school performance records. In their study, Gradella et al. (2011) also included children aged two years and those aged 3-4 years in their analysis. The maximum age group was up to 19 years old (Åstrøm and Okullo, 2003). Other six studies included participants aged up to 17 years.

Twelve years was the most common age group investigated, and this threshold was used as the minimum or maximum age limit in eleven studies (Table 10).

2.4.7.12.6 Exposures

The included studies investigated different OHCs as exposures. Dental caries was the most OHCs investigated, as 23 studies assessed this dental condition. The term "oral health" was used to describe exposure in 14 studies. Dental pain was investigated in ten studies under different terms (oral pain, toothache and dental pain). Three studies described oral hygiene and gingival bleeding on probing, whereas four investigated malocclusion. Moreover, five studies assessed dental trauma (David et al., 2006, Muirhead and Locker, 2006, Jürgensen and Petersen, 2009, Piovesan et al., 2012, Neves et al., 2016).

2.4.7.12.7 Exposure measures

The assessment of the OHCs as the exposure was through clinical examination or perceived OH. The clinical data were obtained either by a clinical examination conducted by the researchers or using a previously recorded dental examination or dental records. The perceived OH was self-reported either by the child or their parents (see Appendix 5).

Twenty studies assessed OHCs through clinical examination. DMFT index was used to measure dentine dental caries in 14 studies (Petridou et al., 1996, David et al., 2006, Jürgensen and Petersen, 2009, Gradella et al., 2011, Piovesan et al., 2012, Krisdapong et al., 2013, Paula et al., 2016, Kaewkamnerdpong and Krisdapong, 2018, Osman and Alsayed, 2015, Freire et al., 2008, Astrøm and Okullo, 2003, de Paula et al., 2015a, Gherunpong et al., 2006). Additionally, the DMFS index was used to measure dentine dental caries in one study (Petridou et al., 1996), dmft index in two studies (Osman and Alsayed, 2015, Paula et al., 2016), df-t index in one study (Garg et al., 2012), ICDAS in one study (Neves et al., 2016) and the PUFA index in one study (Gradella et al., 2011).

Additionally, other studies adopted specific criteria to define caries. Viviane and Sandra (2003) measured caries in terms of the presence or absence of caries lesions. Sandra et al. (2005) used the criteria established by the Brazilian Ministry of Health survey, and Seirawan et al. (2012) recorded dental caries as cavitated and non-cavitated caries lesions.

Among the studies that investigated dental trauma, only one specified the Traumatic Dental Injury index (TDI) as a measurement tool to assess dental trauma (Neves et al., 2016).

Oral hygiene status was assessed in three studies according to the amount of dental biofilm and dental calculus using the Oral Hygiene Index Simplified (OHI-S) (David et al., 2006, Kaewkamnerdpong and Krisdapong, 2018, Gherunpong et al., 2006). Similarly, two studies used bleeding on probing (BOP) (Paula et al., 2016, de Paula et al., 2015a) to evaluate gingival health. Additionally, four studies assessed malocclusion using different measurements, like the Index of Orthodontic Treatment Need (IOTN) (Gherunpong et al., 2006), self-perceived malocclusion (Bernabé et al., 2007) and Dental Aesthetic Index (DAI) (de Paula et al., 2015a). Furthermore, Neves et al. (2016) examined malocclusion based on the presence of at least one of the following occlusal deviations: overbite (>2 mm), overjet (>2 mm), anterior open bite, anterior or posterior crossbite. Five studies utilised previously recorded dental data or dental records, including the National Health Interview Survey (NHIS) in the US (Gift et al., 1992, Naavaal and Kelekar, 2018), the WHO Global Oral Data Bank for DMFT among 12-year-olds (Egri and Gunay, 2004), The British Association for the Study of Community Dentistry (BASCD) for 5-year-olds survey in the UK (Muirhead and Marcenes, 2004). Detty and Oza-Frank (2014) evaluated untreated dental caries using the Basic Screening Survey of Ohio 2009-2010. Two other studies used data from school's data screening programs (Milgrom et al., 1998, Muirhead and Locker, 2006)

Seven papers used the parental perception of their child's OHS (Pongpichit et al., 2008, Blumenshine et al., 2008, Butani et al., 2009, Jackson et al., 2011, Agaku et al., 2015, Nasuuna et al., 2016, Guarnizo-Herreño and Wehby, 2012) and another study used parental reporting of dental care (Naavaal and Kelekar, 2018). While self-reported dental health was applied in five cross-sectional studies (Jiang et al., 2005, Bernabé et al., 2007, Bernabe et al., 2007, Pau et al., 2008, Petersen et al., 2008), Paula et al. (2015) applied both parental and child's perception of OH and dental caries.

Finally, toothache or dental pain was investigated in ten studies using self-structured questionnaires (Jürgensen and Petersen, 2009, Pau et al., 2008), Child-OIDP (C-OIDP) (Krisdapong et al., 2013), and CPQ_{13} (Piovesan et al., 2012), Sameer et al.

(2016). Pongpichit et al. (2008) developed a form to collect dental pain and school absenteeism information. The other three studies used the parental perception of children's toothache in the last 12 months (Maharani et al., 2017, Seirawan et al., 2012, Jackson et al., 2011). Another study utilised previously recorded data (BASCD) (Muirhead and Locker, 2006).

2.4.7.12.8 Outcome

Twenty-two studies examined school performance, while eleven studies used school attendance. The other six studies employed both outcomes.

2.4.7.12.9 Outcome measures

The outcome of interest was assessed using school records or by self-reported measures. Fourteen studies measured overall school performance or subject's grades (Petridou et al., 1996, Muirhead and Marcenes, 2004, Muirhead and Locker, 2006, Detty and Oza-Frank, 2014, Paula et al., 2016, Nasuuna et al., 2016, Maharani et al., 2017, Kaewkamnerdpong and Krisdapong, 2018, Osman and Alsayed, 2015, de Paula et al., 2015a), teacher's report (Viviane and Sandra, 2003, Garg et al., 2012), passing or failing at school (Freire et al., 2008) and the Egri and Gunay (2004) used different educational indicators like adult literacy rate and the student-teacher ratio for primary level.

In contrast, seven studies measured school performance by a self-report questionnaire. Of those specific studies, four used OIDP as a proxy measure of self-reported school performance (Bernabé et al., 2007, Bernabe et al., 2007, Astrøm and Okullo, 2003, Gherunpong et al., 2006), whereas three studies used direct self-reporting (Jiang et al., 2005, David et al., 2006, Petersen et al., 2008). In one study (Blumenshine et al., 2008), school performance was reported by the parents.

School attendance data was obtained from school records in two studies (Pongpichit et al., 2008, Sameer et al., 2016). In seven studies, the parents or guardians enquired about their children's school attendance (Milgrom et al., 1998, Sandra et al., 2005, Butani et al., 2009, Gradella et al., 2011, Neves et al., 2016, Agaku et al., 2015, Naavaal and Kelekar, 2018). Self-reported school attendance in 12-year-old adolescents was used in one study (Jürgensen and Petersen, 2009), whilst both parents and adolescents reported missing school hours in the Gift et al. study (1992).

Combined school performance and school absenteeism were measured in two studies and obtained from school records (Piovesan et al., 2012; Seirawan et al., 2012). Similarly, two studies combined both outcomes using students self-reported measures (Pau et al., 2008, Krisdapong et al., 2013). C-OIDP was used in both studies as a proxy measure of school performance. Additionally, two studies used parents' perceptions of school performance and attendance (Jackson et al., 2011, Guarnizo-Herreño and Wehby, 2012).

2.4.7.12.10 Confounders

Overall, there were 43 confounders controlled for in the 39 studies. However, 15 studies did not control for any confounder. In three studies, the level of confounder control was unknown because of the unavailability of the full text. Three studies controlled more than ten confounders: 11 confounders (Jackson et al., 2011); 14 confounders (Kaewkamnerdpong and Krisdapong, 2018) and 19 confounders (Guarnizo-Herreño and Wehby, 2012). Gender, age and race/ethnicity were the confounders that were controlled the most. Important confounders, such as SES and family structure, were considered and controlled in very few studies despite their importance in shaping every aspect of the children's development (Amato, 2005) (see Appendix 6).

2.4.7.12.11 Results of the included studies

Among the 39 primary studies, 16 studies examine the association between clinical measures of dental caries and school performance (Petridou et al., 1996, David et al., 2006, Piovesan et al., 2012, Paula et al., 2016, Kaewkamnerdpong and Krisdapong, 2018, Osman and Alsayed, 2015, Freire et al., 2008, Egri and Gunay, 2004, Muirhead and Locker, 2006, Muirhead and Marcenes, 2004, Detty and Oza-Frank, 2014, Seirawan et al., 2012, Astrøm and Okullo, 2003, de Paula et al., 2015a, Garg et al., 2012, Gherunpong et al., 2006). Generally, the results of these studies suggested a negative association between dental caries and school performance, regardless of age and demographic characteristics, except in 3 studies (Piovesan et al., 2012, Seirawan et al., 2012, Paula et al., 2016). The studies argued that psychosocial and socioeconomic factors mediated the association between dental caries and school performance.

In contrast, the ten studies using the parental or child perception of OHS reported an association between OH and school performance (Jiang et al., 2005, Bernabé et al., 2007, Bernabe et al., 2007, Petersen et al., 2008, Blumenshine et al., 2008, Jackson et al., 2011, Nasuuna et al., 2016, Piovesan et al., 2012, de Paula et al., 2015a, Guarnizo-Herreño and Wehby, 2012).

It was observed that most of the studies using self-perceived OH measures did not specify the OHCs related to school outcomes. Some studies tended to specify certain conditions like TDI and malocclusion (Jürgensen and Petersen, 2009, Muirhead and

Locker, 2006, Neves et al., 2016, Piovesan et al., 2012). Nevertheless, only two studies that measure TDI reported nonsignificant associations with school outcomes (Piovesan et al., 2012, Neves et al., 2016). Regarding malocclusion, Neves et al. (2016) reported no link between malocclusion and school absenteeism, while Bernabé et al. (2007) found that only 15.5% of children aged 11-12 years in Peru reported impacts due to self-perceived malocclusion during the last three months.

Further, nine studies examined the association between clinical measures of dental caries and school attendance (Osman and Alsayed, 2015, Sandra et al., 2005, Gradella et al., 2011, Jürgensen and Petersen, 2009, Krisdapong et al., 2013, Milgrom et al., 1998, Neves et al., 2016, Piovesan et al., 2012, Seirawan et al., 2012). Three studies did not report an association between dental caries and missing school days (Seirawan et al., 2012; Krisdapong et al., 2013; Osman and Alsayed, 2015). However, two studies suggested that dental visits were the main factor in school absence because of the oral problem. For example, Gift et al. (1992) reported 51 million school hours lost annually because of dental visits and OH problems in the USA. In contrast, Naavaal et al. (2018) reported 34 million school hours lost annually because of emergency dental care.

Toothache or dental pain was investigated in ten studies and was usually considered the primary mechanism by which OHCs influenced school absence (Jackson et al., 2011, Krisdapong et al., 2013). Seirawan et al. (2012) found that dental pain reported by parents was associated with school absence and grade point average in primary and elementary school children in the US. Similar results were reported by Piovesan et al. (2012). Maharani et al. (2017) conveyed a significant link between toothache and school performance. However, a reanalysis of their data conducted by Quadri et al. (2019) revealed no evidence for such claimed association as the initial result was due to an error when interpreting the results. Despite that, two studies reported the prevalence of missing school days because of dental pain to be 18% in Saudi Arabia (Sameer et al., 2016) and 6% in Thailand (Pongpichit et al., 2008). However, they did not support the claim by testing a formal hypothesis. Pau et al. (2008) has shown that 32% of children reported the impact of pain on going to school and learning in class compared with 67% of those who did not report the impact of dental pain on their school life. Finally, Jürgensen and Petersen (2009) and Muirhead and Locker (2006) also reported an association between dental pain and missing school days.

2.4.7.13 Results and conclusions of the systematic reviews

Both de Paula and Mialhe (2013) and Ribeiro et al. (2018) described the selected studies, but no meta-analysis was undertaken. de Paula and Mialhe (2013) concluded that school performance and school attendance were associated with OHCs. On the contrary, Ribeiro et al. (2018), based on the findings of two good quality papers, suggested no association between poor OH and school performance unless mediated by socioeconomic and psychosocial factors. Thus, the study could not support the association. It is important to mention that Rebelo et al. (2019) and Ruff et al. (2019) justified combining the data in a meta-analysis using a random-effects method.

Consequently, Rebelo et al. (2019) suggested that children with one or more carious teeth or those with a poor parental perception of their child's OH were more likely to experience poor school performance and poor school attendance (Table 11).

Table 11. The result of the relation between OH measures and school outcomes from Rebelo et al. (2019) metanalysis

	Decayed tooth/teeth	**Poor parental perception of the child's oral health OH**
Poor school performance	↑ 44%	↑ 51%
Poor school attendance	↑ 57%	↑ 35%

At the same time, Ruff et al. (2019) reported that children and adolescents with poor OH have a higher probability of having low academic performance (OR: 1.52; 95% CI, 1.20-1.83) and high school absenteeism (OR: 1.43; 95% CI, 1.24-1.63), than children with better OH.

2.4.7.14. Risk of bias

The methodological quality assessment was performed on all the systematic reviews, except for de Paula and Mialhe (2013). However, the quality assessment tool and the rating scale varied among these reviews.

Ruff et al. (2019) used the modified NOS for non-randomised studies. The studies were classified as low risk of bias (≥ 4 points) and high risk of bias (<4), giving the cross-sectional and the case-control equal scores. Similarly, Rebelo et al. (2019) used the modified NOS but different scales. Cohort and case-control were rated as low-risk studies if they received a score of 9 stars, those with scores of 6-8 stars were evaluated as moderate, whereas those with less than five stars were considered low quality. The cross-sectional studies had to score 7 to earn a low-risk assessment, 4-6 stars were scored as moderate, and those with three or less were assessed as low quality.

Ribeiro et al. (2018) used the National Heart, Lung and Blood Institute tool with ten items scale. Accordingly, the studies that discussed all the ten items were evaluated as good. In contrast, papers that discussed seven items were considered fair.

Likewise, the authors evaluated papers as of poor quality if they did not discuss the validity and reliability of exposure, whilst the use of self-reported outcome measures and no confounders statistical analysis was evaluated. This reflects the variations of their results concerning the quality assessment (see Table 12).

Rebelo et al. (2019) evaluated two studies as low quality and the rest as moderate quality. Ruff et al. (2019) evaluated four studies as having a high risk of bias and the remaining as low risk of bias, while Ribeiro et al. (2018) assessed two studies as having good quality, one was fair and the remaining as being of poor quality.

Table 12. The risks of bias results from the three reviews (Rebelo et al., 2019, Ruff et al., 2019, Ribeiro et al., 2018)

Authors	**Rebelo et al., 2019**	**Ribeiro et al., 2018**	**Ruff et al., 2019**
Petridou et al., 996			High risk
Viviane and Sandra., 2003		Poor	
Jiang et al., 2005	Moderate		High risk
David et al., 2006			High risk
Blumenshine et al., 2008	Moderate		
Pongpichit et al., 2008			Low risk
Jurgensen & Petersen., 2009			Low risk
Jackson et al., 2011	Moderate		
Gradella et al., 2011	Moderate		
Garg et al., 2012	Low	Poor	
Guarnizo-Herreno and Wehby., 2012	Moderate		Low risk
Piovesan et al., 2012	Moderate	Good	Low risk
Seirawan et al., 2012	Moderate	Fair	Low risk
Krisdapong et al., 2013	Moderate		Low risk
Detty and Oza-Frank., 2014			Low risk
Agaku et al., 2015	Moderate		Low risk
de Paula et al., 2015a	Moderate	Good	Low risk
Osman & Alsayed., 2015		Poor	
Neves et al., 2016	Low		
Paula et al., 2016	Moderate		Low risk
Sameer et al., 2016	Moderate		High risk
Nausana et al., 2016	Moderate		
Maharani et al., 2017	Moderate		
Kaewkamnerdpong and Krisdapong., 2018	Moderate		
Naavaal and Kelekar., 2018	Moderate		

2.4.7.15 Publication bias

Rebelo et al. (2019) did not test for publication bias because they argued that the meta-analysis included less than ten studies. On the contrary, using funnel plots, Ruff et al. (2019) tested less than ten studies for publication bias. The result suggested a lack of small studies in the current literature.

2.4.7.16 Funding and conflict of interest

Rebelo et al. (2019) and Ruff et al. (2019) reported no conflict of interest. Only de Paula and Mialhe (2013) described its source of funding.

2.4.7.17 Recommendations

Despite the diversity between the four systematic reviews, they reported similar recommendations. All the reviews agreed with the need for more high-quality longitudinal studies involving different populations and age groups. These should consider using valid measures and control for confounders, such as socioeconomic status, family structure, general health and others. They also suggested the adoption of reliable and valid measures to assess OH. When it comes to dental caries, Ribeiro et al. (2018) recommended the use of indices such as Pulpal involvement, Ulceration, Fistula and Abscess (PUFA) and Caries Assessment Spectrum and Treatment (CAST) to account for the different stages of the caries status. Finally, using reliable data, such as school records of both school performance and school attendance, to assess those outcomes will strengthen the results of such studies.

2.4.8 Discussion

The four systematic reviews covered 39 primary studies, encompassing 359,912 children aged between 3 and 19 years. All the reviews suggested an association between OH and school performance and attendance except for Ribeiro et al. (2018).

Nevertheless, there were many methodological differences among the 39 primary studies, limiting the reviews' generalizability and strength. For example, 92% of the studies were cross-sectional, with primarily low or moderate quality. Similarly, roughly 30% of the primary studies relied on self-reported measures of dental caries rather than a clinical examination. Several studies relied on parents’ reports of their child´s oral health (Jackson et al., 2011), raising concerns about the validity of these measures (de Almeida et al., 2013).

Although the remaining studies involved a dental clinical examination, most studies relied on data obtained using the DMFT index to assess dentine dental caries (Kaewkamnerdpong and Krisdapong, 2018) or gathered DMFT data from hospital records (Egri and Gunay, 2004). Despite being the most commonly used index worldwide to assess dental caries (Casamassimo et al., 2009), only cavitated teeth are registered through DMFT, limiting a proper assessment of the severity of dental caries (de Souza et al., 2014).

Only one of the primary studies (Gradella et al., 2011), a moderately well-designed cross-sectional study, accounted for the severity of dental caries and their untreated sequela when exploring links between OH, school performance and school attendance. Nevertheless, this is crucial in assessing such an association, as some studies showed no association between cavitated caries and school performance unless dental pain was present (Seirawan et al., 2012).

In addition, 36% of the studies measured overall school performance based on school grades, while the remaining studies relied on self-reported measures. Some of these studies applied the OIDP index as a proxy for school performance (Bernabé et al., 2007), some used adolescent self-reported measures (Petersen et al., 2008), and one study relied on parents' self-reporting (Blumenshine et al., 2008).

Similarly, only four studies measured the latter via school records of the 12 studies that assessed the link between OH and school attendance. Other studies relied on self-reported measures. However, relying on self-reported measures to assess school outcomes might not be sufficient due to the lack of knowledge of the validity and reliability of those measures, which might result in a recall or social desirability bias (Althubaiti, 2016).

Another relevant aspect to mention is that 43% of the studies primarily used in the review by de Paula and Mialhe (2013) did not aim to study the impact of OHCs on school performance or attendance. For example, some studies aimed to explore the prevalence of oral impacts on children's daily performance using QoL instruments like OIDP or C-OIDP (Bernabé et al., 2007, Astrøm and Okullo, 2003, Gherunpong et al., 2006). In their study, Sandra et al. (2005) aimed to evaluate the psychosocial effect of dental caries using the Parental–Caregivers Perceptions Questionnaire (P-CPQ).

The results of these studies were used to make inferences on the association between OHCs and school performance and attendance, considering the QoL instrument as an indirect measure of evaluating children's school outcomes. Nevertheless, they are not designed specifically to evaluate school outcomes, which might introduce measurement biases. Therefore, combining those studies to examine one specific research question may affect the validity of their results.

Furthermore, most studies on this topic involved children in Western societies, limiting their generalisability, especially in Middle Eastern countries, which have a remarkably higher rate of OHCs (Morgano et al., 2010). Although two of the primary studies (Osman and Alsayed, 2015, Sameer et al., 2016) were cross-sectional studies conducted in Middle Eastern countries, both were evaluated as having poor methodological quality, according to Ribeiro et al. (2018) and Ruff et al. (2019), respectively.

Finally, a noteworthy limitation of the previous studies is that 38% of them did not account for relevant confounders. Some studies accounted for SES and demographics, although school outcomes could also be shaped by other family and psychosocial factors (Banerjee, 2016). Thus, the association between OH and school performance could be confounded or mediated by other relevant aspects, and a comprehensive framework should be considered to investigate the association between the variables. However, unfortunately, such a framework was not evident among the 39 primary studies.

Thus, the question as to the role of OH in school performance and attendance and the pathways which may link these remains unclear among children and adolescents.

2.4.9 Conclusion

This review summarised the evidence on the association between OHCs and school performance and attendance from previous systematic reviews. Their findings suggest that OHCs, particularly dental caries, can negatively affect school performance and the attendance of children and adolescents. Nevertheless, the existing evidence remains unclear due to the many methodological issues of the primary studies. These limitations include the use of unstandardised measures, together with poor adjustment for confounders, both of which mean that it has not been possible to assume a cause and effect relationship between OHCs and school performance and school attendance.

2.4.10 Updates of the systematic reviews

This section presents an update of the primary literature regarding the impacts of OHCs on children's and adolescents' school performance and school attendance. The search was carried out to identify and assess relevant newly published papers from 2018 until July 202. Details regarding search strategy, mesh terms, and Prisma are reported in Appendix 7.

The new search retrieved eight recent observational studies apart from those included in the four systematic reviews. Those studies examined the association between OHCs and school performance and/or school attendance among children and adolescents aged between 5 and 17 years, involving 157,114 participants. The description of the studies, including their main characteristics, primary findings, and limitations, are reported below.

2.4.10.1 Studies' characteristics

The characteristics of the eight studies are described in Table 13. Overall, there were seven cross-sectional studies (Gopalan et al., 2018, Almeida et al., 2018, Guarnizo-Herreno et al., 2019, Darley et al., 2021, Cunha et al., 2019, Karki et al., 2019, Quadros et al., 2021), and one longitudinal study (Ortiz et al., 2021). The studies were conducted in India (Gopalan et al., 2018), Nepal (Karki et al., 2019), and the US (Guarnizo-Herreno et al., 2019), and the rest were from Brazil (Table 13).

The research investigated different OHCs, including dental caries, malocclusion, consequences of untreated dental caries and dental pain. WHO's criteria for classifying dental caries using the DMFT index (Gopalan et al., 2018, Cunha et al., 2019, Quadros et al., 2021) or the D component of DMFT (Karki et al., 2019), or D and M components of DMFS (Ortiz et al., 2021) was used to evaluate dentine dental caries. Almeida et al. (2018) used the CAST index to measure caries and sequela. Interestingly, two studies also measured sequela of dental caries using the pufa/PUFA index (Karki et al., 2019, Quadros et al., 2021). In the remaining studies, questionnaires were used to assess oral conditions (Guarnizo-Herreno et al., 2019, Darley et al., 2021).

In addition to dental caries, one study assessed malocclusion using the DAI (Ortiz et al., 2021), one assessed periodontal problems, overjet and open bite as dentofacial problems (Cunha et al., 2019), and one assessed oral health by OHI-S (Gopalan et al., 2018).

Perceptions of a child's OH was examined in some studies. Guarnizo-Herreno et al. (2019) used caregivers' (primarily parents) ratings to assess participants' current OH (categorised as excellent, very good and good versus fair and poor). Other studies used OHRQoL of life measures like the Child Perception Questionnaire (CPQ8-10) (Almeida et al., 2018), the C-OIDP (Karki et al., 2019), and the OIDP (Cunha et al., 2019). Among these studies, only Karki et al. (2019) used OHRQoL as an outcome measure (along with school performance and absenteeism).

Additionally, dental pain was included in five studies. In two studies, the parents reported the child’s dental pain via questionnaire (Guarnizo-Herreno et al., 2019, Ortiz et al., 2021), while it was recorded in Almeida et al. (2018) during the dental examination. In the two studies, adolescents self-reported dental pain was assessed (Cunha et al., 2019; Darley, 2021).

Psychosocial factors also were considered in three studies. Gopalan et al. (2018) used the Rosenberg self-esteem scale to evaluate children's self-esteem, whereas Ortiz et al. (2021) measured verbal bullying related to OH via a structured questionnaire. Social capital, as indicated by community level of support, crime level, and adolescent level of happiness, was assessed by Cunha et al. (2019).

Overall, all studies used self-administered questionnaires to collect data regarding demographics, SES, and access to dental services, mostly answered by parents, except for Cunha et al. (2019) and Darley et al. (2021), the questionnaire answered by adolescents. However, one study collected children's demographic characteristics from school records (Karki et al., 2019). Two studies did not mention how those data were collected (Guarnizo-Herreno et al., 2019, Quadros et al., 2021). Three studies also collected data regarding the utilisation of dental services (Ortiz et al., 2021, Darley et al., 2021, Cunha et al., 2019).

All eight studies assessed participants' school performance except for Darley et al. (2021). Four of them obtained grades from the school register (Almeida et al., 2018, Ortiz et al., 2021, Karki et al., 2019, Quadros et al., 2021). While Gopalan et al. (2018) included two measures for school performance, one was last year grades of first language and mathematics obtained from the school register, and the second was parent's report of homework completion. On the other hand, Guarnizo-Herreno et al. (2019) used the National Survey of Children's Health (NSCH) data to obtain school performance data originally collected from caregivers via questionnaires. In contrast, Cunha et al. (2019) measured school failure by asking adolescents to inform their year of study, which was converted into years of schooling to differentiate delay and repetition regarding progress according to the expected age.

Darley et al. (2021) measured school absenteeism in the past 12 months based on adolescent's self-report as the outcome measure. School absenteeism was also measured in three studies (Gopalan et al., 2018, Guarnizo-Herreno et al., 2019, Karki et al., 2019), which was recorded for the past academic year from schools' registers except in Guarnizo-Herreno et al. (2019), where participants' caregivers reported school attendance.

2.4.10.2 Results

2.4.10.2.1 School performance

The association between OHCs and school performance was reported in seven studies. Of the six studies that assessed dental caries through clinical examination, two studies (Cunha et al., 2019, Quadros et al., 2021) found a significant association with school performance. Quadros et al. (2021), in a cross-sectional study using path analysis, found a direct positive association between sequela of dental caries and poor school performance, while dental caries was found to influence poor performance via sequela of dental caries among Brazilian adolescents. Similarly, Cunha et al. (2019) found that adolescents with dental caries, tooth loss, and dentofacial problems were more likely to fail at school.

On the other hand, Karki et al. (2019) concluded that dental caries' experience and consequences significantly affect school performance, school attendance, and quality of life among Indian children and adolescents. The adjusted models revealed that the combination of sequela of untreated caries and dental caries was only associated with C-OIDP. Dental caries, sequela, and restored teeth were associated with neither school performance nor attendance. Almeida et al. (2018) and Ortiz et al. (2021) did not find an association between dental caries and school performance. Still, the former found a significant association between CPQ (8-10) and school performance and the latter reported OIDP to be significantly associated with school failure.

Gopalan et al. (2018) found that irregular homework completion was associated with more dental caries among Indian adolescents. However, children with at least one dental problem, including dental caries, could have more school problems and miss one school day by at least 50%. Further, children with poor/fair reported OH were 80% more likely to have school problems and more likely to miss three school days or six by about 60% and 90%, respectively (Guarnizo-Herreno et al., 2019).

Concerning dental pain and other psychosocial factors and school performance, Ortiz et al. (2021) found dental pain and verbal bullying because of OH to be associated with lower school performance but not with other OH clinical measures (DMFS, DAI). Also, Cunha et al. (2019) found that adolescents feeling insecurity, unhappiness, and dental pain were more likely to fail school. However, Gopalan et al. (2018) found no significant association between self-esteem and OH as measured by OHI-S and DMFT.

Except for Gopalan et al. (2018), which stratified the results by gender, all other studies evaluated and adjusted the analysis for some demographic and socioeconomic factors. The final models showed that only a few of those were significantly associated with the outcomes. Being male predicted poor school performance among Brazilian children and adolescents (Ortiz et al., 2021, Quadros et al., 2021), and a higher maternal educational level and living in a family with a high income was associated with high academic performance among Brazilian adolescents (Ortiz et al., 2021). In contrast, Cunha et al. (2019) found that being female, declaring a non-white ethnic group, and being over 16 years old was associated with school failure.

Finally, two studies investigated the association between access and visit to dental care and school performance, but the results showed no significant link between them (Ortiz et al., 2021, Cunha et al., 2019).

2.4.10.2.2 School absenteeism

Overall, all four studies that evaluated the association between OHCs and absenteeism found those to be significantly associated (Gopalan et al., 2018, Guarnizo-Herreno et al., 2019, Darley et al., 2021, Karki et al., 2019). Gopalan et al. (2018) reported a significant association between school absenteeism, caries, and poor gingival health. Similarly, Darley et al. (2021) reported an association between dental pain, frequency of dental visits and school absenteeism. Likewise, Guarnizo-Herreno et al. (2019) showed that children with reported oral health problems were more likely to report poor school attendance. Even though Karki et al. (2019) stated that dental caries and their sequelae were associated with school absenteeism, the link between both was not supported by the final adjusted models.

2.4.10.3 Discussion

As the above studies are more recent, one would expect them to account for previous shortcomings. Thus, producing more robust and conclusive results regarding the association between OHCs and school performance and school attendance.

In fact, some studies accounted for some of the previous limitations, such as the use of more robust measures to assess dental caries (CAST), its sequelae (pufa/PUFA), as well as the use of school records and the adoption of theoretical models. However, this was not clear in the study of Guarnizo-Herreno et al. (2019). This may have something to do with making the study more comparable to its preceding one

(Guarnizo-Herreño and Wehby, 2012). Another factor that may have contributed to the reduction of the quality of the study was the use of secondary data. However, Darley et al. (2021) applied a theoretical model to support their results using secondary data.

Despite that, definitive conclusions concerning the association between OHCs, and school performance and/or school attendance are still unclear. One aspect that might explain such differences is the diversity of the characteristics between studies, such as differences in the measurement of variables and outcomes, country of origin, and the selection of participants. On the other side, the inherent limitations of these studies were another factor that contributed to the observed disparities.

To illustrate such limitations, Gopalan et al. (2018) examined children for dentine caries (DMFT) and gingival health (OHI-S) in 2014. In contrast, school performance and attendance data were obtained from previous academic year school's records. Additionally, the parents reported data regarding homework completion, but it was not clear whether it was from 2014 or the previous academic year. Thus, there is confusion and concern about temporality. Although the authors claimed that the study aimed to evaluate the impact of school performance and attendance on students' OH (reverse causation); however, the theory behind claimed association was not explained.

Similarly, the Karki et al. (2019) study concluded that untreated dental caries and their consequences significantly affected school performance, school attendance, and students' quality of life. However, in the final adjusted models, it was only the combination of pufa/PUFA and dental caries to grade the severity of untreated dental caries (GUDC) associated with C-OIDP. Simultaneously, no relation was demonstrated between dental caries, its sequelae, or the combination of both (GUDC) with neither school performance nor school absenteeism. Thus, the study conclusions were not supported by their results.

Concerning Ortiz et al. (2021), the study was designed to be longitudinal with two years of follow-up to collect OHCs measures (D, M and DAI) and other school performance variables. Nevertheless, the methodology was not accurately described, leading the article to different interpretations. According to the authors, OHCs were measured in 2012, and school performance was recorded in 2014 to establish temporality. However, the authors mentioned reassessment of the participants in 2014 and reported different data than in 2012 for demographics and clinical variables in tables. This suggests that two examinations have been conducted. However, the authors did not report any recalibration for their examiners after two years, nor did they report which clinical data were used to relate OHCs to school performance. One may suggest that 2012 records were used for such a correlation to claim temporality. Though such an interpretation does not seem logical, knowing that in 2012 there were 1134 participants, and in 2014 there were 771 participants. Of them, only 644 had complete academic performance records. The authors did not explain how missing data were handled, if there are any. Finally, the authors acknowledged that their analysis was cross-sectional.

Finally, except for Gopalan et al. (2018), all the other studies used some form of regression analysis to consider confounders. The former study used stratification to account for gender. Ideally, the authors should have reported the OR for both stratified and unstratified models, tested homogeneity between them, and reported adjusted estimates or whether the adjusted models should be reported separately, such as for boys and girls (Kahlert et al., 2017). Unfortunately, only the results of the models were reported (stratified and unstratified). Hence, it was unclear which model fits the data best.

Among seven studies, regression analysis was adjusted for confounders; three did not use theoretical models (Almeida et al., 2018, Guarnizo-Herreno et al., 2019, Karki et al., 2019). The other four studies used theoretical models (Darley et al., 2021, Ortiz et al., 2021, Cunha et al., 2019, Quadros et al., 2021). Two of these studies used hierarchical levels (Cunha et al., 2019; Darley et al., 2021), but no details were given on how the models were developed. In contrast, Quadros et al. (2021) and Ortiz et al. (2021) both explained the grounds of their models and used model fit indices to assess the goodness of fit. Where Ortiz et al. (2021) used multilevel logistic regression analysis, Quadros et al. (2021) used path analysis to measure direct and indirect effects.

The selection of confounders based on fit models is a definitive improvement in the analysis, but the challenge remains if all the confounders were accounted for in the first place. Thus, it is wise to explore other social factors within the child's immediate environment, such as family, school, and peers, that influence their development, including their cognitive and OH (Bronfenbrenner, 1977). Also, exploring different analytical methods may help capture the complex and interrelated pathways between these variables to help reach more valid results.

2.4.10.4 Conclusion

To conclude, many studies have explored the association between OH and school performance and school attendance. However, the nature of the association has not been confirmed to date because of the heterogeneity between studies, data quality, and limited analytical approach.

Table 13. Summaries of recent studies on the impacts of OHCs on school performance and attendance among children and adolescents (2018-2021)

Author-year	Study design	Setting/country	Participant age	Sample size	OH measures	Outcome	Outcome measure	Main findings
Goplan et l., 2018	Cross-sectional	Tiruchengode/ South India	12-15	2014 907 girls 1107 boys	DMFT OHI-S	Self-esteem Absent Performance Homework	Rosenberg (1995) School records Marks for language and mathematics Parents	1. Significant link between school absences, caries, and poor OHI 2. Irregular homework completion associated with caries
Almeida et al., 2018	Cross-sectional	Brazil	6-8	374 189 girls 85 boys	Assessment Spectrum and Treatment (CAST) Dental pain CPQ	School performance	Reading and mathematics (Provinha Brasil exam)	1. No association between school performance and carious or dental pain. 2. Children with lower school performance had higher CPQ scores.
Karki et al., 2019	Cross-sectional	Nepal	5-6 12-15	1137	dmft/DMFT pufa/PUFA C-OIDP	School performance attendances	School register	1. High caries rate and pufa/PUFA has a high impact on C-OIDP, school absenteeism and performance 2. High absent rate associated with poor school performance
Guarnizo-Herreño et al., 2019	Cross-sectional	US	6-17	45711	Parent report of children OH problem Child self-reported OH	School performance	School report if the child has any problem in school	1. At least one dental problem can associate with school problems, and miss at least one school day by at least 50% 2. Poor/fair OH perception can associate with 80% of school problems and link with missing 3 school days or 6 by about 60% and 90%.
Cunha et al., 2019	Cross-sectional	São Paulo-Brazil	Adolescence	5162	Caries Periodontal Open bite overjet OIDP	School failure	Delay and repetition regarding progress according to the expected age	1. Adolescents > 16 years, non-white, female insecurity, unhappiness, dental pain, , caries, tooth losses, dentofacial, periodontal changes were more likely to fail at school

Quadros et al., 2021	Cross-sectional	Manaus-Brazil	12	363	DMFT pufa/PUFA	School grades	School register	1.Dental caries linked with poor school performance via pufa/PUFA 2.Being male predicted poor school performance
Ortiz et al., 2021	Longitudinal -2 years follow-up	Brazil	12	1,134 610 girls 524 boys 771 410 girls 361 boys	DMF-S DAI	School performance 2014	Basic Education Development Index (IDEB) School register	1. Toothache, verbal bullying and being male had a lower academic performance. 2. High SES was associated with high academic performance.
Darley et al., 2021	Cross-sectional	Brazil	13-17	102,072	Dental pain Dental service	School absenteeism	Self-reported questionnaire by adolescent	1. The link between dental pain, school absenteeism, and increased absenteeism rate with increasing dental visits.

2.5 Predictors of school performance and attendance

2.5.1 Overview

In September 2015, the United Nations (UN) Sustainable Development Assembly for 2030 established seventeen global goals to defeat poverty inequality and improve health, with education being the stepping stone of each of the seventeen goals (United Nations, 2010).

Several individuals, parental, family, and environmental factors besides OHCs can restrict children's access to quality education and limit their academic potential (Banerjee, 2016). Because these variables reflect different environment levels, some researchers have proposed a bioecological model to explain school performance and attendance predictors over time (Melvin et al., 2019, Brownell et al., 2016).

The most commonly used bioecological model to explain predictors of school outcomes is the Bronfenbrenner (2005) model of child development. This model views child development as a multifaceted system of relationships influenced by a nested hierarchy of environments, from the immediate settings of parents, peers and schools to overall cultural values and laws (Figure 5). The connections between the individual and their environment shape their development over time.

The centre of the Bronfenbrenner model focuses on the child's own individual biological and physiological factors (e.g., gender, age, knowledge, attitude, skills, and beliefs). The model has different environments around the child’s that might influence the child's attributes and development. These systems are expressed in external layers, including the microsystem, which includes parents, schools, and peers (proximal factors); mesosystem, which includes connections between two systems or two tenets of the child's microsystem (e.g. the association between parents and teacher); exosystem which includes the contexts that shape components of the microsystem but are not directly related to the child (e.g. parent workplace); a macro system which includes culture, laws, politics, and broader society; chronosystem which includes the effect of time, changes and transitions over time (e.g. divorce) (Bronfenbrenner and Morris, 2006). Further, the model argues that the proximal system (microsystem) influences a child's development more than those in the distal system.

This section briefly explains the predictors of children's school performance and attendance, especially those within the children's immediate environment using the Bronfenbrenner (2005) bioecological model.

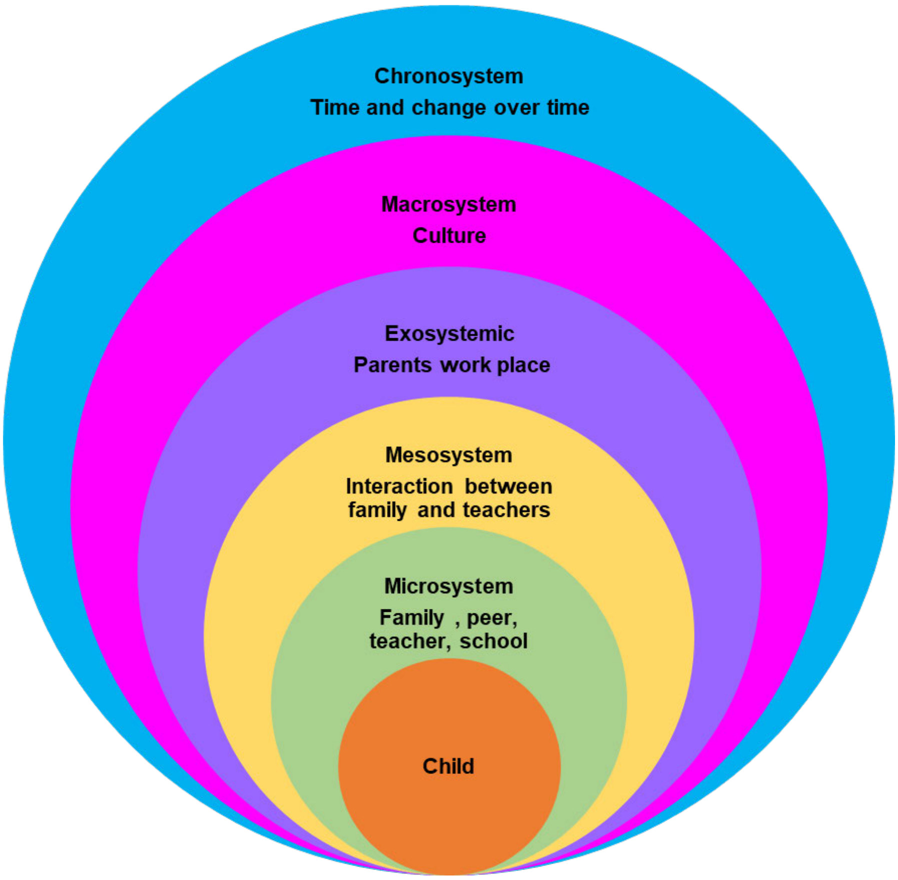


Figure 5. The Bronfenbrenner (2005) bioecological model for child's development

2.5.2 Child's characteristics

Bronfenbrenner and Morris (2006) identified individual characteristics as demand, resource, and force attributes. Demand is one of the attributes of the individual that directly appears to others, including age, gender, and ethnicity. Resource attributes refer to individual skills, abilities, disabilities, and experience. Force attributes include behavioural factors that influence individual development.

2.5.2.1 Demand

Demand attributes such as gender and ethnicity have been linked to school performance and attendance. School performances (Spinath et al., 2014, Epstein et al., 1998) and school attendance (Corville-Smith et al., 1998, Gubbels et al., 2019) tend to be higher among females than male students, particularly in countries where equal educational opportunities are in place. The reason for this gap is not well understood. However, some researchers have suggested that individual attributes like intelligence, motivation and self-regulation can explain this variation to some extent (Spinath et al., 2010). However, others found no association between gender and school performance (Chambers and Schreiber, 2004), while the link between gender and school attendance rate might differ by type of absenteeism (Skedgell and Kearney, 2018).

Race has been shown to influence student academic life in the US. African American and Hispanic students showed lower scores at school than White students (Seyfried, 1998). In addition to poverty and fewer resources to invest in their children's education (Banerjee, 2016), both former groups experienced discrimination and were disconnected from their classmates and schools, which provided an unfavourable environment to achieve higher grades (Crosnoe et al., 2004). Also, a report by the US

Department of Education (2016) indicated that Indian, Pacific, and Black students were more likely to miss school classes than their white peers. However, Maynard et al. (2017) found that racial differences were associated with other factors like older age, alcohol and marijuana use, and fighting, which increased the risk for lower academic engagement and poor school performance among those minority groups.

Recent data from the UK shows mixed results when exploring how child poverty and education outcomes varied for different ethnic communities. For example, children from Bangladeshi and Pakistani backgrounds were the most likely to live in low SES conditions among all ethnic groups in the UK; however, they had higher educational outcomes than the national average (Antonopoulos et al., 2021).

2.5.2.2 Resource

A range of resource attributes was also linked to school outcomes, including biological and psychological factors. Below average intelligence (IQ) and cognitive abilities have been considered one of the main predictors of school performance (Roth et al., 2015).

Consistent with the critical period model, some studies have shown that low birth weight influenced cognitive development and abilities in childhood (Farajdokht et al., 2017) and adulthood (Grove et al., 2017). A recent systematic review studied the association between very low birth weight (<1500g=VLBW) and cognitive functions in children (Farajdokht et al., 2017). Evidence from forty-four longitudinal studies found that VLBW babies showed a higher incidence of adverse cognitive outcomes, including low IQ, poor language skills, learning and memory deficits, attention deficit, poor academic performance, and behavioural problems compared with normal birth weight children.

Malnutrition and chronic health conditions are essential resources influencing children's school outcomes. At the age of three, malnutrition has been linked to poor cognitive functions at the age of 11 in Mauritius, alongside anti-social behaviour at the age of 8, 11, and 17 years (Liu et al., 2004). Iron deficiency, anaemia, zinc and vitamins A, B2, B1, B6, D3, and E deficiencies have been linked with long-lasting cognitive development problems (Liu et al., 2004). Disabilities such as hearing impairment (Roberts et al., 2002), visual impairment (Simons, 2005), asthma (Forrest et al., 2013), epilepsy (Schouten et al., 2002), cerebral palsy (Beckung and Hagberg, 2002), sickle cell (Schatz et al., 2001), thalassemia (Nash, 1990), haemophilia (Shapiro et al., 2001), obesity (Caird et al., 2014), and type I diabetes have been linked to poor academic performance (McCarthy et al., 2003). Another group of health-related conditions related to genetic disorders that might influence children's school achievement is neurobehavioral disorders, including specific learning disability (SpLD), autism spectrum disorder, attentive deficit hyperactivity disorder (ADHD), and Tourette syndrome (Forrest et al., 2013, Karande and Kulkarni, 2005). The association between most of these health conditions and academic performance is mediated by school absenteeism due to medication or hospital visits (Jones et al., 2009).

2.5.2.3 Force

Force attributes represent many children's behaviours that can influence their school life. For example, self-regulation, defined as the individual's capability to control their thoughts, emotions, and behaviours to maintain goal-oriented action, was positively associated with school performance (Weis et al., 2013) and school attendance (Balkıs et al., 2016). Self-regulated students are more proactive at school because they have goals, develop a creative learning environment, apply effective learning measures and have self-efficacy beliefs (Zimmerman, 2011).

Another example of force attribute is school engagement, known as effective involvement in the learning process inside and outside the classroom (Kuh, 2007). Low levels of student school engagement cause academic struggles, behavioural problems, high rates of absenteeism, and high dropout rates (Fredricks et al., 2004). Engagement might be cognitive, which refers to students' effort to exceed school requirements or invest in their learning process (Metallidou and Vlachou, 2007). Engagement might be emotional in terms of their value and feelings about school, but it is challenging to observe their inner feeling. However, this can also be manifested as fear or enthusiasm for homework and interactions with teachers and school extracurricular activities (Reschly and Christenson, 2006). Engagement can also be a behavioural aspect, manifested by student concentration and participation in in-class activities by asking and answering questions or participating in extracurricular activities (Skinner et al., 2008). However, the three definitions are argued to be correlated; for example, it has been suggested that behavioural engagement is shaped by emotional engagement (Pekrun et al., 2002). Similarly, studies on cognitive engagement relate to student emotions and behaviours toward learning (Zimmerman, 1990).

School dropout is a serious problem related to student disengagement and poor school achievement (Fredricks et al., 2004). Most research focusing on this correlation argue that behavioural engagement is a strong predictor of school dropout. Studies have shown that less engaged students, as reflected by high school absenteeism, make less effort, do not do homework, and do not participate in extra-curricular activities (Ekstrom et al., 1986). Also, students who skip school and are suspended from school are more likely to drop out of school (Connell et al., 1995). These results have been confirmed by a longitudinal study carried out in a high school in Canada (Archambault et al., 2008).

2.5.3 Microsystem/mesosystem

Parents or caregivers, teachers, and peers are part of the children's microsystem. Positive connections between these create a balanced and inductive environment for growth and learning (Bronfenbrenner, 1977).

2.5.3.1 Parents

Important parental factors related to student performance and school attendance include parent-child interaction in terms of early life attachment, children´s academic activities, and parenting style. These attributes have been considered effective predictors of student school engagement, motivation to attend school and attain higher school performance (Ansong et al., 2017, Blondal and Adalbjarnardottir, 2014, Gubbels et al., 2019).

The type of association and attachment between parents and children established from birth plays a vital role in predicting children's future social interactions with teachers and peers. They also influence children´s desire for learning, curiosity, emotional control, independence, and self-esteem (Sroufe, 2005). Ekman (2004), in his book 'Emotions Revealed', stated that infants' brains are ingrained in only six feelings: fear, joy, sadness, anger, surprise, and disgust. Therefore, infants under three years old should be fostered with the primary caregiver and provided unconditional love, support, safety, and a stable environment to have a healthy life. Attunement or harmony between parent and infant is critical between 6 and 24 months of children's life to instil healthy emotions like empathy, forgiveness and appreciation. Deficits in meeting these needs could impair the development of the infant brain, emotions, maturation, and enthusiasm for schooling and education attainment (Clarke and Younas, 2017).

Parental school involvement generally refers to the active participation of parents in children's education process (Jeynes, 2000, Jeynes, 2017). It refers to different dimensions, including parental expectations of their children's school potential, monitoring and involvement with children´s homework and progress, attendance of school meetings about children´s progress, and participation and volunteering in school activities (Epstein and Dauber, 1991). Thus, it could consider a microsystem or a mesosystem as it involves dimensions connecting parents to child and parents to school and teacher.

In 2003, 2005, 2012, and 2017, Jeynes performed four meta-analyses to identify the association between parental involvement and school performance in primary and elementary schools. The analyses of 21 studies (1988-1999) suggested that parental involvement generally influenced academic achievement among primary school children despite differences in ethnicity or gender (Jeynes, 2003). Moreover, parental involvement influenced standardised test scores more than cumulative average grades. This result was confirmed in each of the four meta-analyses (Jeynes, 2003, Jeynes, 2005, Jeynes, 2012, Jeynes, 2017). In another meta-analysis, Kim and Hill (2015) examined the same association among kindergarten to 12th-grade children. Overall, the study found an association stronger in longitudinal studies than in cross-sectional ones. Father's and mother's involvement in education was significantly associated with student attainment, although mothers were more involved in children's academic activities than fathers.

The association between poor parental involvement and higher rates of school absenteeism has been confirmed (Kearney, 2008). Mothers with low academic expectations for their children and who are less likely to engage in extracurricular activities were found to have children with higher absence rates at school (Hancock et al., 2018).

Parenting style is another relevant family characteristic that influences children's school life. Masud et al. (2015) conducted a systematic review to examine the association between adolescent parenting style and school performance. The study reviewed 39 studies, including four longitudinal and 35 cross-sectional studies, published between 1987 and 2013. All primary studies confirmed the association between parenting style and academic performance and concluded that the authoritative style (high responsiveness, high demanding) was the most effective style to enhance children's school performance.

Pinquart (2016) conducted a comprehensive meta-analysis, integrating 308 original papers that assessed parenting dimensions with children’s school achievement published between 1974 and 2015. The study found that parent responsiveness, behaviour control, autonomy granting, and authoritative parenting were positively linked with school performance, although the effect was small. On the other hand, harsh parenting, psychosocial control, neglect, authoritarian, and permissive caring were associated with lower school achievement.

In addition, parenting style has been associated with chronic student absenteeism and high school dropout rates (Melvin et al., 2019). Blondal and Adalbjarnardottir (2014) conducted a longitudinal study to examine the association between parenting style and student retention in high school adolescents from Iceland from 14 to 22-years old. The result revealed that adolescents with authoritative parents were more likely to complete high school than non-authoritative parents.

The reason why authoritative parenting provides more advantages to children's school life is that authoritative parents (high responsiveness, high demanding) adopt specific achievement strategies like the high expectation of success, coupled with independent and critical thinking that positively influence their children's behaviours toward learning (Aunola et al., 2000). In contrast, children who experienced neglectful parenting were low academic performance because of maladaptive achievement strategies and behaviours. The permissive parenting style is described by high responsiveness but low control. Children exposed to this parenting style performed worse than children under the authoritative parenting style but better than children under the neglectful style (Pinquart, 2016).

2.5.3.2 Peers

Classmate peers are another tenet of an individual's microsystem that can impact learning engagement, especially during adolescence (Wang and Degol, 2014). The youth period has been described as the wish to 'fit in' period (Hamm et al., 2014). To avoid rejection and embarrassment, adolescents might adopt and display similar academic norms and beliefs to their classmates (Rambaran et al., 2017). Throughout the academic year, being together in school might also influence the similarity of academic norms among peers. Wong et al. (2018) recently explored the influence of peers on student emotional, cognitive, and behavioural engagement in Finland (N=1419; mean age=16). The study found that peers profoundly influenced the three dimensions of engagement. The study also found that adolescents with peers who valued school the most and were committed to learning were more likely to transfer these values to classmates. Also, Ansong et al. (2017) tested the association between parents, peers, teacher support, and student engagement in Ghana in adolescents aged 12 to 23 years. The study found that classmate support was the strongest predictor of school engagement.

2.5.3.3 Teachers

Teachers are a powerful instrument in the learning process as they can provide formal and informal social support. A constructive teacher-student association depends on warmth, empathy, and time and positively impacts student engagement and academic outcomes (O'connor et al., 2011). Hattie (2009), in his book 'Visible Learning', synthesised 800 meta-analyses relating to school attainment. It was concluded that the quality and nature of a teacher-student association had a greater influence on student achievement than student SES. According to Stipek (2006), students who performed poorly in school had a poor association with their teachers. Positive teacher expectations can raise motivation and engage students in class, increasing academic performance and school attendance (Tyler and Boelter, 2008).

2.5.3.4 Family structure

Family is the first environment where the child interacts. Since birth, family is the main source of the essential needs and amenities like care, food, love, shelter and factors needed for good physical, emotional, and cognitive development (Peet et al., 2015). Many family characteristics like structure, size, and stability can impact children' school life (Bronfenbrenner, 1996).

Studies have found that children raised in two-parent families showed better and more stable educational attainment than those raised in single-parent families (Oberlander and Black, 2011). Growing up in a single-parent family reduced children's educational achievement (Garriga and Martínez-Lucena, 2018) and increased the risk of delay in high school graduation and university attendance (Cavanagh and Fomby, 2012).

The explanation of schooling disadvantages according to the type of family structure is based on the conceptual model of parental investment from Coleman (1988); as much as parents invest financial, human, and social resources in their children's education, the better educational attainment for their children. According to Amato (2005), children raised by two parents had higher income, saved more money, were offered more time, supervision and care, and greater help with homework. Importantly, when one of the parents was in deficit in their social role, the second parent could make up the deficit (Amato, 2005). In contrast, upbringing in a single-parent household meant that the parental resources were reduced compared with two biological parents. Also, step-parents were less likely to invest or allocate resources for the education of their stepchildren (Coleman, 1988). However, a longitudinal study showed that the negative influence of the family structure on children school attainment was either decreased or eliminated when family socioeconomic resources were accounted for (Sun and Li, 2011).

In line with the above-mentioned theory, there have been many studies that have reported an inverse association between family size and children's academic achievement in terms of the use of resources (the quality and quantity model) (Becker, 1962, Becker and Lewis, 1973, Becker and Tomes, 1976, Becker and Barro, 1988, Becker, 1993).

This theory has been challenged, especially by (Black et al., 2005), who argued that the amount and quality of studies are insufficient to demonstrate a cause-effect association between education and family size. Consequently, Black et al. (2005) conducted a cohort study involving entire Norway’s population aged 16-74 years from 1986-to 2000. The study found a negative association between family size and education attainment, but the effect was attenuated when birth order was considered or use twin births suggesting association but not a cause-and-effect association. Similar results were found in Israel (Angrist et al., 2010).

However, family instability, such as divorce before school entry, is exceptionally critical in predicting poor academic achievement (Heard, 2007), acquisition of behavioural misconduct (Ryan and Claessens, 2013), alcohol misuse and drugs (Cavanagh and Fomby, 2012), and school absenteeism (Gubbels et al., 2019).

2.5.3.5 Family SES

Previous literature has shown that the higher the SES, the better the school performance (White, 1982, Sirin, 2005, Murphy, 2018) and the better school attendance rate among children (Henry, 2007, Morrissey et al., 2014).

Sirin (2005) investigated the evidence for the period 1990-2000 to determine the effect of family SES on children's school performance. The review concluded that SES influenced student academic scores directly through material resources and indirectly through the provision of social capital necessary for cognitive and social skills development and, therefore, to adapt to the school environment.

The direct influence of a family's SES on children's education outcomes means more resources to invest in their children education (Hsin and Xie, 2017). Such investment might have various forms, including stimulating children’s physical and general health and cognitive development with a healthy lifestyle, better housing conditions, and a safe neighbourhood (Evans et al., 2010). These features are less common in children from low-income families. Further, children from a high social class often benefited from private hired tutors, books, computers and other resources that facilitated their learning processes (Sirin, 2005). SES can also determine the quality and type of school children are admitted to (Murphy, 2018).

In contrast, the family can result in harmful health and safety conditions such as malnutrition, inadequate health care and environmental hazards that affect school and cognitive skills (Marmot, 2005, Burnett et al., 2015). Furthermore, living in poverty can result in poor quality housing (including dampness and crowding), increasing children’s risk of infectious and respiratory diseases, toxic materials like lead and smoking that can impair brain function (Evans et al., 2010). Thus, such exposures can increase missing days at school or late attendance (Morrissey et al., 2014).

Families with low SES tended to be overwhelmed with extra working hours, leaving children at home to care for themselves and/or relying upon elder children to look after their younger siblings, thus reducing the time available for homework or playing (US Census Bureau, 2006). They tended to experience conflicts and instability in their parent's relationship (Heard, 2007). Slack et al. (2004) revealed that parenting style became more rigorous as income decreased, eventually leading to child abuse and neglect. Hussey et al. (2006) reported that children raised in poverty were 1.5 times more likely to be physically abused, emotionally neglected, and two times more likely to report sexual abuse than well-nurtured children. These figures are also linked with parents alcohol or drug use. Child abuse is one of the important risk factors for children and adolescent depression (Jones et al., 2009) and school failure (Karande and Kulkarni, 2005). Child depression or chronic stress creates unconducive conditions for their learning, distracting their attention and concentration (Erickson et al., 2003) impairing their cognitive, memory and innovations (Lupien et al., 2001). These factors are related to 50% of school absenteeism (Jones et al., 2009).

However, evidence has shown that family socioeconomic conditions during childhood appeared to be more relevant in shaping children’s development later (Duncan et al., 2013). Inequality in education starts in the womb (Banerjee, 2016) and persists over time (Pearce et al., 2016). Each period in childhood, starting from the prenatal period, is considered critical or sensitive to the environment if exposed to adverse social circumstances (i.e., family income), and they can influence a child's educational development in different ways (Shonkoff, 2000). For example, consistent with Barker's hypothesis (Barker, 1990), living in an underprivileged family during the prenatal stage, as indicated by low birth weight and preterm birth, is associated with adverse outcomes across an individual's life. Such relationship includes the influence of social inequalities on cognitive development, learning difficulties and poor school performance in later life (Farajdokht et al., 2017, Martinson and Reichman, 2016). According to Karande and Kulkarmi (2005), up to 33% of children born between 32 and 35 of gestational age, and up to 25% of children born <2000g, are at higher risk of experiencing school difficulties in late childhood even if they do not have any neurological impairments. The association mentioned above is mediated by poor vocabulary, nonverbal intelligence, and problems with mathematics and concentration. A similar finding was reported in the meta-analysis (Allotey et al., 2018). Low birth weight children accounted for 38%-48% of the variation in vision impairment and were associated with lower scores in motor functions, behaviours, reading, mathematics, and spelling in elementary school children, and persisted to high school except for mathematics.

Another causal pathway through which family SES affects school outcomes in early life is via cognitive abilities (Hsin and Xie, 2017). Keane and Wolpin (1997) revealed that the most important period for cognitive development is early to middle childhood. During this period, families with high SES can offer greater material resources to develop children's learning skills, reinforcing their academic performance (Korenman et al., 1995). For example, Weizman and Snow (2001) found that children from a low

SES family experienced limited language skills because of the poor speaking skills of the caregiver, including the use of short sentences and a less comprehensive grasp of the language. Coley (2002) stated that 36% of parents with low SES read to their toddlers every day. In contrast, 62% of high-income parents read to their children on a daily basis.

2.5.4 Conclusion

To conclude, student school performance and attendance is essential for optimising a child's development. Besides OHCs, other aspects of the child's immediate environment, including parental and family factors, can influence these school outcomes. Nevertheless, most of them have not been considered when studying the association of OHCs with school outcomes in studies conducted to date. Yet, given that SES, parental and family factors can influence both OH and school outcomes, it suggests that integrating the micro-mesosystem from the bioecological model to Heilmann et al. (2015) life course framework provides an interdisciplinary framework to understand the associations between OHCs and school performance and attendance. The modification of Heilmann et al. (2015) was explained in the next section.

2.6 Theoretical framework of the present study

2.6.1 Overview

Although two models have been proposed to explore the link between OH status and quality of life measures (Wilson and Cleary, 1995, Locker, 1988), no models have been developed to investigate the possible influence of OH conditions on school outcomes. Yet, school performance and school attendance have been examined as one of the children's quality of life indicators in some OHRQoL measures, such as the Oral Impact on Daily Performance (OIDP) (Gherunpong et al., 2004) and Paediatric Oral Quality of Life POQL (Huntington et al., 2011).

This study adopted Heilmann et al. (2015) (Figure 5) for the OH life course framework (previously explained in Chapter 2, Section 2.2.4 (P.42)) modified to include the Bronfenbrenner bioecological-life course model (2005) (see Figure 6).

Both Heilmann et al. (2015) and the Bronfenbrenner (2005) models emphasise the importance of social, economical, biological, behavioural, and psychological factors on human development over time. However, within the bioecological model, the microsystem is the most influential level (Bronfenbrenner, 2005). The system looks specifically at the child’s life course within the context of family and school, considering their interrelationships (mesosystem) and their impacts on children’s development, including their educational one. Accordingly, adding it into the Heilmann et al. (2015) framework would provide theoretical explanations of how early life environment (family) is associated with children’s OH, school performance, and attendance. Additionally, it completes the Heilmann et al. (2015) framework for OH to explain other risk and protective factors of children’s OH from the context of family and their interrelationships.

Further, the Heilmann et al. (2015) framework recognises the interrelationship between oral and general health and their impacts on their quality of life. This pathway enabled this study to test the association of OH status with school performance and school attendance, considered important indicators of children's quality of life.

Thus, integration of the factors from the micro-mesosystem of the bioecological model into Heilmann et al. (2015) framework can explain the association and the pathways between OH and children's school outcomes by considering the most important factors related to both OH and school outcomes from the child's early and current life. The section below provides a further explanation of the modifications.

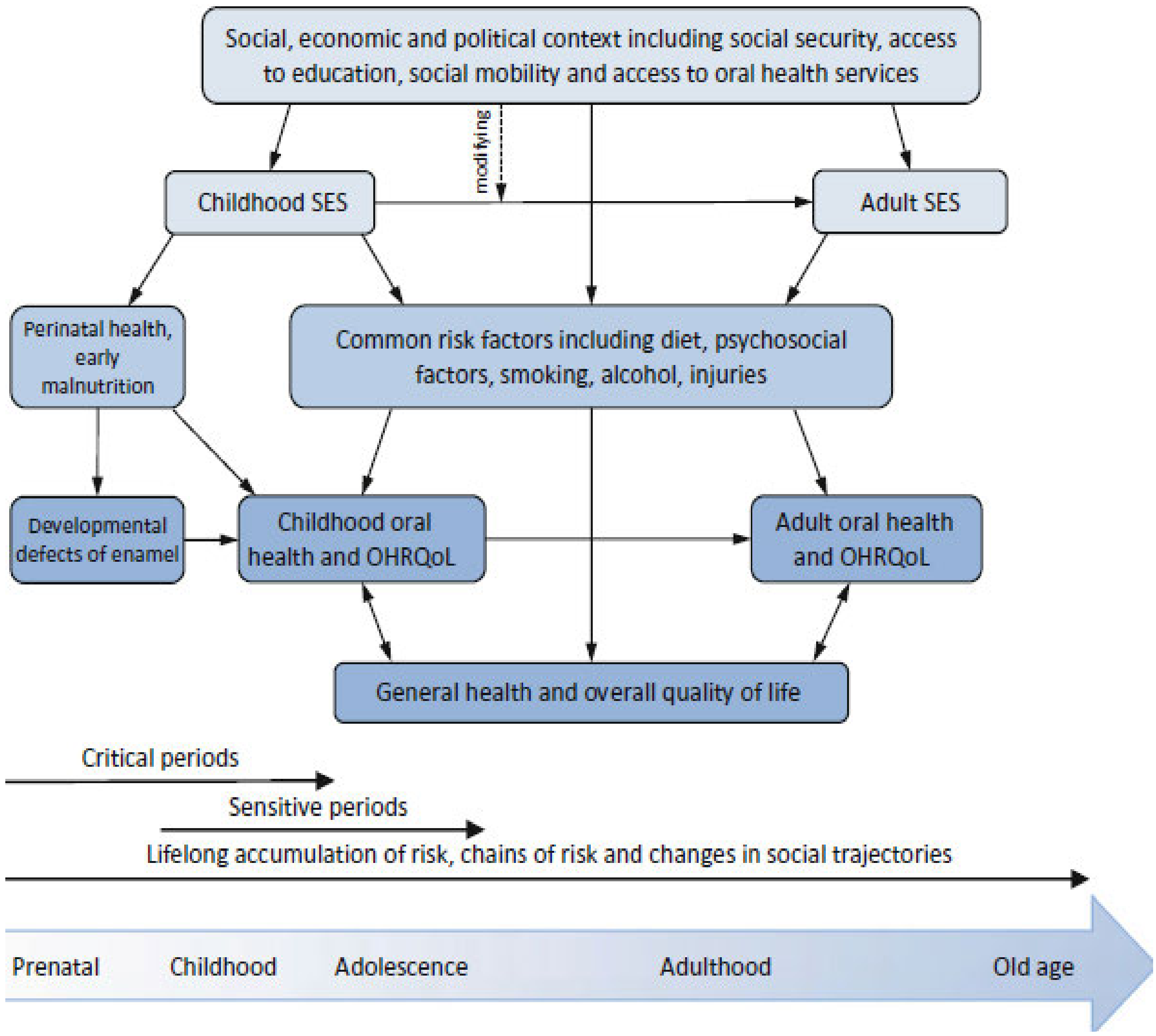


Figure 6. Life course framework for OH (Source: Heilmann et al, 2015)

2.6.2 Modifications to the Heilmann et al. (2015) framework

The modification of Heilmann et al. (2015) involved four main points (Figure 6):

1. The modified framework targeted children OH instead of adult SES; thus, birth SES and middle childhood SES (7-8 years old) were considered instead of childhood and adulthood SES.

2. The framework explored the SES, biological, behavioural, parental factors accumulated within four periods of the child's life, considering social patterns, temporal ordering, and interrelationships. The four periods included one critical period (birth) and two sensitive periods (birth-2 years, 3-6 years old) that were explored retrospectively, and the current stage of life was cross-sectionally (Grade 2, 7-8 years old).

3. Family-related factors, parenting style, and parent academic involvement were integrated within the common risk factors pathway instead of only considering lifestyle and behavioural factors.

4. The final step in the model, whereby the impact of OH on general and quality of life were assumed, was changed to study the association of OHCs with school performance and attendance.

Thus, the framework generally hypothesised that low SES at birth and age 7-8 would shape the children's biological, behavioural, parental and psychosocial resources in such a way as to promote the development of OHCs; hence they would exhibit low school performance and attendance. Conversely, children who experienced high SES at birth at age 7-8 would show little or no evidence of OHCs and exhibit better school attendance and performance than those living within a low SES family. Further details are discussed in Section 3.9.3.3.2.

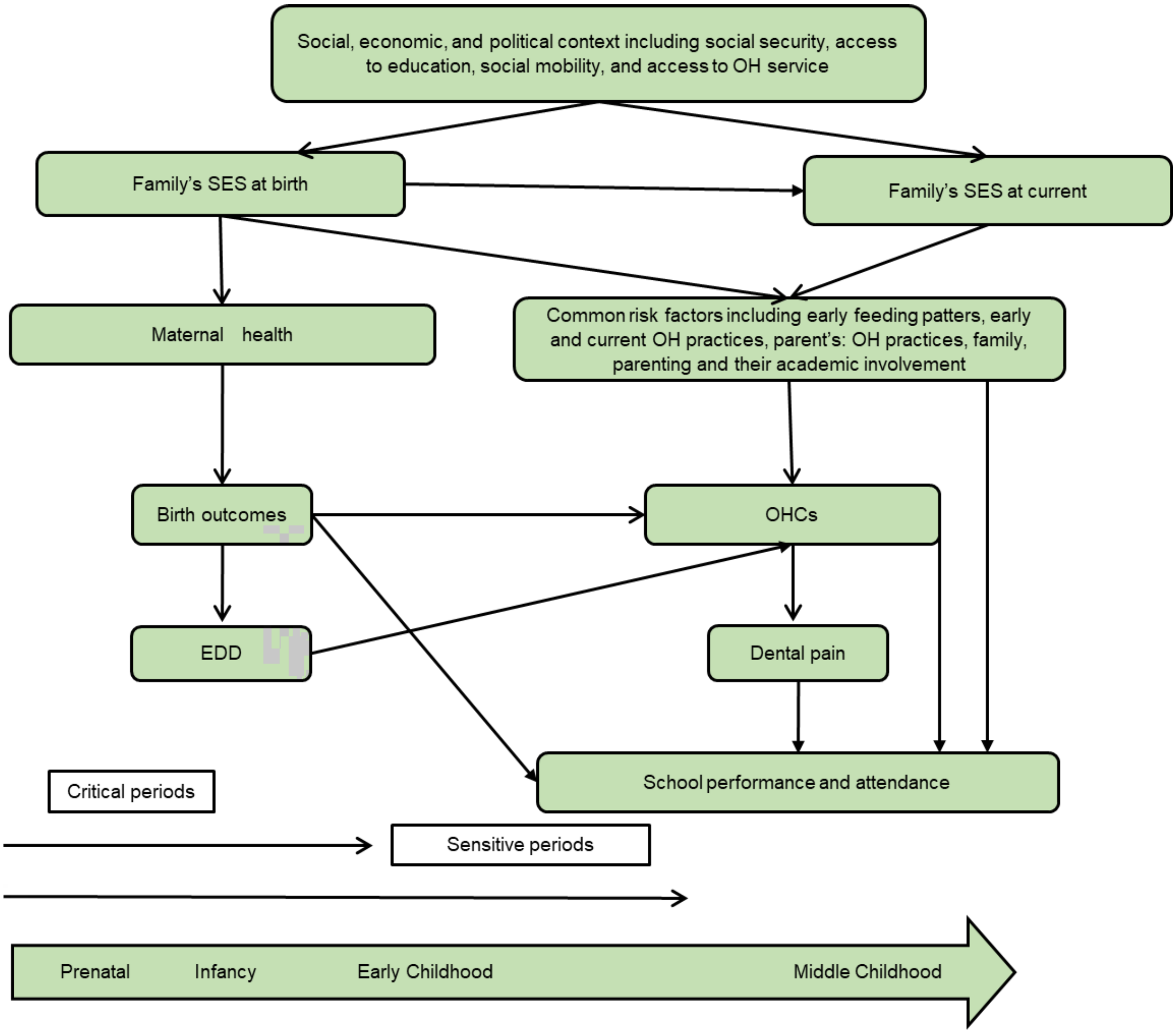


Figure 7. Modified from Heilmann et al.'s (2015) life course framework for OH

2.7 Rationale for the study

The rationale for the current study was to identify the associations and the pathways between OHCs and children's school performance and school attendance in the Middle Eastern area that have not been sufficiently explored in the existing literature, using a life course approach. Second, the present study addressed life course factors that could influence OHCs, school performance and school attendance.

The impacts of oral diseases on school performance and school attendance among schoolchildren have been studied extensively in four recent systematic reviews as previously discussed (de Paula and Mialhe, 2013, Ruff et al., 2019, Ribeiro et al., 2018, Rebelo et al., 2019), and in further eight epidemiologic studies recently published. However, a definitive conclusion related to the association could not be reached. This is mainly due to the predominance of cross-sectional design studies, concerns regarding validity and reliability of the exposure and outcome measures, and the flaws and poor methodological quality of some studies, as explained in Sections 2.4.7.

In addition, one common major limitation of the previous studies is that the authors did not account for relevant variables that might confound the association between OHCs and school performance and school attendance. The lack of a theoretical framework to analyse such an association is also noteworthy. Many environmental factors like SES, school and family characteristics may influence children's school performance and attendance (Epstein and Sheldon, 2002, Banerjee, 2016). Those factors can also influence the development of OHCs among children (Abreu et al., 2015). Thus, it would be relevant to investigate the complex association between OHCs and school performance and school attendance, considering the environmental and family factors using one comprehensive framework, such as the life course approach.

The life course framework can be considered well-suited to OH epidemiology, as most dental diseases are chronic conditions with multiple causes and are influenced by social conditions (Nicolau et al., 2003). Recently, different life course models have been applied in dental research to examine the factors related to OHCs (Abreu et al., 2015). However, most of the available studies used regression analysis to evaluate the association between variables based on the life course approach. Whilst such an approach is considered well suited for life course studies, it poses some limitations worth mentioning. First, regression analysis only measures direct effects, whereas indirect effects cannot be measured (Berndt and Williams, 2013). Thus, the complex interrelationship between the life course variables cannot be captured sufficiently well. Second, the variables can act either as predictors or outcomes (Petrocelli, 2003). Thus, it is not possible to test a chain of linear associations between predictors. Third, the regression analyses only measured variables, while SEM incorporates measured and indirectly measured (latent constructs) variables. Thus, a regression cannot estimate the combined effect of directly measured independent variables into indirectly observed constructs. While in SEM, directly observed independent variables do not act alone; instead, conceptually consistent independent variables act together to add to the prediction of dependent variables (Berndt and Williams, 2013).

Finally, all studies exploring the association of OHCs with school performance and school attendance and the studies that explored life course factors of children were predominantly conducted in Western societies, limiting their generalisability, especially in Middle Eastern countries, where the burden of oral diseases is significantly higher (Morgano et al., 2010).

OHCs, academic school performance and school attendance might share common predictors. Exploring those variables through a life course approach might help identify critical opportunities for tackling them and stimulating protective factors to provide evidence-based interventions, targeting the key life stages (age-graded).

Thus, to the researcher's knowledge, this is the first study conducted in the Middle East to explore the influence of environmental, behavioural, biological, and parent’s characteristics on the association between oral diseases and schoolchildren's performance and school attendance using a life course approach. The study accounted for most of the factors related to the development of OHCs, which can influence academic performance and school attendance among children. Furthermore, the study was planned to measure OHCs and perceived oral health status and school outcomes using valid and reliable measures. Also, the study design was time-ordered-cross-sectional to verify the temporal relationship between OHCs and school outcomes. Finally, the study hypotheses were analysed using a robust statistical technique (structural equation modelling) (Berndt and Williams, 2013).

Chapter 3. Methodology

This section explains the population and methods used in this study.

3.1 Study design

The study was a time-ordered-cross-sectional design conducted with 466 schoolchildren in Grade 2 in four government primary schools rated as “good” in Muharraq Governorate in KoB and their parents between 2019 and 2021.

The study is called a time-ordered-cross-sectional because exposures and outcome measures were collected once but at different time points for the same participants (Menard, 2002). This design has been suggested to be appropriate to assume temporal orders between the exposures and the outcome variables (Menard, 2002).

School performance and school attendance data were the outcome variables for children in Grade 2. School performance was measured at the end of the 2019-2020 school year (June 2020), considering children’s final cumulative grades. School attendance data were obtained from school records by days of absence for six months (September 2019- February 2020).

The exposures included social, biological, behavioural, parental, and clinical data collected at the beginning of September 2019. Parents completed a questionnaire detailing children’s characteristics and environment at birth (retrospectively) and presently. Children were interviewed and dentally examined to assess dental caries, dental trauma, malocclusion, enamel development defects (see Section 3.4 for further details of study measures).

3.2 Geographic location

The study was conducted in the Muharraq Governorate in the KoB. The KoB is a small archipelago located in the Arabian Gulf. It covered a total area of 777.95 km^2 and comprised a population of 1,501,611 in 2019 (Information & eGovernment Authority-KoB, 2019). The Human Development Index for Bahrain was 0.85 in 2019, ranking the country 42^{nd} out of 189 countries; according to United Nations Development Programme (UNDP) (2020), Bahrain is divided into five health regions: Capital, Muharraq; Central; Southern and Northern. Muharraq is the second-largest city in Bahrain, in terms of population density, with a population of 97,458 (World Population, 2019).

The estimated total number of Grade 2 schoolchildren in Muharraq was 2,480: 1,195 males (48%) and 1,285 females (52%) (Education and Quality Authority-KoB, 2019) 2019**.** In Muharraq, the mean number of decayed, missing and filling teeth (d_4mft) for six-year-olds was 4.46 from 2011-to 2012 (Naseeb, 2016). This was an increase of 1.01 on the mean of dmft compared to the 2005 oral health survey.

3.3 Selection of population

3.3.1 Target population

The target population consisted of Grade 2 government school children of both genders in the KoB in addition to their parents.

3.3.2 Population source and setting

The population source comprised all children in Grade 2, aged 7-8-years in 2019-2020 and their parents. All participants were attending government primary schools in the Muharraq Governorate.

The government education system in the KoB is segregated by gender. Recently Ministry of Education (MOE) started quality evaluation for each school in KoB. The quality and qualification assurance (QQA) committee applied the assessment, where schools receive a specific quality score: 'outstanding', 'good', 'satisfactory' or 'inadequate'. The QQA examine a school's quality based on three tenets: quality of processes (students' support and guidance, and teaching, learning process), quality of outcomes (students' academic performance and their personal development), and quality assurance of outcomes and processes (leadership, management). Private schools were not included in the study as they have different curricula from public schools.

The list of all students attending primary schools in Muharraq was not available. Thus, a random sampling process involving all schools with different scores was not possible. Therefore, the researcher had to sample the schools as a unit instead of sampling the individuals. However, since the schools were already clustered according to the quality score, the researcher restricted the sample to only those rated as 'good'. Selecting good-rated schools is more logical than selecting the other two extremes of outstanding or inadequate schools. Similarly, it forms a midpoint between the acceptable school ratings of outstanding and satisfactory". Furthermore, it prevents the influence of different school-level factors that may influence school academic performance and school attendance.

3.3.3 Study group

The study group comprised schoolchildren aged 7-8 years old enrolled in Grade 2 from 'good' rated government schools in the Muharraq Governorate in 2019-2020.

3.3.4 Exclusion criteria

Schools were excluded according to the following criteria:

- Primary schools located in governorates other than Muharraq Governorate.
- Primary schools are rated as 'outstanding, 'satisfactory', or 'inadequate'.
- Primary schools with mixed primary-intermediate stages.
- Primary schools with no Grade 2 classes.
- Private schools.

The exclusion criteria for children from the selected schools were:

- Children not enrolled in Grade 2.
- Children less than seven years of age or older than eight years of age.

3.3.5 Sampling and recruitment

The study applied a non-probability sampling technique whereby all schoolchildren in Grade 2 in 'good' rated government primary schools were recruited for the reasons explained earlier.

School's latest ratings were retrieved online from the Ministry of Education (MOE) of the KoB website for the Muharraq governorate: http://www.bqa.gov.bh/En/Reports/SchoolsReports/Pages/default.aspx. There were 23 government primary schools in Muharraq. Of them, nine were rated 'outstanding'; six were rated 'good', six 'satisfactory' and two 'inadequate' in 2018-2019. Most of the available reports were the third quality evaluation reports for the 2018-2019 academic year. Six primary schools in Muharraq Governorate rated as 'good' by Bahrain's MOE were selected (Education and Quality Authority-KoB, 2019), three schools with male students and three schools with female students (see Appendix 8). Of these schools, one school with male students did not have Grade 2 classes and thus was excluded. One school with female students was also excluded because it had mixed primary and intermediate stages. The remaining four schools had 528 children (see Figure 8).

The researcher visited the identified schools in September 2019 to arrange the application of the study with headteachers and children. The parents of all of the children who enrolled in the identified schools and their children in Grade 2 were invited to participate. The researcher visited each classroom to explain to the children the study's objectives and their roles in delivering and returning the informed consent (IC) (Appendix 9) and the questionnaire for their parents in relation to the dental examination. Class headteachers and researchers distributed IC and parents' questionnaires to children during school enrolment to be handled by their parents.

Of the 528 schoolchildren, one female child aged ten years was excluded due to the age criterion. Further, 18 children who participated in the pilot study were excluded from the main study, and 33 students refused to participate. The potential sample size, therefore, was 477 children. Eleven children were also excluded from the analysis because they did not return the parent's questionnaire. Therefore, the final sample consisted of 466 children.

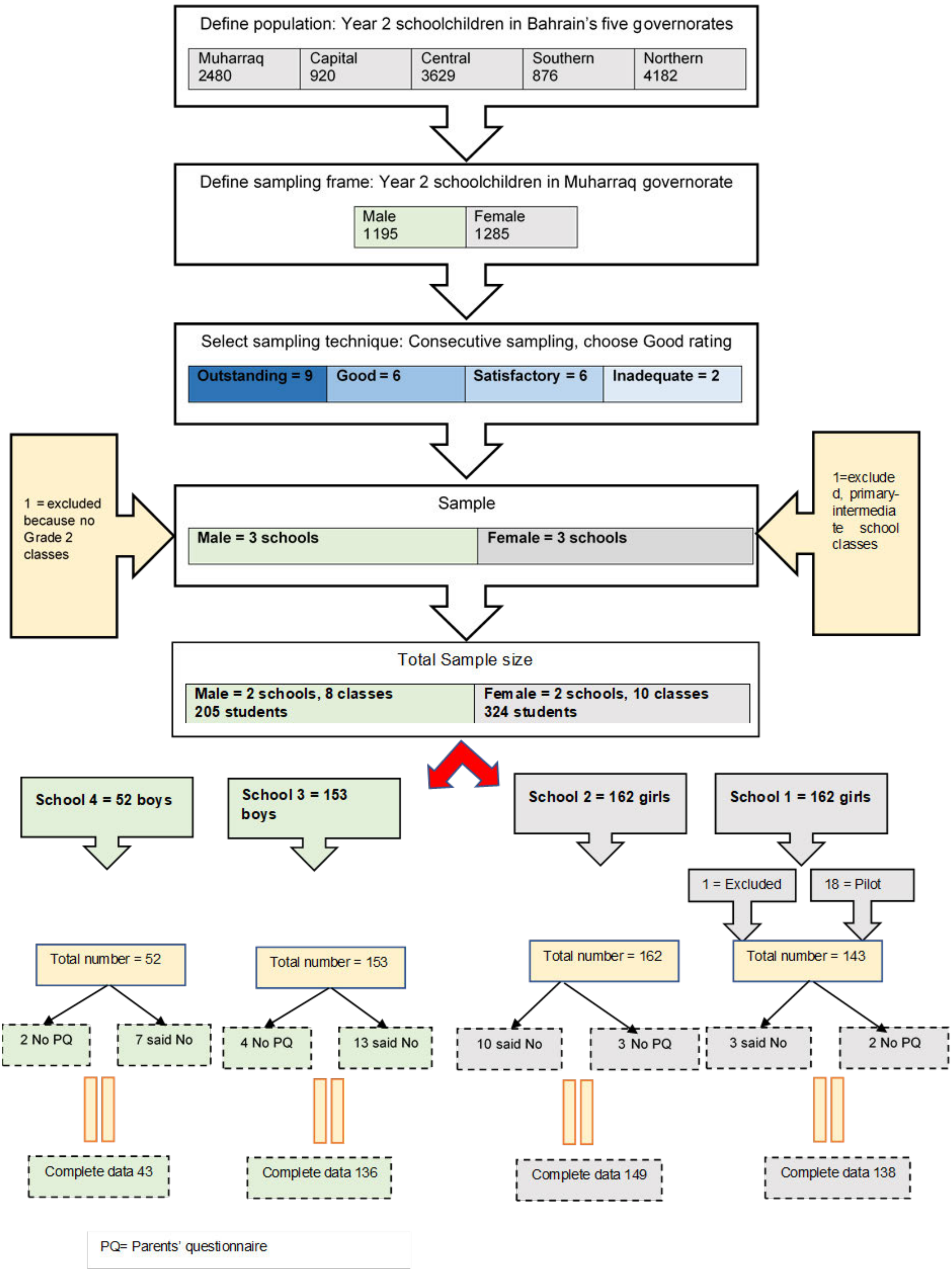


Figure 8. Flowchart of the sampling process

3.3.6 Sample size calculation

To achieve a 5% or less standard error, with a 95% confidence interval in an estimated prevalence of 50% of children reporting excellent school performance, 385 children were minimally required. Likewise, in an estimated prevalence of 50% of children having 100% attendance, 385 children were minimally required. Anticipating a 20% drop-off, the final sample size required was 462. Furthermore, the sample size as regards this study was determined based on the use of the structural equation modelling (SEM) analysis technique. According to Hair et al. (2014), a sample size of at least 200-400 is considered suitable for SEM. Further, the authors also advised that SEM analysis become too sensitive to a sample size of 500, making the model fit difficult. Therefore, the concern for this study was to have a 400-sample size at a minimum.

3.4 Data collection instruments

Different instruments were employed to collect the data, including parents' self-administered questionnaires, face-to-face interviews, children's clinical and anthropometric examinations, WhatsApp media, and school records. Questionnaires were initially developed in English and subsequently translated into Arabic (the PhD candidate native language). This will be detailed in Section 3.6.1.

- The parent's questionnaire was answered by either mother or father and used to collect data regarding the child's and family's demographics, biology, behaviours, besides socioeconomic and parental factors (Appendix 10). The selection of factors was based on the review of Heilmann et al. (2015) life course framework for OH and exploring factors related to OH and school performance and school attendance, which was discussed in Chapter 3. The questionnaire consisted of five sections and 176 items, with primarily closed-ended questions.

- The face-face interviews with children collected data regarding the child's Oral Health-Related Quality of Life measures (OHRQoL) and children's perceived support from teachers and peers (Appendix 11).
- A clinical form was developed to collect the child's OH status, height and weight (Appendix 12, 13). The clinical form was based on the guidelines of the dental indices employed.
- Online communication via mobile phone (WhatsApp) was conducted to collect the school performance (outcomes) data at the end of the 2019-2020 academic year.
- School records were used to obtain data on children's absence days (2019-2020).

3.5 Variables

The following sections explain all the variables measured in this study in the parent's questionnaire and children's face-face interviews and clinical examinations. Finally, it explains the outcomes measures. Table 20 summarises the variables, including the instruments, measures and how they were analysed.

3.5.1 Parent's self-administered questionnaire variables

The questionnaire consisted of five sections: demographics, family structure and current SES, family structure and SES at the time of the child's birth, health and OH behaviours and perceptions, parenting style and parent's academic involvement (Appendix 10).

3.5.1.1 Demographics

The demographic characteristics comprised the child's age, gender, place of birth, ethnicity, and area of residence (Items 5-9).

3.5.1.2 Current life variables

The current life variables included information regarding when the child was in Grade 2 (currently-7-8 years old) (2019-2020).

3.5.1.2.1 Family structure

This includes the family type (Item 10), parent's marital status (Item 11), along with the current number of siblings (Item 12).

3.5.1.2.2 Family SES

SES of the family was assessed according to the educational level of the parents (Items 13, 17), their occupation (Items 15, 19), total household income (Item 21). Housing conditions were assessed in terms of tenure (Item 22), the number of rooms in the household excluding kitchen and toilets (Item 23) and the number of people living in the household (Item 24). Overcrowding was indicated when more than two individuals per room were in the household (Hatton and Martin, 2010).

3.5.1.2.3 Oral health behaviours

Parent’s and children’s oral health behaviours included frequency of tooth brushing, flossing, sugar consumption, use of mouth wash and dental visits (Items 25-36), use of toothpaste (Item 44), fluoride level (Item 43), as well as spit or rinse procedure (Item

45). To determine the fluoride level, parents were asked to write the name of the fluoride toothpaste used if they did not know the concentration.

3.5.1.2.4 Health status

Children's health status indicators were assessed by the presence of chronic health conditions (Item 56) or neurobehavioural disorders, body mass index (BMI), current use of medication (Item 57) and general health perception reported by their parent (40). Parents' (mother & father) health perceptions (Items 38, 40), smoking status (Items 52, 53), and type of smoking (Items 54, 55) were also obtained.

3.5.1.2.5 Parent’s characteristics

This part included the parent's academic involvement and parenting style.

3.5.1.2.5.1 Parent's academic involvement

Assessment of parental academic involvement was conducted using the questionnaire developed by Ames et al. (1993), which had been previously employed (Jeynes, 2005, Jeynes, 2017) and validated with Ghanaian students (Ansong et al., 2017). The instrument consisted of seven Items (163-176) questioning parental involvement in children's schooling. These were answered using a five-point Likert scale from 'never’ (1) to 'always’ (5).

3.5.1.2.5.2 Parenting style

Where possible, both parents were assessed. The Parenting Style Dimension Questionnaire (PSDQ) was employed to evaluate parenting style (Robinson et al., 1995). The questionnaire consists of 32 items (Items 99-162) that assess features of parenting styles. The scale includes 15 items to assess the authoritative style, 12 items to assess the authoritarian style, and five items to assess the permissive style, using a five-point Likert scale from 'never' (1) to 'always' (5). To classify the parents' preferred style, the scores were added up and divided by the total number of questions at the end of each section. The highest mean score indicated the preferred parenting style. Validation of the instrument had previously been carried out on a different population (Olivari et al., 2013, Robinson et al., 1995). Robinson et al. (2001), reported the Cronbach's alpha (α) to be acceptable for authoritative (α = .86), authoritarian (α = .82) and low for permissive (α = .64).

3.5.1.3 Early life variables

The children's early life variables included information from childbirth until six years (Items 58-94) (see details below).

3.5.1.3.1 Family structure

Current family structure was measured the same way at birth (Items 58-61).

3.5.1.3.2 Family SES

Current family socioeconomic status (CSES) was assessed similarly to BSES (Items 62-70).

3.5.1.3.3 Maternal health status

This includes variables related to the mother during her pregnancy of the participant; mother's age (Item 71): mother's health status was assessed by asking her to report yes/no if she had the following conditions: gestational diabetes (Item 72), hypertension (Item 73), smoking (Item 75) and postnatal depression (Item 77). Also, a question was asked to determine the type of birth (Item 76).

3.5.1.3.4 Children's birth outcomes and feedings pattern (birth-2 years old)

The birth outcomes variables included gestational age at birth (Item 78) and birth weight (Item 79), and birth order (Item 61). Feeding patterns during infancy included exclusive breastfeeding for the first six months (Item 80), duration of breastfeeding (Item 81), bottle-feeding (Item 82), feeding at night (Item 82), sweet drinks (Item 83), use of pacifier (Item 84) and duration of pacifier use among those who answered yes to the previous question (Item 85).

3.5.1.3.5 Children's oral health behaviours (3-6 years old)

Parents reported early oral health status and behaviours in yes/no questions. This included time of the initiation of tooth brushing (Item 87), adult supervision of tooth brushing (Item 88), the pattern of dental visits (Item 89), experience of dental pain (Item 90) and presence of primary dental caries (Item 91).

3.5.1.3.6 Early learning (3-6 years old)

Early learning variables included children's enrolment in pre-school/nursery (Item 93), previous grades (Grade 1) (Item 95) and previous days of absence (Items 96-98) reported by one of the participant's parents for the academic years (2018-2019). Grade 1 was categorised according to the MOE classification and contained six levels: 'excellent', 'very good ', good', 'average', 'acceptable' and 'failed'. School absence days were classified into; 1-5 days, 6-9 days, ≥ 10 or no absences for one academic year. The limit concerning permitted days absent in the KoB is ten days per academic year. Hence, this was the categorisation (MOE-KoB, 2017).

3.5.2 Child's face-face interview variables

3.5.2.1 Teacher and peers' social support

Social support can be defined as "behaviours that, whatever directly or indirectly, communicate to an individual that she or he is valued and cared for by others"(Barnes and Duck, 1994). This includes children at school being supported by their parents (discussed above), in addition to teachers and peers.

The child's assessment of teacher and peer perceived support was conducted using questions adapted from Ansong et al. (2017). The original questions were developed and validated (Torsheim et al., 2000) using a five-point Likert scale with Norwegian school adolescents. However, considering the limited capacity of children to understand the five points relating to the Likert scale (Mellor and Moore, 2014), the Likert scale was replaced by three options in this study: 'no’ (0), ‘sometimes' (1) and 'yes' (2). Face icons were used to facilitate understanding by the children.

3.5.2.2 Oral health-related quality of life

OHRQoL was collected from the children via face-to-face interviews and measured using the Paediatric Oral Health-Related Quality of Life (POQL) (Huntington et al., 2011). The reasons for choosing this instrument were as follows:

- The POQL has ten items used in clinical and population-based studies, suggesting that it is suitable for application in a school setting. Moreover, little time is required to complete it.
- The POQL covers four functional dimensions: physical, role, social and emotional. Similarly, it contains questions regarding pain and any impact – from

the child's perspective – of oral health conditions on school attendance and attention in class, which are in line with the primary aim.

- The scale measures each item in terms of 'how often?' (frequency) and 'how much were you bothered?' (severity) using simple Likert scales of 0-3 and 0-4, respectively.
- Validity was tested and confirmed by face, discriminant and convergent validity (Huntington et al., 2011).
- The internal consistency (Cronbach's alpha) for the total score was 0.83. The test-retest (2-4 weeks) interclass correlation was 0.75 and therefore acceptable.

To measure the overall quality of oral health and health in general, both children and their parents were asked one global question (Rowan, 1994).

POQL (Huntington et al. 2011) scores were calculated by multiplying the frequency response (0–3) by the severity response (0–4). Impact scores were then summed and converted to a percentage (x100/120) to give an overall POQL score ranging from 0 to 100, with higher scores reflecting poorer OHRQoL.

3.5.3 Clinical examination

This included the OH examination and the anthropometric measures.

3.5.3.1 Oral health conditions

3.5.3.1.1 Malocclusion

Dental trauma risk factors related to malocclusion were measured. Malocclusion was recorded in the presence or absence (yes/no) of the following conditions, lip incompetence, overjet and anterior open bite (Soares et al., 2018, Neves et al., 2016).

Lip competence was described if the maxillary incisors were covered by the lip, while lip incompetence was defined if a larger part of the crown height was visible in the resting position (Zaleckien et al., 2020).

The incisor relationship was measured according to the WHO (1997) guidelines. The overjet was measured to the nearest whole millimetre as the horizontal distance from the labial incisal edge of the most prominent maxillary incisor to the facial surface of the correspondent lower incisor parallel to the occlusion plane. In contrast, the anterior open bite was classified with no vertical overlap between the maxillary and mandibular anterior teeth. When maxillary teeth were positioned lingually to mandibular teeth, it was defined as an anterior crossbite.

3.5.3.1.2 Dental trauma

Dental trauma was assessed in upper and lower central and lateral incisors. Each tooth was examined and coded according to the criteria used in the UK Children's Dental Health Survey 2013 (UK -CDHS) (O'Brien, 1994) (see Table 14). Thus, dental trauma was reported as present when any type of injury or tooth discolouration was diagnosed or absent (yes/no).

Table 14. Dental Trauma Index (UK-CDHS, 2013)

Code	Type of dental trauma
0	= No trauma
1	= Discolouration
2	= Fracture involving enamel
3	= Fracture involving enamel and dentine
4	= Fracture involving enamel, dentine, and pulp
5	= Missing due to trauma
6	= Acid-etch composite restoration
7	= Permanent replacements including crow, denture, bridge pontic

3.5.3.1.3 Dental plaque

Dental plaque was evaluated according to the UK-CDHS (2013) criteria (Anderson et al., 2015). Subsequently, the mouth was divided into six sextants; each was visually examined at the buccal and lingual surfaces. The dental plaque status was coded according to 0 = no visible dental plaque, 1 = visible dental plaque, and 9 = assessment cannot be made (e.g., missing teeth). The average plaque condition was recorded and not the worse area in the segment.

3.5.3.1.4 Enamel Developmental Defect (EDD)

Enamel developmental defects were measured using the FDI modified EDD guidelines (Clarkson and O'Mullane, 1989) presence or absence (yes/no). Only each tooth's buccal or labial surfaces were examined (Ramesh et al., 2011). EDD was recorded as present if any conditions in Table 15 were diagnosed. Three types of defects were considered in this study according to the explanation below:

- In demarcated opacity, the enamel's thickness and morphology are normal, but its translucency is altered due to the occurrence of large organic material remnants between the crystal appetites (Koch et al., 1987). These lesions present with a clear border separating the abnormal and normal enamel. Their colour may range from white to cream and yellow to brown (Seow, 2014)

- Diffuse opacity involves normal enamel thickness with changes in enamel translucency (Seow, 2014), but there are no clearly defined boundaries between the lesion and the surrounding enamel. The lesion tends to be white, appearing opaque with a linear, patchy or confluent distribution. It frequently presents on incisal edges or one-third of the crown.
- Enamel hypoplasia is a malformation of enamel that reduces its thickness. Clinically, it is seen as grooves or pits and the partial or total loss of surface enamel (William et al., 2006).

Table 15. Modified FDI, EDD index (Clarkson and O'Mullane, 1989)

Code	Type of EDD
0	Normal
1	Demarcated opacities
2	Diffuse opacities
3	Demarcated and diffuse opacities
4	Hypoplasia
5	Hypoplasia and opacities

3.5.3.1.5 Dental caries

The researcher examined dental caries using the International Caries Detection and Assessment System (ICDAS) (Ismail et al., 2007, Pitts and Stamm, 2004). The ICDAS system was chosen because of the evidence related to the high validity, feasibility, reliability, and reproducibility of epidemiological studies. The necessity of non-cavitated lesions detection was demonstrated. It enables early, and follow-up detection of dental caries and provides a comprehensive assessment of dental caries according to the stages of a carious lesion, activity and topography (Mendes et al., 2010, Ekstrand et al., 2018, Shoaib et al., 2009, Ismail et al., 2007, Braga et al., 2009, Pitts and Stamm, 2004).

ICDAS is a 'two digits" coding system. The first digit code (ranging from 0 to 9) represents the condition of the current restoration and sealants (see Table 16). The second digit (ranging from 0 to 6) refers to caries lesions severity (Ismail et al., 2007) (see Table 17). Code 1 for caries was not used as no air syringes were available during the examinations at the schools (Neves et al., 2016). Thus, all code 1 were excluded including pits and fissures, smooth surfaces, free smooth surfaces, CARS (caries associated with restorations and sealants); instead, all teeth surfaces, including pits and fissures, have been examined starting from Code 2. The examiners were trained to use the ICDAS as described in Section 3.8.1.1.

Table 16. ICDAS codes for restoration (Ismail et al., 2007)

Code	Criterion
0	Sound, specifically, surface not restored or sealed (use with the codes for primary caries)
1	Sealant, partial
2	Sealant, full
3	Tooth-colour restoration
4	Amalgam restoration
5	Stainless steel crown
6	Porcelain, gold, PFM crown or veneer
7	Lost or broken restoration
8	Temporary restoration
9	Used for the following conditions:
	No examination of the tooth surface, i.e., surface excluded (code 96)
	A tooth is missing because of caries (code 97)
	A tooth is missing for reasons other than caries (code 98)
	Unerupted tooth surface (code 99)

Table 17. ICDAS codes for caries severity (Ismail et al., 2007)

Code	Criterion
0	Sound tooth surface: no evidence of caries after 5 seconds of air drying
1	The first visual change in enamel: opacity, or discolouration (white or brown) is visible at the entrance to the pit or fissure seen after prolonged air drying
2	The distinct visual change in enamel is visible when wet. The lesion must be visible when dry
3	Localised enamel breakdown (without clinical visual signs of dentinal involvement), seen when wet and after prolonged drying
4	Underlying dark shadow from dentine
5	Distinct cavity with visible dentine
6	Extensive (more than half the surface), distinct cavity with visible dentine

3.5.3.1. 6 Consequences of untreated dental caries

The Pulp-Ulcer-Fistula-Abscess index (PUFA) was used to evaluate the presence or absence (yes/no) of any clinical consequences of untreated dental caries (Monse et al., 2010). As shown in Table 18 below, in the PUFA coding, the uppercase letter denotes the condition in permanent teeth, with the lowercase letter describing the condition in primary teeth. The number of lesions presented in the child's mouth for each of the four forms of odontogenic infection was recorded.

Table 18. PUFA codes (Monse et al., 2010)

Permanent teeth	Primary teeth	Description
P	p	pulpal involvement
U	u	ulceration
F	f	fistula
A	a	abscess

3.5.3.2 Anthropometric measures

The child's weight and height were recorded to assess body mass index (BMI) using a high-quality balance beam. The US Centre for Disease Control and Prevention (CDC) growth chart and calculator were used to estimate BMI according to age and gender by percentile. Accordingly, children were classified as underweight if their BMI was < 5th percentile, 5th to < 85th were normal, 85 to < 95 were overweight and > 95 were obese (CDC, 2019).

3.5.4 Outcome variables

School performance in a primary school in the KoB was measured by calculating the average cumulative grades for each academic year out of 100 scale points, then categorised as indicated in Table 19. In this study, the average of 9-10 academic subjects for 2019-2020 was calculated and measured as a numerical scale out of 100 points. School attendance was measured based on the number of missing days at school. The headteacher recorded student attendance every day throughout the whole academic year. Days absent were retrieved from schools' records for the first term (September 2019 to February 2020), as during the second term, students were attending schools remotely because of the COVID-19 pandemic.

Table 19. Grading classifications in the KoB

Grades %	Category
< 50	1 Failed
59-50	2 Acceptable
69-60	3 Average
79-70	4 Good
89-80	5 Very good
100-90	6 Excellent

Table 20. Summary of the measurement and analysis of the study variables

Item number in the questionnaire/variable	Reference if available	How was it measured? Categories	Type of Variable	How was it analysed?
Parent's questionnaire				
Demographic				
3. Mother's age			Numerical	
4. Father's age			Numerical	
5. Child's age			Numerical	
6. Gender		2 Male / 1 Female	Nominal	
7. Place of birth		2 Bahrain / 1 Outside Bahrain	Nominal	
8. Ethnicity	(Information & eGovernment Authority-KoB, 2019)	1 Bahraini 2 GCC (Gulf Cooperation Council) 3 Arab 4 Asian 5 African 6 European 7 Others	Nominal	1 Asian 2 Arab 3 Bahraini
9. Area of residence	(Mappr.co, 2014)	1 Muharraq Governorate 2 Capital Governorate 3 Central Governorate 4 Southern Governorate 5 Northern Governorate	Nominal	
Current family SES and structure				
10. Family type		1 Single parent family (i.e., only one parent and the child/children live together) 2 Extended Family (i.e., the parents and the child/children live with one or more of the grandparents, uncles, aunts and cousins) 3 Nuclear family (i.e., the parents and the children live together)	Nominal	
11. Marital status		1 Widowed 2 Divorced 3 Married	Nominal	
12. Number of siblings	(Cinar et al., 2008a)		Numerical	

13 & 17. Level of education	(Information & eGovernment Authority-KoB, 2020b)	1 Not educated 2 Primary school education (1-6 years) 3 Intermediate school education (7-9 years) 4 Secondary school education (10-12 years) 5 College/University 6 Post-college	Ordinal	0= not educated ≤ 9 years of education > 9 years of education 9 years of compulsory schooling in the KoB
15 & 19. Employment status	(Bureau, 2015)	1 Unemployed 2 Self-employed 3 Employed in the private sector 4 Military 5 Retired 6 Government employee (GE) on the salary scale for public jobs 7 GE on the salary schedule for specialised jobs 8 GE on the salary scales for judges' jobs 9 GE on the salary schedule for executive jobs 10 GE on the salary scale for academic jobs 11 GE on the salary scale for diplomatic jobs	Ordinal	1 Unemployed/retired 2 Self/private employee 3 Government employee
21. Household Income	(Bureau, 2015)	1 BD<200 2 BD 200-399 3 BD 400-599 4 BD 600-799 5 BD 800-999 6 BD ≥ 1000	Ordinal	1 BD† ≤399 2 BD 400- 799 3 BD ≥800
22. Tenure		1 Rented flat 2 Owned flat 3 Rented house 4 Owned house 5 Others (please specify)	Nominal	1 Living with a parent 2 Rented 3 Owned
23 & 24. Crowding: number of people per room	(Hatton and Martin, 2010)	Crowded = 1 ≤2 people per room Not crowded = 2 >2 people per room		
OH practices and behaviours				
25, 28, 31. Frequency of tooth brushing	(Nicolau et al., 2003)	0 Never 1 Once a day 2 Twice a day 3 More than twice a day	Ordinal	1 Never or weekly 2 Once or twice 3 More than twice
26, 29, 32. Frequency of dental flossing				

27, 30, 33. Frequency of mouth wash rinsing 34, 35, 36. Frequency of Sugary snacks		4 Weekly		
43-44. Use of fluoride or specify type of toothpaste	(Department of Health-UK, 2021)	1 500 2 1000 3 1350-1450 4 ≥ 5000 5 Other	Ordinal	
45. Rinse or spit (for child)	(Department of Health-UK, 2021)	1 Rinse with water 2 Rinse with mouth wash 3 Spit the toothpaste only without rinsing with water 5 I do not know	Nominal	1 Rinse 2 Spite
46-51. The pattern of dental visits	(Nicolau et al., 2003)	0 Do not visit 1 Emergency 2 Check-up 3 Other	Nominal	0 Never/ Emergency 1 Regular visits
37-42. Perceived OH and health perception	(Rowan, 1994)	0 Poor 1 Fair 2 Average 3 Good 4 Excellent	Ordinal	
Health and OH behaviours				
52,53. Parent's smoking		0 No / 1 Yes	Nominal	
54, 55. Type of smoking		1 Cigarette 2 Pipe 3 E-cigarette 4 Other	Nominal	
56. Child's health condition	(Karande & Kulkarni, 2005)	0 Normal 1 Asthma 2 Iron deficiency 3 Sickle cell diseases 4 Epilepsy 5 Cerebral palsy 6 Thalassemia 7 Type I diabetic Mellitus 8 Disabilities: hearing, mental, visual, speech	Nominal	0 No/ 1 Yes

		9 Autism 10 ADHD 11 Other		
57. Child's medication		0 No / 1 Yes	Nominal	
40, 41. Parents general health perception	(Rowan, 1994)	0 Poor 1 Fair 2 Average 3 Good 4 Excellent		
Parent's psychosocial factors				
99-162. Parenting Style Questionnaire	(Robinson et al., 1995)	1 Permissive 2 Authoritarian 3 Authoritative	Nominal	
63-170 Parent academic involvement	(Ames, 1993)	Scale 0-28	Numerical	
Early life variables				
Family structure and SES at the time of childbirth (early life)				
58. Family type		1 Single parent family 2 Extended Family 3 Nuclear family	Nominal	
59. Marital status		1 Widowed 2 Divorced 3 Married	Nominal	
60. Number of siblings	(Cinar et al., 2008a)		Numerical	
61. Birth order	(Nicolau et al., 2003)	1 First 2 Second 3 Other	Ordinal	1 First 2 Second or more
62 & 65. Level of education		1 Not educated 2 Primary school education (1-6 years) 3 Intermediate school education (7-9 years) 4 Secondary school education (10-12 years) 5 College/University 6 Post-college		0= not educated ≤ 9 years of education > 9 years of education

63 & 66. Employment status	(Bureau, 2015)	1 Unemployed 2 Self-employed 3 Employed in the private sector 4 Military 5 Retired 6 GE on the salary scale for public jobs 7 GE on the salary schedule for specialised jobs 8 GE on the salary scales for judges' jobs 9 GE on the salary schedule for executive jobs 10 GE on the salary scale for academic jobs 11 GE on the salary scale for diplomatic jobs	Ordinal	1 Unemployed/retired 2 Self/private employee 3 Government employee
69. Household Income	(Bureau, 2015) Bahraini dinars (BD1 = £2.03)	1 BD<200 2 BD 200-399 3 BD 400-599 4 BD 600-799 5 BD 800-999 6 BD ≥ 1000	Ordinal	1 BD† ≤399 2 BD 400- 799 3 BD ≥800
70. Tenure		1 Rented flat 2 Owned flat 3 Rented house 4 Owned house 5 Other (please specify)	Nominal	1 Living with a parent 2 Rented 3 Owned
71. Number of rooms			Numerical	
Mother's demographic characteristics and health during pregnancy				
71. Age			Numerical	
72. Diabetes		0 No / 1 Yes	Nominal	
73. Hypertension		0 No / 1 Yes	Nominal	
74. Other conditions		0 No / 1 Yes	Nominal	
75. Smoking		0 No / 1 Yes	Nominal	
76. Delivery method		1 Caesarean section 2 Normal birth	Nominal	
77. Prenatal depression		0 No / 1 Yes	Nominal	
Child's birth outcomes and feeding patterns from birth-2 years old				
78. Birth weight	(Kemfang Ngowa et al., 2014)	1 Low birth weight (i.e., less than 2500 g) 2 Normal (i.e., equal to or more than 2500 g)	Nominal	
79. Gestational age	(Kemfang Ngowa et al., 2014)	1 Pre-term birth (i.e., less than 37 completed weeks of gestation)	Nominal	

		2 Normal (i.e., equal to or more than 37 completed weeks of gestation)		
81-82 Feeding	(Nicolau et al., 2003)	1 Bottle-feeding only 2 Breast and bottle 3 Exclusive breastfeeding		
83. Sugar night feeding		1 Yes / 0 No	Nominal	
84. Use of pacifier	(Declerck et al., 2008)	1 Yes / 0 No	Nominal	
85. Time of using a pacifier		1 From birth 2 At 6 months 3 After 6 months 4 I cannot remember	Ordinal	
86. Duration of using a pacifier	(Poyak, 2006)	1 Less than two years 2 Equal or more than two years 3 I cannot remember 4 Few months	Ordinal	
Child's OH behaviours at 3-6 years old				
87. Start brushing	(Department of Health-UK, 2021)	0 Not brushing 1 At more than one year 2 At equal to or less than one year	0rdinal	
88. Supervised toothbrushing	(Department of Health-UK, 2021)	0 Never 1 Occasionally 2 Mostly 3 Always	Ordinal	0 No / 1 Yes
90. Dental pain		0 No / 1 Yes	Nominal	
91. Dental caries in primary teeth		0 No / 1 Yes	Nominal	
92. Dental treatment		0 No / 1 Yes	Nominal	
Child's early learning				
95. Final general academic performance Grade 1		1 Failed, 2 Acceptable, 3 Average, 4 Good, 5 Very good, 6 Excellent	Ordinal	
96. School absence Grade 1	(MOE-KoB, 2017)	0 No of absences 1 Days absent from 1-5 days 2 Days absent from 6-9 days 3 Days absent ≥10	Ordinal	

97. Absence because of OH		0 No /1 Yes	Nominal	
Child's face-face interview				
Social support	Teacher and peer (Torsheim et al., 2000) (Ansong et al.,2017)	Scale 0-12	Numerical	
POQL	(Huntington et al., 2011)	Percentage Number of events	Scale	
General H/OH	(Rowan, 1994)	0 Poor 1 Fair 2 Average 3 Good 4 Excellent	Categoric al Ordinal	
Clinical examination				
Lip competent	(Zaleckien et al., 2020)	0 No/ 1 Yes	Nominal	0 No / 1 Yes
Over jet (positive)	(UK-CDHS, 2013)	Positive overjet	Nominal	≤ 6mm / 0 N0, > 6mm / 1 Yes
Overbite		0 No / 1 Yes	Nominal	0 No / 1 Yes
Anterior open bite		0 No / 1 Yes	Nominal	0 No / 1 Yes
Anterior crossbite		0 No / 1 Yes	Nominal	0 No / 1 Yes
Dental trauma	(UK-CDHS, 2013) (O'Brien, 1993)	Table 14	Nominal	0 No / 1 Yes
Dental plaque	(UK-CDHS, 2013)	Average visible plaque condition of each sextant	Nominal	Total areas with plaque/6 total segments
Enamel developmental defects	FDI modified DDE (Clarkson and O'Mullane, 1989)	Table 15	Nominal	0 No / 1 Yes
Dental caries	ICDAS (Ismail et al., 2007)	Table 17	Ordinal	Total count of enamel caries, ICDAS caries codes 2-3 (d_{2-3}) Total count of dentine caries, ICDAS caries codes 4-6 (d_{4-6})
Treated teeth	ICDAS (Ismail et al., 2007)	Table 16	Nominal	Total count of: Extracted teeth because of dental caries = code 97

				Filled teeth because of caries= ICDAS restoration codes= 3-8
PUFA	PUFA index (Monse et al., 2010) (UK-CDHS, 2013)	Table 18	Nominal	0 No / 1 Yes
Child BMI (CDC)	(CDC, 2019) CDC (2000)	Height in cm Weight In Kg	Numerical	1 Underweight =< 5th percentile 2 = Normal 5th - <85th percentile 3 = Overweight 85th - <95th percentile 4 = Obese ≥ 95th percentile
Outcomes				
School performance		By mobile phone: sending an image of a child's grades	Numeric	Out of 100
School attendance		School records for days absent from September – February 2020	Numeric	

Note: How it was analysed column when left empty means it has been analysed in the same way it was measured.

3.6 Design of study instruments

3.6.1 Questionnaire design and translation

Initial versions of the questionnaires were developed in the English language. To facilitate a cross-cultural and conceptual translation, the forward-translation and back-translation procedure recommended by the WHO (Guillemin et al., 1993) was used to translate the questionnaires, participant information sheets and informed consent forms.

3.6.1.1 Forward-translation

Two bilingual professionals independently performed the first translation from English to Arabic (the primary researcher; a periodontist, YAL) with Microsoft Word Translator 365 (6 April 2019) to emphasise concept equivalence rather than word-to-word translation. The Arabic versions were then compared and revised by both translators.

3.6.1.2 Expert panel

The process involved three professionals: bilinguals in Arabic and English (the primary researcher; a periodontist, YAL and a paediatric dentist, SHK). The panel at this step reviewed and resolved inadequate expressions/concepts between both versions and combined them into one version.

3.6.1.3 Backward-translation

The first Arabic versions were translated back into the English language by two professionals independently. The resulting two back-translated versions were then compared to the original text in the English language, with corrections made accordingly. Subsequently, the corrected versions were forward translated into the Arabic language.

3.6.1.4 Evaluation

The resulting Arabic documents were evaluated by Mrs MA, a native Arabic speaker (an education specialist in the Scientific Research Directorate at Bahrain's MOE) (15 April 2019). Moreover, the suggested changes were considered and applied. This resulted in the generation of a set of research instruments in Arabic of sufficient quality for pre-testing.

3.6.1.5 Pre-testing

The questionnaires were tested for understanding with twenty parents of different age groups and SES and twenty schoolchildren in August 2020, after which the questionnaires were adjusted accordingly. Slight changes were made to the wording and numbering of items. All changes were documented and applied to derive the final Arabic version.

3.6.1.6 Reliability

Internal consistency measured by Cronbach's alpha (α) and reproducibility measured by interclass correlation coefficients (ICC) were tested for the Arabic questionnaires and discussed in the results section.

3.7 Ethical considerations

3.7.1 Permissions and liaison

Ethical approval to conduct this study was obtained from the University of Sheffield (see Appendix 14), the MOE in Bahrain (see Appendix 15) and the Bahraini Ministry of Health (see Appendix 16).

Permission from Bahrain's MOE was required and granted to facilitate access to the study population, contact parents, collect consent forms from them, and collect clinical data. Permission from Bahrain's Ministry of Health was required and again granted to retrieve each child's birth weight and gestational age from the health records. However, this data was not used as only 76 records were obtained. Finally, informed consent from the children's parents/guardians was obtained before data collection.

Furthermore, it should be noted that initially, it was planned to collect school's performance and attendance data via parent's questionnaires. However, because of the COVID-19 pandemic, the schools in the KoB operated online only. So, communication with parents was only possible by phone. Hence, the researcher had to change the data collection procedures regarding the study outcomes. An ethical amendment for the University of Sheffield and MOE in Bahrain was applied and retrieved (Appendix 17, 18) to contact parents directly for their children's grades and retrieve days absent from school records.

3.7.2 Ethical principles

Ethical principles including honesty, integrity, anonymity, confidentiality, autonomy and non-maleficence were maintained and enforced during the research process. Procedures such as recruitment, gaining participants' consent, data transfer and storage, in addition to ensuring child safety, were conducted according to strict ethical guidelines.

3.7.2.1 Autonomy and informed consent

Scientific honesty was maintained in acquiring parents informed consent forms. The consent form provided the parents with the following information: the purpose of the study, its benefits and risks, study duration and the researcher's contact number to call should they require any clarification. They were assured of anonymity and confidentiality. Their autonomy was maintained throughout the process by their being given the choice of whether or not to participate and the option to withdraw from the study at any time. Prepaid envelopes were provided with which to return the IC forms. The children were also given the option to withdraw from the study at any time. It is important to mention that the researcher visited the schoolchildren in their classes to explain the research purpose and encourage them to participate.

3.7.2.2 Anonymity

Participants' personal data was pseudonymised for the principal researcher and fully anonymised for the remainder of the research team. The personal data for all participants was collected in sealed envelopes and then transferred by the primary researcher onto an encrypted Excel spreadsheet.

Each participant received a unique study identification number composed of two letters and four numbers. These identification numbers were used on the clinical forms questionnaires and to save parents contact numbers to hide the participant's identity. These were generated using Microsoft Excel 365. The following formula creates a list of random numbers:

(CHAR(RANDBETWEEN(65,90))&CHAR(RANDBETWEEN(65,90))&RANDBETWE EN(1000,9999).

3.7.2.3 Confidentiality

Confidentiality was maintained by storing the collected data without any participant identity information. Personal data was stored in the primary researcher's laptop, protected and encrypted with the assistance of the University of Sheffield. This data was also stored as a backup on the primary researcher's personal space on the University of Sheffield drive. Only the researcher had access to this storage. Moreover, following the 3-2-1-rule for backup, all the anonymised data was shared with the primary researcher's supervisors via Google Drive at the University of Sheffield.

The primary researcher was the only person who had access to the master Excel spreadsheet that matched each participant's personal data to their study identification number. Furthermore, this spreadsheet was stored separately from the self-reported questionnaires containing the parents' telephone numbers, which were kept in a locked cabinet in the primary researcher's office at the University of Bahrain (UOB), to which only the researcher had access. Every Excel spreadsheet used in this study was protected using a password known only to the primary researcher.

3.7.2.4 Non-maleficence

Non-maleficence was maintained so that no harm or risk was expected in collecting the data. Oral examinations were non-invasive and straightforward, performed using only a mirror and, if needed, a dull probe. Examiners underwent training before performing the examinations.

3.8 Conduct

3.8.1 Training

3.8.1.1 Initial ICDAS training and reproducibility assessment

ICDAS training was conducted in June 2019 with a reference examiner (CD), who led a two-day session. Two examiners were trained: the principal researcher (SM) and a periodontist (YA).

On the first day (10 June 2019), the examiners undertook a 90-minute ICDAS e-learning programme (https://www.iccms-web.com/content/resources/elearning). **On the second day** (11 June 2019), they participated in four hours of preclinical workshops and discussions with the reference examiner (CD).

For training, reproducibility of the application of the ICDAS codes was first performed using 40 photographs of extracted teeth and 40 extracted teeth. The reference examiner undertook the gold standard assessment ahead of the training. Inter- and intra-reliability tests were performed. An unweighted Kappa coefficient was applied to estimate reliability for the first ICDAS code because the data was nominal (Cohen, 1960) and a weighted Kappa coefficient for the second code because the data was ordinal (Cohen, 1968). There was a substantial agreement of 0.65 and above weighted kappa targeted (Landis and Koch, 1977). The results revealed substantial agreement, as presented below.

Table 21. Unweighted Cohen's Kappa for first ICDAS code

	Unweighted Cohen's Kappa value		
	Gold standard	**Examiner 1**	**Examiner 2**
Examiner 1	0.85	0.70	0.84
Examiner 2	0.93	0.84	0.92

Table 22. Weighted Cohen's Kappa for second ICDAS code

	Weighted Cohen's Kappa value		
	Gold standard	**Examiner 1**	**Examiner 2**
Examiner 1	0.92	0.85	0.92
Examiner 2	0.94	0.92	0.94

3.8.1.2 Additional training

Prior to conducting the main study, further clinical training and calibration were conducted within the pilot study (September 2019) (see Section 3.8.5, Page 163). The training included revising ICDAS and dental indices criteria and codes with examiners and recorders, followed by calibration.

A senior lecturer in the nursing division (M) trained a nursing student and a research team on measuring the weight and height of children with respect to BMI measures. The scale was calibrated by placing a known standard mass (metal ball= 4 KG) on the scale, where the reading was easily verified.

Two interviewers were also trained by the principal researcher beforehand on administrating and conducting interviews with the children in a friendly manner.

3.8.2 Equipment

The OH examination required minimal equipment such as a dental plain mirror (No.4), a Community Periodontal Index (CPI) probe (disposable and non-disposable), orthodontic ruler, headlights (AUNOL, 400 lumens), cotton rolls, gauze, clinical sheets, toothbrushes, a pen with recording sheets and the personal protective equipment necessary to maintain infection control and reduce cross-contamination, for instance, gloves, masks, waste disposal units and containers for sterilising instrument. All non-disposable instruments were sterilised at the dental hygiene clinic if required. However, most of the examinations were covered by the use of non-disposable instruments.

In relation to BMI, a high-quality balance beam was required for measuring weight and height (Salter Bracknell HS-200M Physician: Mechanical Standing Height and Weight Scale).

Two desktops, six student desks and six chairs were used to facilitate the examination.

3.8.3 Procedures

The oral health examination, BMI measurements and completion of children's face-to-face interviews were conducted on the same day, in that order, in the library or the sports hall of the schools (September-November 2019). Separate stations were provided for each of the three procedures. The collection of the parent's questionnaire occurred from September to December 2019.

3.8.3.1 Dental clinical data collection

Two desktops were arranged end-to-end so that each child could lie on them in a supine position. The examiner was seated behind the child's head and wore a headlight (chargeable). Two student desks, placed to one side, held the OH instruments.

The dental examinations were performed to collect oral health measures in the following order: malocclusion, dental trauma; dental plaque; EDD; ICDAS and PUFA indices. First, the child was examined to identify lip competence and malocclusion conditions in the resting position with the support of the orthodontic ruler with teeth in centric occlusion. Then the incisors were inspected for dental trauma. Subsequently, the oral cavity was screened visually both buccally and lingually by segment for the dental plaque with the assistance of a dental plain mirror only. The examiners used gauze or a soft disposable toothbrush to wipe plaque off gently before registering EDD, ICDAS and PUFA indices. The teeth were dried with cotton rolls and gauze and examined in the following order: upper right; upper left; lower right; lower left (ICCMS 2018: https://www.iccms-web.com/course/8).

Concerning EDD, any lesions less than 1 mm in diameter were not recorded. Labial of anterior and buccal posteriors was inspected because these are the most common places to discover EDD (Ramesh et al., 2011). Relating to the ICDAS, teeth surfaces were visually inspected from distal, occlusal/incisal, mesial, facial and lingual surfaces to evaluate restoration and dental caries severity following the ICDAS criteria (Ismail et al., 2007). The WHO probe with ball ended equipment was used to check surfaces for discontinuity and remove dental plaque. PUFA examinations involved visual detection only; no instruments were involved. The lips and cheeks were gently retracted to visualise soft tissues (Monse et al., 2010).

3.8.3.2 BMI collection

The scales employed measured both weight and height simultaneously. The student nurse measured height and weight according to CDC (2000) guidelines as follows:

- The children were instructed to remove their shoes and head coverings to ensure accurate measurements.
- Each child stepped onto the scale platform, facing away from the scale. The weight value was recorded to the nearest 0.1 kg.

- For the height measurement, the child remained standing on the platform with their back against the stadiometer rule, with their legs straight, arms at their sides, and shoulders relaxed. The examiner lowered the headpiece until it touched the crown of the child's head firmly. The reading was recorded to the nearest 0.1 cm.

3.8.3.3 Questionnaires

Face-face interviews were conducted in groups of three children in the library or the sports hall of the schools after the dental exam. Parents' questionnaires were sent in September 2019 through their children and collected in a sealed envelope in the same way.

3.8.3.4 School performance and attendance

In June 2020, Grade 2 grades were collected online from parents via phone. The principal researcher contacted all eligible parents by phone through web WhatsApp, with a password-protected computer, and enquired to send a photograph of their child's 2020 Grade 2 school report.

The photos of the grades were collected without any personal identity. The parent’s contact numbers were saved in Google drive and identified by the participant’s identification number. The research used a new mobile number and linked it to WhatsApp online. Thus, data were not transferred to a mobile device but directly transferred into the password-protected laptop, without any personal details.

Regarding (2019-2020) attendance, the data were obtained from school records in October 2020. Days of absence during the school year from September 2019 to February 2020 were collected.

3.8.4 Personnel

In total, ten individuals participated in the data collection of this study. A nursing faculty was responsible for BMI training; the leading researcher and a periodontist conducted the dental clinical examinations. A nursing student took the anthropometric measures, two dental hygienists acted as recorders, whilst another two dental hygienists conducted the face-to-face interviews. Finally, two more individuals participated as research organisers.

3.8.5 Pilot study

In September 2019, the clinical measures were tested with 18 schoolchildren. The pilot study had several purposes. First, it enabled the examiners to familiarise themselves with the ICDAS and other clinical measures employed, clinical calibration and demonstrated how long it would take to conduct each examination and interview. Additionally, it raised any issues regarding the feasibility and coherence of the clinical examinations and interviews.

The results of the calibration are presented in the Result's Chapter. The pilot study revealed the difficulty associated with the online recording of clinical examinations. Therefore, using the manual exam form was a more time-saving option. Furthermore, the time for conducting individual interviews was very time-consuming. Hence, the decision was made for each interviewer to interview a group of three children at a time. Finally, the pilot study indicated high enamel and dentine caries, with ICDAS prevalence equal to 83.3% among the 18 schoolchildren, with 11.1% having clinical consequences of dental caries. On the other hand, the dmft mean was 9.83 (95%CI= 5.04/14.63).

3.8.6 Data transfer

The chief researcher transferred the data from the research instruments to the SPSS data file (November 2019-March 2020 & June-November 2020). The study was password-protected. 10% of the data were randomly selected and checked for accuracy.

3.9 Data analysis strategies

The analysis included three stages: descriptive, data screening, and a two-step structural equation modelling (SEM) procedure; 1) confirmatory factor analysis (CFA), and 2) the structural model (SM).

3.9.1 Descriptive

Descriptive analysis was used to answer Objective 1 (P. 4). All descriptive analysis was performed using Statistical Package for Social Sciences (SPSS) versions 25 and 26. The distribution of the variables and reported frequencies, percentages, mean values, standard deviations, and prevalence measures have been calculated. The alpha (Type I error) was set at 5% for all analyses.

Results of the clinical calibration and the reliability questionnaire were also reported. The clinical calibration, which included the inter-and intra-reliability tests, were assessed and targeted 0.65 and above kappa coefficient (substantial agreement) (Landis and Koch, 1977). The reliability of the questionnaires was assessed using the internal consistency test Cronbach's alpha and the test-retest reliability with Pearson's intraclass correlation (ICC). Cronbach's alpha estimate value above 0.70 was considered acceptable (Tavakol and Dennick, 2011), and Pearson with ≥ 0.40 was considered a moderate association (Dancey and Reidy, 2007).

3.9.2 Data screening

Before starting the structural equation modelling procedure, data were screened using SPSS (25 and 26) and the software package Analysis of Moment Structures (AMOS), versions (25 and 26) for missing values, outliers, and normality.

To avoid the problem of missing data, when conducting the study, the researcher checked any returned questionnaires for missing data before receiving the completed questionnaires. If any questionnaires had missing information, the children were asked to return them for the parent to complete. Children who failed to return the parent's questionnaire were excluded from the analysis. Data were screened to evaluate the total amount and the pattern of missing data to find the appropriate techniques to deal with missing data (Byrne, 2001). The randomness of the missing data was tested using Little's (1988) Chi-square statistics.

Further, the data were screened for univariate and multivariate outliers. Hair et al. (2014) described outliers as cases with substantially diverse scores from the rest of the observations in a dataset. Kline (2016) defines a univariate outlier "as an extreme value on one variable, whereas a multivariate outlier is a combination of extreme values on two or more variables". It has been suggested that the outliers should be deleted because they can affect model fit estimates and parameter estimates and cause a negative variance (Dillon et al., 1987). However, Hair et al. (2014) advised that the outliers should be retained to ensure the generalisability of the study unless they are genuinely aberrant.

Thus, although the univariate outliers were detected in this study by determining the frequency distributions of the observed data's Z scores, it was considered extreme when it was below or above the mean by (-/+ 3.29 SD) (Kline, 2018). While, the multivariate outlier was examined using the Mahalanobis distance (D^2) (Byrne, 2001). Mahalanobis distance (D^2) “measures the distance in standard deviation units between each observation compared with the mean of all observations” (Byrne, 2001). In this study, the researcher measured D^2 using Amos version 25. Observations with a D^2 measurement with a p-value < 0.001 were considered to be multivariate outliers (Kline, 2016). Despite measuring them, outliers were retained and not deleted.

Normality was assessed by skewness and kurtosis (flat/peaked) tests. According to Hair et al. (2014), data with skewness between +/- 2 and kurtosis between +/ -7 was deemed not to have a severe skew or kurtosis and not severely non-normal. Even when normality was not assumed, the bootstrapping procedure within SEM analysis can handle non-normal data (Byrne, 2001).

3.9.3 Structural equation modelling (SEM)

Stage 3 in the analysis plan included the application of SEM to answer Objective 2-4 (P.4). SEM is a multivariate statistical approach that combines both the measurement and structural models. The approach allows concurrently testing the associations among multiple independent and dependent constructs (Hair et al., 2014). Thus, SEM was applied in this study by first testing the measurement model and then the structural model. The procedure was performed for both steps with maximum likelihood (ML) and 900 bootstrapping estimations using AMOS (25 and 26). The 900 bootstrap samples were resampled to produce less biased standard errors, to report the 95%

Bias-corrected (BC) confidence interval (CI) (Mooney, 1993), to deal with multivariate non-normal data (Byrne, 2001), and to assess mediation effect (Hayes, 2009).

3.9.3.1 Confirmatory factor analysis (CFA)

The first step in building the SEM model was testing the measurement model through CFA. CFA is a process of testing how the measured variables represent a smaller number of constructs. CFA was used to confirm the a priori assumed association between a set of indicator factors (measurement items) and the latent factors (Byrne, 2001). Therefore, CFA was performed in this study by first identifying the model constructs based on the theoretical model (Section 2.6.2) and evaluating the proposed model. Generally, Hair et al. (2014) recommended two methods to evaluate the validity of the measurement model: (1) evaluating the goodness of fit (GOF) criteria indices with model estimates and modification indices, (2) and finding specific evidence of construct validity (loading estimates). In this study, the measurement model was evaluated by CFA by means of three types of indices, namely absolute fit indices, increment fit indices and parsimonious fit indices and the magnitude and significance of loading factors on the correspondence between the indicators and latent variables (Hair et al., 2014). The final step also was completed by examining the modification indices (MI) from the Amos output. The MI examined every possible association not assumed in the model (Byrne 2001). Hair et al. (2014) suggested that if the MI is 4.0 or higher, the fit could be improved by adding additional links or eliminating those items. However, they also recommended that the decision be consistent with the theory, not solely on MI values.

The absolute fit indices are used to evaluate the adequacy of the overall model fit. These indices include the Chi-square test statistic/degree of freedom ($\chi 2$/df) ratio, the root-mean-squared error of approximation (RMSEA), standardised root mean residual (SRMR) and the goodness of fit (GFI). The increment fit indices compare the assumed model with a baseline model and include the comparative fit index (CFI). The parsimonious fit indices are utilised to evaluate which model among a set of competing models is best. This index includes the adjusted goodness-of-fit index (AGFI). A non-significant chi-square indicates that the model is an acceptable representation of the association among the observed variables. However, significant results are expected in studies with a sample size > 250 (Hair et al., 2014). Thus, in this study, Chi-squared/degree of freedom ratio <3 (X^2/df) (Hu and Bentler, 1999), SRMR ≤ 0.08 and RMSEA values < 0.06, GFI, CFI and AGFI ≥ 0.90 were used to indicate an acceptable model fit (Byrne, 2001, Vehkalahti, 2011, Hair et al., 2014).

In addition to the GOF criteria, other standardised estimates can also be applied to evaluate the measurement model. Hair et al. (2014) suggested that all factor loadings (standard regression weight) should be statistically significant (P ≤ 0.01) and that their values should be 0.5 or higher or ideally be greater than 0.7 or if less than the variable could be specified for deletion (Hair et al., 2014). In contrast, Bagozzi (1991) proposed a factor loading with 0.3 as an acceptable value. However, lower loading values are expected with a complex theoretical model and sample size exceeding 400-500 (Hair et al., 2014). Thus, in this study, additional consideration was given to the significance of factor loadings, considering the complexity of the theoretical model and the sample size of 466 participants.

3.9.3.2 Structural model (SM)

Following the CFA, the full SM was developed by adding observed variables to examine the hypothesised associations between all variables. The full model fit was assessed using the indices mentioned above in CFA.

A parsimonious model was created by eliminating non-significant paths (p>0.05) from the full SEM's model. The difference in Chi-square and degrees of freedom between full and parsimonious models were calculated to evaluate both models' significant difference (Werner and Schermelleh-Engel, 2010). The parsimonious model was accepted if the difference was not statistically significant (*P>0.05)*. This calculation was performed in an online programme https://www.graphpad.com/quickcalcs/PValue1.cfm.

Then, the direct (the direct path from one variable to the next) and indirect (other variables mediated the link between two variables) paths linking latent and observed variables were estimated (Gunzler et al., 2013). The BC bootstrap 95% CI was used to assess mediation by examining the statistical significance of indirect paths (Hayes, 2009). The estimated indirect paths usually reflect the total indirect effect for all possible mediators on one variable without distinguishing the effect of specific mediators. AMOS, however, can identify the specific mediators with their exact significant indirect paths by using the Plugin and User Defined Estimands functions.

Thus, the online forum http://statwiki.gaskination.com/index.php?title=Plugins was used to guide the installation of Plugin and Estimands function and the estimation of the specific significant indirect paths and mediator with AMOS in this study.

3.9.3.3 Proposed full model for Structural Equation Modelling

The modified Heilmann et al. (2015) (Section 2.6.2) life course framework and literature review Chapter 2 was used to develop the proposed full structural model.

The study sample size restricted the number of included variables in the hypothesised model. The sample size is crucial for SEM, Hair et al. (2014) suggested that if the sample size is 300, then the recommended number of constructs would be seven or fewer with three indicators, and the expected loading factor values would be ≤ 0.45. They further suggested that if the sample size exceeds 400-500 participants, the number of constructs can be larger than six with three-four indicators each. However, the SEM analysis becomes too sensitive with low factor loadings, and the model will be a challenging fit.

Following that recommendation and based on the proposed theoretical framework, the measurement model was performed with six latent variables, each with 3-4 indicators. Then, twelve observed variables were added to the measurement model to create the full structural model (Figure 9). To confirm that the sample size is sufficient for the proposed SEM model, the sample size was calculated using an online website (https://www.danielsoper.com/statcalc/calculator.aspx?id=89). The result indicated that the required minimum sample size was 236 to detect a minimum effect size of 0.3, the statistical power of 0.95 and the probability level of 0.05, and a sample size of 400 would be required for the model identification.

3.9.3.3.1 Summary of the included variables

Latent variables: Early life

1. Family's SES at the time of the child's birth (BSES) with four indicators: mother's level of education, household income, mother's employment, and father's level of education.

2. Child's birth outcomes with three indicators: birth weight, gestational age, and birth order.

Latent variables: Current life

3. Family's current SES (CSES) with three indicators: mother's level of education, household income, and father's level of education.

4. Mother's oral health practices (OHPs), with three indicators: mother's toothbrushing, mother's flossing, and mother's use of mouthwash.

5. Child's current OHPs with four indicators: child's toothbrushing, child's flossing, child's sugar consumption, and child's use of mouthwash.

6. Parent’s characteristics with three indicators: mother's parenting style, father's parenting style, and mother's academic involvement.

Observed variables: Early life

1. Maternal chronic health conditions during pregnancy (CHCs)

2. Exclusive breastfeeding after birth

3. Supervised tooth brushing (TB)

4. Enamel developmental defects in primary teeth (EDD)

Observed variables: Current life

5. Dental plaque

6. Enamel (ds_2_3)

7. Dentine caries (ds_4_6)

8. pufa

9. Filled or extracted primary teeth because of caries (Treated)

10. Current dental pain

11. Absent days for Grade 2

12. Academic School performance for Grade 2

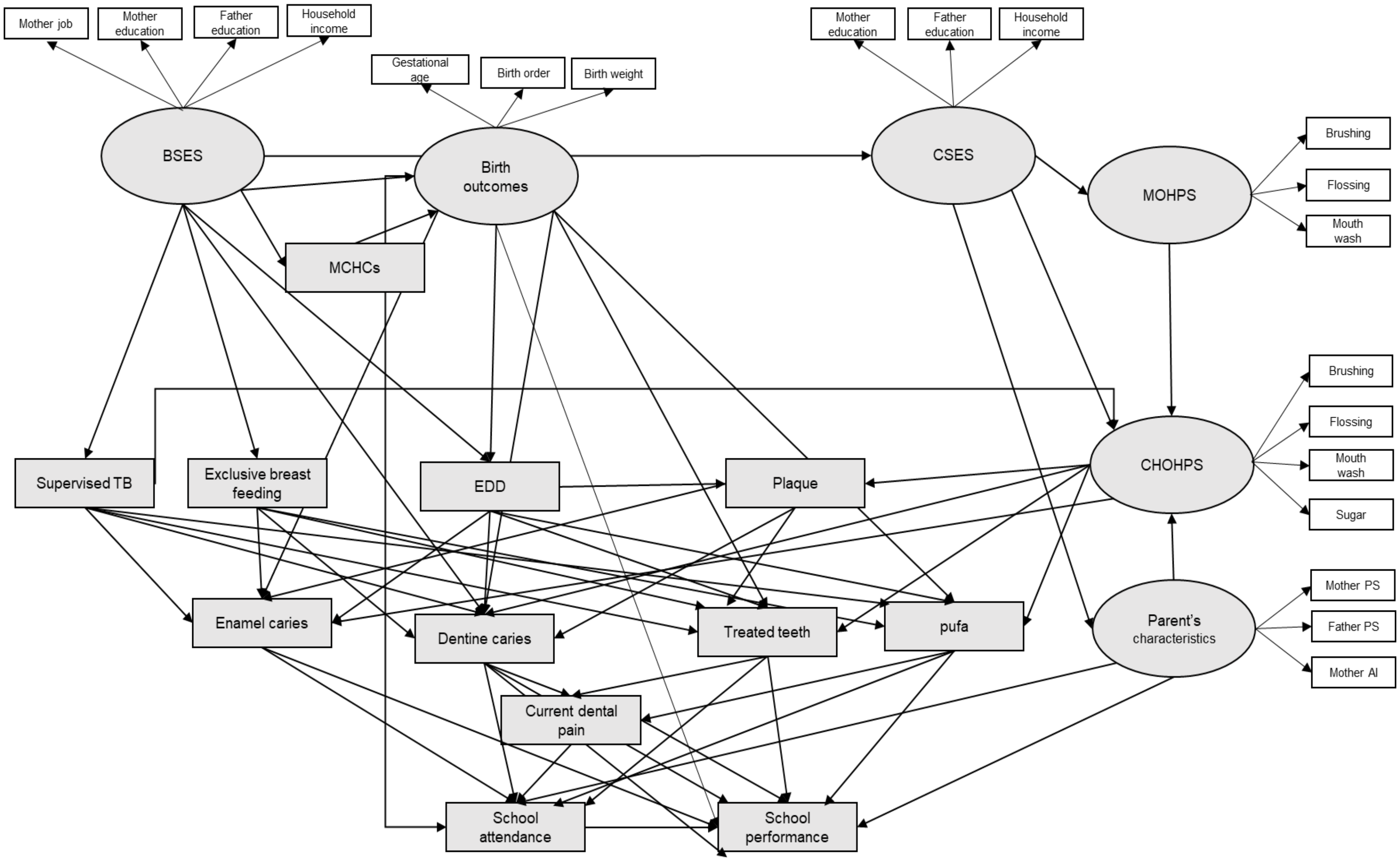


Figure 9. The proposed full model for the Structural Equation Modelling analysis

3.9.3.3.2 Research hypotheses

The proposed full SEM model aimed to examine the association between OHCs and school outcomes (attendance, performance) using the modified Heilmann et al. (2015) life course framework. This was achieved by; testing the critical and accumulation models to analyse the social, biological, behavioural, and parental pathways that linked early and current life exposures with children's current OHCs; examining the association and the possible mediators that linked OHCs with children's school outcomes. Thus, the following sections explain first the cut-off points of classifying the constructs as high/low, inadequate/inadequate and supportive/unsupportive (Table 23), then the detailed hypotheses testing procedure.

Table 23. Cut-off points for classification of constructs variables

Variables		
1. SES	**High SES if**	**Low SES if**
A. Mother's employment status	A. Mother's employment status	A. Mother's employment status
• Unemployed/retired	• Government employee	• Unemployed/retired
• Self/private employee		• Self/private employee
• Government employee		
B. Mother's level of education at child's birth	B. Mother's level of education at child's birth	B. Mother's level of education at child's birth
• Not educated	• >9 years	• Not educated
• ≤9 years		• ≤9 years
• >9 years		
C. Father's level of education at child's birth	C. Father's level of education at child's birth	C. Father's level of education at child's birth
• Not educated	• > 9 years	• ≤9 years, or not educated
• ≤9 years		
• >9 years		
D. Family income at child's birth	D. Family income at child's birth	D. Family income at child's birth
• BD† ≤399	• BD ≥800	• BD <800
• BD 400- 799		
• BD ≥800		
2. Birth outcomes	**Desirable birth outcomes**	**Undesirable birth outcomes**
A. Child's birth weight	A. Child's birth weight	A. Child's birth weight
• Low birth weight (<2500 g)	• Normal (≥2500 g)	• Low birth weight (<2500 g)
• Normal (≥2500 g)		
B. Child's gestational age	B. Child's gestational age	B. Child's gestational age
• Preterm birth (<37 weeks)	• Normal (≥37 weeks)	• Preterm birth (<37 weeks)
• Normal (≥37 weeks)		
C. Child's birth order	C. Child's birth order	C. Child's birth order
• First	• First	• Second or more
• Second or more		

3. Mother's and child's OH practices	**Adequate OH practices**	**Inadequate OH practices**
A. Toothbrushing	A. Toothbrushing	A. Toothbrushing
• Never or weekly	• > 2 times per a day	• ≤ 2 times per day/week or never
• Once or twice		
• More than twice		
B. Mouth wash (MW)	B. Mouth wash (MW)	B. Mouth wash (MW)
• Never or weekly	• > 2 times per a day	• ≤ 2 times per day/ week or never
• Once or twice		
• More than twice		
C. Flossing (CMF)	C. Flossing	C. Flossing
• Never or weekly	• > 2 times per a day	• ≤ 2 times per day/ week or never
• Once or twice		
• More than twice		
D. Sugar consumption	D. Sugar consumption	D. Sugar consumption
• Never or weekly	• ≤ 2 times per day/week or never	• > 2 times per a day
• Once or twice		
• More than twice		
4. Parent's characteristics	**Supportive parent's characteristics**	**Unsupportive e Parent's characteristics**
A. Mother's and father's parenting style	A. Parenting style	A. Parenting style (MPS)
• Permissive	• Authoritative	• Permissive
• Authoritarian		• Authoritarian
• Authoritative		
B. Mother academic involvement score	High score of academic involvement	The low score of academic involvement

3.9.3.3.2.1 Early and current life factors linked to OHCs

3.9.3.3.2.1.1 Critical period model

The model assumed that the exposures that happened at the time of the child's birth would associate with the development of OHCs in the current stage of life of Grade 2 children (Heilmann et al., 2015). The accumulation of these factors might influence children's OHCs either independently or cluster by SES (Ben-Shlomo and Kuh, 2002). Therefore, the following hypotheses were tested:

1. Children born into a family with high SES would have better OH at the age of 7-8 years (Abreu et al., 2015)(Figure 10a);
2. Children born with undesirable birth outcomes were more likely to have OHCs at 7-8 years old (Nicolau et al., 2003) (Figure 10a);
3. Children with EDD in primary teeth were more likely to have dental caries (Zhou et al., 2011, Masumo et al., 2013) (Figure 10a);
4. Low SES is linked with undesirable birth outcomes and EDD development as a cluster of risks; hence, those factors would associate with worse children's OHCs at 7-8 years of age (Figure 10b).

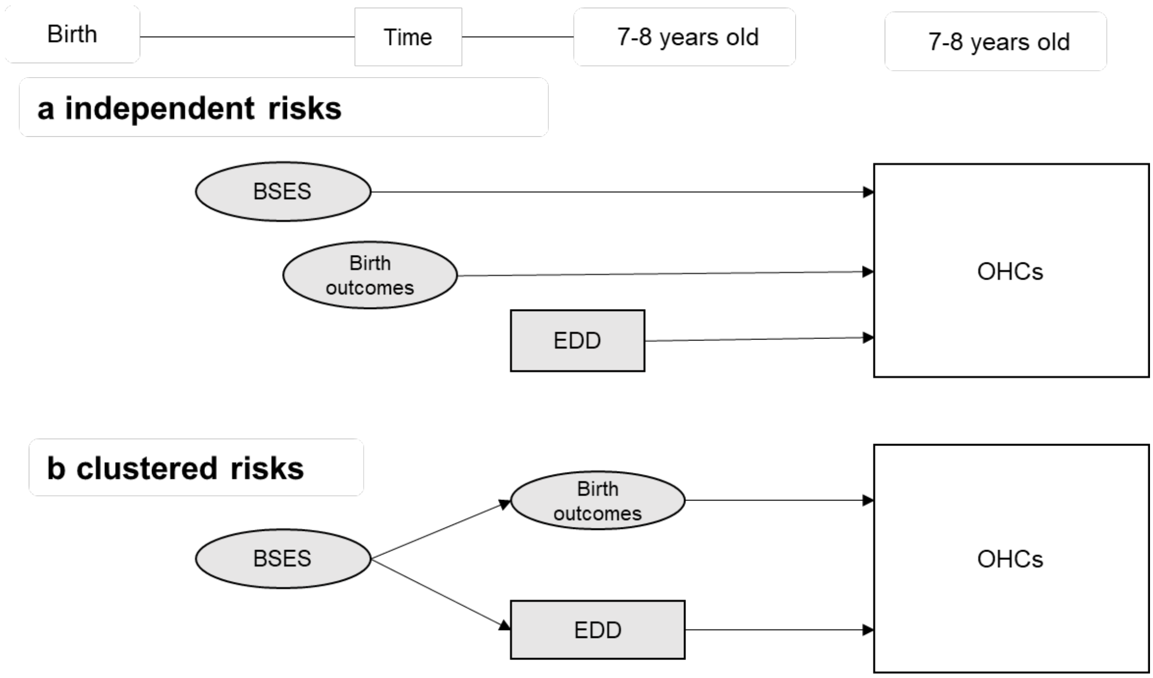


Figure 10. Life course model (Ben-Shlomo and Kuh, 2002), critical period model; a) independent risks; b) clustered risks

3.9.3.3.2.1.2 Accumulation model with the chain of risks

Chain of risk with additive effect model

Low BSES might influence maternal health during pregnancy, resulting in hypertension and diabetes, which increases the risk of low birth weight and preterm birth (Kramer, 2000). These undesirable pregnancy outcomes may subsequently associate with EDD (Jacobsen et al., 2014). Consequently, EDD would increase dental plaque accumulation, and finally, the dental plaque would increase the risk of developing dental caries (Zhou et al., 2011);

Thus, in this model, each of the factors mentioned above would increase the subsequent exposure and would independently increase the risk of poor OHCs irrespective of later exposure (Ben-Shlomo and Kuh, 2002) (Figure 11a);

Chain of risk with trigger effect model

The model assumed that low BSES have no direct effect on the child's OHCs at 7-8 years of age. Instead, low BSES would trigger the risk of having maternal CHCs during pregnancy. Thus, maternal CHCs can influence a child's birth outcomes, which would trigger the development of EDD. As a result, EDD increases dental plaque accumulation, hence the risk of dental caries. In this model, each risk led to another; only the final link in the chain can influence the development of such chronic conditions (Ben-Shlomo and Kuh, 2002) (Figure 11b);

Risk clustering

Low BSES could lead to a cluster of risk behaviours such as no exclusive breastfeeding (0-2 years old) (Meedya et al., 2010) and unsupervised tooth brushing (3-6 years old) (Declerck et al., 2008) and these behaviours together or independently would increase the risk of worse OHCs in 7-8-year-olds (Figure 11c).

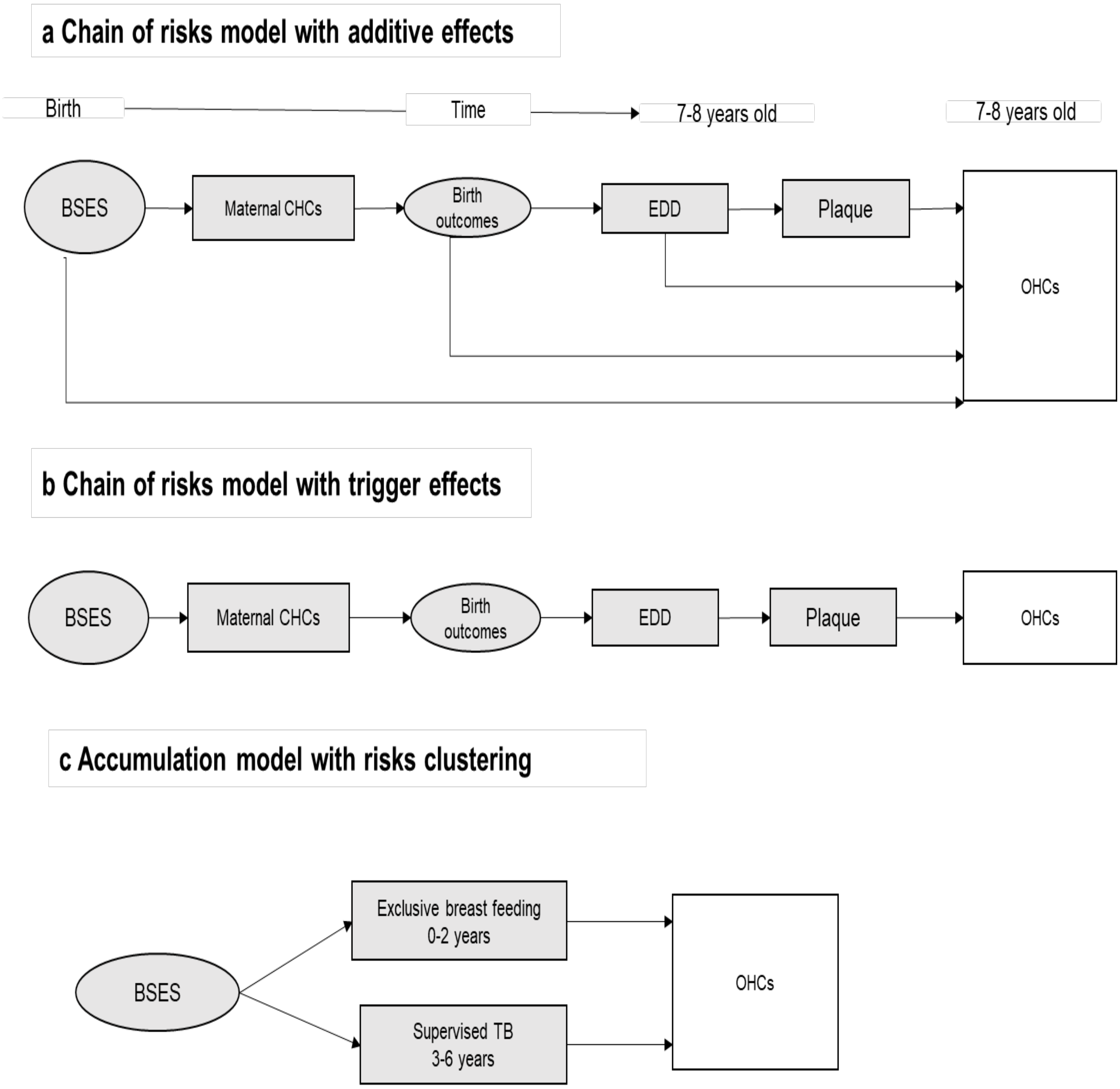


Figure 11. The accumulation of risks models

3.9.3.3.2.1.3 Association between BSES and CSES

The model assumed that BSES predicted the current family's SES. Thus, low current SES might shape a cluster of parental factors associated with the children's oral health practices (OHPs) and OHS (Figure 12). Hence the following hypotheses were tested:

1. A family's low BSES associated with low CSES (Thomson et al., 2004);

2. Low CSES associated with inadequate OHPs among mothers (Hooley et al., 2012). At the same time, a mother's OHPs predicted their children's OHPs (Hooley et al., 2012). Therefore, either children's OHPs associated with their OHCs directly or dental plaque would mediate the association between their OHPs and OHCs (Shenkin et al., 2004);
3. Low CSES associated with unsupportive parental characteristics like practising a non-authoritative parenting style (Ballantine, 2001, Howenstein et al., 2015) and low mother academic involvement (Andersen et al., 2021). Consequently, parental characteristics are associated with children's OHPs (Howenstein et al., 2015, da Silva et al., 2018). Therefore, either children's OHPs linked with their OHCs directly or dental plaque mediated the association between their OHPs and OHCs.

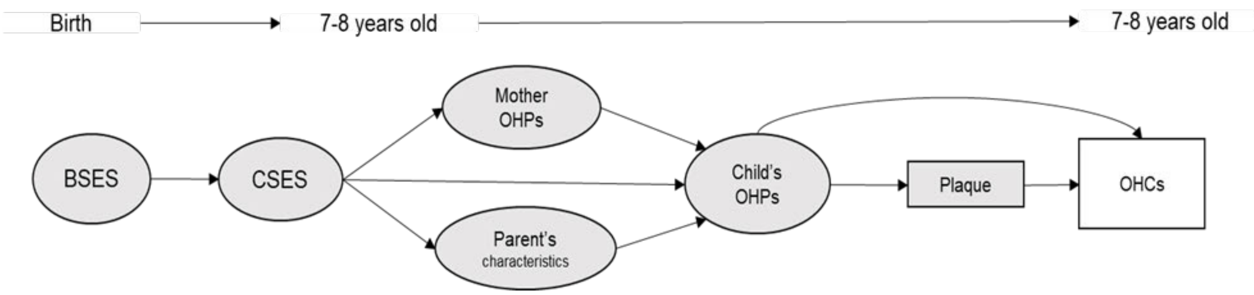


Figure 12. The relation between BSES and CSES and children's current OH

3.9.3.3.2.2 Association between OHCs and school performance and attendance

Finally, the model assumed adjacent associations between the child's clinical OH and school performance (Osman and Alsayed, 2015) and school attendance (Butani et al., 2009). The association could be direct or mediated by other factors. Thus, the following hypotheses were tested:

1. OHCs were directly associated with low school performance and poor school attendance;
2. The association of OHCs with low school performance and poor school attendance were mediated by dental pain (Piovesan et al., 2012);
3. The association of OHCs with low school performance and poor school attendance were mediated by the consequence of dental caries (Quadros et al., 2021);
4. OHCs mediated the association of low SES with low school performance and school attendance (Seirawan et al., 2012);
5. The association between OHCs and low school performance was mediated by school attendance (Fornander and Kearney, 2019);
6. Biological, social, behavioural, and parental factors in children's early and current life course were also related to their school performance and attendance.

Chapter 4. Results

4.1 Introduction

This chapter presents the results of this study. The results are presented in five main sections.

Section 4.2 shows the final sample size and response rate.

Section 4.3 gives a descriptive breakdown of the collected data in relation to the variables collected at baseline (September 2019).

Section 4.4 summarizes the results of the questionnaires reliability and the clinical calibration.

Section 4.5 screens data for missing, outlier and normality.

Section 4.6 tests the comprehensive interrelationships among the variables using SEM.

4.2 Response rate

Five hundred and ten children and their parents were invited, but 33 refused to participate. A total of 477 children (292 girls and 185 boys) and their parents enrolled on the study in September 2019, when baseline data was collected. However, 11 (2%) of the parents failed to return the completed questionnaires, resulting in their children (five girls and six boys) being excluded from the final sample. Otherwise, data collection was carried out successfully, and the response rate was 98%.

4.3 Descriptive statistics

4.3.1 Socio-demographics

Of the 466 schoolchildren, 287 (61.6%) were females, and 179 (38.4%) were males. Nearly three-quarters (72.5%) of them were Bahraini, while 21% were from Arab countries such as Egypt and 1.5% from other Gulf Cooperation Council Countries (GCC). The remaining 5.2% were from Asia (Pakistani). Almost all children (98.7%) lived within the Muharraq Governorate, only 6 (1.3%) living elsewhere. The mothers' ages ranged from 23-60 years old, with a mean age of 35.8 years (SD = 6.0). The fathers were marginally older, ranging from 24-73 years old, with a mean of 41 years (SD = 7.8) (Table 24).

Table 24. Demographic profile of 466 participants at baseline

Independent variable	%	Frequency
Gender		
Male	38.4	179
Female	61.6	287
Total	*100.0*	*466*
Age		
7	91.2	425
8	8.8	41
Total	*100.0*	*466*
Place of birth		
KoB	80.7	376
Outside KoB	19.3	90
Total	*100.0*	*466*
Ethnicity		
Bahraini	72.5	338
GCC	1.3	6
Arab	21.0	98
Asian	5.2	24
Total	*100.0*	*466*
Area of residence		
Muharraq Governorate	98.7	460
Capital Governorate	0.2	1
Southern Governorate	0.4	2
Northern Governorate	0.6	3
Total	*100.0*	*466*

	Mean	Median	Mode	SD	Range
Father's age	41.0	41	43	7.8	24-73
Mother's age	35.8	35	32	6.0	23-60

4.3.2 Current socioeconomic circumstances

4.3.2.1 Parents' level of education

Nearly two-thirds of the parents had completed more than nine years of formal education. A third of the mothers (33.3%) and nearly half of the fathers (46.1%) had completed their education at secondary school, while another 29.8% of mothers, and 24% of fathers, had graduated from university (see Table 25 below).

4.3.2.2 Parents' employment status

Three quarters (74.5%) of the mothers had no salaried occupation, while almost all (98%) of the fathers were employed, over half of them in the military (44%). Of the employed mothers, the majority (14.4%) worked for the government, mostly (11.8%) in less well-paid positions. Similarly, only a third held jobs on higher salary scales than the fathers who worked in government positions (18.7%) (Table 25).

Table 25. Participant's current socioeconomic circumstances

Current SES	Mother		Father	
	%	Frequency	%	Frequency
Level of education				
Uneducated	8.2	38	1.7	8
Primary	11.8	55	2.1	10
Intermediate	13.3	62	17.2	80
Secondary	33.3	155	46.1	215
College/university	29.8	139	24.0	112
Postgraduate	3.2	15	8.6	40
No response	0.4	2	0.3	1
Total	*100.0*	*466*	*100.0*	*466*
Employment status				
Unemployed	74.5	347	1.9	9
Self-employed	0.4	2	6.4	30
Private sector employee	5.6	26	12.2	57
Military	2.4	11	44.0	205
Retired	2.4	11	10.3	48
GE-public jobs salary scale	11.8	55	18.7	87
GE-specialised jobs salary scale	1.3	6	2.4	11
GE -judges salary scale	0.0	0	0.2	1
GE -executive jobs salary scale	0.4	2	1.3	6
GE -academic jobs salary scale	0.9	4	1.1	5
GE -diplomatic jobs salary scale	0.0	0	0.9	4
No response	0.3	2	0.6	3
Total	*100.0*	*466*	*100.0*	*466*

4.3.2.3 Household income

Nearly half (45%) of the participants were from households with a monthly income of less than 600 Bahraini dinars (BD). However, 28.1% of them were from high-income households, earning at least 800 BD per month (Table 26).

4.3.2.4 Housing tenure

Approximately two-thirds of families (65.9%) did not own their homes, and a further 5.6% of them were still living with their parents (Table 26).

4.3.2.5 Housing crowding

Nearly half of the families (45.5%) lived in overcrowded conditions, namely two or more people per room. The number of rooms per home ranged from 1 to 11 (mean no. of rooms = 3.2; SD = 1.4) (Table 26).

Table 26. Participant's household income and housing conditions

	Household				
	%			Frequency	
Household monthly income					
BD <200 (low)	6.4			30	
BD 200-399 (low)	10.5			49	
BD 400-599 (moderate)	28.1			131	
BD 600-799 (moderate)	26.5			123	
BD 800-999 (high)	13.1			61	
BD ≥1000 (high)	15.0			70	
No response	0.4			2	
Total	*100.0*			*466*	
Housing tenure					
Rented flat	51.1			238	
Owned flat	10.1			47	
Rented house	14.8			69	
Owned house	18.4			86	
Other: living with parents	5.6			26	
Total	*100.0*			*466*	
Housing crowding					
>2 people per room (overcrowded)	45.5			212	
≤2 people per room (non-crowded)	54.5			254	
Total	*100.0*			*466*	
	Mean	**Median**	**Mode**	**SD**	**Range**
Number of rooms in the home, excluding kitchen and bathrooms	3.2	3	2	1.4	1-11
Number of people living in the home	6.4	6	5	2.3	1-22

4.3.3 Current family structure

Eighty-five per cent of the children lived with both parents, while 10.7% and 4.3% were from extended and single-parent families, respectively. The number of siblings ranged from 0 to 11, with most children (71.9%) having three or fewer siblings (mean no. of siblings = 3.2, SD = 2.0) (Table 27).

Table 27. Participant's current family structure

Family structure	%		Frequency		
Family type					
Single parent	4.3		20		
Extended	10.7		50		
Nuclear	85.0		396		
Total	*100.0*		*466*		
Parent'/s' marital status					
Widowed	1.3		6		
Divorced	3.4		16		
Married	95.3		444		
Total	*100.0*		*466*		
	Mean	**Median**	**Mode**	**SD**	**Range**
Number of siblings	3.2	3	2	2.0	0-11

4.3.4 Current OH behaviours

Generally, parents reported once or twice daily toothbrushing for themselves and their children. However, according to parents, few children (6.6%) did not brush or brush their teeth weekly. Moreover, few of the children used dental floss (15.7%) or mouthwash (21.5%) (Table 28).

Nearly two-thirds of mothers, fathers, and children (61.2%, 58.2%, and 63.1%, respectively) consumed sugar once or twice daily, and 23% of children consumed sugar more than twice a day (Table 28).

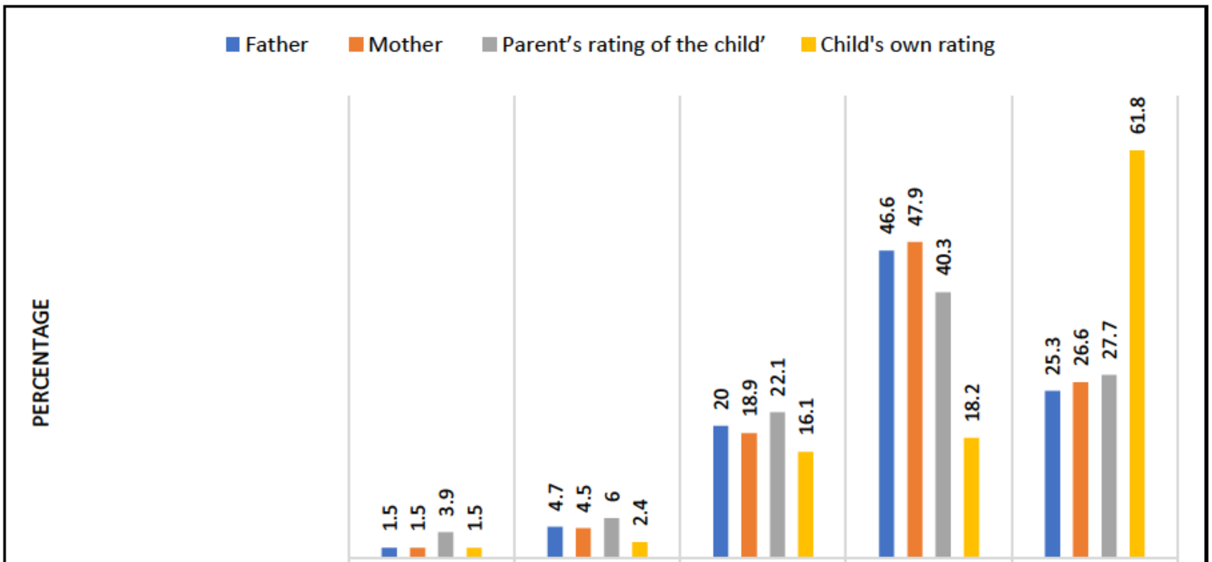
Regarding the pattern of dental attendance, although 24% of parents had regular check-ups, nearly 60% visited the dentist only in an emergency, and 7.2% had never been to the dentist. Similarly, 67.4% of children visited the dentist only in an emergency, and 12.2% had never been to the dentist (Table 28).

The majority of parents (85%) reported using toothpaste containing fluoride in the concentration 1350-1450 ppm (parts per million). The most popular toothpaste was Sensodyne (14.8%), closely followed by Signal (12.9%) and Colgate (9.6%). Among children, however, the proportion reported to use 1350-1450 ppm fluoridated toothpaste was less than half (43.5%), a quarter (25.5%) used toothpaste with lower fluoride concentrations and 3.9% used toothpaste with no fluoride in it at all. Moreover, there was a 24.5% no-response rate for this question, indicating that 24.5% of the children did not use toothpaste of any sort. The most used brands by children were Signal (7.6) and Colgate (5.7%). Most children (92%) were reported to rinse with water after brushing, with only 1.7% spitting out any remaining toothpaste without rinsing.

Parent’s OH ratings were almost similar. Most parents perceived themselves and their children as having good OH. Only 1.5% of both parents reported having poor OH. Parental perception of their children’s OH did not match the child’s perception; 27.7% of parents perceived their children as having excellent; OH, while 61.8% of children perceived themselves as having excellent OH (Figure 13).

Table 28. Oral health behaviours of children and parents' participants

Oral health behaviours	Mother		Father		Child	
	%	F	%	F	%	F
Toothbrushing regime						
Never	1.9	9	3.3	15	3.6	17
Weekly	0.9	4	1.1	5	3.0	14
Once a day	15.5	72	20.8	97	34.1	159
Twice a day	59.0	275	52.1	243	50.9	237
More than twice a day	22.1	103	21.0	98	8.4	39
No response	0.6	3	1.7	8	0.0	0
Total	*100.0*	*466*	*100.0*	*466*	*100.0*	*466*
Use of dental floss						
Never	53.0	247	52.1	243	84.3	393
Weekly	17.0	79	14.8	69	4.5	21
Once a day	17.8	83	18.5	86	7.1	33
Twice a day	7.5	35	8.2	38	2.6	12
More than twice a day	4.1	19	4.7	22	1.5	7
No response	0.6	3	1.7	8	0.0	0
Total	*100.0*	*466*	*100.0*	*466*	*100.0*	*466*
Use of mouthwash						
Never	36.5	170	38.4	179	78.5	366
Weekly	15.7	73	15.9	74	0	0
Once a day	25.7	120	23.2	108	17.4	81
Twice a day	12.9	60	12.7	59	4.1	19
More than twice a day	8.6	40	8.1	38	0.0	0
No response	0.6	3	1.7	8	0.0	0
Total	*100.0*	*466*	*100.0*	*466*	*100.0*	*466*
Use of fluoridated toothpaste	%			F 16	3.9	18
No fluoride	3.4			11	15.4	72
500 ppm	2.4			22	10.1	47
1000 ppm	4.7			396	43.5	203
1350-1450 ppm	85.0			8	2.6	12
Other	1.7			13	24.5	114
No response	2.8			*466*	*100.0*	*466*
Total	*100.0*					
Spit or rinse (toothpaste)						
Rinse with water					92.1	429
Rinse with mouthwash					3.2	15
Spit (no rinsing)					1.7	8
Do not know					3.0	14
Total					*100.0*	*466*
Consumption of sugar						
Never	10.7	50	11.6	54	4.3	20
Weekly	16.7	78	14.2	66	9.6	45
Once a day	43.8	204	36.7	171	35.2	164
Twice a day	17.4	81	21.5	100	27.9	130
More than twice a day	10.8	50	14.4	67	23.0	107
No response	0.6	3	1.6	8	0.0	0
Total	*100.0*	*466*	*100.0*	*466*	*100.0*	*466*
Visits to dentist						
Do not visit	5.6	26	8.8	41	12.2	57
Emergencies only	60.3	281	58.8	274	67.4	314
Regular checkup	24.9	116	23.2	108	20.4	95
Other	8.4	39	7.3	34	-	-
No response	0.8	4	1.9	9	0.0	0
Total	*100.0*	*466*	*100.0*	*466*	*100*	*466*



	Poor	Fair	Average	Good	Excellent
Father	1.5	4.7	20	46.6	25.3
Mother	1.5	4.5	18.9	47.9	26.6
Parent's rating of the child'	3.9	6	22.1	40.3	27.7
Child's own rating	1.5	2.4	16.1	18.2	61.8

Figure 13. OH rating of parents, parent's rating of the child's OH, and child's own rating

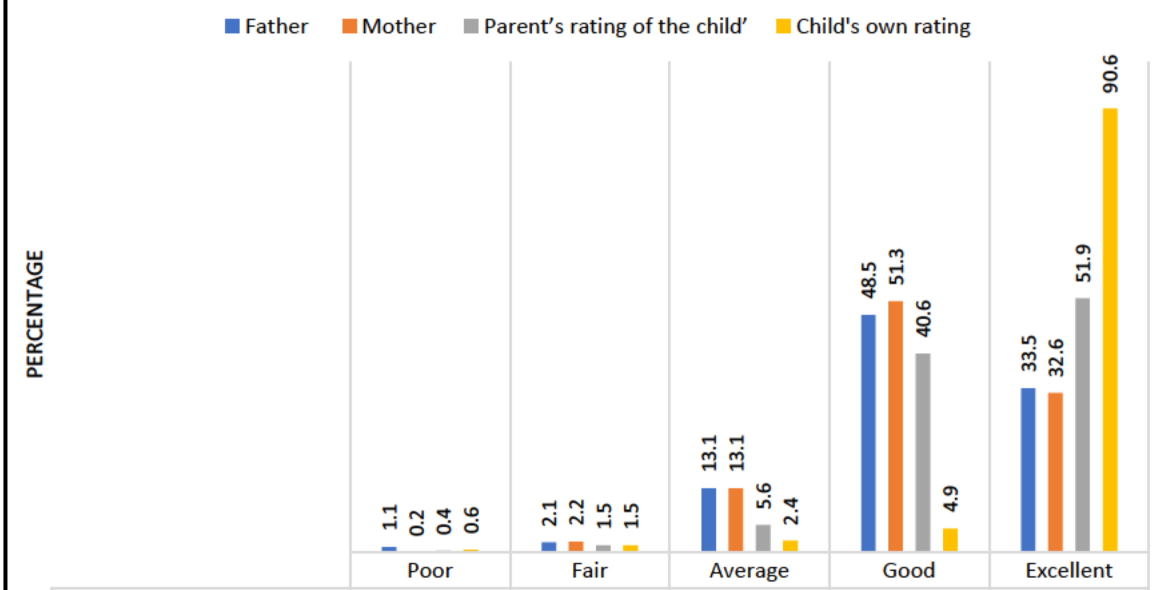
4.3.5 Current health: perceptions, behaviours, and status

More than 80% of parents perceived themselves as having good to excellent general health, while 13% of both fathers and mothers reported having average health (Table 29; Figure 14). 29.2% of fathers and 2.8% of mothers reported that they smoked tobacco. Among those fathers, cigarettes were the preferred medium (64.2%), shisha (77%) was the favourite among the mothers.

Parental perception of their children's health did not match the child's perception; 51.9% of parents perceived their children as having excellent general health, while 90.6% of children perceived themselves as having excellent general health (Figure 14).

Table 29. Health perceptions, behaviours, and status of participants

	Mother		Father		Child	
	%	F	%	F	%	F
General health (parents' ratings)						
Poor	0.2	1	1.1	5	0.4	2
Fair	2.2	10	2.1	10	1.5	7
Average	13.1	61	13.1	61	5.6	26
Good	51.3	239	48.5	226	40.6	189
Excellent	32.6	152	33.5	156	51.9	242
No response	0.6	3	1.7	8	0	0
Total	*100.0*	*466*	*100.0*	*466*	*100.0*	*466*
Tobacco smoking						
Non-smoker	96.6	450	70	326		
Smoker	2.8	**13**	29.2	**136**		
No response	0.6	3	0.8	4		
Total	*100.0*	*466*	*100.0*	*466*		
Mode of smoking						
Cigarettes	23.0	3	64.2	87		
Shisha	77.0	10	31.4	43		
Electronic cigarettes	0.0	0	4.4	6		
Total	*100.0*	*13*	*100.0*	*136*		
Chronic health conditions						
Normal (none)					90.6	422
Asthma					2.8	13
Iron deficiency					1.3	6
Epilepsy					0.2	1
Disability (sight or speech)					0.9	4
Autism					0.2	1
ADHD					0.4	2
Other					3.6	17
Total					*100.0*	*466*
Current medication						
Not taking medication					95.9	447
Currently taking medication					4.1	19
Total					*100.0*	*466*
BMI percentile						
Underweight (<5th)					7.7	36
Normal BMI (5th-85th)					61.8	288
Overweight (85th-95th)					11.8	55
Obese (≥95th)					18.7	87
Total					*100.0*	*466*



	Poor	Fair	Average	Good	Excellent
Father	1.1	2.1	13.1	48.5	33.5
Mother	0.2	2.2	13.1	51.3	32.6
Parent’s rating of the child’	0.4	1.5	5.6	40.6	51.9
Child's own rating	0.6	1.5	2.4	4.9	90.6

RATING

Figure 14. Health rating of parents; parent’s rating of the child health, and child’s own rating

Less than 10% of the children had chronic health conditions. Of them, nearly a third of those children were asthma (2.8% of the total sample). However, 6.8% reported having other conditions like glucose-6-phosphate dehydrogenase (G6PD) deficiency, allergies, leukaemia, eczema, urinary tract infection, and others (Figure 15).

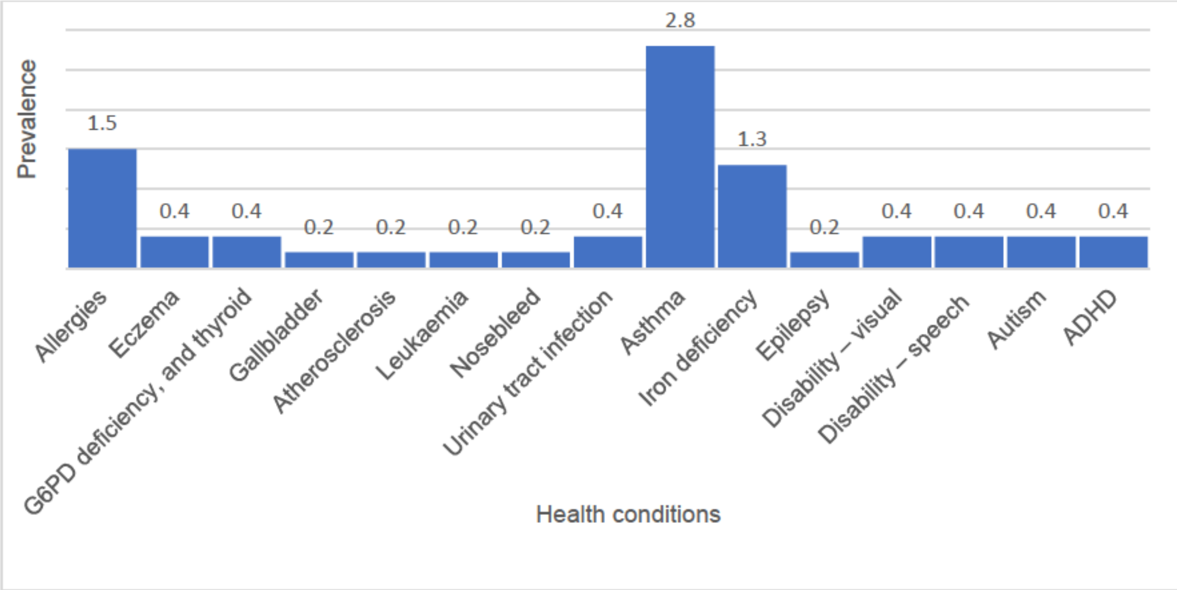


Figure 15. Prevalence and type of chronic health conditions among children

Interestingly, obesity was another condition of concern among children in Muharraq. Nearly one third (31%) of children were overweight or obese, which was true for both genders (see Figure 16).

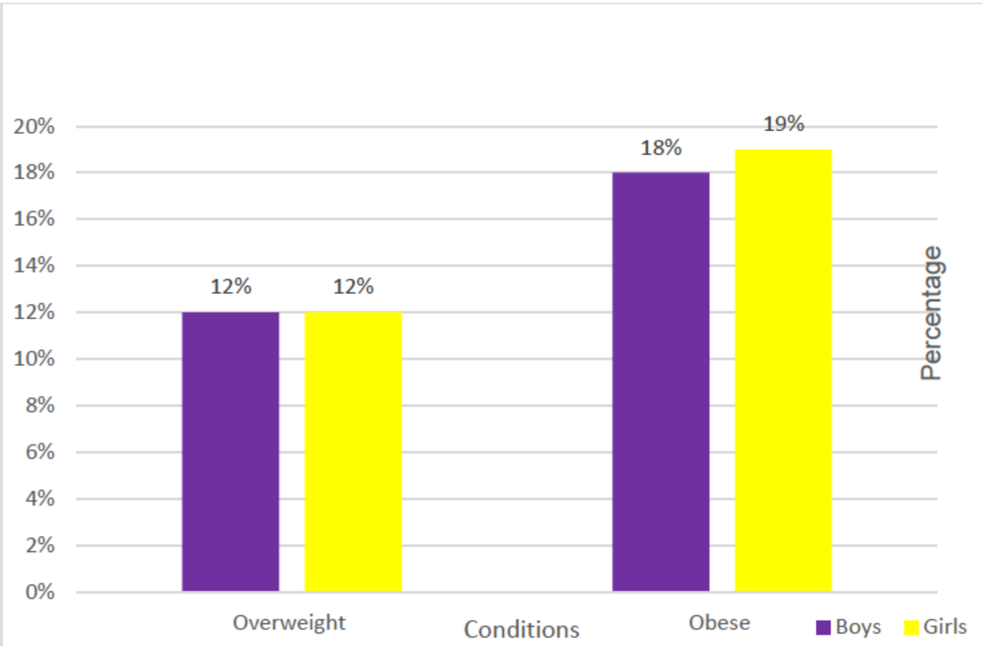


Figure 16. Prevalence of overweight and obesity by gender

4.3.6 Early life factors

4.3.6.1 Socioeconomic circumstances at the time of the child's birth

4.3.6.1.1 Parents’ levels of education

A third of mothers (65.7%) and more than three quarters (77.2%) of the fathers completed more than nine years of study. The most frequent level of education among both fathers (45.3%) and mothers (34.5%) was the attainment of a secondary school certificate (Table 30).

4.3.6.1.2 Parent’s types of employment

Three-quarters of the mothers (74.7%) were not in salaried employment when the child was born, contrasting with only 3.2% of the fathers. Almost half of the fathers (46.4%) were in the military, and a further 22.3% were public sector workers, mostly teachers (Table 30).

4.3.6.1.3 Household income

Less than a quarter of the families had a household income of ≤399 BD per month. The majority (77.4%) fell into the moderate- and high-income groups (400 BD per month or more) (Table 30).

4.3.6.1.4 Housing tenure

A quarter (25.3%) of the families owned their house or flat when their child was born. Nearly all the remaining families rented the house, with just a few (7.1%) living with their parents (Table 30).

Table 30. Participant's socioeconomic circumstances at the time of child's birth

Early life SES	Mother		Father	
	%	Frequency	%	Frequency
Level of education				
Uneducated	9.0	42	2.6	12
Primary school	11.8	55	3.0	14
Intermediate school	13.6	63	17.2	80
Secondary school	34.5	161	45.3	211
College/university	27.7	129	25.1	117
Postgraduate	3.0	14	6.2	29
No response	0.4	2	0.6	3
Total	*100.0*	*466*	*100.0*	*466*
Type of employment				
Unemployed	74.7	348	3.2	15
Self-employed	1.1	5	5.6	26
Employed in the private sector	7.1	33	13.4	62
Military	0.8	4	46.4	216
Retired	0.2	1	3.4	16
GE - public jobs salary scale	13.4	62	22.3	104
GE - specialised jobs salary scale	0.8	4	2.6	12
GE - judges' salary scale	0	0	0	0
GE - executive jobs salary scale	0	0	0.8	4
GE - academic jobs salary scale	0	0	1.1	5
GE - diplomatic jobs salary scale	1.5	7	0.4	2
No response	0.4	2	0.8	4
Total	*100.0*	*466*	*100.0*	*466*

	Household	
	%	Frequency
Household monthly income		
BD <200 (low)	6.9	32
BD 200-399 (low)	15.7	73
BD 400-599 (moderate)	35.4	165
BD 600-799 (moderate)	21.2	99
BD 800-999 (high)	10.5	49
BD ≥1000 (high)	10.1	47
No response	0.2	1
Total	*100.0*	*466*
Housing tenure		
Rented flat	46.4	216
Owned flat	5.6	26
Rented house	21.2	99
Owned house	19.7	92
Other: living with parents	7.1	33
Total	*100.0*	*466*
Number of rooms in the house, excluding kitchen and bathrooms		
≤3	76.8	358
>3	23.2	108
Total	*100.0*	*466*
(Mean: 3; Median: 3; Mode: 2; SD: 1.9; Range: 1-25)		

4.3.6.2 Family structure

Most of the children (83.9%) were born in a nuclear family, and 15.0% were born in an extended family. The number of siblings ranged from 0 to 14, with the majority of the children (53.9%) having more than two siblings. The children's birth order ranged from the first to the fifteenth, with the largest quadrant (31.5%) being the fourth or later. However, 24.3% were their parents' first child (Table 31).

Table 31. Participant's family structure at the time of child's birth

Family structure	%	Frequency
Family type		
Single	1.1	5
Extended	15.0	70
Nuclear	83.9	391
Total	*100.0*	*466*
Family marital status		
Widowed	0.4	2
Divorced	2.6	12
Married	97.0	452
Total	*100.0*	*466*
Child's birth order		
First	24.3	113
Second	23.2	108
Third	21.0	98
Fourth or later	31.5	147
Total	*100.0*	*466*
(Mean: 3.0; Median: 3.0; Mode: 1; SD: 2.0; Range: 1-15)		
Number of siblings		
0	22.7	106
≤2	23.4	109
>2	53.9	251
Total	*100.0*	*466*
(Mean: 2.0; Median: 2; Mode: 1; SD: 1.9; Range: 0-14)		

4.3.6.3 Maternal demographic and health conditions

When the child was born, the mother's age ranged from 16 to 53 years (mean age: 28.7 years; SD = 6.0). During pregnancy, about 12.9% of the mothers had diabetes mellitus, and 8.6% had hypertension. Only 1.5% of the mothers smoked during pregnancy. Few mothers (5.2%) reported having other health conditions such as asthma, iron deficiency or a thyroid problem, while 8.4% of them reported having postnatal depression. The majority of mothers (71.2%) delivered their child normally, the rest undergoing caesarean section (Table 32).

Table 32. Mother's demographic and health during pregnancy

Biological/health factor	**%**	**Frequency**
Age		
≤28 years	52.8	246
>28 years	46.6	217
No response	0.6	3
Total	*100.0*	*466*
(Mean: 28.7; Median: 28; Mode: 30; SD: 6.3; Range: 16-53)		
Medical condition: Diabetes		
Yes	12.9	60
No	86.9	405
No response	0.2	1
Total	*100.0*	*466*
Medical condition: Hypertension		
Yes	8.6	40
No	91.2	425
No response	0.2	1
Total	*100.0*	*466*
Other medical condition(s)		
Yes	5.2	**24**
No	94.6	441
No response	0.2	1
Total	*100.0*	*466*
Type of other medical condition		
Asthma	12.5	3
B12, Fe deficiency	4.2	1
Infection	4.2	1
Iron deficiency	54.1	13
Thyroid	25.0	6
Total	*100.0*	*24*
Smoking during pregnancy		
Yes	1.5	7
No	98.3	458
No response	0.2	1
Total	*100.0*	*466*
Prenatal depression		
Yes	8.4	39
No	91.4	426
No response	0.2	1
Total	*100.0*	*466*
Delivery method		
Normal birth	71.2	332
Caesarean section	28.6	133
No response	0.2	1
Total	*100.0*	*466*

4.3.6.4 Children's birth outcomes and feeding practices

Most children were born with normal gestational age and normal birth weight; 11% were born prematurely, while 11.2% had a low birth weight. Regarding feeding practices, almost a third (27.9%) of the children were exclusively breastfed during the first six months, while 19.1% were bottle-fed only, the remainder (52.8%) being both bottles- and breastfeeding. Nearly a quarter of the parents bottle-fed their child with a sweetened drink at bedtime (Table 33).

Just over a quarter of the children (25.3%) used a pacifier, and the majority of those (81.4%) used the pacifier from birth. Most commonly (55.9% of pacifier users), pacifiers were used for a duration of more than a few months but less than two years, although 21.2% of pacifier users used one for longer than that.

Table 33. Children's birth outcomes and feeding practices in infancy

	%	Frequency
Gestational age		
Preterm birth (less than 37 weeks)	11.0	51
Normal (equal to or more than 37 weeks)	88.8	414
No response	0.2	1
Total	*100.0*	*466*
Birth weight		
Low birth weight (less than 2500 g)	11.2	52
Normal (equal to or more than 2500 g)	88.6	413
No response	0.2	1
Total	*100.0*	*466*
Feeding practices		
Breastfeeding only	27.9	130
Bottle feeding only	19.1	89
Breast and bottle feeding	52.8	246
No response	0.2	1
Total	*100.0*	466
Nighttime sweet drinks		
Yes	24.9	116
No	74.9	349
No response	0.2	1
Total	*100.0*	*466*
Use of pacifier		
Yes	25.3	**118**
No	74.5	347
No response	0.2	1
Total	*100.0*	*466*
Timeframe of using a pacifier		
From birth	81.4	96
Began at 6 months	5.9	7
Began after 6 months	3.4	4
Cannot remember	9.3	11
Total	*100.0*	*118*
Duration of using a pacifier		
A few months	11.9	14
Less than two years	55.9	66
Two years or more	21.2	25
Cannot remember	11.0	13
Total	*100.0*	*118*

4.3.6.5 Child's OH behaviour at 3-6 years old

Most children (85.4%) had started brushing their teeth older than 12 months. Less than half of the sample (40.6%) always brushed their teeth under parental supervision; only 4.5% had never had their toothbrushing supervised by their parents.

Before enrolling in school, 48.9% of the children experienced dental pain, 57.3% had developed caries in primary teeth, and 47% had undergone dental treatment (Table 34).

Table 34. Children's OH status and OH behaviours at 3-6 years old

Oral health factors or behaviour	%	Frequency
Age when started brushing teeth		
Not brushing	0.4	2
Older than 12 months	85.4	398
12 months or younger	14.2	66
Total	*100.0*	*466*
Supervised toothbrushing		
Never	4.5	21
Occasionally	28.3	132
Mostly	26.6	124
Always	40.6	189
Total	*100.0*	*466*
Dental pain		
Yes	48.9	228
No	51.1	238
Total	*100.0*	*466*
Dental caries in primary teeth		
Yes	57.3	267
No	42.7	199
Total	*100.0*	*466*
Dental treatment		
Yes	47.0	219
No	53.0	247
Total	*100.0*	*466*

4.3.7 Child's early learning

Most children (72.7%) were enrolled in kindergarten and spent 1-3 years there before entering primary school (Table 35).

At Grade one, nearly four-fifths of the children (77.9%) were rated 'Excellent' for their overall performance as reported by their parents. Over half (55.1%) of the children were absent for 1-5 days during their Grade 1 academic year, while another third (33.3%) attended school every day. Few children (12.4%) were absent from school because of dental problems. The main reason for this (46.6% of dental-related absences) was dental pain (Table 35).

Table 35. Children's early learning outcomes

Children's academic performance and attendance	%	Frequency
Attended kindergarten?		
Yes	72.7	**339**
No	27.3	127
Total	*100.0*	*466*
If 'Yes', years at kindergarten		
One	37.2	126
Two	38.6	131
Three	24.2	82
Total	*100.0*	*339*
Overall academic performance		
Acceptable	0.4	2
Average	1.7	8
Good	4.1	19
Very good	15.9	74
Excellent	77.9	363
Total	*100.0*	*466*
School attendance		
No absences	33.3	155
Absent for 1-5 days	55.1	257
Absent for 6-9 days	8.2	38
Absent for ≥10 days	3.4	16
Total	*100.0*	*466*
Any absences because of a dental problem(s)		
Yes	12.4	**58**
No	87.6	408
Total	*100.0*	*466*
Reason(s) for absence(s)		
Caries	15.5	9
Cheek injury	1.7	1
Surgery	1.7	1
Extraction	3.4	2
Infection	10.3	6
Pain	46.6	27
Pain, caries, infection	3.4	2
Pain and treatment	10.3	6
Treatment	7.1	4
Total	*100.0*	*58*

4.3.8 Child's school outcomes (Grade 2)

Similarly, with Grade one, most of the children were rated as having an excellent overall academic performance for Grade 2 (79%) (Table 36). Figure 17 shows the mean score of school performance among male (mean= 93.8, SD= 6.5) and female (mean= 93.5, SD= 6.5). A Mann-Whitney U test displayed no significant difference (U = 25511, p = 0.133) in school performance between male and female schoolchildren. On the other hand, children have been absent from 1-22 days per the first term of the academic year (2019-2020) (Table 36). The mean score of absence day among females (mean= 1.7, SD= 2.2) was higher than the mean score among males (mean= 1.4, SD= 2.8) (Figure 18). The Mann-Whitney U test displayed a significant difference (U = 21304, p = 0.001) in school absence between male and female schoolchildren.

Table 36. Children's school performance and school attendance for Grade 2

Children's academic performance and attendance	%	Frequency			
Overall academic performance					
Average	0.9	4			
Good	4.3	20			
Very good	15.8	74			
Excellent	79.0	368			
Total	*100.0*	*466*			
School attendance					
No absences	37.6	155			
Absent for 1-5 days	57.3	257			
Absent for 6-9 days	3.6	38			
Absent for ≥10 days	1.5	16			
Total	*100.0*	*466*			
	Mean,95%CI	**Median**	**Mode**	**SD**	**Range**
Absence school days	1.5 1.3/1.8	1	0	2.2	1-22
School performance	93.5 92.9/94.1	96.0	90.0	6.5	65-100

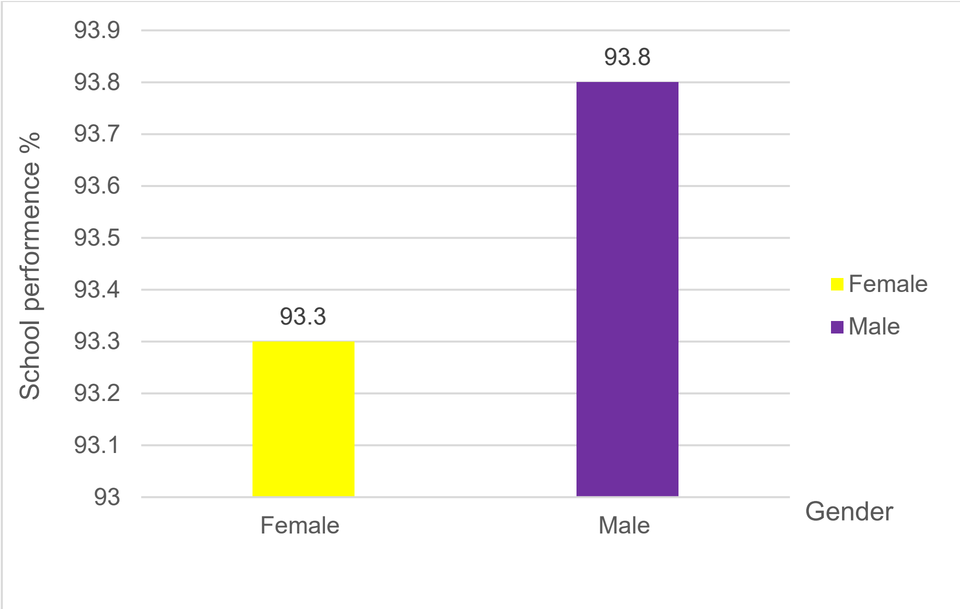


Figure 17. School performance per gender for the academic year (2019-2020)

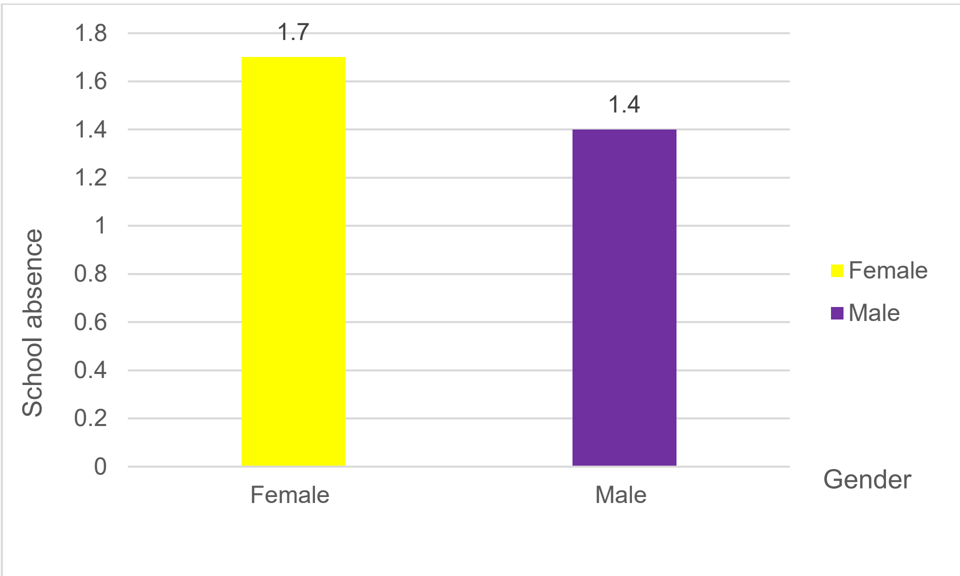


Figure 18. School absence days per gender for the first term (2019-2020)

4.3.9 Parent's characteristics and social support

4.3.9.1 Parenting style

Based on the PSDQ (Robinson et al. 1995) questionnaire, most parents' (91.9% of mothers, 88.2% of fathers) answers indicated an authoritative parenting style (Table 37).

4.3.9.2 Parents' academic involvement

The scores from the seven relevant items on the questionnaire were totalled, yielding each parent's overall score for academic involvement. Scores ranged from 0 to 28, with higher scores reflecting higher involvement. The mother's mean academic involvement score (20.7) was higher than the father's mean score (14.7). The median academic involvement score for mothers was 21, compared to a median of 15 for fathers (Table 37).

4.3.9.3 School social support

School social support was calculated by adding the scores from the six relevant items. The total ranges from 0 to 12, with higher scores indicating greater support. The mean social support score among children was 11.3, with SD equal to 1.5 (Table 37).

Table 37. Parent's characteristics and social support of participants

Variables	Mother		Father	
	%	Frequency	%	Frequency
Parenting style				
Permissive	3.2	15	5.2	24
Authoritarian	2.6	12	3.2	15
Authoritative	92.1	429	88.2	411
Permissive and Authoritative	0.9	4	1.1	5
Authoritarian and Authoritative	0.2	1	0	0
Permissive, Authoritarian and Authoritative	0.4	2	0	0
No response	0.6	3	2.3	11
Total	*100.0*	*466*	*100.0*	*466*

	Mean, 95%CI	Median	Mode	SD	Range
Parental academic involvement – mothers	20.7 20.3/21.2	21	28	5.3	0-28
Parental academic involvement – fathers	14.7 14.0/15.4	15	0	7.5	0-28
Social support from teachers and peers	11.3 11.2/11.5	12	12	1.5	0-12

4.3.10 Paediatric oral health-related quality of life (POQL)

The distribution of POQL scores was positively skewed, indicating that few impacts were reported among the sample (Figure 19). The mean (SD) POQL score was 8.8 (SD: 12.0), the median was 3.8, the first quartile was 0.0, and the third quartile was 13.3.

Most children rate their OH and general health as excellent (61.8% and 90.6%, respectively) (Table 38). The majority (67.6%) of the children reported minimally one impact on their quality of life. In contrast, one third (32.4%) did not report any impact. Pain, difficulty in eating, and crying were the events most reported by the children (Table 39).

Table 38. POQL scores of 466 children (100%) child

	Mean95%CI	Median	Mode	Range	SD	Percentile 25,50,75
POQL overall Impact %	8.8 7.7/9.9	3.8	0	0-78	12.0	0.0 3.8 13.3
POQL by number of events reported	2.2 2.0/2.4	2	0	0-10	2.4	0 2 3
	%			**F**		
OH perception Poor Faire Average Good Excellent *Total*	1.5 2.4 16.1 18.2 61.8 *100*			7 11 75 85 288 *466*		
	%			**F**		
General health perception Poor Faire Average Good Excellent *Total*	0.6 1.5 2.4 4.9 90.6 100			3 7 11 23 422 *466*		

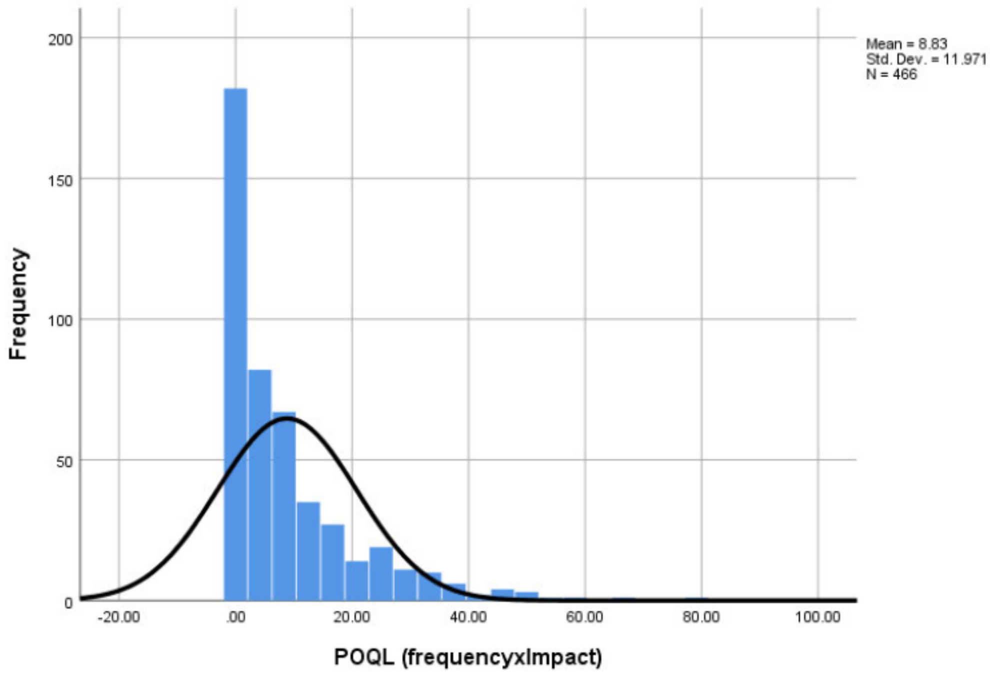


Figure 19. POQL scores were distributed among 466 children

Table 39. POQL items scored by 466 children (100%)

Item	Did not happen		Once in a while		Some of the times		All the times	
Dental pain	289	(62.0%)	58	(12.5%)	71	(15.2%)	48	(10.3%)
Difficulty eating	320	(68.7%)	40	(8.6%)	71	(15.2%)	35	(7.5%)
Attention at school	383	(82.2%)	34	(7.3%)	44	(9.4%)	5	(1.1%)
Missing schools	389	(83.4%)	32	(6.9%)	39	(8.4%)	6	(1.3%)
Avoid smiling	368	(79.0%)	32	(6.9%)	56	(12.0%)	10	(2.1%)
Worry less attractive	383	(82.2%)	20	(4.3%)	50	(10.7%)	13	(2.8%)
Unhappy with look	404	(86.7%)	19	(4.1%)	30	(6.4%)	13	(2.8%)
Angry	391	(84.0%)	23	(4.9%)	44	(9.4%)	8	(1.7%)
Worry	384	(82.4%)	30	(6.4%)	33	(7.1%)	19	(4.1%)
Cry	309	(66.3%)	48	(10.3%)	76	(16.3%)	33	(7.1%)
Sum up								
Children reported 0 events	151 (32.4%)							
Children reported ≥ 1	315 (67.6%)							

4.3.11 Clinical data

Between September and November 2019, 466 students were examined by two examiners, and 10286 teeth were screened (Table 40).

Table 40. Number of children and teeth examined

Children/teeth	Number
Total children examined	466
Children with permanent teeth present (along with primary)	452
Children with only primary teeth present (no permanent teeth yet)	14
Children examined by examiner 1/ recorder 1 (51.93%)	242
Children examined by examiner 2/ recorder 2 (48.07%)	224
Primary teeth examined	6,644
Permanent teeth examined	3,642
Total teeth examined	10,286

4.3.11.1 Dental caries

The ICDAS results displayed the prevalence of enamel and dentine caries to be greater in the primary dentition (93.1%) than in permanent dentition (45.8%) (Table 41). Total ICDAS mean of enamel and dentine caries per teeth surface was considered (Table 41, 42). Overall, the ICDAS distribution was positively skewed (Figure 20). The mean (SD) overall ICDAS score was 19.5 (13.9), the median was 18.0, the first quartile was 8.0, and the third quartile was 28.0. The mean of ICDAS were slightly higher for male (mean=19.8, SD= 13.7) than female (mean= 19.3, SD= 14) schoolchildren (Figure 21); however according to the Mann-Whitney U test, the difference was not significant (U = 26449, p = 0.589). ICDAS scores 4-6 were converted into dmfs/DMFS (Iranzo et al., 2013) to facilitate comparison between ICDAS and DMF.

Table 41. Dental caries measures according to ICDAS and dmfs/DMFS

Dental caries for primary and permanent dentition	
Number of teeth missing due to caries	225
Number of children with no present or past caries experience (ICDAS)	31
Number of children with no present or past caries experience (D_4MFS)	48
Prevalence of dental caries (ICDAS), 95%CI	93.5%, 92/95
Prevalence of dental caries (D_4MFS/d_4mfs), 95%CI	89.7%,88.6/91.4
Dental caries (primary teeth)	
No. of children with no present caries experience (ICDAS) in primary teeth	32
No. of children with no past or present caries experience (ICDAS) in primary teeth	32
No. of children with only dental caries according to ICDAS	434
No. of children with no past or present caries experience (d_4mfs) in primary teeth	48
No. of children with only dental caries according to dmfs	418
Prevalence of dental caries in primary teeth (ICDAS)	93.1%, 92/95
Prevalence of dental caries in primary teeth (d_4mfs)	89.7%, 88.6/91.4
The difference between ICDAS and dmfs prevalence for primary teeth	3.4%
Dental caries (permanent teeth)	
No. of children with no present caries experience (ICDAS) in permanent teeth	245
No. of children with no past or present caries experience (ICDAS) in permanent teeth	245
No. of children with only dental caries according to ICDAS	207
No. of children with no past or present caries experience (D_4MFS) in permanent teeth	384
No. of children with only dental caries according to D_4MFS	82
Prevalence of dental caries in permanent teeth (ICDAS)	45.8%, 43/49
Prevalence of dental caries in permanent teeth (D_4MFS)	18.1%, 6/30
The difference between ICDAS and DMFS prevalence for permanent teeth	27.7%

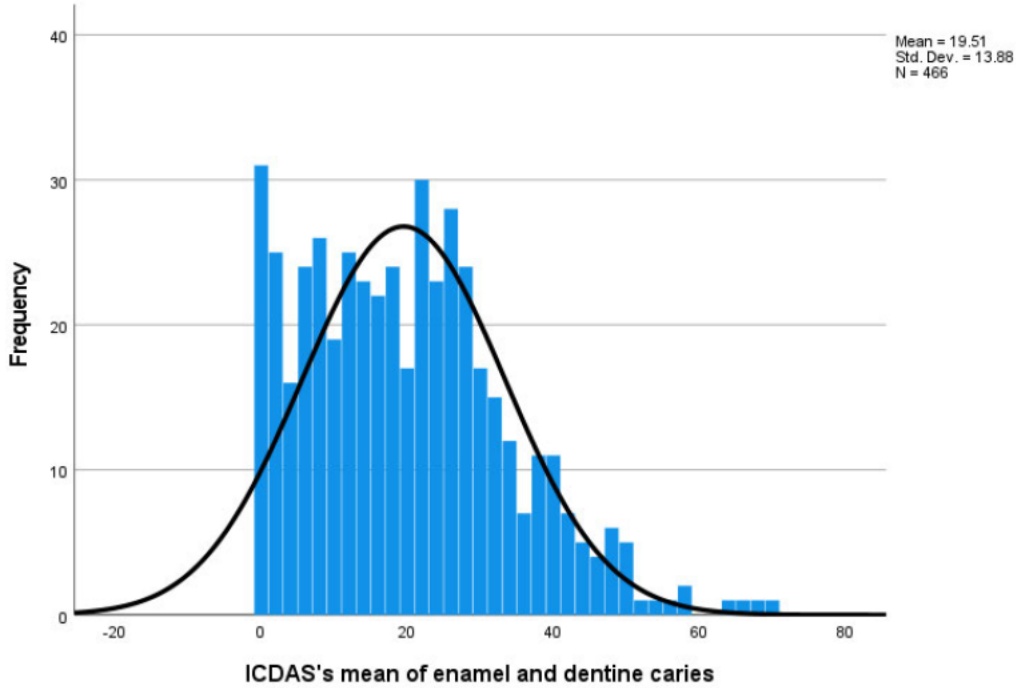


Figure 20. Distribution of ICDAS means among 466 children

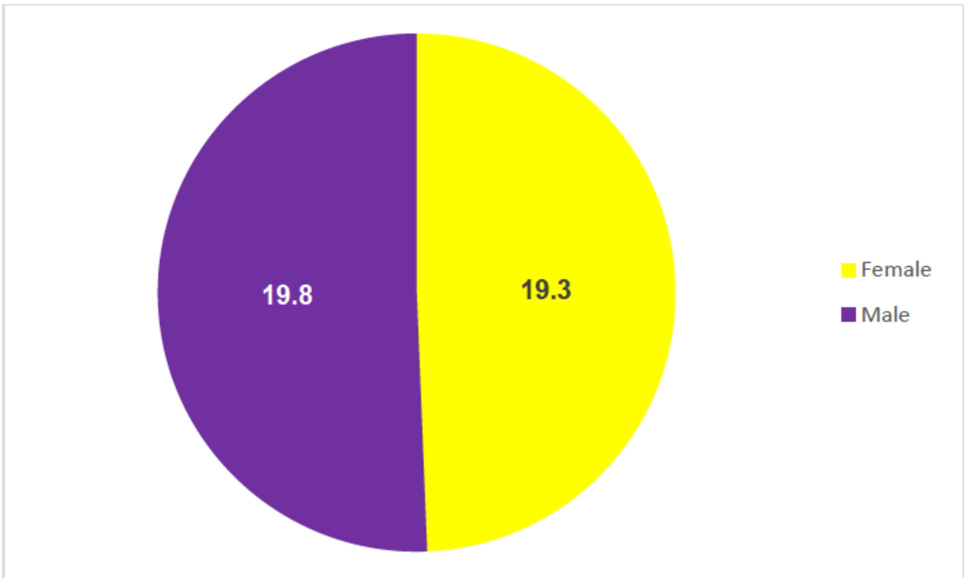


Figure 21. ICDAS mean per gender among 466 children

Table 42. ICDAS mean and total counts in primary and permanent dentition of 466 children

	Mean	95%CI	Median	Mode	Range	SD	Percentile 25,50,75
ICDAS mean for primary and permanent surfaces	19.5	18.2/20.8	18	0	0-70	13.9	8.0 18.0 28.0
Total counts of surfaces with ICDAS scores 2 and more in primary surfaces ds (2-6)	17.9	16.7/19.1	17	0	0-68	13.0	7.0 17.0 26.0
Total counts of surfaces with ICDAS scores 2 and more in permanent surfaces DS (2-6)	1.6	1.3/1.8	0	0	0-20	2.6	0.0 0.0 2.0
Total counts of surfaces with ICDAS scores 2-3 in primary surfaces ds $_{(2-3)}$	1.6	1.4/1.7	1	0	0-11	1.9	0.0 1.0 2.0
Total counts of surfaces with ICDAS scores 4-6 in primary surfaces ds $_{(4-6)}$	16.3	15.2/17.5	15	0	0-68	12.9	6.0 15.0 24.3
Total counts of filled primary surfaces related to caries	0.2	0.0/0.2	0	0	0-5	0.6	0.0
Total counts of missed primary surfaces related to caries	2.4	1.0/2.7	0	0	0-25	4.3	0.0 0.0 5.0
Total counts of sound primary surfaces	46.7	45.1/48.2	47	52	0-88	17.1	35.0 47.0 58.0
Total counts of surfaces with ICDAS scores of 2 and more surfaces with fillings (f) and surfaces of extracted teeth (m)= ds $_{(2-6)}$fm	20.2	19.1/21.7	19	0	0-70	14.0	9.0 19.0 30.0
Total counts of surfaces with ICDAS scores 2-3 in permanent surfaces DS $_{(2-3)}$	1.2	1.0/1.3	0	0	0-14	2.0	0.0 0.0 2.0
Total counts of surfaces with ICDAS score 4-6 in permanent surfaces DS $_{(4-6)}$	0.4	0.3/0.6	0	0	0-20	1.5	0.0
Total counts of permanent surfaces filled due to caries (F)	0.0	0.0/0.01	0	0	0-1	0.2	0.0
Total counts of permanent surfaces missed due to caries (M)	0.0	0.0/0.0	0	0	0-5	0.2	.00
Total counts of permanent sound surfaces	33.0	31.9/34.2	36	28	0-52	12.5	27.0 36.0 43.0
Total counts of surfaces with ICDAS scores of 2 and more surfaces with fillings (F) and surfaces of extracted teeth (M)= DS $_{(2-6)}$FM	1.6	1.4/1.8	0	0	0-20	2.7	0.0 0.0 2.0

4.3.11.2 Clinical consequences of untreated dental caries

PUFA/pufa prevalence was 25.7% (Table 43), primary teeth were 24.7%, and permanent teeth were 1.8%. The Untreated Caries PUFA Ratio was 8.6%, implying that 8.6% of the D+d component evolved into an odontogenic infection. The main component of PUFA/pufa was pulpal involvement (13.7%).

Table 43. Prevalence and most prevalent consequences of untreated caries in primary and permanent teeth among participants

PUFA/pufa at primary and permanent dentition - child level	
Total number of students with PUFA/pufa	120
Prevalence of PUFA/pufa	25.7%, 22/30
Total number of teeth with PUFA/pufa	218
PUFA/pufa mean. 95%CI	0.47, 0.4/0.6
First most prevalent PUFA/pufa condition - (P/p)	13.7%
Second most prevalent PUFA/pufa condition - (PU/pu)	9.4%
Common PUFA condition with one code only-child level	
First most prevalent (P/p)	13.7%
Second most prevalent (U/u)	12.5%
pufa primary teeth-child level	
No. of students with pufa	115
Prevalence	24.7%
Sum of all pufa in primary teeth	211
pufa mean, 95%CI	1.2, 1.2/1.3
First most prevalent condition in pufa (p)	13.1%
Second most prevalent condition in pufa (pu)	9.4%
First most prevalent condition- one code pufa (p)	13.1%
Second most prevalent condition- one code pufa (u)	12.2%
PUFA permanent teeth-child level	
No. Of students with pufa	8
Prevalence of PUFA	1.8%
Sum of all PUFA in permanent teeth (teeth no.)	11
PUFA mean, 95%CI	1.0, 1.0/1.03
First most prevalent condition in PUFA (p)	0.7%
Second most prevalent condition in PUFA (a)	0.4%
First most prevalent condition- one code PUFA (A)	0.9%
Second most prevalent condition- one code PUFA (P)	0.7%

4.3.11.3 Dental trauma

Only four children presented dental trauma on maxillary and mandibular permanent incisor teeth (prevalence = 0.9%) (see Table 44).

Table 44. Dental trauma in permanent incisors of children

Dental Trauma Index	
Total number of students with dental trauma on maxillary and mandibular permanent incisor teeth	4
Prevalence of dental trauma on maxillary and mandibular permanent incisor teeth	0.9%
Prevalence of dental trauma on maxillary and mandibular permanent incisor teeth (when excluding students with no permanent incisor teeth)	0.9%
First most prevalent condition at the children level (fractured enamel)	0.7%
Second most prevalent condition at the children level (discolouration)	0.2%

4.3.11.4 Malocclusion

Malocclusion conditions that might increase the risk of dental trauma were generally low (Table 45).

Table 45. Malocclusion conditions among children

Condition	Prevalence	Number of children with the condition
Incompetent lip	10.2%	47
Overjet	3.4%	16
Overbite	2.1%	10
Anterior open bite	6.7%	31
Anterior cross-bite	2.6%	12

4.3.11.5 Enamel development defect (EDD)

The overall prevalence of EDD was 17.2%. EDD was more prevalent in the permanent dentition (17.0%) than in the primary dentition (1.5%), with central incisors and first permanent molars being the most affected teeth. Demarcated opacities were the most common defects identified (14.2%) (Table 46).

Table 46. EDD prevalence and most common type among children

EDD for primary and permanent dentition	
Total number of children with EDD	80
Prevalence of EDD	17.2%
First, most prevalent EDD condition was Demarcated opacities	14.2%
Second most prevalent EDD condition was Hypoplasia)	2.2%
EDD for primary teeth	
No. of children with primary tooth EDD	7
Prevalence of EDD	1.5%
Sum of all primary teeth with EDD (teeth no.)	16
First, most prevalent condition was Demarcated opacities	0.9%
Second most prevalent condition was Hypoplasia	0.6%
EDD for permanent teeth	
No. of children with permanent tooth EDD	77
Prevalence of EDD	17.0%
Sum of all permanent teeth with EDD (teeth no.)	239
First, most prevalent condition was Demarcated opacities	14.4%
Second, most prevalent condition was Hypoplasia and Diffused opacities	1.8%

4.3.11.6 Dental plaque

The prevalence of dental plaque was 84.3%, with a mean of 65.5 (SD=37.7, 95% CI=62.0/68.9), a median of 83.3, a mode of 100, and a range of 0-100 (Table 47).

Table 47. Prevalence of dental plaque among children

	Children	
	% of sample	Frequency
Plaque-free (0%)	15.7	73
100% plaque	40.3	188
Some plaque, but <50%	13.5	63
≥50% plaque, but <100%	30.5	142
Total	*100*	*466*

4.4 Reliability of the study measures

4.4.1 Reliability of the questionnaires

4.4.1.1 Internal reliability

The reliability of the parenting styles and dimensions questionnaire, the parental academic involvement questionnaire, and the child's social support and POQL was tested using Cronbach's alpha. The results revealed acceptable to good internal consistency (see Table 48).

Table 48. Internal consistency of parenting style questionnaires

Questionnaire	Cronbach's alpha
Parenting style	0.89
Parental academic involvement	0.85
School social support	0.70
POQL	0.90
α ≥0.9 Excellent 0.9 > α ≥ 0.8 Good 0.8 > α ≥ 0.7 Acceptable 0.7 > α ≥ 0.6 Questionable 0.6 > α ≥ 0.5 Poor 0.5 > α (Tavakol and Dennick, 2011)	

4.4.1.2 Test-retest reliability

The reliability of questionnaires was tested by calculating ICC using Pearson's correlation. The results revealed very strong to moderate reliability (see Table 49).

Table 49. Test-retest results for parenting style questionnaires by ICC

Questionnaire	ICC
Parenting style	0.53
Parental academic involvement	0.94
School social support	0.93
POQL	0.84
1.00 Perfect 0.80-.99 Very strong 0.60-0.80 Strong 0.40-0.60 Moderate 0.20-.040 Weak 0-.20 Very Weak (Dancey and Reidy, 2017)	

4.4.2 Reliability of dental clinical measures

The initial inter-and intra-calibration tests against the gold standard revealed substantial to perfect agreement between the two examiners for ICDAS (Section 3.8.1.1). Further, the calibration during the pilot study showed substantial to almost perfect agreement between and within examiners (Table 50).

Table 50. Inter- and intra-rater reliability of dental clinical measures

	Inter-examiners Kappa coefficient	Intra-examiner 1 Kappa coefficient	Intra-examiner 2 Kappa coefficient
ICDAS restoration code/Unweighted	0.89	0.93	1.00
ICDAS caries code/Weighted	0.77	0.87	0.88
Lip competency	1.00	1.00	1.00
Overjet	0.88	1.00	1.00
Overbite	0.90	0.91	1.00
Open bite	0.61	1.00	1.00
Anterior cross-bite	1.00	1.00	1.00
EDD	0.93	1.00	1.00
PUFA	0.75	0.89	1.00
Dental trauma	0.91	1.00	1.00
Dental plaque	0.84	0.87	0.87

1) Kappa < 0: poor agreement,
2) Kappa between 0.0 – 0.20: slight agreement,
3) Kappa between 0.21 – 0.40: fair agreement,
4) Kappa between 0.41 – 0.60: moderate agreement,
5) Kappa between 0.61 – 0.80: substantial agreement,
6) Kappa of 0.81 and above: almost perfect agreement.
(Landis and Koch, 1977)

4.5 Data screening

The data were screened for missing values, outliers, and normality before conducting SEM.

4.5.1 Missing values

Though there are no definite cut-off values to evaluate how much considers a large amount of missing information, Cohen et al. (1983) suggested that 5-10% of missing data on a particular variable is not large. According to Hair et al. (2014), if missing data is less than 10% of observations, and the pattern of missing data is random (i.e., missing completely at random = MCAR), any approach to deal with this problem is assumed to produce acceptable results. Appendix 19 presents the frequency and percentage of missing data for the variables involved in the analysis. Thus, 41 cases showed 0.54% missing values in 20 variables among the 32 included in the analysis. The maximum percentage of missing data was 3.4%, and the lowest was 0.2%.

Although the amount of missing data was low, the randomness of the missing data was tested using Little's (1988) Chi-square statistics. The test revealed a nonsignificant p-value (Little's MCAR test: Chi-Square = 517.370, DF = 19504, Sig. = 1.000), indicating it is safe to assume the data was MCAR. Therefore, the values and the pattern can be considered negligible. However, because SEM requires a dataset without missing values, means and medians were used to replace the missing values (Donner, 1982).

4.5.2 Outliers

Appendix 19 shows the univariate and multivariate analyses. The univariate outliers were detected for the continuous values by determining if the frequency distributions of Z scores of the observed data were below or above the mean by (-, + 3.29 SD) (Kline, 2018). On the other hand, the multivariate outliers were detected by measuring the Mahalanobis D^2 with a p-value < 0.001 (Kline, 2016).

Although the results in Appendix 19 indicates some univariate and multivariate outliers, Hair et al. (2014) suggest that the outliers should be retained to ensure generalisability. Accordingly, the outliers in this study were retained.

4.5.3 Data normality

Appendix 19 shows the normality test results measured by AMOS based on skewness and kurtosis tests. According to Hair et al. (2014), data having skewness between +/-2, and kurtosis between +/ -7, is considered not to have severe skew or kurtosis and not be severely non-normal. The eight variables showed non-normal distribution.

Therefore, a bootstrapping procedure was performed with SEM. Bootstrapping is a resampling procedure to create multiple sub-samples from the original data set with multiple parameters estimated (Byrne, 2001). The procedure uses the subsample to draw inferences about the population without assuming normality (Zhu, 1997).

4.6 Structural equation modelling

This section presents the results of the measurement and the structural models for the SEM and formal testing of the study hypotheses.

4.6.1 Measurement model

The measurement model was specified with six latent and 20 observed variables explained in the next section. Table 51 shows the distribution of those variables in relation to school performance and school attendance. The model was evaluated by GOF indices, model estimates and modification indices.

Table 51. Latent variables distributions according to children's school performance and school absence days

Variables	School performance N %, Mean, SD			School absence days Mean, SD		Type of variable
	Total N (%)	Mean	SD	Mean	SD	
1. Birth-SES						Latent exogenous
A. Mother's employment status						Observed, endogenous
• Unemployed/retired	351(75.3)	93.3	6.5	1.6	2.6	
• Self/private employee	38(8.2)	93.2	6.0	2.0	1.7	
• Government employee	77(16.5)	94.8	6.0	1.3	2.0	
B. Mother's level of education at child's birth						Observed, endogenous
• Not educated	42(9)	91.0	7.2	1.3	2.0	
• ≤9 years	118 (25.3)	92.3	6.3	1.5	3.3	
• >9 years	306 (65.7)	94.3	6.1	1.5	2.1	
C. Father's level of education at child's birth						Observed, endogenous
• Not educated	12 (2.6)	91.7	7.4	2.4	3.0	
• ≤9 years	94 (20.2)	91.5	7.4	3.0	3.1	
• >9 years	360 (77.2)	94.2	5.9	1.5	2.2	
D. Family income at child's birth						Observed, endogenous
• BD† ≤399	106 (22.7)	91.9	7.3	1.3	1.6	
• BD 400- 799	264 (56.7)	93.5	6.3	1.7	2.9	
• BD ≥800	96 (20.6)	95.2	4.8	1.4	1.5	
2. Current SES						Latent exogenous
A. Current family income						Observed, endogenous
• BD ≤399	81 (17.4)	92.4	7.0	1.9	2.6	
• BD 400- 799	254 (54.5)	93.1	6.7	1.6	2.8	
• BD ≥800	131 (28.1)	95.0	5.1	1.2	1.3	
B. Current father's level of education						Observed, endogenous
• Not educated	8 (1.7)	90.0	8.1	1.5	1.8	
• ≤9 years	90 (19.3)	91.8	7.1	1.8	3.2	
• >9 years	368 (79)	94.0	6.1	1.5	2.2	
C. Current mother's level of education						Observed, endogenous
• Not educated	38(8.2)	90.9	7.2	1.1	1.5	
• ≤9 years	117(25.1)	92.5	5.9	1.8	3.4	
• >9 years	311(66.7)	94.2	6.3	1.5	2.0	

3. Birth outcomes						Latent exogenous
A. Child's birth weight						Observed, endogenous
• Low birth weight (<2500 g)	52 (11.2)	93.5	6.5	1.5	3.3	
• Normal (≥2500 g)	414 (88.8)	93.5	6.4	1.6	2.3	
B. Child's gestational age						Observed, endogenous
• Pre-term birth (<37 weeks)	51(10.9)	93.2	6.6	1.5	1.9	
• Normal (≥37 weeks)	415(89.1)	93.5	6.3	1.6	2.5	
C. Child's birth order						Observed, endogenous
• First	113(24.2)	93.5	6.6	1.7	2.6	
• Second or more	353(75.8)	93.5	6.3	1.5	2.4	
4. Mother's OH practices (OHPs)						Latent exogenous
A. Toothbrushing						Observed, endogenous
• Never or weekly brushing	16(3.4)	88.6	8.0	1.8	1.9	
• Once or twice	347(74.5)	93.5	6.3	1.5	2.4	
• More than twice	103(22.1)	94.2	5.8	1.5	2.5	
B. Mouth wash						Observed, endogenous
• Never or weekly brushing	246(52.8)	93.7	6.5	1.5	2.7	
• Once or twice	180(38.6)	93.5	5.9	1.7	2.2	
• More than twice	40(8.6)	92.2	7.4	1.1	1.7	
C. Flossing						Observed, endogenous
• Never or weekly brushing	329(70.6)	93.5	6.5	1.5	2.4	
• Once or twice	118(25.3)	93.6	5.6	1.6	2.5	
• More than twice	19(4.1)	93.2	7.8	1.5	1.4	
5. Child's OHPs						Latent exogenous
A. Toothbrushing						Observed, endogenous
• Never or weekly brushing	32(6.9)	89.9	7.5	2.0	3.0	
• Once or twice	395(84.7)	93.8	6.2	1.6	2.4	
• More than twice	39(8.4)	92.7	6.7	1.0	1.5	
B. Flossing						Observed, endogenous
• Never or weekly brushing	413(88.6)	93.6	6.3	1.5	2.4	
• Once or twice	46(9.9)	92.4	6.5	1.9	2.3	
• More than twice	7(1.5)	91.5	10.8	1.7	2.2	
C. Mouth wash						Observed, endogenous
• Never or weekly brushing	366 (78.5)	93.8	6.2	1.5	2.5	
• Once or twice	81(17.4)	92.5	6.8	1.9	2.1	
• More than twice	19(4.1)	91.3	7.4	0.9	0.8	

D. Sugar consumption						Observed, endogenous
• Never or weekly brushing	65(13.9)	92.7	6.7	1.6	2.8	
• Once or twice	294(63.1)	93.9	6.2	1.5	2.1	
• More than twice	107(23)	92.8	6.8	1.6	3.0	
6. Parent's characteristics						Latent exogenous
A. Mother's parenting style						Observed, endogenous
• Permissive	15 (3.2)	89.0	8.6	1.6	1.8	
• Authoritarian	12 (2.6)	92.8	5.2	1.3	1.8	
• Authoritative	439 (94.2)	93.7	6.4	1.6	2.5	
B. Father's parenting style						Observed, endogenous
• Permissive	24 (5.2)	91.3	6.3	2.2	4.4	
• Authoritarian	15 (3.2)	92.8	6.4	1.1	1.5	
• Authoritative	427 (91.6)	93.6	6.4	1.5	2.3	
C. Mother's academic involvement	466(100)	20.8	5.2			Observed, endogenous

4.6.1.1 Goodness of fit indices

Table 52 shows the recommended criteria for GOF indices and summarises the obtained results of the model fit indices.

In detail, the significant Chi-square test (X^2=332.760, df= 151) at $p<0.05$ indicated that the model was not a good fit. However, Hair et al. (2014) argued that relying solely on the Chi-square test is not enough and can be misleading, as this test is susceptible to sample size. Thus, another GOF was used to evaluate the specification of the model. The result revealed that the values of SRMR= 0.051, RMSEA= 0.05, GFI= 0.93, CFI= 0.95, and AGFI= 0.91. These values were consistent with the recommended criteria, indicating that the model fits the data.

Table 52. The recommended and the obtained fit indices for the measurement model using CFA

Index	**Reference**	**Recommended criteria**	**Obtained criteria**
***χ2/df* ratio, p**	(Hu and Bentler, 1999)	X^2 /df < 3, P >0.05	1.45. P=<0.001
SRMR	(Hair et al., 2014; Byrne, 2001)	≤ .08	0.051
RMSEA	(Hair et al., 2014; Byrne, 2001)	< 0.06	0.05
GFI	(Hair et al., 2014; Byrne, 2001)	≥ 0.90	0.93
CFI	(Hair et al., 2014; Byrne, 2001)	≥ 0.90	0.95
AGFI	(Hair et al., 2014; Byrne, 2001)	≥ 0.90	0.91

4.6.1.2 Model estimates

Table 53 shows the standardised regression weights provided by Beta (β) (factor loadings) related to total effects between variables and the square multilabel correlation (R-square). All variables revealed significant loading ($p \leq 0.01$) despite being lower than the recommended level of 0.30 in some variables (Bagozzi et al., 1991). However, none of the items with ≤ 0.30 was eliminated from the model, as this would violate the 3-4 indicators rule, hence model fit (Hair et al., 2014).

The first latent variable was the family's SES at the time of the child's birth (BSES) with four indicators: mother's level of education, household income, mother's employment, and father's level of education. The mother's level of education showed the highest loading value (0.998), and family income was with the lowest loading value, while the father's level of education presented a medium effect value (0.390).

The second latent variable was the family's current SES (CSES) with three indicators: the mother's level of education, household income, and father's level of education. Similarly, the mother's level of education presented with the highest loading value (0.994). Thus, the results might indicate that maternal related factors might be more important than parental and income in defining family SES.

The third latent variable was the child's birth outcomes with three indicators: birth weight, gestational age, and birth order. Gestational age and birth weight almost had a similar regression weight (0.747 and 0.740, respectively). While birth order had a lower loading value (0.207), it showed a significant loading and deleting it would cause the model to be unidentified.

The fourth latent variable was the mother's oral health practices (OHPs), with three indicators: mother's toothbrushing, mother's flossing, and mother's use of mouthwash.

Though all the variables had significant loadings, surprisingly, the use of mouthwash was the factor with the highest loading value (0.791).

The fifth latent variable was the child's current OHPs with four indicators: child's toothbrushing, child's flossing, child's sugar consumption, and child's use of mouthwash. Similarly, mouth wash had the highest loading value (0.840), and sugar consumption had the lowest loading value (-0.195).

The sixth latent variable was the parent’s characteristics with three indicators: mother's parenting style, father's parenting style, and mother's academic involvement. Mother parenting style presented with the highest loading (0.708), indicating that the mother related factors were the most important.

Table 53. Standardised regression weights of the measurement model: ß, R-square, BC 95% CI, and bootstrapping SE according to the CFA model

Parameter			**Estimate β**	**BC 95% CI**	**P-value**	**R-square**	**Bootstrapping SE**
Father's level of education	<---	BSES	.390	.283/0.471	.004	.152	.037
Mother's level of education	<---	BSES	.998	.973/1.027	.003	.995	.026
Mother's job	<---	BSES	.353	.307/.398	.001	.125	.016
Household income	<---	BSES	.187	.104/.290	.001	.035	.016
Mother's level of education	<---	CSES	.994	.973/1.013	.002	.988	.020
Father's level of education	<---	CSES	.362	.267/.451	.003	.131	.035
Household income	<---	CSES	.211	.131/.299	.001	.045	.018
Flossing	<---	Mother's OHPs	.296	.142/.418	.003	.088	.041
Use of mouth wash	<---	Mother's OHPs	.791	.647/1.096	.001	.626	.195
Teeth-brushing	<---	Mother's OHPs	.205	.081/.322	.006	.042	.025
Sugar consumption	<---	Child's OHPs	-.195	-.298/-.077	.003	.038	.022
Use of mouth wash	<---	Child's OHPs	.840	.724/.951	.003	.706	.097
Flossing	<---	Child's OHPs	.478	.322/.605	.002	.229	.066
Teeth-brushing	<---	Child's OHPs	.234	.114/.350	.002	.055	.028
Mother parenting style	<---	Parent's characteristics	.708	.259/.933	.003	.501	.208
Father parenting style	<---	Parent's characteristics	.536	.255/.723	.001	.288	.112
Mother academic involvement	<---	Parent's characteristics	.312	.127/.596	.004	.097	.099
Birth weight	<---	Birth outcomes	.740	.528/.980	.003	.547	.222
Birth order	<---	Birth outcomes	.207	.066/.331	.002	.043	.027
Gestational age	<---	Birth outcomes	.747	.521/.974	.003	.557	.198

4.6.1.3 Modification indices (MI)

The final step was done through the evaluation of the MI output. The results revealed four possible relations that the model did not estimate. The MI assumed an association between the father's level of education at birth and the current time. Further, it assumed that the mother's tooth brushing and flossing were also related to child brushing and flossing. Since those relations are sound in the literature (Bernabe et al., 2011, Özbek et al., 2015) and consistent with the theoretical framework of the study, covariances were added between their error terms (Hair et al., 2014) (Figure 22).

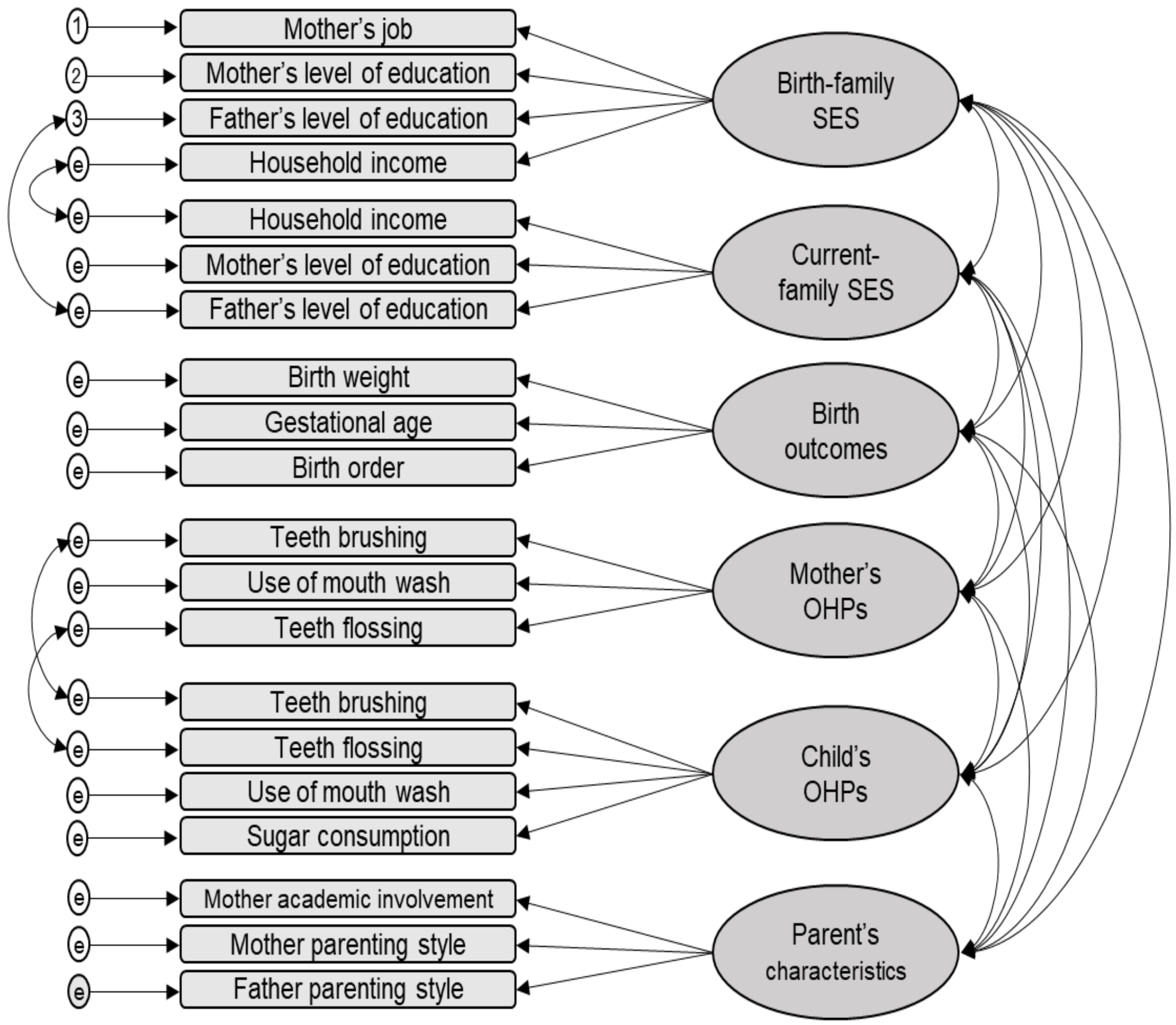


Figure 22. Measurement model with six latent variables and 20 observed variables

4.6.2 Parsimonious model

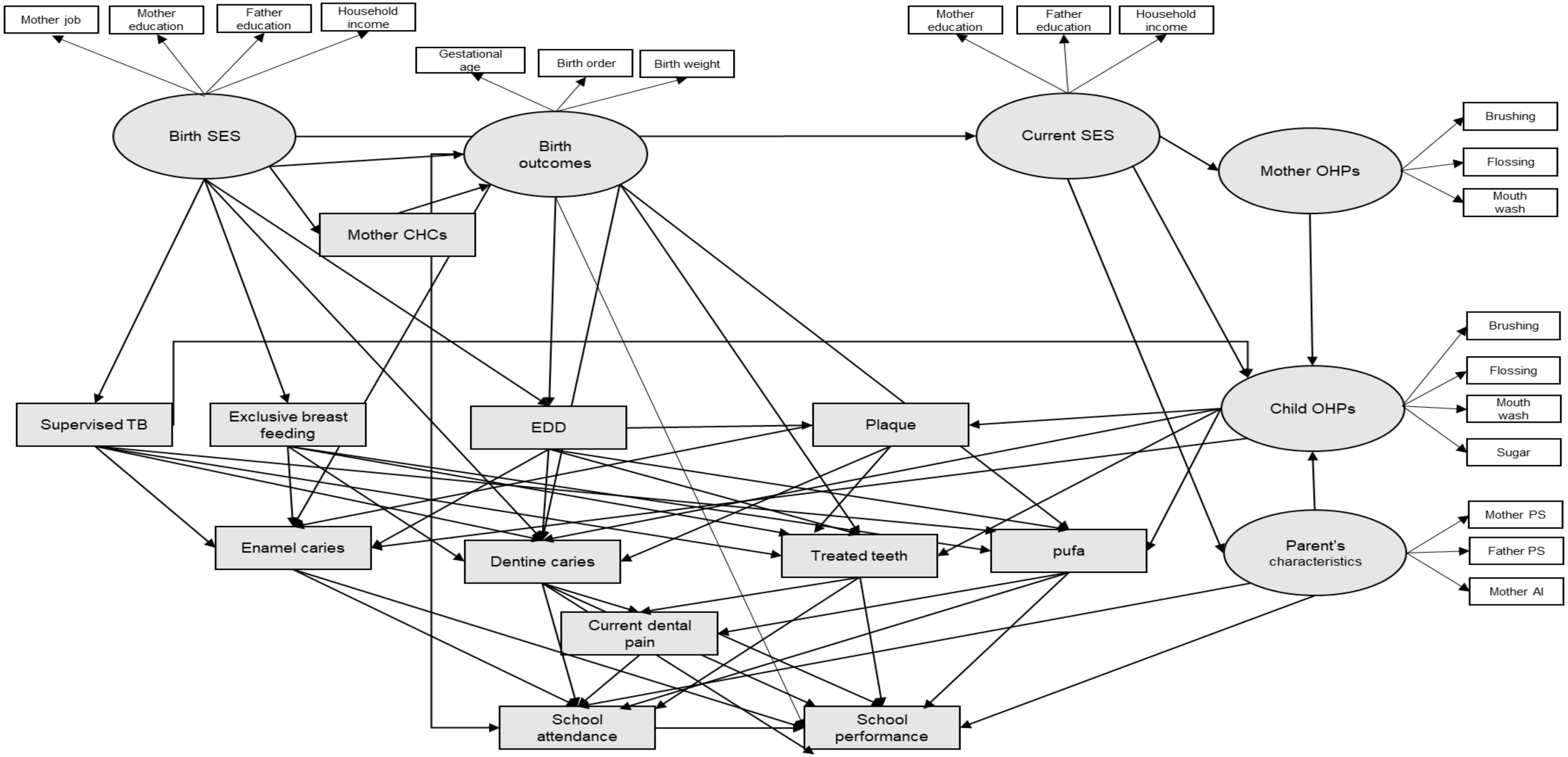
After adding twelve observed variables to the measurement model, the full model was estimated and met all the recommended criteria (Table 54: Figure 23). Table 55 shows the distribution of the 12 observed variables according to children's school outcomes.

However, all non-significant paths ($p>0.05$) were deleted to obtain a parsimonious model described in Section 3.9.3. The fit indices for the parsimonious models met all the pre-established criteria for an acceptable model fit (Table 54). The absolute fit indices, i.e., GFI and RMSEA, were 0.92 and 0.03, respectively. The incremental fit indices, i.e., CFI, were 0.95, and the parsimony fit measure, i.e., AGFI, was 0.91. Which all were within or above the recommended criteria. Additional to these indices, the χ^2 / df ratio was within the threshold level supporting these findings.

The X^2 difference between the full and parsimonious models was 33.69 (df=46) and was not statistically significant ($p=0.911$). This suggests that removing the non-significant paths was not relevant to the model, and the parsimonious model was accepted (Figure 21). Solid lines indicate direct effects for the final statistically parsimonious model, and dashed lines indicate indirect effects. The full model can be found in Chapter 8, Appendix 21.

Table 54. Fit indices for the full structural model and the parsimonious model

	$\chi 2/df$	SRMR	RMSEA	GFI	CFI	AGFI
Criteria	$X^2/df < 3$	≤ .08	< 0.06	≥ 0.90	≥ 0.90	≥ 0.90
Full model	1.50	0.052	0.03	0.92	0.95	0.90
Parsimonious model	1.43	054	0.03	0.92	0.95	0.91

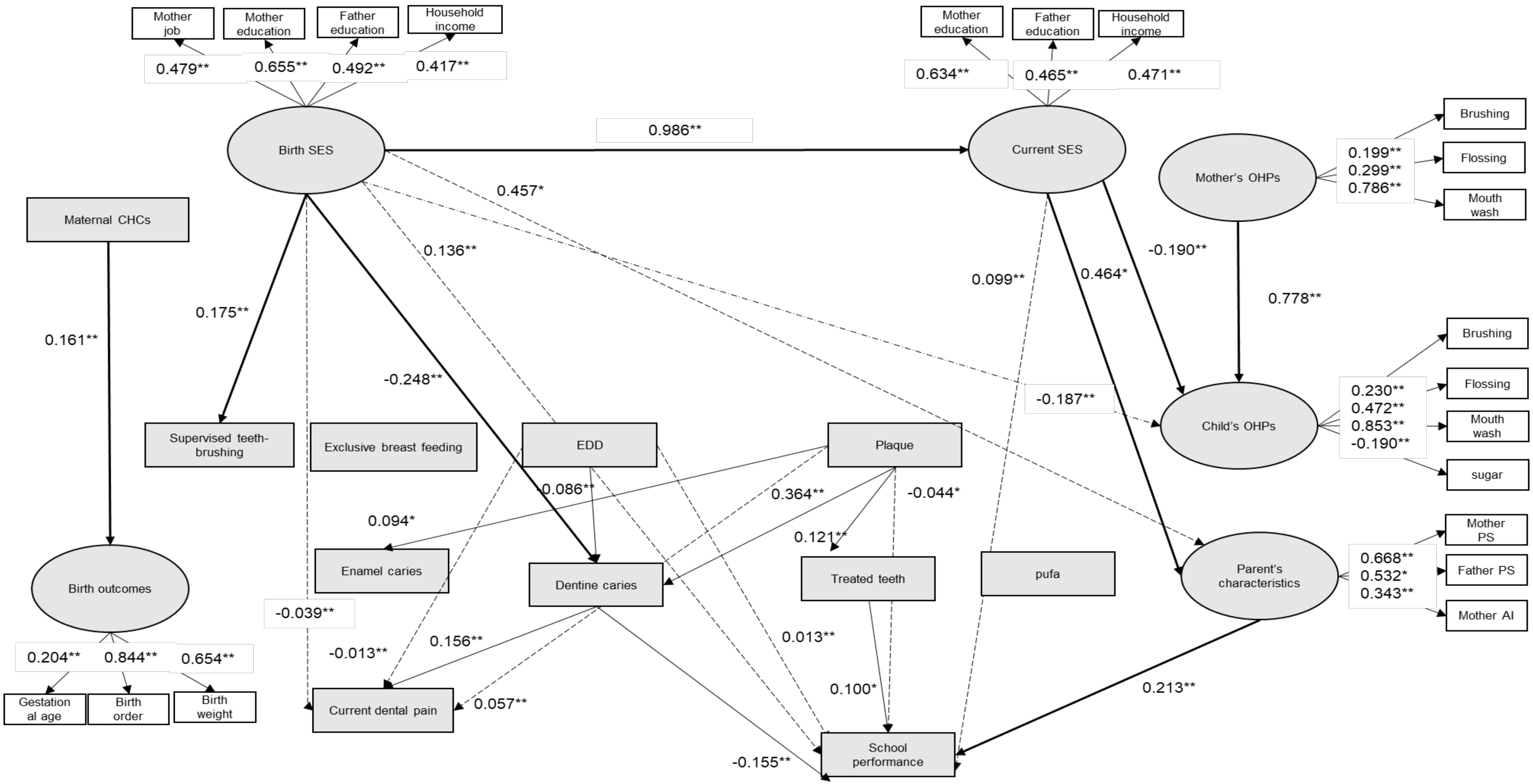


Note: Abbreviations stand for EDD (enamel developmental defects), OHPs (oral health practices), PS (parenting style), AI (academic involvement), TB (toothbrushing), CHCs (chronic health conditions)

Figure 23. Structural model of the life course framework for OH as proposed by Heilmann et al. (2015), after mapping latent variables from CFA adding observed variables, and assuming paths between all the variables

Table 55. Observed variables, according to children's school performance and school absence days

Nominal observed variables	**School performance N %, Mean, SD**			**School absence days Mean, SD**		**Type of variable**
	Total N (%)	**Mean**	**SD**	**Mean**	**SD**	
1. EDD						Observed, endogenous
• No EDD	459(98.5)	93.5	6.4	1.5	2.4	
• Yes EDD	7(1.5)	93.3	4.0	3.3	3.8	
2. Maternal chronic health conditions (CHCs)						Observed, endogenous
• Yes	107(23.0)	93.7	6.2	1.7	3.1	
• No	359((77.0)	93.4	6.4	1.5	2.2	
3. Exclusive breast feeding						Observed, endogenous
• No	336(72.1)	93.4	6.5	1.5	2.5	
• Yes	130(27.9)	93.9	6.0	1.7	2.3	
4. Supervised tooth brushing						Observed, endogenous
• No	153(32.8)	93.4	6.5	1.3	2.1	
• Yes	313(67.2)	93.5	6.3	1.7	2.6	
5. Child's dental pain						Observed, endogenous
• No	289(62.0)	93.7	6.3	1.6	2.7	
• Yes	177(38.0)	93.2	6.4	1.4	1.9	
6. pufa in primary teeth						Observed, endogenous
• No	351(75.3)	93.6	6.1	1.6	2.6	
• Yes	115(24.7)	93.3	7.1	1.5	2.0	
Continues observed variables	**Mean**	**Median**	**Mode**		**SD**	**Type of variable**
7. Enamel caries in primary teeth (ds_2_3)	1.6	1	0		1.9	Observed, endogenous
8. Dentine caries in primary teeth (ds_4_6)	16.3	15.0	0		12.9	Observed, endogenous
9. Treated primary teeth	2.5	0.0	0		4.3	Observed, endogenous
10. Plaque	65.5	83.3	100		37.7	Observed, endogenous
11. Absence days	1.6	1	0		2.4	Observed, endogenous
12. School performance	93.5	95.4	93.5		6.4	Observed, endogenous



Note: * p < 0.05, ** p < 0.01, β = bootstrapped standardised estimate. Solid line = direct effect; Dash line= indirect effect, the error terms and indicators were deleted to ease the interpretation
Abbreviations stand for EDD (enamel developmental defects), OHPs (oral health practices), PS (parenting style), AI (academic involvement)

Figure 24. Significant direct and indirect effects for the parsimonious model

4.6.3.3 Results of hypothesis testing from parsimonious model

This section displays the results of the hypothesis testing from the parsimonious model. First, the section presents the early and current life factors associated with children’s OHCs at the current age of life (7-8 years). Second, the section presents the association between OHCs and children's performance and attendance.

Table 56 summarises the results of the direct and indirect associations between the variables, showing only the significant associations. The indirect paths in Table 56 reflect the total indirect effect for all possible mediators, while Table 57 presents the specific significant indirect paths and mediators.

Table 56. Significant direct and indirect relations between the variables in the parsimonious model

Parameter			Total effect	Direct effects	Indirect effects	Bootstrap SE	BC 95% CI
CSES	<---	BSES	0.986**	0.986**		0.012	0.957/1.006
Supervised TB	<---	BSES	0.175**	0.175**		0.058	0.048/0.278
Child's OHPs	<---	BSES	-0.187**		-0.187**	0.062	-.313/-0.074
Parent's characteristics	<---	BSES	0.457*		0.457*	0.144	0.200/0.724
Dentine caries	<---	BSES	-0.248**	-0.248**		0.051	-0.344/-0.153
Dental pain	<---	BSES	-0.039**		-0.039**	0.015	-0.074/-0.016
School performance	<---	BSES	0.136**		0.136**	0.063	0.048/0.280
Dentine caries	<---	EDD	-0.086**	-0.086**		0.028	-0.137/-0.026
Dental pain	<---	EDD	-0.013**		-0.013**	0.006	-0.028/-0.004
School performance	<---	EDD	0.013**		0.013**	0.006	0.004/0.030
Birth outcomes	<---	Maternal CHCs	0.161**	0.161**		0.063	0.048/0.291
Child's OHPs	<---	Mother's OHPs	0.778**	0.778**		0.082	0.575/0.924
Child's OHPs	<---	CSES	-0.190**	-0.190**		0.062	-0.317/-0.076
Parent's characteristics	<---	CSES	0.464*	0.464*		0.146	0.202/0.727
School performance	<---	CSES	0.099**		0.099**	0.067	0.018/0.257
Enamel caries	<---	Plaque	0.094*	0.094*		0.044	0.008/0.180
Treated teeth	<---	Plaque	0.121**	0.121**		0.044	0.026/0.202
Dentine caries	<---	Plaque	0.364**	0.364**		0.038	0.286/0.433
Dental pain	<---	Plaque	0.057**		0.057**	0.018	0.023/0.097
School performance	<---	Plaque	-0.044*		-0.044*	0.020	-0.085/-0.006
Dental pain	<---	Dentine caries	0.156**	0.156**		0.047	0.064/0.248
School performance	<---	Dentine caries	-0.155**	-0.155**		0.052	-0.250/-0.047
School performance	<---	Treated teeth	0.100*	0.100*		0.037	0.029/0.171
School performance	<---	Parent's characteristics	0.213**	0.213**		0.083	0.058/0.379

Note: **P<0.01, *P<0.05, β = boot strapped standardised estimate, SE = standard error, Bias-corrected 95 % confidence interval = BC 95% CI

Table 57. The specific indirect paths and mediators in the parsimonious model

Indirect Path	β	Unstandardized estimates	95% CI	P-Value
Child's OHPs <--- CSES <---BSES	-0.187**	-0.229	-0.371/-0.110	0.008
Parent's characteristics <--- CSES <--- BSES	0.457**	2.181	0.687/4936	0.003
School performance <--- Parent's characteristics <--- CSES <---BSES	0.457**	1.707	0.451/4.095	0.003
School performance <--- Parent's characteristics <--- CSES	0.099**	1.551	0.0435/0.003	0.007
Dental pain <---Dentine caries<--- BSES	-0.039***	-0.052	-0.097/-0.024	0.001
School performance <--- Dentine caries <---BSES	0.039**	0.675	0.278/1.305	0.004
School performance <--- Parent's characteristics <---CSES	0.099**	1.551	0.435/3.500	0.003
School performance <--- Treated teeth <---Plaque	0.012**	0.002	0.001/0.004	0.008
Dental pain <--- Dentine caries <--- Plaque	0.057**	0.001	0.000/0.001	0.001
School performance <---Dentine caries <---Plaque	-0.056**	-0.010	-0.016/-0.004	0.004

Note: **P<0.01, *P<0.05, β = boot strapped standardised estimate, Bias-corrected 95 % confidence interval = BC 95% CI

4.6.2.1 Early and current life factors linked to OHCs

This section presents the results of testing different life course models (critical, accumulation) to analyse the early and current social, biological, behavioural, and parental conditions associated with developing OHCs among children aged 7-8 years (Objective 2).

4.6.2.1.1 Critical period hypothesis

Testing the critical period model revealed that only BSES predicted child's OHCs among the critical period factors (Figure 25).

On the one hand, a high family's SES at birth was directly associated with a low level of dentine caries when the child was 7-8 years old (β= -0.248**, SE=0.051, BC 95% CI=-0.344/-0.153), and indirectly associated with less dental pain (β= -0.039**, SE=0.051, BC 95% CI=-0.074/-0.016). However, BSES was not associated with enamel caries, pufa, treated teeth, dental plaque, birth outcomes and EDD (Figure 25a).

On the other hand, none of the paths estimated from birth outcomes to OHCs revealed significant associations (the p-value for the path estimates was > 0.05) (Figure 25b; Appendix 21).

Finally, having high EDD in primary teeth was directly associated with having a low level of dentine caries (β= -0.086**, SE= 0.028, BC 95% CI= -0.137/-0.026) and indirectly linked with a low level of dental pain when the child was 7-8 years old (β= -0.013**, SE=0.006, BC 95% CI=-0.028/-0.004). In other words, children with EDD were less likely to have dentine caries and, therefore, less likely to experience dental pain (Figure 25d).

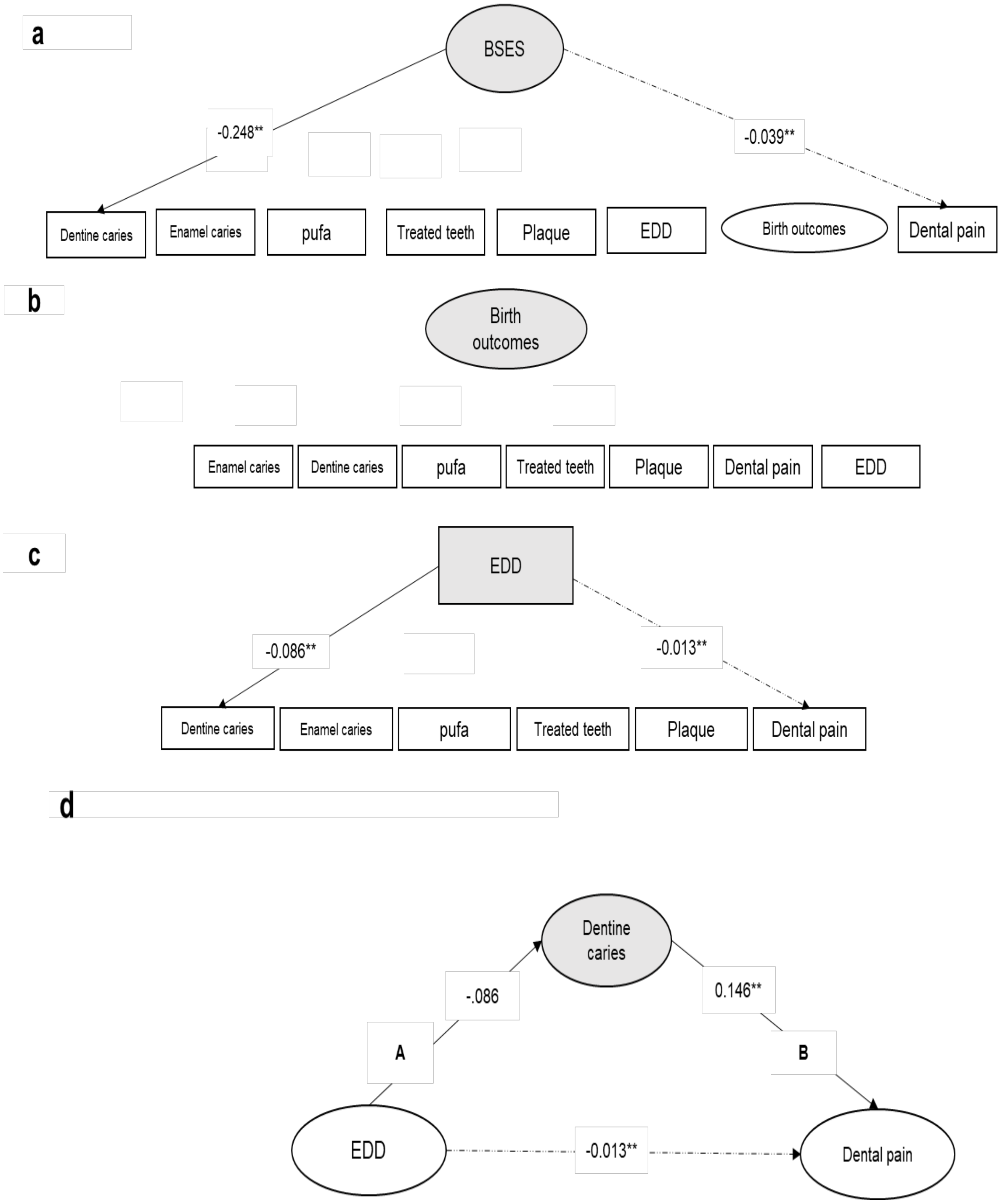


Figure 25. The critical period model: the path estimates between BSES (a), birth outcomes (b), EDD (c) and child's OHCs independently and dependently from BSES, and mediation effect of dental caries (d)

4.6.2.1.2 Accumulation model with the chain of risks

The chain of risk model results with additive and trigger effects revealed that OHCs were unnecessary to be a subsequent chain of risks driven by SES (Figure 26).

To clarify, the paths between BSES and maternal CHCs, the path between birth outcomes and EDD, and the path between EDD and plaque were non-significant (Appendix 21). The only significant paths in the chain were between maternal CHCs and a child's birth outcomes (β= 0.161**, SE= 0.063, BC 95% CI= 0.048/0.291) (Figure 26a). In other words, mothers without chronic conditions during pregnancy were more likely to have a baby with a normal weight of ≥2500g, normal gestational age of ≥37 weeks, and ≥second birth order.

This indicated that each risk in the proposed chain did not trigger or add to another (Figure 26a). Rather, some risks have an independent effect on developing OHCs, especially dental caries. To illustrate, the results revealed that BSES and EDD directly affect a child's level of dentine dental caries, as mentioned earlier. Further, dental plaque has a direct positive association with dentine caries (β=0.364**, SE= 0.038, BC 95% CI= 0.286/0.433), enamel caries (β=0.094*, SE=0.044, BC 95% CI= 0.008/0.180), and treated teeth (β=0.121**, SE= 0.044, BC 95% CI= 0.026/0.202), and indirectly related to dental pain through dentine caries (β=0.057**, SE=0.018, BC 95% CI= 0.023/0.097) (Figure 26b).

Similarly, when testing the influence of BSES in developing risk behaviours that would lead to OHCs, the model was not fully supported (Figure 26c). To illustrate, the results revealed that high BSES was directly associated with parents' supervised tooth brushing when the child was three years old (β= 0.175**, SE= 0.058, BC 95% CI=

0.048/0.278), but BSES was not associated with the child's exclusive breastfeeding. Further, the paths between those behaviours and OHCs were not significant.

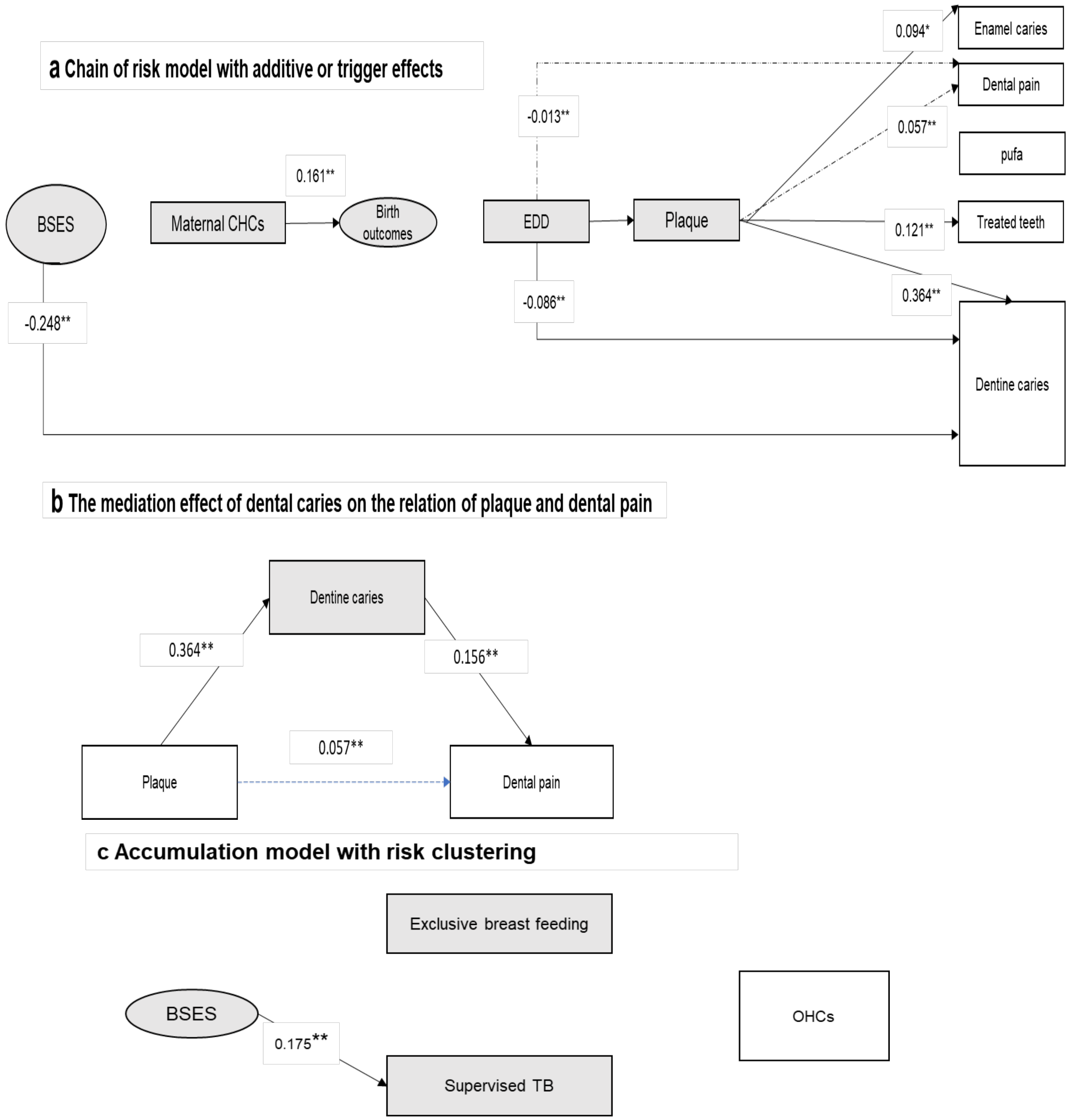


Figure 26. Accumulation of risk models

4.6.2.1.3 Association between BSES and CSES

Figure 27 shows the association between BSES and CSES and the possible behavioural and parental pathways that link CSES and OHCs among children.

The results indicated that high BSES predicted high current SES (β=0.986**, SE= 0.012, BC 95% CI= 0.957/1.006) (Figure 27). In addition, CSES mediated the indirect association between BSES and the child's OHPs (β=-0.187**, SE= 0.062, BC 95% CI=-.313/-0.074) (Figure 26a), as well as the indirect link between BSES and parent's characteristics (β= 0.457*, SE= 0.144, BC 95% CI=0.200/0.724) (Figure 28b). Thus, it means that high BSES and CSES associated with children's inadequate OHPs (brushing, flossing, use of mouth wash frequencies = ≤ 2 times/day, and sugar= > two times/day) and supportive parent's characteristics (parents with authoritative parenting style, high mother's academic involvement).

Analysing the behavioural pathway between family current SES and OHCs, revealed that the family's CSES directly predicted the child's OHPs (β= -0.190**, SE= 0.062, BC 95% CI=-0.317/-0.076), without the mediation effect of mother's OHPs frequencies. However, the result did not find an association between child's OHPs and their current dental plaque or OHCs (Figure 27, Appendix 21). Interestingly, adequate mother's OHPs was directly associated with adequate child's OHPs (β=0.778**, SE= 0.082 0.575/0.924).

Additionally, when testing the parental characteristics pathway between the family's CSES and child's OHCs, the models found that CSES directly associated with the parent's characteristics (β=0.464*, SE= 0.146, BC 95% CI= 0.202/0.727); however, parents' characteristics were not related to the child's OHPs or their OHCs (Appendix 21).

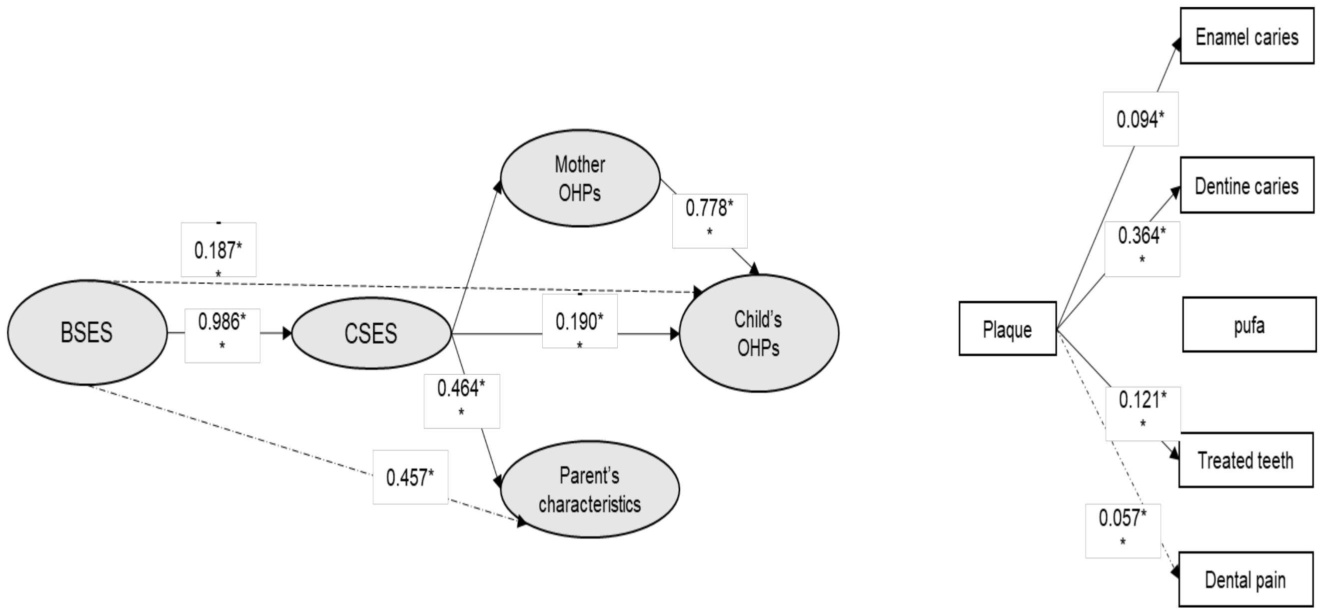


Figure 27. The association between BSES and CSES

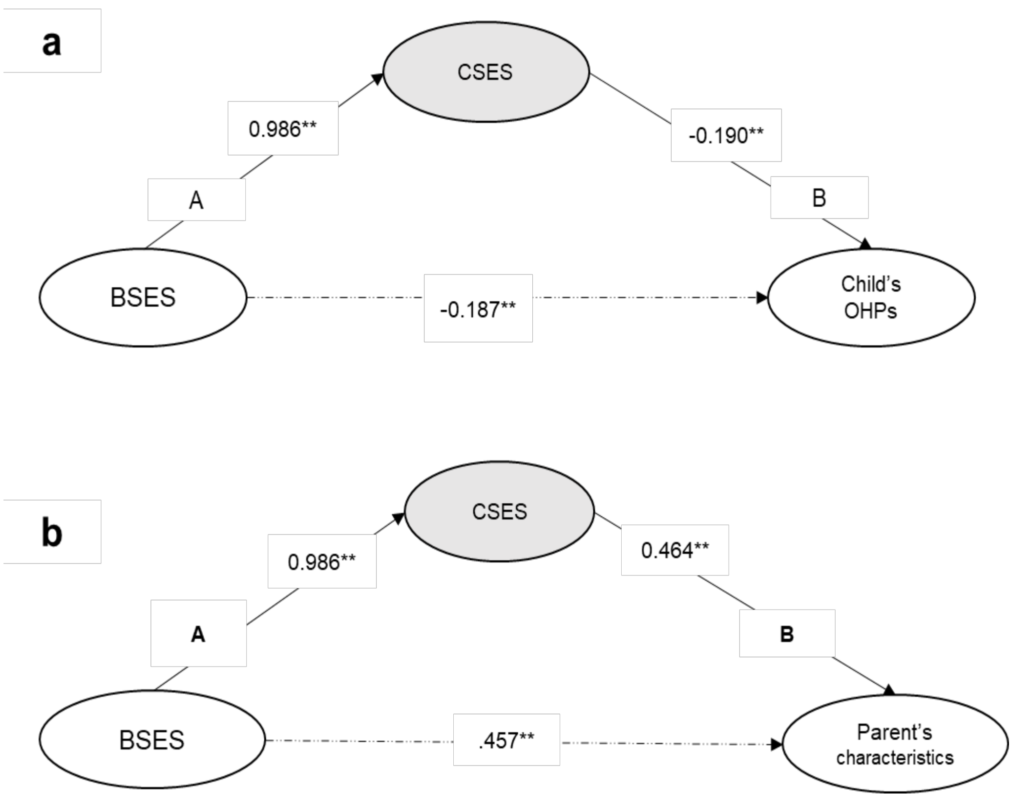


Figure 28. The mediation effects of CSES between BSES and child's OHPs (a) and between BSES and parent's characteristics (b)

4.6.2.2 Association between OHCs and school performance

This section presents the results of examining the association between OHCs and school performance (Objective 3). School attendance was removed as no factors were related to it (Appendix 21).

Testing the direct relations between OHCs and school performance revealed that dentine dental caries was directly associated with low school performance (β= -0.155**, SE= 0.052, BC 95% CI= -0.250/-0.047). Treated teeth was also directly associated with high school performance (β=0.100*, SE= 0.037, BC 95% CI= 0.029/0.171) (Figure 29).

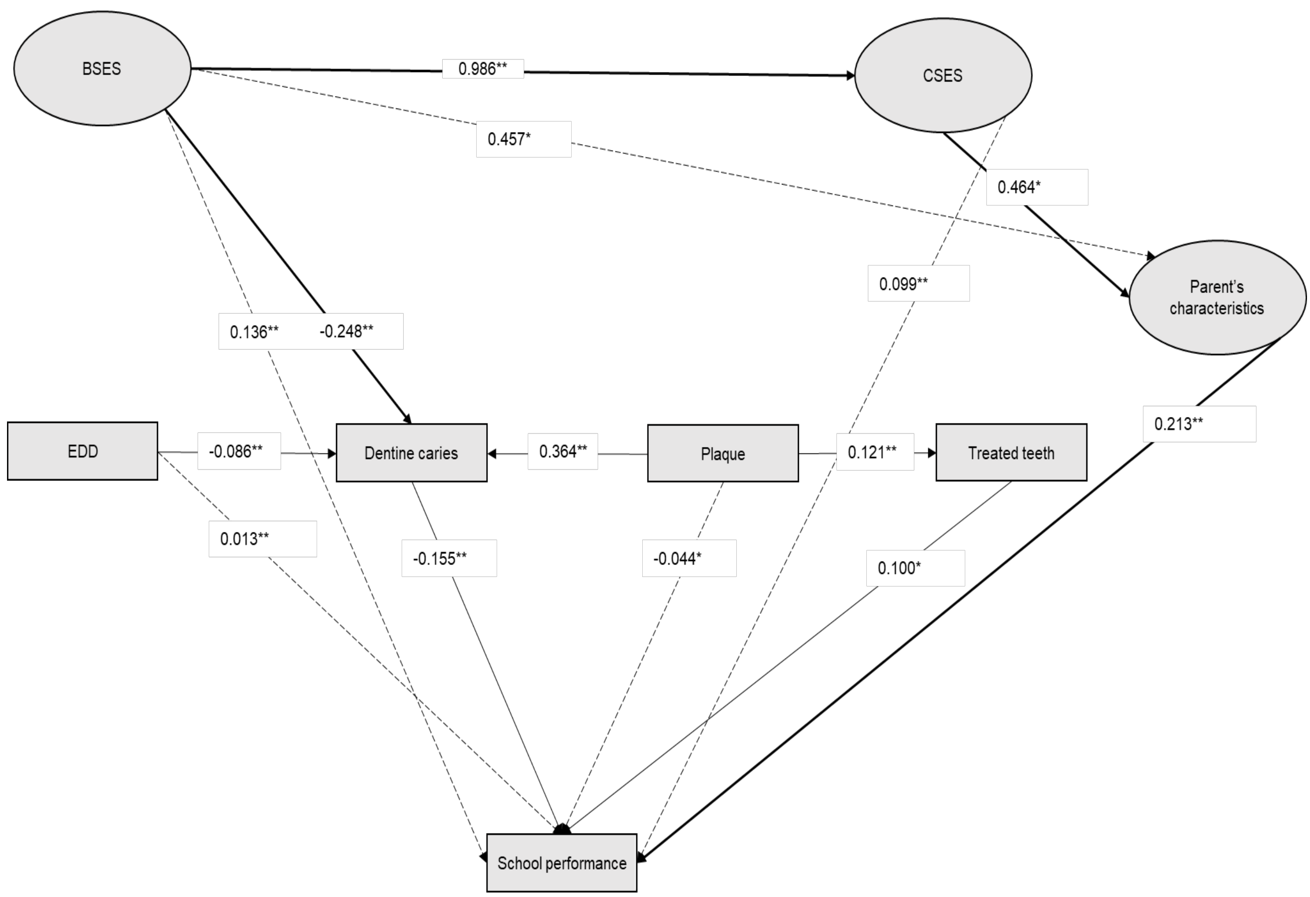


Figure 29. The relation between OHCs and school performance

Further, testing mediations revealed that dental plaque was indirectly associated with poor school performance via dentine caries and treated teeth (β=-0.044**, SE= 0.020, BC 95% CI= -0.085/-0.006) (Figure 30).

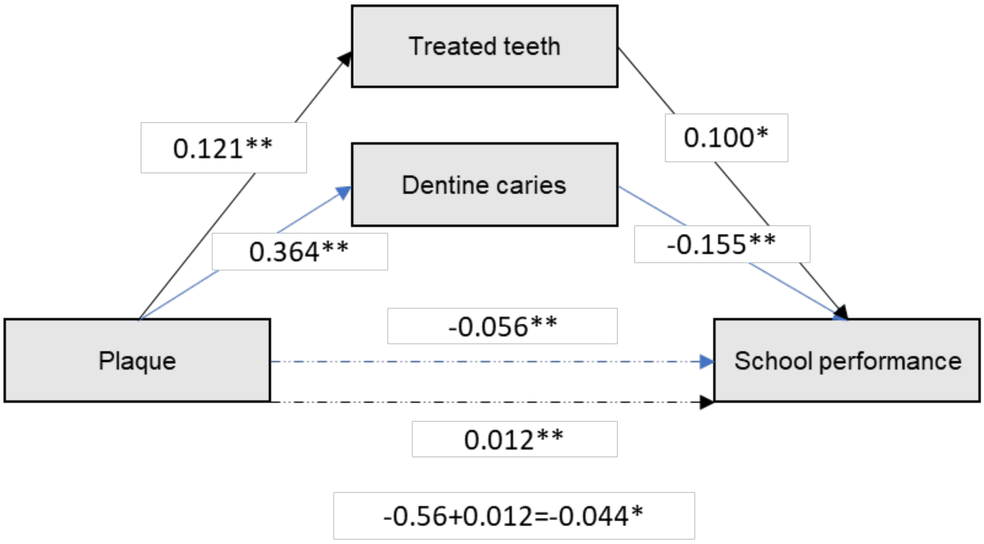


Figure 30. The mediation effect of treated teeth and dentine caries on the link between plaque and school performance

On the other hand, no significant associations were found between pufa, enamel caries, dental pain, and school performance. Thus, pufa, and dental pain were not significant mediators between OHCs and school performance. Although the results revealed that if dentine caries increased among children, they were more likely to experience dental pain (β=0.156**, SE= 0.047, BC 95% CI= 0.064/0.248); however, such an association was not related to children's school performance.

Similarly, school attendance was not a significant mediator between OHCs and school performance. The path between OHCs and school attendance was neither significant nor between school attendance and school performance (Appendix 21).

Finally, testing the mediation effect of OHCs between SES and school performance indicated that dentine caries mediated the positive association between BSES and children's school performance. Thus, high BSES was indirectly associated with higher school performance via dentine caries (0.039**, 95% CI= 0.278/1.305) (Figure 31).

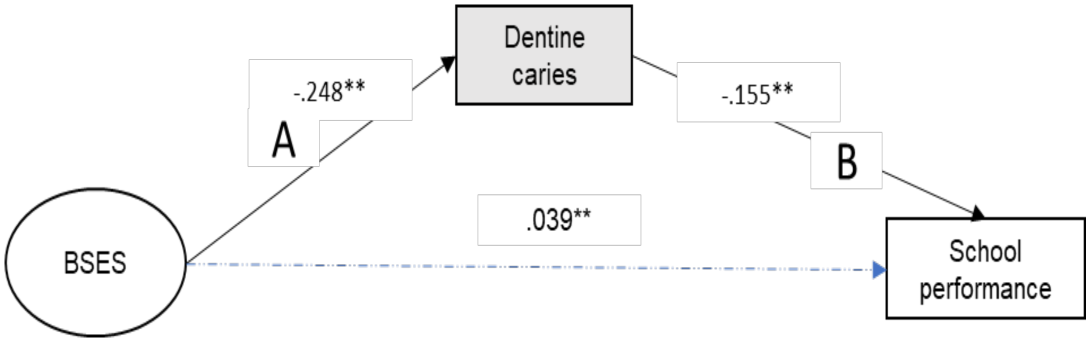


Figure 31. The mediation effect of dental caries on the link between BSES and school performance

4.6.2.3 The association between other life course factors and school performance

Besides the link with BSES via dentine caries, the results also revealed high CSES linked with high school performance via parent's characteristics (0.099**, SE= 0.067, BC 95% CI= 0.018/0.257) (Figure 32) (Objective 4). In the same time parent's characteristics linked directly with better children's school performance (β= 0.213**, SE= 0.083, BC 95% CI= 0.058/0.379). Thus, BSES and CSES predicted parents with supportive characteristics like authoritative parenting styles and mothers with high academic involvement. In return, parents with supportive characteristics were associated with high school performance among children (Figure 33).

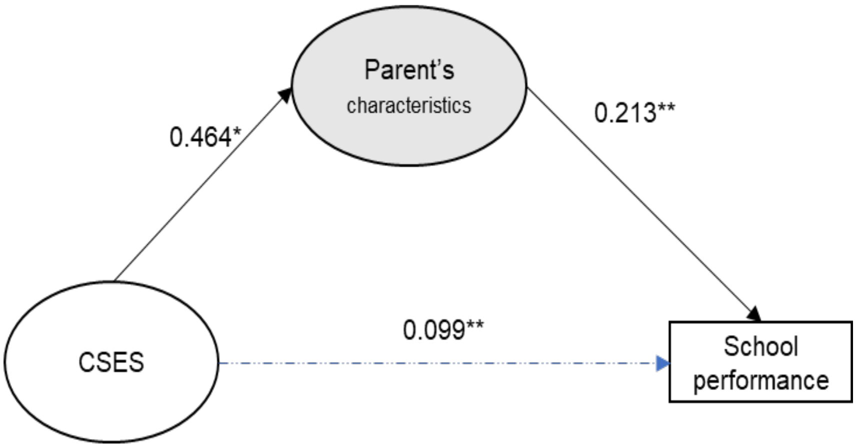


Figure 32. The mediation effect of parent's characteristics in the link between CSES and school performance

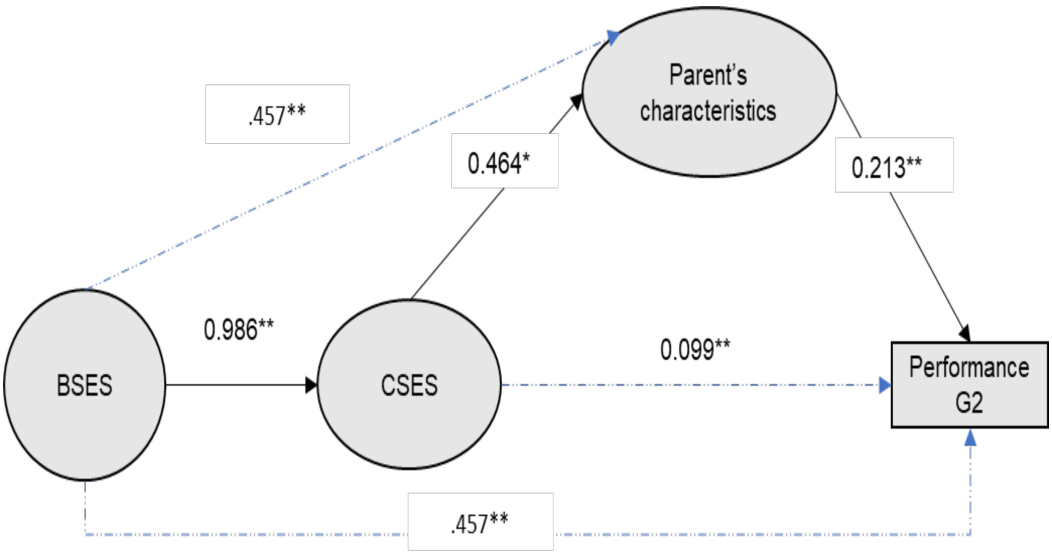


Figure 33. The association between social and parental factors with children school performance

4.6.3 Summary of the results

To summarise, a total of 466 children aged 7-8 years old, along with their parents, were enrolled in this study in September 2019 (response rate = 98%). Most participants were Bahraini (72.5), some (22.5%) were from other Arab countries, and 5% were Asian. Half of the families received a moderate monthly income (400-600 BD). Further, 74.5% of mothers were unemployed, while 98% of the fathers were employed. Only 14.6% of children lived with single or extended families, while the remaining children lived with both parents.

Regarding OHCs, dental caries and clinical consequences of dental caries were generally more prevalent in the primary teeth than in the permanent ones. The prevalence of dental caries and PUFA/pufa were 93.4% and 26.5%, respectively. Unlike that, EDD was more prevalent in permanent teeth, with a prevalence of 17.0%. The majority of children (67.6%) reported at least one impact of OH on their quality of life.

Testing the association of OHCs with school performance and school attendance demonstrated that social factors in early life were significant predictors of poor OH and low school performance among children aged 7-8 years old. Also, the results revealed that dentine dental caries was directly associated with low school performance. Conversely, treated teeth and parents' characteristics were directly associated with high school performance.

Chapter 5. Discussion

5.1 Introduction

This study examined the associations between OHCs and school performance and attendance among schoolchildren aged 7-8 years old in Muharraq, KoB, using OH's Heilmann et al. (2015) life course framework. The four main objectives of the present research were: firstly, to describe the prevalence of OHCs in Muharraq city among children attending good, rated schools; secondly, to analyse the relevant social, biological, behavioural, and parental pathways that linked early and current life exposures with children's current OHCs through testing different life course models (critical and accumulation models); thirdly, to examine the association of OHCs with school performance and attendance among schoolchildren, including the direct and indirect links and possible mediators; fourthly, to explore the possible early and current life's course social, biological, behavioural and parental factors that might associate with children school outcomes besides OHCs. It was hypothesised that low SES at birth and age 7-8 would shape the children's biological, behavioural, parental, and psychosocial resources in such a way as to promote the development of OHCs; hence they would exhibit low school performance and attendance. Conversely, children who experienced high SES at birth at age 7-8 would show little or no evidence of OHCs and would exhibit better school attendance and performance than those living within a low SES family.

5.2 Summary of the key findings

The prevalence of enamel and dentine caries and their clinical consequences were 93.4% and 25.7%, respectively. The second most prevalent condition was enamel defect, with 17.2%.

Regarding the early life course factors linked with OHCs, the only significant factor was low SES at birth. High BSES was directly associated with a low level of dentine caries and indirectly with a low level of dental pain among children in Grade 2 in Muharraq. At age 7-8, a high level of the dental plaque was an important factor associated with a high level of enamel and dentine caries, dental pain, and treated teeth. On the other hand, none of the early and current life courses behavioural and parental factors was associated with OHCs.

It was found that dentine dental caries was negatively and directly linked with children's school performance, while dental plaque was negatively and indirectly linked with school performance. Conversely, treated teeth were directly associated with high school performance. Parents' SES was also significantly related to children's school performance via dentine caries and parental factors. On the other hand, none of the family SES and parental nor OHCs were associated with children's school attendance.

5.3 Discussion of Objective 1

To describe the prevalence of OHCs among 7-8 years old schoolchildren of the good, rated schools in the city of Muharraq

5.3.1 Prevalence of dental caries

Although there is widespread published research on dental caries among diverse populations and age groups worldwide, there is no published data from KoB. This study is the first to comprehensively assess dental caries through clinical examination by ICDAS, their sequela (PUFA/pufa) and consider their impact on children's quality of life (measured using the POQL) in KoB.

ICDAS was used because it is a validated measure of caries experience. The system can detect and assess the severity and progress of caries lesions ranging from the first visible signs of dental caries in enamel to an excessive cavity with visible dentine (Ismail et al., 2007). The system is compatible with life course theories, as it acknowledges that the dental caries process is not limited to the presence or absence of cavitated lesions; instead, it is the result of different developmental stages. Understanding these stages over time can provide valuable information not only for caries diagnosis, prognosis and the clinical management of dental caries ranging from preventive to operative care but also regarding the determinants of caries at different stages of life and proposing the best timing of interventions necessary to reverse the disease process (Pitts and Ekstrand, 2013).

The Kappa index for the ICDAS examination was substantial in this study; the weighted and unweighted kappa values were>0.65, indicating an acceptable level of agreement between and within examiners, similar to other studies (Braga et al., 2009, Honkala et al., 2011). This indicates that ICDAS presented good reproducibility and accuracy in detecting dental caries (Jablonski-Momeni et al., 2008, Ekstrand et al., 2018).

The study found that the prevalence of ICDAS code >1 was 93.4%, greater in the primary dentition (93.0%) than in the permanent dentition (45.8%). The means for enamel caries were 1.5 in the primary dentition and 1.2 in the permanent dentition, while for dentine caries, the means were 16.3 and 0.43, respectively among the total sample. Only 6.5% of the examined children might be a caries-free, however, because the exclusion of Code 1, this should be interpreted with caution. The prevalence of clinical consequences of untreated dental caries (PUFA/pufa ≥ 1) was 25.7. This prevalence confirmed the high incidence of severe caries in this world region. Among the limited number of studies that have measured dental caries in primary teeth using ICDAS, the prevalence shown in this study is unusually high. For example, in India, Arangannal et al. (2016) found that the prevalence of dental caries among 2,796 schoolchildren aged 5-15 was 68.8%, and almost 65% among those aged 7-8 years. A study conducted in Brazil using ICDAS≥3 found the prevalence to be 47.9% among 836 children aged 3-5 years old (Neves et al., 2016). Nevertheless, a similar prevalence of high caries has been reported in Estonia (Honkala et al., 2011) and Brazil (Mendes et al., 2010) using the same measure.

Honkala et al. (2011) argued that the total caries experience is usually higher in mixed dentition since the primary teeth are exposed to risk factors like sugar for a longer period. Additionally, the longer exposure time can explain why the primary dentition has a higher rate of dentine caries than the permanent dentition. Some might also argue that the prevalence might be higher because of the inclusion of the active and non-active lesions in contrast to DMFT, which only account for active dentine lesions (Potlia et al., 2016).

The downside of using the ICDAS system was that it was difficult to compare the prevalence of caries among countries in the same region since most studies have used the DMF/dmf index, following the WHO criteria. Even though the ICDAS system has been adopted by many recently, comparing results was also challenging because there is inconsistency in reporting and presenting the dental caries experience (ElSalhy et al., 2019). A current systematic review found that among 126 papers reporting dental caries findings using ICDAS, 44 different measuring methods were used. For example, total counts of combined caries scores for surfaces or teeth, total counts of every score, and central tendency and dispersion measures. Despite the difficulty in comparing different epidemiological studies, this range of options demonstrates the system's flexibility, enabling it to accommodate the needs of different ICDAS researchers.

This study counted the total ICDAS measure to summarise caries progression or regression among the population (ElSalhy et al., 2019). Additionally, it categorised dental caries into enamel and dentine to examine how different types of caries can influence children’s school outcomes and to help in determining categories of treatment needed (ElSalhy et al., 2019). The flexibility of the system facilitated comparisons with WHO-reported data. The ICDAS II established code four or three as an equivalence cut-off point between the ICDAS and WHO indices (Iranzo-Cortés et al., 2013). Thus, the system exhibits high adaptability to different uses in epidemiologic research.

To compare caries prevalence among Muharraq schoolchildren with other regions of the world, in this study, ICDAS scores 4-6 were converted into dmfs/DMFS (Honkala et al., 2011). The prevalence of dental caries using dmfs/DMFS was 89.7% in primary teeth and 45.8% in permanent teeth, whereas the mean of dmfs/DMFS was 6.3 and 0.3, respectively. Thus Muharraq city is falling behind in meeting the global goal of

2020 to reduce the “proportion of children and adolescents who have dental caries experience in their primary or permanent teeth” (Hobdell et al., 2003).

Comparing the results of this study with those of the last OH survey (2011) in Muharraq, there is a trend toward a greater prevalence of dental caries despite the country’s efforts to improve OH (Naseeb, 2016). In 2011 the prevalence of dental caries in primary teeth among children aged 6 in Muharraq was 82%, with a mean equal to 4.5. The corresponding mean in the current study shows a 1.8 increase, at 6.3. This, however, could be attributed to the difference between age group, as the sample in this study were two years old younger than the previous OH survey. Although caution must be taken when comparing the prevalence of dental caries with other areas, our sample was restricted to children attending good quality schools, which might limit the generalisability of the study’s findings to other schools.

In contrast to the studies in Sections 2.3 and 2.4 of the literature reviews, Muharraq exhibited the highest prevalence of dentine dental caries in the primary dentition. The reported prevalence and dmft means are as follows, 60% (3.5); 66.9% (3.6) and 39% (1.6) in Brazil; China; and Uganda, respectively (Peres et al., 2005, Sun et al., 2017, Birungi et al., 2017); in Scotland, only dmfs was recorded (3.6) (Bernabé et al., 2017); and in Sudan, only a low dmft ≥ four prevalence was recorded (51%) (Osman and Alsayed, 2015).

Bahrain, Qatar, Saudi Arabia, Kuwait, the United Arab Emirates (UAE), and Oman together, these countries constitute the GCC (At-Twaijri, 1990). The GCC population shares similar SES, culture, traditions, religion, and language; these similarities were one of the bases for creating the GCC (At-Twaijri, 1990). However, the prevalence and the means of dmft of caries in the primary dentition in Muharraq showed a slightly higher trend than in other cities in the GCC countries. For example, Kowash et al. (2017) reported that the prevalence and the mean of dentine dental caries were 74.1% and 3.1, respectively, in the primary dentition among 540 children aged five years old in Ras Al Khaimah in the United Arab of Emirates (UAE). In contrast, Farooqi et al. (2015) reported that the prevalence and the mean of dental caries were 78% and 3.7, respectively, among 397 children aged 6-9 years old in Dammam city in Saudi Arabia. A similarly high prevalence and mean of dmft in the primary dentition was observed in some Asian countries, such as 90% (6.8), 84.5%, and 77.7% (6.2) in Indonesia, China, and Thailand, respectively (Adiatman et al., 2016, Li et al., 2017, Krisdapong et al., 2014).

In contrast to findings from other Mediterranean regions and African countries, the caries level among primary teeth was found to be highest in Muharraq, the prevalence and means recorded in other countries being as follows: 62% (4.4); 70%(4.2); 76.4% (3.3); 52.5% (2.3); and 20.2% (0.9), in Yemen, Syria, Jordan, Sudan, and Tanzania, respectively (Alshoraim et al., 2018, Qadri et al., 2012, Rajab et al., 2014, Elidrissi and Naidoo, 2016, Mwakayoka et al., 2017), respectively.

The figures for Arab children and the Middle East were considerably greater than those recorded for children in the Western region. The mean dmft in Germany, the UK, Scotland, and Sweden, was 2.9, 0.8, 1.3, and 2.0, respectively (Lee et al., 2021, Jones et al., 2017, Koch et al., 2017). However, it was close to the dft mean in the US (4.3) (Dye et al., 2015).

The data above shows a geographically disproportional distribution of dental caries in the primary dentition and that the rate of dental caries was higher in Muharraq and GCC than in the developed countries and the African region. The trends in dental caries could be attributed to differences in sample sizes, varying age ranges of the participating children and geographical location. However, the decrease in dental caries among the developed countries was judged to be due to progress in prevention measures and high access to dental care, despite the inconsistent results showing that dental caries continues to be more prominent among the disadvantaged population in many of these countries (Kassebaum et al., 2015). In contrast, it has been observed that developing countries, including KoB, have recently started to show an upward trend in caries prevalence due to an increase in sugar consumption, insufficient fluorides exposures and limited access to OH services (Kassebaum et al., 2015, Lagerweij and van Loveren, 2015).

The WHO data indicates that dental caries has been declining worldwide, with the greatest reduction observed in the high- and middle-income countries. In contrast, the decline is less explicit in low-income countries (Lagerweij and van Loveren, 2015). However, the WHO lists a few exceptions where caries prevalence has risen, such as the Gambia and Saudi Arabia (WHO, 2013). In this sense, KoB and the whole GCC need to be included in this list of exceptions, and further investigation is needed because the GCC countries are considered high-income (World Bank, 2020) but experience a high rate of dental caries.

KoB is thus considered by the World Bank (2020) to be a high-income country. The gross domestic product (GDP) per capita for KoB was about 22,402 in 2020, which places KoB in the top 50. The HDI value for 2019 was 0.852. This value ranks Bahrain in the 42nd position out of 189 countries and as a very high human development area in the UNDP's. Thus, the assumption that high-income countries have a better standard of OH is not met in KoB (Watt et al., 2019). Similarly, Korea and Hong Kong have very high HDI scores, but the prevalence of caries is high (>50%) compared with

Europe (Chen et al., 2019). It might be that the HDI reflects the development level of the whole country and that the SES of a specific city or district cannot be reflected in this index.

Other reasons for variations in findings may be due to marked differences in health services and sugar consumption, as indicated above. Oral health services in Bahrain are incorporated within primary health care, through 27 primary health centres, under the MOH umbrella. Dentists, dental hygienists, and dental assistants are the main dental workforce in MOH. The government has funded free OH services for all (MOH-KoB, 2014), while non-Bahraini pay a nominal amount, which the Government greatly subsidies. Since 1986, there has been an OH survey in KoB every five years, collaborating with the WHO. However, the survey tends to measure only disease prevalence; neither determinants nor impact of diseases on people's lives have been measured. Thus, unfortunately, it leads to curative dental care rather than preventive.

Identifying social inequality in Bahrain will not help eliminate oral diseases; instead, it will help determine policies targeting the disadvantaged group. Also, there was no data to explain the relation between OH and SES in Bahrain before this study. An OH survey in 2005 showed that children attending private schools demonstrate less dental caries than those attending government-run schools, but no further investigations have been taken.

The available services and workforces in MOH are struggling to meet the growing population's needs (MOH-KoB, 2014). The Organization for Economic Cooperation and Development (OECD) suggested a 20,000 average population per health centre as a benchmark for KoB. Thus, although the number of health centres has increased to 27 since 2006, most health services are serving well above this number (MOH-KoB, 2014). As suggested by Health Information Directorate, the acceptable dentist to population ratio for KoB was 1/5000 (Ahmed et al., 2000). However, only 110 dentists with a few specialities and 60 dental hygienists are working with the MOH currently (MOH-KoB, 2019). The numbers are below the suggested ratio; as a result, accessibility and availability are hindered. Moreover, the MOH operates a salary-based remuneration system with no incentives, leading to early retirement and the movement of many specialists to the private sector, making many services unaffordable for a large section of the population, especially non-Bahrainis.

With regard to OH promotion strategies implemented by dental hygiene services, in KoB, dental hygienists used a targeted prevention approach, applying fissure sealant and fluoride varnish to all government-school children. Although this would appear to be a practical method of saving resources for high-risk individuals (Rose et al., 2008), its effectiveness in reducing dental caries is not evident given the high prevalence of caries among KoB schoolchildren, nor has the impact of the fluoride and fissure sealant programmes ever been evaluated to determine their implications or efficiency. Another strategy used by dental hygienists in Bahrain is to promote positive oral health behaviours through OH education, distributing toothpaste and toothbrushes among government school pupils from Grade 1. However, there is little instruction about using the correct amount of fluoride in toothpaste or the concept of ‘brush and spit’ rather than rinsing the mouth with water after brushing. It was found that 92% of the children in the current study rinse out the toothpaste with water; thus, most of the fluoride, if used, is being diluted and not used effectively.

Another reason why clinical preventive interventions such as topical fluorides and fissure sealant are ineffective in controlling caries in Bahraini children, despite their proving highly effective in other regions (Li et al., 2020), is maybe high sugar consumption. Although children spend most of their time at school, there are no policies to reduce sugary snacks at schools –- the schools continue to serve children sugary drinks and snacks, which counteract OH care. This study found that 71.9% of the schoolchildren surveyed consume ≥1 sugary snack daily. Similarly, a previous study on KoB among schoolchildren found the mean daily intake of total sugars to be 101.3 g and 89.1 g for boys and girls, respectively (Gharib and Rasheed, 2011). This value is considered extremely high compared to the recommended intake of sugar (< 5% of the total energy intake) (WHO, 2015). The evidence suggests that caries continues to progress if the individual's total energy intake of free sugars is above 10% (Moynihan and Kelly, 2014). Even in the presence of an optimal level of fluoride, evidence showed that free sugar consumption as low as 2–3% of total energy intake is enough to increase the risk of caries (Sheiham and James, 2015).

Although this study did not capture the link between sugar and the rate of dental caries, life course evidence confirms the accumulative effects of sugar intake on caries increment (Broadbent et al., 2008); and, specifically, that progression of dental caries from age 6 to age 18 is constantly and positively linked with high patterns of sugar consumption throughout the life course (Peres et al., 2016). In order to understand this association in KoB, longitudinal studies would be needed.

Additionally, this study showed that families with high SES consumed more sugar than families with low SES. This is because the growth of the KoB economy is accompanied by a substantial shift from traditional healthy foods to diets rich in fat, sugar and red meat (Musaiger, 2000). The sugar consumption rate in KoB among children is alarming, putting them at risk of future dental caries and diabetes, obesity, and other chronic conditions (Sheiham and Watt, 2000). Concomitantly, this study found that 31% of the schoolchildren were overweight or obese across both genders. Thus, adopting a common risk approach in early life can help to prevent most of these conditions.

Although dental caries levels showed a declined trend in the primary dentition among children in different parts of the world, caries being a rapidly progressive condition of childhood has shifted—the concern now related to their slow progression and cumulative nature that manifest in older age (Whelton, 2004). This is illustrated clearly through the Dunedin study, wherein a cohort of 1,037 was tracked from 5 up to the age of 38 (Broadbent et al., 2013). Roughly 40% of this cohort were classified as low caries, 45% as moderate caries, and 15% as high caries. Interestingly, the annual increase in caries remained steady throughout the 32 years. This indicates that the risk of caries is not only a concern among children but that it continues throughout life.

Therefore, it can be argued that KoB, with its high level of caries in children's primary teeth, should be considerably more proactive in its prevention strategies, especially given the evidence linking caries in primary teeth with caries in permanent teeth and later life risk as a dose-response relationship (Peres et al., 2009). Accordingly, it needs to be recognised that the preventive efforts in KoB should be not only more effective and more closely monitored than at present, but that they should begin earlier, at pre-school age, in a kindergarten setting and with parental participation.

5.3.2 Prevalence of EDD

Using the modified EDD index (Clarkson and O'Mullane, 1989), the prevalence of EDD was found to be greater in permanent teeth (17%) than in primary teeth (1.5%) in this study, in line with other research (Seow et al., 2011, Slayton et al., 2001). This may be because primary teeth presented with more caries experience (89.7%) or had been exfoliated already.

Compared to other evidence using the modified EDD index, in the same age group (7-8 years), the present study indicated a lower prevalence than studies in Australia (58%) (Seow et al., 2011) and Spain (52%) (Robles et al., 2013), whereas it was higher than a study conducted in Libya (2.9%) (Fteita et al., 2006).

Some studies examined the prevalence of EDD in terms of Molar Incisor Hypomineralization (MIH) using the criteria of the European Academy of Paediatric Dentistry (EAPD), whereby only first molars and incisors are examined (Weerheijm et al., 2003).

Interestingly, the present findings revealed that the first molars and incisors in permanent dentition were the most affected sites by EDD (Section 4.3.11.5), thus facilitating comparisons with studies that examined MIH using the EAPD criteria. Accordingly, at 14.4%, the prevalence of MIH in the current study was similar to the global mean (13.1% to 14.2%) (Schwendicke et al., 2018) but lower than results reported prevalence of 20%, 20.2%, 19.8%, and 17.7% in Sudan (Abdalla et al., 2021), Iran (Ahmadi et al., 2012), Japan (Saitoh et al., 2018) and Nigeria (Oyedele et al., 2015), respectively. Higher prevalence of MIH was reported to be 25.1%, 26.7%, 27.2%, and 33.2% in Saudi Arabia (Hazim et al., 2018), in Lebanon (Elzein et al., 2020), in Dubai (Hussain et al., 2018), and in Sweden (Jälevik et al., 2018), respectively. Egypt, in contrast, showed a very low prevalence (2.3%) (Saber et al., 2018).

In the present study, demarcated opacities were the most dominant type amongst the affected teeth. This result was compatible with Dubai, Sweden, and Sudan (Hussain et al., 2018, Jälevik et al., 2018, Abdalla et al., 2021). In addition, this study revealed that the maxillary teeth were more affected by MIH than the mandibular teeth, which is consistent with the results from Dubai and Sudan (Hussain et al., 2018, Abdalla et al., 2021), but not with those of Lebanon and Saudi Arabia (Elzein et al., 2020, Hazim et al., 2018) where a similar pattern of MIH was found in both upper and lower jaws. The present study also found that MIH affected the mandibular and maxillary molars more than the incisors, which mirrored the findings from Dubai (Hussain et al., 2018) but contradicted those for Sudan (Abdalla et al., 2021).

The association between environmental, biological factors and EDD was not supported in the current study. Although the causes of EDD and MIH are not very clear, it is generally agreed that EDD is caused by various factors, including genetic and environmental such as malnutrition and exposure to chemicals like fluoride (Heilmann et al., 2015). What is clear is that EDD provides valuable information regarding the timing of teeth development and can be used as an indicator for early life disadvantages (Heilmann et al., 2015). Another relevant point is that EDD has been linked to dental caries, and it has been used in life course research as an early life stressor in the chain of risk model (Peres et al., 2005). Thus, an early diagnosis of EDD might aid in the prevention of dental caries in early and later life.

5.4 Discussion of Objective 2

To analyse the social, biological, behavioural, and parental pathways that link early and current life exposures with children's current OHCs by testing the critical and the accumulation life course models considering social determinants of OH.

5.4.1 Early and current life factors linked to OHCs

The study analysed the relevant social, biological, behavioural, and parental pathways that linked early and current life exposures with children's current OHCs by testing the critical and accumulation life course models considering social determinants of OH.

Regarding the critical period model, the study indicated that socioeconomic factors were more important than biological and behavioural factors in determining the children's current OH. These results do not support the argument that dental caries experience is "programmed" in early life, as is the case for the development of chronic conditions (Barker, 1998). In accordance with previous studies (Peres et al., 2005, Sun et al., 2017, Zhou et al., 2012, Zhou et al., 2011), but not with Nicolau et al. (2003), the study found no association between LBW, PB, and dental caries. This result mirrors the finding of a current meta-analysis (Occhi-Alexandre et al., 2020), which noted that 28 out of 36 observational studies showed no association between LBW, PB, and dental caries. Bernabé et al. (2017) argued that the inconsistent results might be because the association was assessed within a cross-sectional study rather than a longitudinal study; thus, the accumulation of the diseases over time could not be measured. However, Zhou et al. (2011, 2012) found no association between LBW and caries in their cross-sectional and longitudinal studies. In the current study, the low prevalence of LBW (11.2%) and PB (10.9%) children may hinder the detection of a statistical association between LBW, preterm and dental caries.

Heilmann et al. (2015) suggested that low birth weight is linked to childhood caries through EDD. The current study did not support this hypothesis, and most of the studies previously mentioned in Section 2.3 did not evaluate this pathway. The reason might be related to the use of regression analysis, which only allows the study of associations between blocks of independent factors and one dependent factor; the interrelationships between the set of independent variables cannot be assessed (Berndt and Williams, 2013). Further, Peres et al. (2005) argued that the stunting condition is more related to the severity of dental caries than birth weight because it reflects long-term cumulative nutrition deficiency, which might affect the formation of the organic dental matrix EDD, then caries.

In this study, such a pathway was evaluated using SEM, but the association was still not supported. This could be explained by more substantial evidence for the relation between impaired foetal growth and EDD in infants with very LBW (<1500 grams) (Jacobsen et al., 2014). Thus, it is possible that such an association existed but was masked because a very LBW was not recorded in this study.

Although it is now evident that EDD increases susceptibility to caries (Costa et al., 2017), unlike Zhou et al. (2011; 2012), the study found that dentine caries was reduced if there were EDD present. This may be because the prevalence of EDD in primary teeth was only 1.5%, such that the association could not be captured. Furthermore, the most prevalent EDD found in this study was demarcated opacities, while evidence suggests that hypoplasia is the EDD most frequently associated with early childhood caries (ECC) (Matee et al., 1994). In this study, conditions were measured at only one point in the child's life; thus, the EDD detected is expected to contribute to an increased risk of future caries.

Although mothers' exclusive breastfeeding has previously been found to be socially patterned and associated with the level of dental caries among children (Birungi et al., 2017), the current study did not find this to be the case; this result is in accordance with (Bernabé et al., 2017). The reason that exclusive breastfeeding was not socially patterned might be that 74% of the total population of Bahrain is Muslim (Information & eGovernment Authority-KoB, 2020a), and in Islam, women are advised to breastfeed until their child is two years old. Thus, this behaviour seems to be influenced by religion or maybe beliefs and cultural norms (Osman et al., 2009). The association between breastfeeding and dental caries is not agreed upon in the literature. Some research suggested that breast milk is cariogenic (Bowen and Lawrence, 2005), while other studies suggested that breastfeeding can positively influence oral health outcomes, including a lower occurrence of malocclusion (Peres et al., 2015) and dental caries (Cui et al., 2017). In this study, the effect of breastfeeding might be masked by the effect of visible dental plaque and SES.

The influence of early life SES on dental caries in primary teeth has been well established from life course framework studies (Abreu et al., 2015). The results of this study further confirm this association. However, most previous studies focused on one indicator of SES, either occupation or education, or considered each parent's SES separately. For example, Zhou et al. (2011) found that maternal SES-related factors at a child's birth are more important than paternal SES-related factors affecting caries in later life. In contrast, Peres et al. (2005) found the father's level of education at the child's birth to be a crucial predictor of dental caries in 6-year-old children. Other studies (Peres et al., 2003; Zhou et al., 2012) concluded that family income in early life was associated with a child's dental caries throughout their life course. The differences in assessing which variables can determine the family's SES position might be related to the analytical method. Most of the studies mentioned above used regression analysis, where the researcher cannot utilise multiple indicators to indicate SES; regression analysis does allow the inclusion of blocks of variables, but it cannot estimate the combined effects of observed independent variables into a construct (Berndt and Williams, 2013). In this study, SEM was used, and thus education, occupation, and income variables did not act alone as they would in regression analysis. Instead, in SEM, those variables were used as indicators of SES latent variables to predict other dependent variables. Thus, the CFA and the SEM models found that the mother's and father's level of education, mother's employment status, and household income at the child's birth SES significantly represented the family's SES at the child's birth. However, the mother’s level of education showed the highest loading of the SES construct, confirming that maternal education was a powerful marker for SES.

In their cross-sectional study of adolescents in Brazil, Nicolau et al. (2005) identified a clear pathway by which SES in early life and throughout the life course may influence the acquisition of risk behaviour related to dental caries, such as a high level of sugar consumption and a low level of daily tooth brushing. Lu et al. (2011) found the chain of risks model well suited to explain the relation between early SES, utilisation of dental services, and dental caries in adolescents in Hong Kong.

However, this study found that SES at birth and through life shaped some behaviours such as the child's toothbrushing being supervised, the child’s current OH practices (brushing, flossing, mouth wash use, sugar consumption), and the parents’ parenting styles. However, contrary to the hypothesis, none of these behavioural and psychosocial factors accounted for the SES disparities in caries experience.

The findings show that OHPs had no significant association with OHCs, which is in line with Zhou et al.’s (2011) conclusions, contrary to those of Wong et al. (2012). While a diet rich in extrinsic sugars has been shown to be cariogenic for children (Marshall et al., 2005), different viewpoints regarding the association between the consumption of extrinsic sugars and dental caries have been reported. In a systematic review, Burt et al. (2001) suggested that the relation between sugar and dental caries was less affinitive than previously because of the prevalent use of fluoridated toothpaste. On the other hand, Habibian et al. (2001) recommended that the association depends on consumption's total frequency. Compared with more than four times (Nicolau et al., 2003) and seven times per day (Habibian et al., 2001), the current research found no association between the intake of sweets more than twice a day and dental caries. In this study, 74.5% of parents reported that their children brushed once and twice, 22% reported that their children brushed more than twice a day, and 32% reported that they didn't supervise their children's toothbrushing habits. However, the mean visible plaque among the children was 65.48%, indicating that the children were not brushing their teeth effectively. Accordingly, the relation between OHPs and dental caries was challenging to detect, whereas the relation between visible plaque and enamel and dentine caries, treated teeth, and dental pain was significant. Although toothbrushing, if accurately adapted, can clean plaque, the toothbrushing habits of student in this research was not significantly related to OHCs. Thus, the result is perhaps due to the ineffective toothbrushing behaviours of these schoolchildren. The results, echoing Zhou et al. (2011), indicate that visible plaque is a more reliable indication of current toothbrushing habits.

Another relevant finding was that the family's SES at the time of the child's birth predicted its SES when the child reached middle childhood. This might support the cumulative risk model; however, using a cross-sectional design study enabled the examination of the link between family SES trajectories from birth to middle childhood and OHCs and OHPs. Interestingly, the study found that children's OHPs were shaped directly by their parents' current SES and mother's OHPs and indirectly by early-life SES. However, the most controversial finding was that if the parents' SES increased, the frequency of OHPs decreased, and sugar consumption increased; although this result is significant, it was found to have only a small effect (β= -0.19). This finding contradicts life course evidence (Peres et al., 2007) and refutes the common belief that disadvantaged people are more prone to adopt unhealthy OH self-care (Sabbah et al., 2009). Most of the life course studies described earlier did not highlight the possible pathways between family SES and children's OHPs. However, evidence from a recent life course study among adults explained such pathways (Broadbent et al., 2016). The study suggested that early SES and parental OH beliefs were associated with the study participants' OH beliefs at different life stages.

Positive OH beliefs in early adulthood predict people's OHPs (Broadbent et al., 2016), and thus, the association between SES and OHPs could be mediated by OH beliefs. However, although OH beliefs were not examined in the current study, some of its findings suggest that parents might have been less aware of the importance of primary teeth. For example, 79.4% of parents reported that their children never visited the dentist or that they visited the dentist for treating primary teeth only in an emergency; this despite dental services for all citizens of KoB being provided free of charge. Eighty-five per cent of parents reported that they started brushing their children's teeth after 12 months of age. Moreover, although most parents (85%) in this study reported using toothpaste containing fluoride themselves, there was a 24% no-response rate for the question asking them what type of toothpaste their children used. This may indicate that for 24% of parents, this question was irrelevant since their children did not use toothpaste of any sort, or possibly that they did not know the answer, being unaware of the importance of using fluoridated toothpaste at this stage.

Given this, it, therefore, seems essential to explore how parents' OH knowledge and beliefs might shape children's OHCs and OHPs in this region, particularly in cases where SES have an adverse effect on those outcomes. It is worth mentioning here that KoB is considered a high-income country by the World Bank (2020), with a largely unexamined culture and set of beliefs, especially in relation to OH. Moreover, although

GCC countries, including the KoB, have experienced economic growth, it has been argued that the GCC continue to share some features of developing countries, such as poor low health literacy rates and health profiles (Alkhamis et al., 2014). This combination of economic growth and ignorance concerning health matters has resulted in many Arab countries experiencing increased consumption of refined sugars compared with other developing countries, mainly Africa (Petersen, 2004).

A few studies have used SEM to measure the association between SES, behavioural factors, and dental caries. One of these was conducted by Polk et al. (2010) and produced results in line with the current study. Polk et al.'s cross-sectional study of 530 9th- and 11th-grade Pennsylvania students, and their parents, was designed to determine differences in OHPs and the extent to which preventive measures accounted for the SES difference in caries experience across the sample. Using SEM, the study showed that lower SES was associated with severity and rate of dental caries. However, OHPs and preventive measures did explain the variations in dental caries defined by SES.

Different studies have examined the effect of the family's oral hygiene-related behaviours on children's OHPs and have found similar results (Özbek et al., 2015, Castilho et al., 2013, Hooley et al., 2012). In parallel with this, the current study found mothers' OHPs to be stronger predictors ($\beta = 0.778$) than parents' SES of children's OHPs. The results indicate that a higher frequency of mothers' OHPs was noticeably correlated with a higher frequency of toothbrushing, flossing, MW use, and a low frequency of sugar consumption among their children. This confirms the importance of socialisation to OH behaviours or the modelling activity whereby children replicate their parents' behaviours (Bandura, 1986). Parental modelling was found to be an effective measure to facilitate important behaviours among children, such as OHPs

(Blinkhorn, 1978) but has rarely been studied. The current study underlined that mothers could play a key role in establishing favourable OHPs among children and transmitting OHPs to them.

5.5 Discussion for Objective 3

To examine the association between OHCs and school performance and school attendance among schoolchildren, including the direct and indirect (mediated) pathways.

5.5.1 The association between OHCs and school performance

The results show that children with dentine caries and dental plaque were more likely to perform less well at school. The association between dentine caries and school performance were not mediated by dental pain, consequences of untreated dental caries, or school attendance. In contrast, dentine caries mediated the association between early-life SES and low school performance. Also, children whose caries were treated were more likely to have a higher school performance. No association was found between OHCs and school absenteeism.

The finding that children with more dentine caries were more likely to have a lower school performance is consistent with previous studies (Detty and Oza-Frank, 2014, Paula et al., 2016, Viviane and Sandra, 2003, Osman and Alsayed, 2015, Cunha et al., 2019, Garg et al., 2012). However, no association was found between dentine caries and school absence. These findings are in accordance with Osman & Alsayed (2015), who found that in a cross-sectional study of 385 Sudanese students aged from 5 to 15 years old, there was no significant association between absenteeism and dental caries contrasting school performance. Similar results were also reported by Krisdapong et al. (2013) and Seirawan et al. (2012).

Despite the general agreement on the negative impact of dental caries on children's quality of life and school outcomes, especially school performance (Rebelo et al., 2019), the question remains: How do dental caries influence school outcomes? Different pathways have been anticipated to describe the association.

The first compelling argument is that the impact of a cavitated lesion, at least on quality of life, is slight when not linked with dental pain or clinical consequences of untreated dental caries (Leal et al., 2012). In parallel with this, Seirawan et al. (2012) argued that the presence of a cavitated lesion is not linked with a child's academic performance unless a toothache is also present. A similar conclusion was reached by Piovesan et al. (2012), who showed that children with higher scores for oral symptoms (including dental pain) – as measured by the CPQ_{33} – were statistically associated with lower grades in the Portuguese skills examination, which suggests that psychosocial factors mediated the relation between dental pain and performance. On the other hand, two studies (Krisdapong et al., 2013, Jackson et al., 2011) argued that dental pain is the primary mechanism by which OHCs influence school absence first, then school performance.

The current study, using SEM, attempted to test these interlinked pathways. However, although dentine caries was found to predict dental pain, the finding that dental pain was not significantly associated with school outcomes suggests that dental pain did not necessarily play a pivotal role in these associations. These results are consistent with previous cross-sectional studies (Almeida et al., 2018, Maharani et al., 2017). However, one explanation of dental pain's lack of significance in the current study may be that dental pain was measured only once, at the beginning of Grade 2, and thus the nature of the pain (chronic or acute), its duration, and whether it occurred at a critical time (for example, during midterm or final exams), were not examined. The inclusion of such factors could cause the association to change, and, as such, future studies are necessary to assess these associations longitudinally. A second potential explanation is that children with dental pain, as opposed to a medical illness, could attend and perform well in school unless they had severe symptoms. The study found that 10% of children reported constant pain, while 62% reported no pain because of OH within the POQL index. This explanation is corroborated by the study conducted by Pongpichit et al. (2008), which found that, compared with absence from school due to dental care and medical reasons, absence due to dental pain was minimal. The current study found that 66.7% of children missed at least one day for non-dental related reasons, while 12.4% reported absence of at least one day per academic year when they were in Grade 1.

Conversely, two studies suggested that dental visits resulting from oral problems such as dental pain are the main factors for school absence. Gift et al. (1992) and Naavaal et al. (2018) reported 52 million and 34 million hours respectively of school lost annually in the US because of dental visits. Recently, Darley et al. (2021) reported similar findings in Brazil, concluding that there was an association between dental pain and school absenteeism and an increase in absenteeism level according to the number of dental visits.

The conflicting results might also be attributed to how dental pain was measured. In the current study, dental pain was measured through the quality-of-life index (POQL) reported by children, similar to previous studies (Seirawan et al., 2012, Maharani et al., 2017). This measure did not indicate whether dental caries caused the pain; it might, for instance, have been a result of exfoliation since the children were transitioning from deciduous to permanent dentition (Garg et al., 2012). Almeida et al.'s (2018) cross-sectional study of 374 Brazilian 6- to 8-year-old children avoided this bias by collecting dental pain data using the CPQ8-10 instrument and confirming it with clinical examination. However, it did not establish an association between school performance and dental pain or carious lesions.

Regarding the mediator role of the clinical consequences of untreated caries on the association between caries lesion and school outcomes, this was not observed in the current study, contradicting the findings of a recent study by (Quadros et al., 2021). This association was examined in only four studies, as described in Section 2.4: Quadros et al. (2021), Almeida et al. (2018), Karki et al. (2019) and Gradella et al. (2011). Of the four, only Quadros et al. (2021), through path analysis, found dental caries to be associated with children's school performance via consequences of untreated dental caries. Almeida et al. (2018) did not find an association between caries, their sequela and school performance, while Karki et al. (2019), despite concluding that untreated dental caries and their consequences significantly affected school performance and attendance, their final adjusted models demonstrated no relation with either school performance or absenteeism. Gradella et al. (2011) concluded that the consequences of untreated caries was associated with toothache and eating certain foods among pre-school children but was not associated with absences. Quadros et al. (2021) recorded the prevalence of untreated dental caries to be 19.6%, while in this study, the prevalence was higher (24.7%) but was not associated with either school performance or absences. This slightly unanticipated result may be due to some dental caries sequelae like ulcer, fistula, and even fully open necrotic pulp, not resulting in dental symptoms. Other differences may be related to differences in age group, sample size, method of analysis, and the number of variables considered.

Thus, the argument that dental pain and the consequences of untreated dental caries predict school absenteeism then school performance was not supported in the present study, despite using a robust analytical approach and considering many of the risks related to both outcomes. It is worth mentioning that most of the studies that reported a relation between school attendance and performance found unauthorised, chronic absence, or school truancy, to be seriously associated with poor school performance over time and subsequent dropout, which was primarily observed in middle and high school children (Melvin et al., 2019, Klein et al., 2020). Chronic school absence is determined as missing at least 15% of days of a school year for any reason (Allison and Attisha, 2019). The reasons behind chronic absence are mainly the consequences of poverty, such as poor mental and physical health, poor living conditions, violence, abuse, alcohol and drug use (Gennetian et al., 2018, Melvin et al., 2019).

In light of this, the evidence in Section 2.4 suggests that OHCs may not cause chronic absence at school, as among the five studies that obtained absence from school records, the reported prevalence of absence because of OH was consistently below 15%. Pongpichit et al. (2008), for instance, reported only 0.5% OH-related absence per academic year among children aged 9-13 years old in Thailand, while Sameer et al.'s (2016) survey of 16–18-year-olds in Saudi Arabia found that just 13% of them missed more than three days. Osman and Alsayed (2015) reported that 1.7% of their cohort of children aged between 5 and 15 years old in Sudan missed around 7-9 days for OH reasons, and Seirawan et al. (2012) reported that 5.5% of their sample of US children aged 6–16 missed school because of dental issues. In the current study, the prevalence of Grade 2 children being absent for eleven or more days (i.e., for longer than the authorised allowance of ten days) over three months for any reason was found to be 1.5%. Since these children were young and thus still dependent on their parents, they fall within the age group wherein problematic absence is difficult to observe (Malcolm et al., 2003).

A psychosocial pathway is also suggested to explain the association between pain and sequela of dental caries and school outcomes. Ortiz et al. (2021) argued that children with toothache who report verbal bullying because of OH would suffer from social exclusion. The resulting emotional disturbance may impact their social behaviours, sleep patterns (Perazzo et al., 2020), school attendance and reduced attentiveness in class. Similarly, Barasuol et al. (2017) argued that sequela of dental caries can cause aesthetic concerns and that children can be bullied because of this, which in turn affects their socialising process at school.

A current United Nations Educational, Scientific and Cultural Organization (UNESCO) (2019) report revealed the prevalence of school bullying among 11- to 15-year-olds in 144 countries in 2019, reporting that 32% of students worldwide had been bullied by their peers at school one or more days at the time of data-gathering in the past month. The Middle East region had the third-highest prevalence of bullying (after Sub-Saharan Africa and North Africa), with 41.1% of schoolchildren being bullied at least once over the same period. The report indicated that children who are appraised as different in any way are more likely to be bullied and that physical appearance is the main reason for bullying.

The current study did not examine the influence of bullying; however, in the POQL index, the effect of OHCs on the children's social behaviour was measured. It was found that 79% reported that they did not avoid smiling, 82.2% reported that they did not worry about being less attractive, 86% reported that they were not unhappy with their physical appearance, and 82% reported that they were not angry about their teeth. This suggests that bullying because of OHCs at this young age may be less likely; however, it should be further examined in the future.

Another clear pathway suggested by Piovesan et al. (2012), Paula et al. (2016), and Seirawan et al. (2012) were that socioeconomic factors play an integral role between OHCs and school outcomes. However, regression analysis did not test the indirect pathways in the suggested relation. In parallel with their argument, this study found that early life disadvantages were associated directly with dental caries and indirectly with children's school performance, suggesting that dental caries played a mediation role. This result supports the social origin hypothesis and the critical period and chain of risk life course models. Based on this, children who experience low SES at the time of their birth were more likely to have dentine caries and then low school performance, regardless of their current SES. Further, dentine caries in primary teeth result from disadvantages in early life and are considered critical early life exposures that can restrain academic potential in middle childhood.

During the last decades, the literature has frequently revealed that exposure to early life risk factors, like family instability, maltreatment, and poverty, can negatively influence children's academic performance (Farajdokht et al., 2017, Anthony et al., 2014, Hussey et al., 2006). However, this is perhaps the first life course study to illustrate that dentine caries in the primary dentition is also an important early life risk for education attainment. This study’s results are consistent with the hypothesis that inequalities in OH (Peres et al., 2011) and inequality in education start in the womb (Banerjee, 2016) and persist over time.

Another promising finding was that children with treated teeth were more likely to have better academic performance. This contradicts the Brazilian case-control study with 1,149, 8–10-year-old students, which found that dental caries, even if treated, were risk indicators of poor school performance (Paula et al., 2016) but is consistent with Petridou et al.'s (1996) cross-sectional study, which concluded that better school performance was linked with better dental health among Greek adolescents aged 12 to 17. Research in this area is limited, but some evidence has been found that after dental caries treatment, the OHRQoL of children improves, as reflected in the mean of Scale of Oral Health Outcome for 5-Year-Old Children (SOHO-5) (Dantas et al., 2015), $CPQ_{8\text{-}10}$ (de Paula et al., 2015b), and POQL (Cunnion et al., 2010). This emphasises the relevancy of children accessing dental care at school to mitigate the negative impact of dental caries on their school outcomes and quality of life by early prevention and treatment interventions when needed.

This study also found a dental plaque indirectly predicted children's academic performance, in line with Maharani et al. (2017), who found that among children aged 10-11 years, the odds of having lower grades were twice as high for those with substantial plaque. However, our results clarified that the relation was mediated by the dentine caries and treated teeth conditions. This finding confirms the importance of reinforcing toothbrushing programmes in schools, as they are considered the simplest individual preventive measure to control plaque, reduce caries in later life, and provide effective long-term maintenance of OH (Raviteja et al., 2017). It has been observed that childhood is a good time to establish healthy habits that last for life as children seem to be amenable, and their personality and mental maturations are starting to develop (Ceyhan et al., 2018).

It can be argued that Bahraini culture plays a significant role in explaining some of the differences between the findings of this study and those of previous studies. A technical argument that might be important is that most of the available evidence has been gleaned from Western societies, whereas this study's data is from the Eastern Arab region. These two societal groupings differ significantly in their systems of and approach to education; the education system in the Eastern Arab region is collectivism-oriented (Haj-Yahia, 1997), while individualism is the most distinctive feature of Western societies (Triandis et al., 1988). Collectivistic societies are mainly group-oriented; to succeed in a group, individuals need to give an opinion congruent with the prevailing religion and values despite what they believe. In this environment, the goal of learning is to become productive members of society; children are raised to be persistent in attaining high educational results, so they work hard at school and do enormous amounts of homework. The education system is teacher-centred, and students must submit to the authority of the teachers. The education process is mainly based on book learning and memorisation (Hofstede, 2001, Kaur and Noman, 2015).

Conversely, in individualistic societies, individuals are considered more important than groups. The system encourages critical thinking and creativity. Students are encouraged to study according to their aptitude and desire for learning. Further, students are active in the learning process; they can express their feelings and opinions and argue freely with their teachers; unlike the collectivistic system, mistakes are considered a favourable chance to attain maturity and develop their personality (Hofstede, 2001, Kaur and Noman, 2015). Thus, grades do not matter as much as they do in the eastern educational system.

These issues demonstrate how much Bahraini society values education to gain higher grades and work hard towards them, which might dissuade children from talking freely to their parents about their dental pain and OH problems. This is reflected in the findings of this study. To illustrate, it was found that 61.6% of mothers were highly involved in their children's education process, and 79.2% of children scored ‘Excellent’ in their final grades with no failures. This raises some interesting questions regarding the value of OH against the value of the education process. In KoB, is having enamel caries, dental pain, or an oral ulcer an adequate reason for missing a school day or performing less well academically? Do parents know or believe in the connection between OH and general well-being?

Another cultural factor that might result in Bahraini schoolchildren avoiding mentioning dental problems to their parents is fear of the dentist. Unfortunately, there is no available data on KoB to support this argument. However, since KoB and Saudi Arabia (GCC) are considered homogeneous communities (At-Twaijri, 1990), recent evidence from Saudi Arabia can depict the situation in KoB. Alshuaibi et al. (2021) found that the prevalence of dental fear among 816 Saudi schoolchildren aged 7-11 was 50-70%, which is much higher than the 6-20% recorded for European children (Luoto et al., 2009). However, the high prevalence was attributed to the children's young age. The difference in prevalence between Arab and developed countries may be ascribed to the differences in culture and organisation of healthcare delivery services. In developing countries, curative measures are emphasised more than preventive measures so that children utilise healthcare services mainly when in pain, while in developed countries, preventive measures are the most common service (Alshoraim et al., 2018).

Consequently, in KoB, children usually view dentists as merchants of pain because they visit them only for dental treatment, not routine check-ups like in the west; moreover, parents use “going to the dentist” to symbolise fear, scare or punish their children. The current study found that over 60% of the parents and children visited the dentist only in an emergency. Thus, because of dental treatment anxiety, children may not communicate their OH problem or utilise the dental service (Shafi et al., 2015), and they are unlikely to take time off school to seek dental care, even though that care is available for free. In the POQL interviews, 83.5% of the children in this study reported that they did not miss school because of OH issues.

Inconsistent results among the different studies might also be clarified by heterogeneity in study design, participant's age, measures of school outcomes, analysis method, geographical region, sample size, and the number of variables included. Furthermore, such wide-ranging variations make comparisons between studies difficult.

5.6 Discussion for Objective 4

To explore the early and current life course social, biological, behavioural and parental factors associated with children's school outcomes in addition to OHCs.

5.6.1 Other predictors of school performance

In addition to the two models, critical period and chain of risk, this study also showed that the accumulation of risks could influence children's school performance. Children who experienced favourable SES at the time of their birth and currently were more likely to exhibit high academic performance. The study found that supportive parental characteristics such as practising an authoritative parenting style and having a mother who is highly involved with school life mediated the association between SES and academic performance in the same way as dental caries. This means that families with high SES in early and current life are most likely to provide a supportive environment for children; hence, they have higher academic achievement than their counterparts.

These findings are consistent also with the bioecological theory of Bronfenbrenner (2006). The theory acknowledged that child development is shaped by the interactions between SES and key social contexts, including families and schools. Thus, children's education development is determined not only by family SES but also by family-child interaction in terms of parenting and family-school interaction in terms of their academic involvement.

Scholars have long claimed that parenting style varies according to family SES; different parenting styles determine different emotions and settings at home (Darling and Steinberg, 1993), with reasonable evidence confirming this link. Bronfenbrenner (1958, p. 420) concluded that “parent-child relationships in the middle-class are consistently reported as more acceptant and equalitarian, while those in the working-class are oriented toward maintaining order and obedience”.

Similarly, the positive link between family SES and academic involvement is well-established (Al-Matalka, 2014, Benner et al., 2016).

Therefore, it is now widely accepted that parenting style and academic involvement mediate family SES and children’s academic performance (Wang et al., 2021, Zhang et al., 2020). Several explanations are given for this indirect effect. In a systematic review, Conger and Donnellan (2007) suggested that SES influences the family’s functions through various stress and investment processes. Thus, a parent with low SES is often traumatised by economic worries, overwhelmed with extra working hours, lacking in material and psychological resources, and has little time for rearing children, all of which result in low responsiveness and warmth toward their children and the embracing of an authoritarian parenting style. Conversely, a parent with high SES is likely to experience lower life stressors and therefore be more capable of investing financial, social, and human resources in the development of their children, exhibiting greater responsiveness and warmth toward their children and adopting an authoritative parenting style (Xie and Li, 2018).

Likewise, in explaining the relation regarding academic involvement, parents with low SES, struggling to support their families, are often too busy working to take the time necessary to help their children in school. Thus, it is difficult for these parents to academically support their children or attend school events and activities (Barg, 2019). There is also the factor that if the parents themselves have a low level of education, they may not provide effective involvement because of limited educational levels and low self-efficacy (Tazouti and Jarlégan, 2019). Providing useful advice on academic matters and strategies for success and fostering independent and critical thinking that can positively influence their children's learning behaviours (Aunola et al., 2000) maybe beyond their capabilities, causing them to inhibit their children's academic outcomes.

The current study did not support the association between children's early and current environmental exposures and school attendance. However, robust evidence establishes beyond doubt that children's SES background is a major predictor of school absenteeism, although the relation is multifaceted and complex (Gennetian et al., 2018, Brownell et al., 2016, Klein et al., 2020). According to Bronfenbrenner's (1977), children from lower SES families confront several individuals and environmental obstacles that disturb their well-being and educational outcomes. The current study did not capture the association between SES background and school attendance for several reasons. Firstly, most problematic absenteeism was reported among older children, while this study’s sample consisted of young children still dependent on their parents. Secondly, absenteeism becomes more of a concern when it is chronic or exceeds the authorised level of absence (15%); the prevalence of children in the sample missing 1-5 days was 57%. Thirdly, maybe because school absence was measured only for the first term of school, thus the period was not enough to capture any related factors. Finally, it can be argued that the schools’ strategies to deal with absence played a significant role in their absenteeism rates. For example, schools in the UK are required by law to register children’s attendance twice a day; if parents fail to ensure the regular attendance of their children, especially those of compulsory school age, they will face penalty or prosecution (Department for Education, 2016). In KoB, it is the same situation; the student can have an authorised absence for ten days; however, if the student misses more than ten days without reporting sensible reasons, the family might face prosecution because attendance at elementary school is compulsory by law (Information & eGovernment Authority-KoB, 2020b). Such upstream strategies could monitor and tackle the absenteeism problem and enforce pupils' attendance and education. In addition to the cultural issue described above, this might explain why attendance was not found to be predicted by any of the factors examined in this study.

Thus, this study applied a bioecological life course framework that examined OH's pathways and academic outcomes. This is important as it provides evidence that interdisciplinary frameworks can be applied to study how multiple exposures during an individual’s early life and subsequent life course can influence their development. It may help design policies and interventions targeting children and their families to improve OH and school outcomes.

5.7 Limitations and strengths

This study has some limitations that should be accounted for when interpreting the findings, as in any research.

The first limitation is that the study was cross-sectional (due to COVID-19). Thus, no causal associations can be assured, and the observed associations might be considered exploratory (Kate Ann, 2006). Furthermore, mediation effects might be over or underestimated in this study when assuming longitudinal effects were evaluated using cross-sectional data (Maxwell and Cole, 2007). Thus, the results of the present should be interpreted with caution. However, Shrout (2011) argued that there still will be some situations where analyses of cross-sectional studies can reflect the mediation effect. Such situations include using well-established theories that describe the causal direction and the temporal process (Shrout, 2011).

In this study, all hypothesised relations were based on reviewing the literature and using the Heilmann et al. (2015) framework. Also, the study design was time-ordered-cross-sectional to verify the temporal relationship between OHCs and school outcomes; OHCs were measured at the beginning of the academic year, while school outcomes were measured at the end of the academic year. Additionally, the study used SEM, which provided a rigorous basis for causal inference and provided an appropriate method for assessing mediation (Pearl, 2009). These advantages would not compete with the use of the longitudinal design study; however, it may have these advantages over a pure cross-sectional design for the causal analysis purpose (Menard, 2002). Ideally, this and similar questions can be addressed by means of a birth cohort or prospective research in which children's life trajectories, school outcomes and OHCs are measured repeatedly.

Another possible limitation is the selection of only ‘Good’ rated schools and sampling them as a unit instead of sampling the individuals. The restrictions were made to reduce the effects of the school’s environment heterogeneity and control the possible effect of contextual confounders on the link between OHCs and school performance and attendance; however, it may limit the generalisability of the findings to schools rated differently on the quality continuum. This limitation could have been overcome by including other differently rated schools, but unfortunately, with the consequences of the COVID-19 pandemic and limited time and resources, this could not be achieved. However, the school's ‘Good’ rating by the QQA in KoB is for overall effectiveness and capacity evaluation; thus, it can be argued that the rating reflects the school environment more than anything else.

Thirdly, early life factors such as birth weight and gestational age were obtained retrospectively and were self-reported by parents, which means they may be subject to recall bias. Efforts were made to obtain this information from the children’s health records, but unfortunately, the records were not available. However, a recent study evaluating the accuracy and validity of early life information reported by parents has yielded very positive results. Moreno-Galarraga et al. (2021) collected parent-reported birth data (birth weight, birth length and gestational age) on 241 children in Spain when those children were 4-6 years old then compared it with the medical records. The ICCs calculated for birth weight, and birth length revealed, respectively, ‘very good’ (0.95) and ‘good’ (0.78) levels of agreement, and the weighted kappa for gestational age was substantial (0.90) (Moreno-Galarraga et al., 2021).

Fourthly, school attendance was measured only for the first term of 2019-2020 because the second term was affected by COVID-19, and children could not enrol in schools. This may have resulted in underestimates of the absence days. Further, the absences and the absences related to dental reasons in Grade 2 were unknown. Thus, the short period and the lack of this information may explain why the study did not find any factor related to school attendance.

Fifthly, Code 1 for ICDAS, which referred to detecting the first visual changes of dental caries after 5 seconds of air drying, was not considered because the examination was conducted at schools, and no portable air syringes were available. This might contribute to uncertainty regarding the number of free caries in children and teeth. Alternatively, it might cause underestimating dental caries and overestimating caries-free surfaces.

Lastly, one important limitation of using SEM is that SEM analysis requires deleting variables during model estimation to get a good model fit, resulting in biased parameter estimates (Tomarken and Waller, 2005). This study’s first model was constructed with most of the variables presented in Chapter 4 (see Appendix 20), which involved 12 latent variables with 54 observed variables. However, the model was not identified in AMOS. A model with this number of variables would require a larger sample size (2129 participants) to yield an acceptable model fit (Hair et al., 2014). Thus, although the study included most of the relevant factors to both OH and school outcomes based on theoretical framework and literature, unfortunately, factors such as child’s health conditions, POQL, dental services, family structure were not included because they yielded insignificant loadings. However, Tomarken and Waller (2005) argued that researchers rarely recognise omitted variables because if a model fits well, it must contain all the necessary variables concerned in the hypothesised model.

Despite these limitations, this study has several strengths. Firstly, it is research that is driven by theory and framework. The life course framework provides multilevel models that explain social determinants and their influence on the common risk factors involved in the development of OHCs and shared in predicting the school outcomes and interplay between OHCs and school outcomes from early life until the current stage of the child's life. Thus, this study is the first to apply a bioecological life course framework that examines the pathways connected to SES, OH, and school outcomes. Further, it is the first study to consider biological, social, behavioural, and parental factors that interplay between OHCs and school outcomes. The study adds knowledge regarding factors associated with children's educational potential and concludes that dental caries was a significant early life factor linked with children's school performance.

The second most significant strength of this study was its use of SEM. Given the complexity of the life course framework, SEM provided multiple advantages over regression. The first is its breadth of capability. SEM is a multivariate statistical method that provides a process whereby to test a theoretical network of directional and nondirectional associations between independent (exogenous) variables and one or more dependent (endogenous) variables (Kline, 2016). However, in regression, only one dependent variable can be tested (Berndt and Williams, 2013). Accordingly, it was possible to simultaneously test different OHCs concerning different school outcomes. The second advantage is that SEM can examine and interpret both direct and indirect effects; thus, it was possible to test different well-established life course models and different types of pathways that might connect OHCs with school outcomes. In SEM, the third advantage is that the combined effect of multiple indicators for each construct can be utilised efficiently, unlike regression, where researchers are restricted by including blocks of predictors (Berndt and Williams, 2013). This enabled the discovery that fathers' and mothers' levels of education are essential life course predictors. These three advantages facilitated the testing of many risk factors along the life course of children that have not previously been considered, especially those related to family (SES, parenting style, academic involvement).

The third strength of this study is that it utilised reliable (and multiple) measures to study the relation and the pathways between OHCs and school outcomes. For example, the use of ICDAS and pufa/PUFA measures enabled an assessment of different types of dental caries (enamel, dentine), their stages, and their severity on children's school outcomes. Besides evaluating the effect of clinical OH issues, the study also examined their psychosocial impact with respect to dental pain. This produced the finding that asymptomatic enamel caries does not affect school performance, whereas dentine caries does. Also, the study concluded that dentine dental caries was associated directly with school outcomes without the mediation effect of dental pain or severity of caries. Unlike previous studies (Section 2.4), 43.6% of them focused on dentine dental caries in the DMFT/dmft index. Despite being the most commonly used index worldwide to measure caries (Casamassimo et al., 2009), only cavitated teeth are recorded through DMFT, limiting a proper assessment of the severity of dental caries (de Souza et al., 2014).

In addition, nearly 30% of them relied on self-reported measures of OHCs (Nasuuna et al., 2016, Pongpichit et al., 2008) rather than a clinical examination to study how specific OH problems might affect children's school outcomes. The question requires quantitative research design; the fundamental philosophy of quantitative research design is positivism (Creswell and Creswell, 2018). The positivist philosophy presumes the use of objectives and scientific measures to develop knowledge. The scientific method requires measurement and a scientific basis for research. It involves the formulation and testing of hypotheses, and this requires mathematical and statistical analysis (Creswell and Creswell, 2018). The analysis of OHCs from parents' perceptions, or students' self-reports, might have subjective interpretations that could create a bias (de Paula and Mialhe, 2013). Further, self-reporting of dental caries and periodontal conditions was revealed to be invalid as a clinical evaluation for an adult population (51- to 86-year-olds) (Pitiphat et al., 2002). This causes serious concern regarding validity when the target population is children since the questionnaires are usually completed by parents, who might have a different perception of their children's OHCs (Ribeiro et al., 2018).

Another reliable measure used in this study is the school records, which supplied data on the children's school outcomes. Previous studies (Section 2.4), in contrast, have mainly relied on self-reported school outcomes (Blumenshine et al., 2008, Petersen et al., 2008), and some of these studies applied the QoL index as a proxy for school performance (Bernabé et al., 2007, Astrøm and Okullo, 2003). Relying on self-reported measures to assess school outcomes might not be sufficient due to the lack of knowledge of the validity and reliability of those measures, which might result in recall bias or social desirability bias (Althubaiti, 2016). Plus, considering the QoL instrument as an indirect measure of evaluating children's school outcomes might generate measurement bias because they are not specifically designed to evaluate them (de Paula and Mialhe, 2013).

Fourthly, the study reached the required sample size of 466 children and their parents with a very high response rate of 98%. This is important to confirm that the results represent the target sample, and the higher the response, the greater the likelihood that the sample will reflect the population (Meterko et al., 2015).

Finally, the study provides OH evidence from an area where research is scarce; it provides a different picture of children's OH from studies conducted from a Western point of view. The first comprehensive life course study conducted in the Arab-Mideast region assesses the relation between OHCs and school outcomes.

Chapter 6. Conclusions and recommendations

6.1 Conclusions

This research has contributed to current knowledge by applying a bioecological life course framework to examine the different possible pathways connecting OH with school outcomes within the context of children's early and current life experiences. It was found that children who experienced high SES at birth had a low rate of dentine caries, hence exhibited high school performance, supporting the critical period and chain of risk models. Similarly, the study found that low SES in early life and currently were associated with low school performance via parent's characteristics, supporting the accumulation of risk and bioecological models. More importantly, the study found that SES in early life was a common factor associated with dentine dental caries, dental pain, and school performance in children's current life course, supporting the theory of the social determinants. On the other hand, dental treatment could be a protective factor linked positively with school performance.

Therefore, it is concluded that low SES, dentine caries, and non-supportive parental characteristics are important indicators of children's low school performance.

The primary conclusions drawn are:

1. Enamel and dentine dental caries and the clinical consequences of untreated dental caries were highly prevalent in Muharraq, with prevalences of 93.5% and 25.7%, respectively.
2. EDD was more prevalent in permanent dentition, with a prevalence of 17.0%.
3. Most children (67.6%) reported at least one impact of OH on their quality of life.

4. High SES in early life was associated with a low level of dentine caries and dental pain among children in Muharraq.
5. Children in Muharraq with a high level of dental plaque were more likely to have OHCs.
6. Children with more dental plaque and dentine caries were more likely to report dental pain.
7. Dentine caries and dental plaque were negatively associated with children’s school performance.
8. Dental treatment was positively linked with children’s school performance.
9. Dentine caries was directly linked with poor school performance without the mediation effect of either dental pain, clinical consequences of dental caries, or school attendance.
10. Family SES was associated with high children's school performance through parental characteristics, both at birth and currently.
11. None of the social, behavioural, biological, parental, or OH conditions was associated with school attendance.

6.2 Recommendations

The study findings indicated that SES, especially in early life, was related to both dental caries and school performance. SES was associated with children's school performance via parent characteristics (parenting style, academic involvement) and dentine caries. Further, dental caries and dental plaque were negatively linked with school performance, while treated teeth were linked positively with school performance. Thus, we provided recommendations to tackle social inequalities and dental caries early in life.

6.2.1 Recommendation for social determinants in early life

It is recommended, therefore, to tackle inequality in early life and throughout the individual's life course. Looking through the life course lens means identifying opportunities within the key life stages from early into older age to reduce risk factors and enhance protective factors through evidence-based interventions (Public Health England, 2019).

Public Health England (PHE) has produced a series of evidence-based papers covering several recommended interventions to tackle inequalities at people's important life stages (Donkin, 2014). Review 1 focuses on early intervention strategies, implemented from conception to early adulthood, to prevent poor outcomes in later life among the disadvantaged population. The review emphasises the evidence on two main topics: parenting and home-to-school transition programmes to reduce the impact of social determinants in early life. Parenting programmes aim to improve parent-child interaction and stimulate supportive parenting. One of the key pieces of evidence relates to children's centres. The research argues that children's centres could positively improve children's and families' well-being, with particular attention given to disadvantaged families to reduce inequalities in child's development and schooling (Donkin, 2014). One effective support programme is the USA's Head Start programme (Kose, 2021). The programme provides comprehensive services to low-income children and families in terms of early education, health, nutrition, and parenting. Evaluations of the programme have shown improvement in children's cognitive, emotional and social development, higher emotional child-parent engagement, constant attention, substantial test scores, and decreased aggressive behaviours (Kose, 2021, Donkin, 2014).

Review 2 focuses on children aged 5-18 years old and building resilient children and families through schools (Allen, 2014). Resilience is the "ability to bounce back" from hardship and have control over things (Allen, 2014). It is believed that resilience aids in increasing proactivity and reducing risk factors in schools to promote well-being (Shi et al., 2021). From 2010 to 2018 in the UK, the Children in Need's Families and Schools Together (FAST) programme effectively bolstered resilience among families and children through schools (Lord et al., 2018). In this programme, families attended eight weeks of workshops within schools to reduce stress and address certain social conflicts. Assessment of the programme has shown a 20% reduction in family conflict, an increase in family-child relationships by 14%, and reductions in emotional disturbance and conduct problems among children by 20% and 18%, respectively (Allen, 2014). Such programmes might be good models to follow whereby to introduce measures to reduce inequality and promote health, both oral and general, in KoB within a family context.

6.2.2 Recommendation for OH promotion

To prevent dental caries and reduce inequalities, strategies should be intersectoral, population base health promotion and common risk factor approaches when possible (Watt et al., 2019), and targeted interventions for the disadvantaged population and priority groups like pregnant women and young children (Public Health England, 2019). Those strategies should target transitions through evidence-based interventions at critical life stages (Department of Health, 2010). Using the Ottawa Charter's five principles for OH promotion (WHO, 1986), the recommendations below could be suitable for KoB at a national level:

6.2.2.1 Public health policies

- Policies to reduce sugar consumption and meet the WHO recommendations: children and adults to reduce their intake of free-sugar to less than 5-10% of total energy intake (WHO, 2015). Such policies would require the industry to reduce the sugar content in food products (Watt et al., 2019). Alternatively, the introduction of sugar taxes on sugary beverages. Data from Mexico shows that sugar taxes decrease sales and consumption and the number of overweight individuals, especially in a low-income population (Colchero et al., 2017).
- Policy to introduce a water fluoridation system. Research in this area has shown that water fluoridation is a cost-effective, safe public health strategy for reducing tooth decay and inequality in a population (Treasure et al., 2002, Belotti and Frazão, 2021).

6.2.2.2 Creating supportive environments

- Restricting TV promotion of unhealthy food and beverages was the most cost-effective population-based measure to reduce obesity in children aged 5–14 years (Magnus et al., 2009). Such a measure is also likely to reduce tooth decay rates.
- Eliminate taxes on OH products and make fluoride toothpaste available and affordable (Kwan and Petersen, 2010).

6.2.2.3 Strengthening community actions

Life course data underlines the vital role of families as fundamental societal units that establish and foster individual and community health (Hanson et al., 2019). Initial research indicates that orienting a family-based health promotion, and disease prevention are promising measures despite evidence for this being scarce, which can be attributed to a lack of initiatives, funding, and policies; within the concept of the life course, such an integration can be pivotal (Thomas et al., 2017).

However, the effectiveness of family-centred OH promotion in reducing ECC was recently tested in Hong Kong through a Randomised Control Trial (RCT) (Yu et al., 2021). At baseline, a total of 580 pregnant women and their partners were recruited, and 436 toddlers were followed up when they became three years old (test, n = 228; control, n = 208; follow-up rate, 75.2%). Oral health education (OHE) was given to the test group via behavioural and educational counselling, while the control group received OHE brochures only. Data regarding feeding habits, OHPs, and OH of the toddlers was obtained by parent's self-administered questionnaires and oral examination annually thru home visits. The results revealed that family-centred OHE for parents thru behavioural and educational counselling was more effective in unleashing good feeding practices and parental toothbrushing habits and reducing dental caries than the distribution of OHE brochures alone.

The family-centred OH promotion has also been delivered via Maternal Child Health Care (MCH) in Australia via the Lift-the-Lip programme (Heilbrunn-Lang et al., 2020). The programme follows families and babies from birth, especially those with low SES; it involves lifting the top lip of a child to check for early signs of dental caries, along with distribution of toothbrushes and toothpaste and a referral system to dental care. The results revealed that MCH provides an ideal context to enable family-centred OH promotion measures and the adoption of good OH behaviours early (Heilbrunn-Lang et al., 2020).

6.2.2.4 Developing personal skills

Toothbrushing to control dental plaque level, spit instead of rinse, proper use of fluoride toothpaste, with the optimum level required for each stage of life, should be reinforced at a national level (Gregory, 2014, Department of Health-UK, 2021).

Research has shown that social media has a similar effect on advertising sugary snacks and foods high in sugar, fat, and salt to traditional media (TV) (Coates et al., 2019). Online social media are readily available, and most individuals access social media daily (Cortesi and Gasser, 2015). Therefore, social media could provide a good platform for a population-based intervention to promote OH, increasing people's awareness regarding the importance of toothbrushing, the proper use of fluoride toothpaste, and the optimum level required for each stage of life. Webb et al. (2010) assessed the effectiveness of Internet-based measures in promoting positive health behaviour via a meta-analysis. The study concluded that approaches based on behavioural theory and those with many behaviour change measures were most effective (Webb et al., 2010).

Further, a recent RCT examined the effectiveness of a theory-based programme applied on an online social media programme (Telegram) to endorse good OH behaviour among Iranian teenagers (Scheerman et al., 2020). The results revealed significant improvements in adolescent toothbrushing habits, plaque, and CPI scores.

6.2.2.5 Reorienting OH care toward prevention

- OH care in KoB needs to shift its goal of dental care from treatment to prevention (Vernazza et al., 2021). Dental care can be reformed by: adopting multisectoral and patient-centred approaches; training OH professionals with the relevant skill mix; increasing the number of dental health professionals so that dental care is accessible to and available for most of the population; changing the salary-based remuneration system to an incentive-based system that encourages preventative and maintenance care of OH, in the same way, that the US pay-for-performance system has shown an improvement in the quality of healthcare (Watt et al., 2019).
- Evaluation of dental caries in KoB should shift from reporting the presence or absence of cavitated lesions to evaluating the different stages of caries development (ICDAS), their severity (pufa/PUFA) and their impact on people's quality of life. Understanding these stages over time can be valuable for early caries detection, prevention, diagnosis, prognosis, and management, including the formulation of optimally timed interventions to reverse the disease process (Pitts and Ekstrand, 2013).

6.2.3 Targeted OH promotion for pregnant and new mothers

Policies should be introduced integrating OH promotion programmes within MCH, or start home visits by dental health professionals or midwives, to provide early life OH promotion interventions targeting pregnant mothers, new mothers and babies in low SES areas or areas with high caries rates (Rogers, 2011, Feldens et al., 2007, Public Health England, 2019). Below are examples of OH interventions that could be implemented within this scope:

- Reinforcing exclusive breastfeeding and providing suitable complementary feeding practices. The Family Nurse Partnership programme in the USA offers planned home visits from early pregnancy until the child is two. Research conducted over 30 years in the USA has shown positive outcomes among low SES families in parents' breastfeeding, smoking, cognitive and emotional behaviours, and children's behaviours (Public Health England, 2019).
- Distribution of fluoride toothpaste and toothbrushes to pregnant women and young babies. In the UK, the three-monthly posting of OHE leaflets, fluoride toothpaste, and brushes to caregivers of children at high risk of dental caries in non-fluoridated areas decreased caries levels by 16% when the children reached five years of age (Davies et al., 2002). In Leeds (UK), regular dental visits by dental health educators providing OH materials, diet and OH instructions in a low SES and non-fluoridated population with a high caries rate resulted after three years in significant progress in feeding habits and toothbrushing frequency, with a decrease in the high consumption of sweet food and drinks, and lower caries level (Kowash et al., 2006).

- Developing toothbrushing and supervised toothbrushing for mothers and babies (Kowash et al., 2006) (El Fadl et al., 2016, Liu et al., 2020). In Israel, training for nurses in providing toothbrushes, toothpaste, and OHE to mothers increased the routine brushing of 6-12-month-old infants' teeth (Sgan-Cohen and Vered, 2005). A recent RCT study in Hong Kong also found that providing family-centred, behavioural, and educational counselling to pregnant women during their MCH visits improved their OH and decreased plaque, bleeding, and gingivitis (Liu et al., 2020).
- Applying priority access for dental care for referring pregnant women who are in need of clinical intervention. In Sydney (Australia), MCH referral of pregnant women to dental care programmes has shown a considerable increase in the use of dental care, women's OH knowledge, and OH outcomes (bleeding, dental plaque, clinical attachment loss, DFT) (George et al., 2018).
- Reducing the transmission of S. mutants from mothers to their babies by providing mouth rinses or varnishes (fluoride and/or chlorhexidine) and xylitol chewing gum to pregnant women and mothers of newborn babies (Rogers, 2011, Twetman, 2013).

6.2.4 Targeted OH promotion for preschool- and school-age children

Dental hygienists in KoB already implement schools-based OH promotion programmes based on WHO (2003) recommendations in all government-run schools, whereby children receive dental screening and OH education, including demonstrations of toothbrushing and applying sealant and fluoride varnish. Nurseries and schools should be used to the optimum as they are considered a vital environment for promoting OH among children, families, teachers, and the whole community from different SES backgrounds (Bramantoro et al., 2021, Kwan et al., 2005). Accordingly, the following are recommended to be applied in KoB:

- A comprehensive re-evaluation of the currently implemented OH promotion intervention programmes. WHO, UNESCO, UNICEF, the World Bank and Educational International launched a joint initiative – FRESH (Focusing Resources on Effective School Health) – to monitor and evaluate school health programmes (FRESH, 2013). This framework could be adapted in KoB for continuous evaluation.
- Interventions should start at preschool and continue to older ages (Bramantoro et al., 2021).
- Engagement of parents, teachers, schoolchildren and dental health professionals in planning and implementing OH interventions (Public Health England, 2014).
- Policies should be initiated to create a healthy school environment; for example, replacing sugary snacks with healthy choices (Rogers, 2011), establishing protocols to control bullying and violence, and tighter smoking control, especially in older age children (WHO, 2003).
- Dental health education should be integrated into the school curriculum, the message being delivered by teachers. It should be age-appropriate for children’s cognitive abilities and the primary health risks they are exposed to at each stage of development, thus enabling children to develop a life-long commitment to maintaining their OH (Public Health England, 2014). As shown in the findings, mothers in KoB are highly involved with their children’s early life;

thus, such a curriculum might influence teachers', children's and families' OH knowledge.

- Introduction of supervised and school-based toothbrushing programmes. The teacher-supervised toothbrushing and fluoride toothpaste distribution (1,400 ppm) programmes in a non-fluoridated deprived area of London (UK) contributed to a drop in dental caries (compared to control schools) of 11–21% over the 21 months (Jackson et al., 2005). Similar results were recently found in Israel and Chennai (Natapov et al., 2021, Samuel et al., 2020).
- Increase fluoride exposure, especially in low SES schools. Since KoB does not have a water fluoridation system, an alternative could be implementing regular school-based fluoride rinsing or providing fluoridated milk (Yeung et al., 2015, DivyaLalitha et al., 2019).
- Referrals and priority access to dental care for children with low SES who need dental treatment (Hong et al., 2020).

6.2.5 Recommendations for better school outcomes

- There should be monitoring by school faculties of OH-related absences and complaints to provide data necessary for evaluation and improvement (Pongpichit et al., 2008).
- The existing education system, centred on memorising, achieving grades, and a teacher-centred approach, should be reconsidered. Children in early-life learning should be allowed a voice and free expression to boost their self-esteem and foster in them the ability to control things around them (Butler et al., 2021). Two review papers from PHE examined successful interventions that

ensure children are given the best start in life, improve early school outcomes and reduce inequality:

- Review 1 considers parenting and home-to-school transition interventions targeting children from conception onwards (Donkin, 2014);
- Review 2 summarises the evidence of the possible measures taken in schools to build resilience for all schoolchildren, families, and teachers in partnership, targeting children aged five to eighteen years (Allen, 2014).

- There should be policies to initiate programmes that enhance skills/behaviours that promote secure attachment, positive parenting practices and parent-child relationships. For example, "Helping Parents to Parent" (Clarke and Younas, 2017), an evidence-based report from the UK's Social Mobility Commission, highlights examples of successively applied interventions from different countries that aim to foster more authoritative parenting styles so that parents become more responsive and sensitive towards their children's emotional, physical, and cognitive needs. The programmes target early-life and preschool- and school-age children and are either universal or focused on low SES groups. They are delivered by teachers, nurses or social workers via schools or health centres, home visiting, or using individual face-to-face sessions.

- It should be government policy that schools promote the academic involvement of parents or caregivers, especially those with lower SES, to enhance positive school outcomes for school-age children. The UK report entitled "How Can Schools Support Parents' Engagement in their Children's Learning?" (Axford et al., 2019) synthesises the best available international evidence on parental engagement in children's learning. The evidence focuses on effective parenting practices associated with positive learning outcomes at different stages of children's development and what schools and early years settings can do to support parents' involvement, particularly for children from disadvantaged backgrounds.

Considering the scarcity of comparable interventional studies from KoB and the Middle Eastern region, I suggest these UK reviews and reports be studied to help determine ways in which inequality in Bahrain can be reduced, academic performance improved, positive parenting practices promoted, and parents or caregivers encouraged to involve themselves in the different stages of Bahraini children's academic lives.

6.2.6 Recommendations for future research

6.2.6.1 Descriptive studies

Update this cross-sectional OH survey in KoB to:

- Evaluate ECC, prevalence, impacts and indicators, targeting preschool children and their families.
- Assess OHCs' prevalence, their stages, severity, impact on QoL, relation to SES and other chronic conditions, and their indicators (Watt et al., 2019).
- Involve parents and assess their OH knowledge and beliefs.

6.2.6.2 Longitudinal studies

Design and execute a prospective birth cohort study with a mixed-method approach in KoB, with OH as one of its focus points from its onset. In KoB, no birth cohort study has ever been conducted, so this would be an opportunity for comprehensive research. Such a project will require good collaboration with experts in this field, a national-level plan to include other disciplines interested in this type of research, and the securing of sustainable, preferably government, funding (Costello and Angold, 2007). The following topics could be studied:

- Inequalities in health, OH, and education with full transparency across the life course (Public Health England, 2019).
- Development of OHCs, their trajectories, risks and protective factors over the life course (Halfon et al., 2018).
- The impacts of family transitions, relations, structure, religion, and culture on the OHCs and school outcomes.
- Pathways involving SES, biological, psychosocial, behavioural, and parental conditions whereby to link OHCs with school outcomes in different stages of life (Halfon et al., 2018).
- Ways in which OHCs like EDD could function as adverse early life indicators for general health and OH in later life (Heilmann et al., 2015).
- Ways in which early caries lesions could be a marker of social deprivation in KoB; this research may help in targeting vulnerable populations with specific needs.

- Ways in which OHCs could be used as a marker for poor school performance and attendance.

6.2.6.3 Interventional studies

Interventional studies are often tailored to evaluate the effectiveness of preventive measures (Thiese, 2014). RCTs are the most common type of interventional study (Machin et al., 2021). The following topics could be studied using an RCT framework:

- The effects of toothbrushing, fluoride varnish and fissure sealant application programmes, and dental treatment, on schoolchildren (Tickle et al., 2016).
- The effects of interventions applied within the family on OH. For example, early childhood interventions include a parent-supervised toothbrushing programme (Natapov et al., 2021).
- The effects of parent's involvement interventions on children's education.

Chapter 7. References

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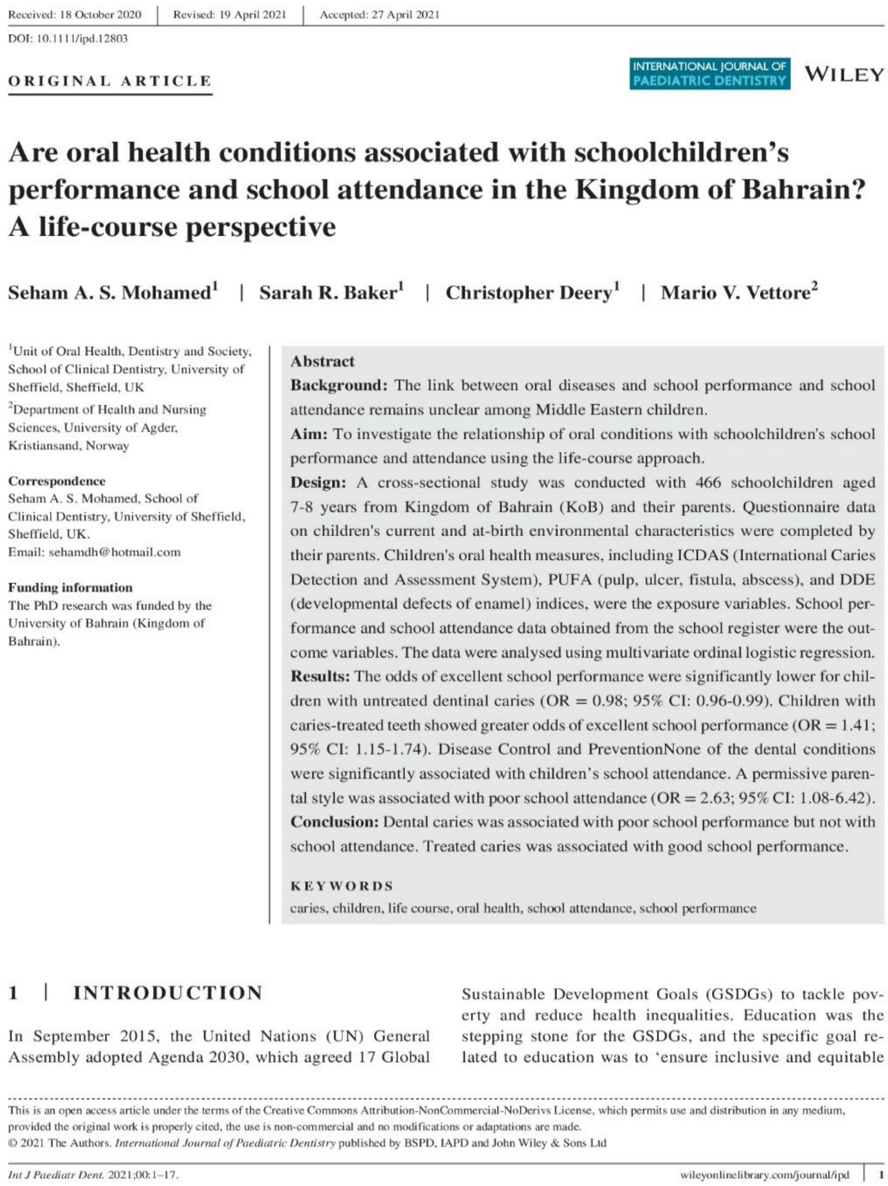
Chapter 8. Appendices

Appendix 1 Published paper

Mohamed SAS, Baker SR, Deery C, Vettore MV. Are oral health conditions associated with schoolchildren's performance and school attendance in the Kingdom of Bahrain? A life-course perspective. Int J Paediatr Dent. 2021 May 10. doi: 10.1111/ipd.12803. Epub ahead of print. PMID: 33971047.


Received: 18 October 2020 | Revised: 19 April 2021 | Accepted: 27 April 2021
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ORIGINAL ARTICLE

INTERNATIONAL JOURNAL OF PAEDIATRIC DENTISTRY WILEY

Are oral health conditions associated with schoolchildren's performance and school attendance in the Kingdom of Bahrain? A life-course perspective

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Abstract
Background: The link between oral diseases and school performance and school attendance remains unclear among Middle Eastern children.
Aim: To investigate the relationship of oral conditions with schoolchildren's school performance and attendance using the life-course approach.
Design: A cross-sectional study was conducted with 466 schoolchildren aged 7-8 years from Kingdom of Bahrain (KoB) and their parents. Questionnaire data on children's current and at-birth environmental characteristics were completed by their parents. Children's oral health measures, including ICDAS (International Caries Detection and Assessment System), PUFA (pulp, ulcer, fistula, abscess), and DDE (developmental defects of enamel) indices, were the exposure variables. School performance and school attendance data obtained from the school register were the outcome variables. The data were analysed using multivariate ordinal logistic regression.
Results: The odds of excellent school performance were significantly lower for children with untreated dentinal caries (OR = 0.98; 95% CI: 0.96-0.99). Children with caries-treated teeth showed greater odds of excellent school performance (OR = 1.41; 95% CI: 1.15-1.74). Disease Control and PreventionNone of the dental conditions were significantly associated with children's school attendance. A permissive parental style was associated with poor school attendance (OR = 2.63; 95% CI: 1.08-6.42).
Conclusion: Dental caries was associated with poor school performance but not with school attendance. Treated caries was associated with good school performance.

KEYWORDS
caries, children, life course, oral health, school attendance, school performance

1 | INTRODUCTION

In September 2015, the United Nations (UN) General Assembly adopted Agenda 2030, which agreed 17 Global Sustainable Development Goals (GSDGs) to tackle poverty and reduce health inequalities. Education was the stepping stone for the GSDGs, and the specific goal related to education was to 'ensure inclusive and equitable

Appendix 2. Search strategies for life course dental caries studies among children and adolescents (2012-2019**)**

1. Search date

From 2012-to 2021

2. Database

Scopus, MEDLINE, PubMed, and Google Scholar

3. Eligibility

The inclusion criteria were studies that explored the relationship between life course and dental caries with a clear definition of the life course theoretical framework, studies with children and adolescents up to 18-years old, and studies from any country but those published in the English language. The exclusion criteria included studies with adults over 18 years old, children and teenagers under 18 years (where it is impossible to analyse data for adults only), and studies published in languages other than English.

The search was carried out by the lead researcher (S.M).

4. Mesh terms

Mesh terms adopted from Abreu et al. (2015) to achieve consistency

Medline/Ovid

1 - life event.mp. OR exp life change events/ OR life course.mp. OR life-course.mp. OR lifecourse.mp. OR life span.mp. OR life-span.mp. OR lifespan.mp. OR life time.mp. OR life-time.mp. OR lifetime.mp.
2 - dental caries/ OR dental fissures/ OR root caries/ OR dental decay.mp. OR dental fissure.mp. OR tooth caries.mp. OR tooth decay.mp. OR caries disease.mp.
3 - adolescent/ OR child/ OR infant/ OR teenager.mp. OR exp child, preschool/ OR exp infant, newborn/ OR preschool children.mp

PubMed and Scopus

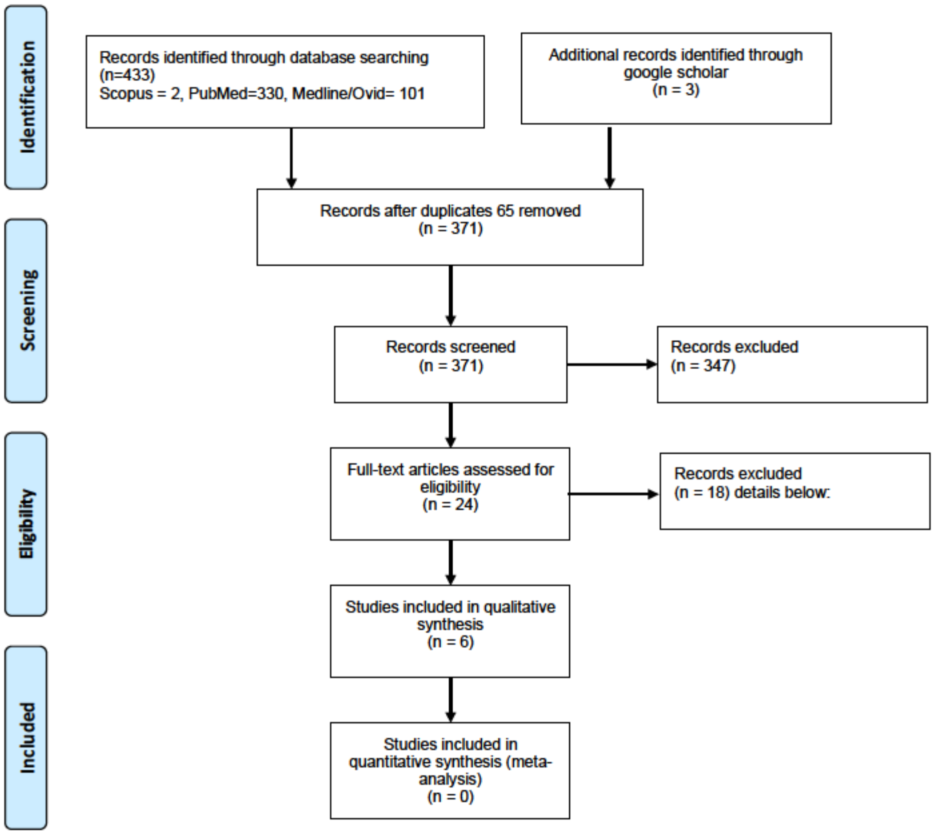
1 - life event OR life change events (Mesh) OR life course OR lifecourse OR lifecourse OR life span OR life-span OR lifespan OR life time OR life-time OR lifetime
2 - dental caries (Mesh) OR dental fissures OR root caries (Mesh) OR dental decay OR dental fissure OR tooth caries OR tooth decay OR caries disease OR tooth disease
3 - adolescent (Mesh) OR teenager OR child (Mesh) OR infant (Mesh) OR preschool child (Mesh) OR newborn (Mesh) OR preschool children OR children

5. Result

Figure 1 illustrates the results of the electronic database search using the PRISMA flow chart. The electronic search recognised 371 articles after removing duplicates;

347 articles did not meet eligibility criteria after screening title and abstract; 22 articles screened in full; 18 were excluded, and six new articles were found that studied dental caries in the life course. Further details are below:

Figure 1 Prisma flow chart for identifying studies of dental caries and life-course in children and adolescents (2012-2021)



5.1 Complete bibliographic details for excluded studies

1. Arantes, R., Welch, J.R., Tavares, F.G., Ferreira, A.A., Vettore, M.V. and Coimbra Jr, C.E.A. (2018). Human ecological and social determinants of dental caries among the Xavante Indigenous people in Central Brazil. *PloS one.* **13**(12), pp. e0208312.
   No life course model identified

2. BaniHani, A., Deery, C., Toumba, J., Munyombwe, T. and Duggal, M. (2018). The impact of dental caries and its treatment by conventional or biological approaches on the oral health ‐ related quality of life of children and carers. *International journal of paediatric dentistry.* **28**(2), pp.266-276.
   Not life course

3. Baxevanos, K., Menexes, G., Lazaridou, A., Coolidge, T., Topitsoglou, V. and Kalfas, S. (2021). Dental caries and psychosocial factors: Testing a conceptual model in adolescents. *Community Dentistry and Oral Epidemiology.* **49**(4), pp. 314-321.
   No life course model identified

4. Bernabe, E., Sabbah, W., Delgado-Angulo, E.K., Murasko, J.E. and Gansky, S.A. (2015). Income gradients in oral health according to child age. *European Journal of Oral Sciences.* **123**(4), pp.260-266.
   Income Inequality

5. Bernabé, E., Ballantyne, H., Longbottom, C. and Pitts, N.B. (2020). Early Introduction of Sugar-Sweetened Beverages and Caries Trajectories from Age 12 to 48 Months. *J Dent Res.* **99**(8), pp.898-906.
   Not available

6. Birungi, N. (2016). Early life course factors, early childhood caries and oral health related quality of life among five-year-olds–a prospective and intergenerational study from eastern Uganda.
   PhD thesis

7. Brondani, M., Amin, M., Poon, B. and Nicolau, B. (2016). Life Course Approach to Oral Health Research Workshop: A Summative Report. *J. Can. Dent. Assoc.* **82**.
   Report

8. Celeste, R.K., Eyjólfsdóttir, H.S., Lennartsson, C. and Fritzell, J. (2020). Socioeconomic Life Course Models and Oral Health: A Longitudinal Analysis. *J Dent Res.* **99**(3), pp.257-263.
   No life course model identified

9. Costa, F.d.S., Agostini, B.A., Schuch, H.S., Correa, M.B., Goettems, M.L. and Demarco, F.F. (2019). Parent-child interaction and stimulation in early life can be related to caries in primary dentition? Hypotheses from a life-course approach. *Medical Hypotheses.* **130**.

Hypothesis

10. Emmanuelli, B., Knorst, J.K., Menegazzo, G.R., Mendes, F.M. and Ardenghi, T.M. (2021). The Impact of Early Childhood Factors on Dental Caries Incidence in First Permanent Molars: A 7-Year Follow-Up Study. *Caries Research.* **55**(3), pp.167-173.
No life course model identified

11. Findley, P.A. and Weiner, R.C. (2020). Oral health across the life course: A role for social work. *Journal of Studies in Social Sciences and Humanities.* **6**(1), pp.1-10.
Review of the literature

12. Hall-Scullin, E., Whitehead, H., Milsom, K., Tickle, M., Su, T.L. and Walsh, T. (2017). Longitudinal study of caries development from childhood to adolescence. *Journal of dental research.* **96**(7), pp.762-767.
No life course model identified

13. Kavaliauskienė, A., Šidlauskas, A., Žemaitienė, M., Slabšinskienė, E. and Zaborskis, A. (2020). Relationships of dental caries and malocclusion with oral health-related quality of life in Lithuanian Adolescents aged 15 to 18 years: A cross-sectional study. *International Journal of Environmental Research and Public Health.* **17**(11), p4072.
Not life course

14. Paixão-Gonçalves, S., Corrêa-Faria, P., Ferreira, F.M., Ramos-Jorge, M.L., Paiva, S.M. and Pordeus, I.A. (2019). Risk of Dental Caries in Primary Teeth with Developmental Defects of Enamel: A Longitudinal Study with a Multilevel Approach. *Caries research.* **53**(6), pp.667-674.
Full article not available

15. Peres, M.A., Sheiham, A., Liu, P., Demarco, F.F., Silva, A.E.R., Assunção, M.C., Menezes, A.M., Barros, F.C. and Peres, K.G. (2016). Sugar Consumption and Changes in Dental Caries from Childhood to Adolescence. *J Dent Res.* **95**(4), pp.388-394.
Trajectories of feedings

16. Reyes, L.T., Knorst, J.K., Ortiz, F.R., Mendes, F.M. and Ardenghi, T.M. (2021). Pathways influencing dental caries increment among children: A cohort study. *Int J Paediatr Dent.* **31**(3), pp.422-432.
Not life course

17. Teixeira, A.K.M., Roncalli, A.G. and Noro, L.R.A. (2016). Factors related to the dental caries incidence in youth: A cohort study in Brazilian Northeastern. *Ciencia e Saude Coletiva.* **21**(12), pp.3871-3878.
Young adults, not children

18. Zemaitiene, M., Grigalauskiene, R., Andruskeviciene, V., Matulaitiene, Z.K., Zubiene, J., Narbutaite, J. and Slabsinskiene, E. (2017). Dental caries risk

indicators in early childhood and their association with caries polarisation in adolescence: a cross-sectional study. *BMC Oral Health.* **17**(1), pp.1-6.
No clear definition for the use of life course model

5.2 Complete bibliographic details for included studies

1. Bernabé, E., MacRitchie, H., Longbottom, C., Pitts, N. B. & Sabbah, W. (2017) Birth weight, breastfeeding, maternal smoking and caries trajectories. *Journal of dental research*, **96**(2),pp.171-178.

2. Birungi, N., Fadnes, L. T., Kasangaki, A., Nankabirwa, V., Okullo, I., Lie, S. A., Tumwine, J. K. & Astrom, A. N. (2017) Assessing causal effects of early life-course factors on early childhood caries in 5-year-old Ugandan children using directed acyclic graphs (DAGs): A prospective cohort study. *Community Dent Oral Epidemiol*, **45**(6), pp.512-521.

3. Priyanka, G. G., Kote, S., Sravanthi, K. V., Chethan, M., Anand, A., Jain, M. & Singh, S. (2019) Life course approach in the assessment of association between dental caries and health capital with family-related characteristics among 12-year-old school children. *Journal of family medicine and primary care*, **8**(7), pp. 2506-2510.

4. Silva, M. J., Kilpatrick, N. M., Craig, J. M., Manton, D. J., Leong, P., Burgner, D. P. & Scurrah, K. J. (2019) Genetic and Early-Life Environmental Influences on Dental Caries Risk: A Twin Study. *Pediatrics*, **143**(5). e20183499

5. Sun, X., Bernabé, E., Liu, X., Gallagher, J. E. & Zheng, S. (2017) Early life factors and dental caries in 5-year- old children in China. *Journal of Dentistry*, **64**,pp. 73-79.

6. Velasco, S. R. M., da Silva Bastos, R., Silva, R. M. & de Lima Navarro, M. F. (2018) Association Between Presence of Enamel Defects, Dental Caries and Socioeconomic Conditions on Brazilian Children. *Pesquisa Brasileira em Odontopediatria e Clínica Integrada*, **18**(1), pp.3727.

Appendix 3. Amstar (Shea 2007)

BMC Medical Research Methodology 2007, 7:10 http://www.biomedcentral.com/1471-2288/7/10

Table 2: AMSTAR is a measurement tool created to assess the methodological quality of systematic reviews.

1. Was an 'a priori' design provided? The research question and inclusion criteria should be established before the conduct of the review.	Yes No Can't answer Not applicable
2. Was there duplicate study selection and data extraction? There should be at least two independent data extractors and a consensus procedure for disagreements should be in place.	Yes No Can't answer Not applicable
3. Was a comprehensive literature search performed? At least two electronic sources should be searched. The report must include years and databases used (e.g. Central, EMBASE, and MEDLINE). Key words and/or MESH terms must be stated and where feasible the search strategy should be provided. All searches should be supplemented by consulting current contents, reviews, textbooks, specialized registers, or experts in the particular field of study, and by reviewing the references in the studies found.	Yes No Can't answer Not applicable
4. Was the status of publication (i.e. grey literature) used as an inclusion criterion? The authors should state that they searched for reports regardless of their publication type. The authors should state whether or not they excluded any reports (from the systematic review), based on their publication status, language etc.	Yes No Can't answer Not applicable
5. Was a list of studies (included and excluded) provided? A list of included and excluded studies should be provided.	Yes No Can't answer Not applicable
6. Were the characteristics of the included studies provided? In an aggregated form such as a table, data from the original studies should be provided on the participants, interventions and outcomes. The ranges of characteristics in all the studies analyzed e.g. age, race, sex, relevant socioeconomic data, disease status, duration, severity, or other diseases should be reported.	Yes No Can't answer Not applicable
7. Was the scientific quality of the included studies assessed and documented? 'A priori' methods of assessment should be provided (e.g., for effectiveness studies if the author(s) chose to include only randomized, double-blind, placebo controlled studies, or allocation concealment as inclusion criteria); for other types of studies alternative items will be relevant.	Yes No Can't answer Not applicable
8. Was the scientific quality of the included studies used appropriately in formulating conclusions? The results of the methodological rigor and scientific quality should be considered in the analysis and the conclusions of the review, and explicitly stated in formulating recommendations.	Yes No Can't answer Not applicable
9. Were the methods used to combine the findings of studies appropriate? For the pooled results, a test should be done to ensure the studies were combinable, to assess their homogeneity (i.e. Chi-squared test for homogeneity, I^2). If heterogeneity exists a random effects model should be used and/or the clinical appropriateness of combining should be taken into consideration (i.e. is it sensible to combine?).	Yes No Can't answer Not applicable
10. Was the likelihood of publication bias assessed? An assessment of publication bias should include a combination of graphical aids (e.g., funnel plot, other available tests) and/or statistical tests (e.g., Egger regression test).	Yes No Can't answer Not applicable
11. Was the conflict of interest stated? Potential sources of support should be clearly acknowledged in both the systematic review and the included studies.	Yes No Can't answer Not applicable

Appendix 4. JBI Data Extraction Form for review for the four systematic reviews

Study details/Author	Ruff, R. R., S. Senthi, S. R. Susser & A. Tsutsui (2018) “Oral health, academic performance, and school absenteeism in children and adolescents: A systematic review and meta- analysis: A systematic review and meta- analysis. The Journal of the American Dental AssociationOral health, academic performance and school absents in children and adolescent”
Objectives	“To conduct a systematic review and meta-analysis of the published literature on the potential association between oral health, school attendance, and academic performance in children aged 5 through 18 years”.
Participants	Children 5-18 years, 139,989 children
Setting/Context	Schoolchildren
Phenomena of Interest	School performance and absenteeism (objective and subjective)
Search Details	English, 1945 through December 2017. Exposures included subjectively or objectively measured caries, oral pain, and periodontitis. Outcomes included school absence and school achievement.
Sources searched	PubMed, Embase, and Google Scholar
Range (years) of included studies	1996-2016
Number of studies included	14 studies
Types of studies included	(12 cross-sectional studies, 1 case-control study, and 1 longitudinal study)
Country of origin of included studies	Greece, China, India, Thailand, Laos, USA, Brazil, Saudi Arabia
Appraisal	The modified NOS for nonrandomized studies
Appraisal instruments used	The modified NOS for nonrandomized studies
Appraisal rating	≥4 low risk, < 4 high risk 4 high risk, and the rest low risk
Analysis	Meta-analysis
Method of analysis	Pooling study-Random effect
Outcome assessed	Objective & subjective OH (DMFT, tooth pain, periodontitis)
Results/Findings	Poor oral health was significantly associated with increased odds of poor academic performance (pooled odds ratio, 1.52; 95% confidence interval, 1.20 to 1.83) and absenteeism (pooled odds ratio, 1.43; 95% confidence interval, 1.24 to 1.63).
Significance/direction	
Heterogeneity	X^2 and I^2
Comments	

Authors /Study details/	De Paula, J. S. & F. L. Mialhe (2013) "Impact of oral health conditions on school performance and lost school days by children and adolescents: What are the actual pieces of evidence? Brazilian Journal of Oral Sciences, 12, 189-198".
Objectives	"Investigate the pieces of evidence and discuss the methods and results of studies that assessed the existence of associations between the oral health status of children and adolescents, their school performance and lost school days due to dental problems".
Participants	193815 children
Setting/Context	schoolchildren
Phenomena of Interest	Academic performance and missing schools' day (Objective & subjective) C-OIDP
Search Details	The initial search =512 studies. One paper was excluded after duplicated. The titles and abstracts of the remaining 511 papers were reviewed for a more detailed evaluation. Only 17 papers included English-language papers (Jan/1970– Apr/2013)
Sources searched	Medline, PubMed Central
Range (years) of included studies	1992-2012
Number of studies included	21
Types of studies included	(7ecological+14cross-sectional)
Country of origin of included studies	Greece, China, India, Thailand, Laos, USA, Brazil, Saudi Arabia, Uganda, Canada, Pakistan
Appraisal	No
Appraisal instruments used	No
Appraisal rating	No
Analysis	No
Method of analysis	NO
Outcome assessed	DMFT, CPI, OHI-S- dental trauma
Results/Findings	Significant associations were found between clinically detected and self-perceived oral health status with school performance and school days lost by children and adolescents
Significance/direction	
Heterogeneity	
Comments	

Authors /Study details/	Rebelo, M. A. B., J. M. Rebelo Vieira, J. V. Pereira, L. N. Quadros & M. V. Vettore (2018) "Does oral health influence school performance and school attendance? A systematic review and meta-analysis. International journal of paediatric dentistry".
Objectives	"To examine the evidence on the possible influence of oral health on school performance and school attendance in children and adolescents."
Participants	157325 children, 18 and under
Setting/Context	schoolchildren
Phenomena of Interest	Academic performance and missing schools' day (Objective & subjective)
Search Details	The initial search identified 9308. Of them, 3706 studies remained after excluding duplicated documents. All titles and abstracts were then reviewed, and 3638 documents were excluded. The full text of the remaining 68. 50 were excluded according to the inclusion criteria. In the end, a total of 18.
Sources searched	MEDLINE, SCOPUS, Web of Science, ScienceDirect, and LILACS
Range (years) of included studies	May 2018
Number of studies included	18
Types of studies included	(1cohort+1case control+16cross-sectional)
Country of origin of included studies	Australia, Indonesia, China, India, Thailand, USA, Brazil, Saudi Arabia,
Appraisal	Yes
Appraisal instruments used	Newcastle-Ottawa Scale (NOS) for cohort studies and case-control - Modified - NOS for cross-sectional studies
Appraisal rating	Cohort=6-8 moderate, ≤ 5- low Cross-sectional= 4-6 moderate, ≤3=low Two low quality, and the rest moderate
Analysis	Yes
Method of analysis	Random effect Meta-analysis
Outcome assessed	DMFT, dmft, and subjective
Results/Findings	Significant associations were found between clinically detected and self-perceived oral health status with school performance and school days lost by children and adolescents
Significance/direction	
Heterogeneity	Was not significant X^2 and I^2
Comments	

Authors /Study details/	Ribeiro, A. P. D., R. F. Almeida, J. G. A. Medonca & S. C. Leal (2018) "Oral health and its effect on the academic performance of children and adolescents. Pediatric Dentistry, 40, 12-17".
Objectives	"To verify whether the child and adolescent oral health affected academic performance."
Participants	2527children, 3-29-years old
Setting/Context	schoolchildren
Phenomena of Interest	Academic performance (Objective only) school, teacher report and grades
Search Details	A total of 2,009 studies were retrieved, 14 of which were critically assessed. The reasons for excluding 1,995 studies were related to the use of quality of life questionnaires as the only measure of oral health. Of the 14 studies critically assessed, only six6,7,9,12-14 were included in the qualitative synthesis. March 2017
Sources searched	PubMed, Lilacs, Web of Science, and Scopus databases
Range (years) of included studies	2003-2015
Number of studies included	6
Types of studies included	(Cross-sectional)
Country of origin of included studies	USA, Brazil, Sudan, India
Appraisal	Yes
Appraisal instruments used	Quality assessment tool for observational cohort and cross-sectional studies developed by the National Heart, Lung and Blood Institute
Appraisal rating	14=good 7= fair no validity and reliability of exposure (no calibration, no reference regarding the number of examiners, and no kappa value for inter-and intra-examiner) and outcome measures (use of subjective criteria to classify students' performance) and no multivariate statistical analysis of t confounder variables = poor quality. Tw good, three poor, and one fair
Analysis	No
Method of analysis	No
Outcome assessed	DMFT, dmft, and present or absent of caries
Results/Findings	4 papers (high risk of bias) children's academic performance and poor oral health were associated - 2 papers (good quality) did not show an association between oral health and academic performance unless mediated by socioeconomic factors.
Significance/direction	No association unless mediated by SES
Heterogeneity	Was not significant X^2 and I^2
Comments	

Appendix 5. The summary of the included studies: exposures, outcomes and results

	Exposure	**Instrument**	**Outcome**	**Instrument**	Result
Agaku – 2015 Cross-sectional	Oral Health	Perceived by the parents	School Attendance (absenteeism)	Parents reporting (Subjectively measured questionnaire on school absenteeism)	Unmet treatment dental need & dental condition was associated with increased school absenteeism. (Mean number of days of school absence, 0.25 higher (95%CI, 0.16 to 0.34) among students with unmet need due to dental condition compared to those with no unmet need).
Astrom & Okull – 2003 Cross-sectional	Caries	WHO (DMFT)	School performance	OIDP (oral impact on daily performance)	44% reported difficulties with eating and 30% didn't like showing their teeth. Then impact was on difficulties with cleaning their teeth 35% was common, followed by difficulties with speaking and completing school activities (34%).
Bernabe - 2007 a Cross-sectional	Malocclusion	Child-OIDP	School performance	OIDP (oral impact on daily performance)	Impact of self-perceived malocclusion primarily affected psychological function such as smiling, emotion and social contact
Bernabe - 2007 b Cross-sectional	Oral health	Child-OIDP	School performance	OIDP (oral impact on daily performance)	Smiling (18.8%) and studying (17.0%) were the most significant impacts on children's everyday activities
Blumenshine – 2008 Ecological	Oral health	Perceived by the parents	School performance	Perceived by the parents	Children with poor OH were 2 times more expected to have poor school performance.
Butani – 2009 Cross-sectional	Oral health	Perceived by the parents	School time lost due to oral health problems	Perceived by the parents	Children in special education classrooms were more likely to miss school for dental care or problems than those in the mainstream classroom
Colares & Feitosa – 2003 Cross-sectional	Caries	Present or not	School performance	Questionnaire (teachers)	Severe ECC was associated with poor academic performance.
David – 2006 Cross-sectional	Caries, OH	WHO; DMFT & OHI-S	School performance	Self-reported (Child report of teacher perceptions of performance)	23% of the children reported poor OH. Factors associated with poor school performance: bad breath, difficulty with eating, visiting the dentist, dissatisfaction

		Questionnaire: SES, self-reports OHK, a single-item teeth self-esteem			with teeth look and caries. Children with poor OH had increased OR (2.5) of poor school performance
De Paula – 2015 Cross-sectional	Caries, gingival health, MO	DMFT, BOP, DAI Questionnaire: family environment (OHRQoL, CPQ11-14, SES, children's health (SUBJECTIVE AND OBJECTIVE)	School performance	Cumulative grades at the end of the academic year (language skills, math, science, social science, and other skills). CPQ11-14,	Socio-environmental factors, self-perception and carious, have a significant impact on school performance. Children with poor OH had increased OR of poor school performance (OR, 5.19; 95% CI, 2.16 to 12.47). Number of people living in household (2.46; 1,15-5.24; P=0.019); Household over-crowding (6.96; 2.73-17.7; P<0.0001); Parental perception (3.18; 1.49-6.81; P=0.003); Carious lesions (5.19; 2.16-12.47; P=0.0002) CPQ† 30 (5.25; 1.87-14.76; P=0.0016).
Detty and Oza-Frank – 2014 Cross-sectional	Caries	Data from the Ohio survey	School performance	Objectively measured school-level	Prevalence of (mean score, 0.065 lower; P ¼ .088) untreated caries at the school level was significantly related to lower school performance
Egri & Gunai – 2004 Ecological	Caries	Previously recorded WHO DMFT	School performance: 6 indicators (1-adult literacy rate, 2-mean years of schooling, 3-pupil-teacher ratio for primary level, 4-educational expenditure as a % of GNP, 5-primary enrolment ratio and 6-% completing a primary level	Human development report	High DMFT of 12-year-old children associated with the completion of primary school % in developing countries.
El-Sayed – 2015 Cross-sectional	Caries	DMFT, dmft	School performance and absenteeism	School reports academic performance: poor, acceptable, good, very good, and excellent.	Academic performance association with /dmft (P=0.008)/DMFT (P=0.023), but not school absenteeism (dmft/ (P=0.712/DMFT P=0.975).

Feitosa – 2005 Cross-sectional	Caries	Examination acc. To the Brazilian ministry of health criteria	School time lost due to OH problems	Questionnaire: parents or guardians.	Children with: severe caries, toothache, eating certain foods were absent from school; we are embarrassed to smile and avoid playing with other children because of their teeth. Severe caries was linked to a negative impact on children's OHRQoL
Freire – 2008 Cross-sectional	Caries & Height	DMFT and DMFS index	School performance	Failure at the school examination	Taller adolescents are associated with lower levels of caries. Social class and performance at school were found to be a cause of school failure, and both associated with height
Garg – 2012 Cross-sectional	Caries	Number d & f teeth (df-t index)	School performance	Overall marks from the teacher: excellent, average, below average	Poor OH is associated with low school performance.
Gherunpong – 200486 Cross-sectional	Caries, MO, OH	WHO; IOTN, OHI-S	School performance	Child-OIDP	High prevalence of OIDP. Oral impacts were a result of difficulty with eating and smiling, studying and maintaining social contacts.
Gift – 1992 Ecological	Dental visits/Problems (routine or emergency)	National health survey/ oral health supplement	School time lost due to oral health problems (Over the last 2 weeks)	Perception	≥ Then 51 million hours of school lost annually by school-age children due to visit the dentist or OH problem at the national level. The lost hours increase with the children's age, among girls and children with low SES, and Hispanic.
Gradella – 2011 Cross-sectional	Caries & sequela	DMFT, PUFA	School Attendance	Perceived by the parents	Dental caries was significantly associated with missing school days but not pufa
Guarnizo-Herreno and Wehby – 2012 Cross-sectional	Oral health	Perceived by the mother (By the parents)	School performance and school attendance	Perceived by the parents	Children with OH problems were more likely to have school difficulties (OR 1.52), to miss school (OR 1.42), and were less likely to do homework (OR 0.76)
Jackson – 2011 Cross-sectional	Oral health	Perceived by the parents Toothache or routine dental care	School performance and missed school	Perceived by the parent's School grades	Children with poorer OH were more expected to have dental pain Children with pain 3 times more likely to miss school, and do poorly in school. Absence because pain have no mediation effect between OHS and performance
Jiang – 2005 Cross-sectional	Oral health	Self-reported by adolescents	School performance	Self-reported (WHO structured questionnaire of (1) general health (2) OH and QoL, (3) OH behaviour and lifestyles (4) OH knowledge and	OH, and treatment needs to be associated with gender, age, unhealthy lifestyle, poor school performance and SES. Perceived OH and needs were linked with poor school performance

				attitudes (5) school performance, (6) spare time activities (7) family status and lifestyle.	
Jurgensen & Petersen – 2009 Cross-sectional	Caries, Trauma, Periodontal status, toothache	WHO (DMFT)	School time lost due to OH problems	Questionnaire (self-reported in the previous 12 months)	Missing schools was related to high DMFT (2.6) and 0.2 for no missed days. High decay was seen in children with dental visits and frequent consumption of sweet drinks. Missed school classes, toothache and several impairments of daily life activities were associated with a high dD-component
Kaewkamnerdpong - 2018	Caries, OH	DMFT, OHI-S	School performance	The total score of the national standard examination.	DMFT was associated with lower school performance. The oral hygiene score was not.
Krisdapong - 2013	Caries, toothache	DMFT (untreated caries)	School performance and school absenteeism	Self-reported (difficulties in attending school, learning, homework (Child-OIDP). School absence due to toothache in the last 3 months.	For children aged 12 and 15 years, severe caries was not related to absences in adjusted models (adjusted OR, 1.7; 95%CI, 0.8 to 3.7) and (adjusted OR, 2.5; 95% CI, 0.9 to 6.8, respectively). Toothache associated with absenteeism
Maharani – 2017 Cross-sectional;	Toothache in the previous 12 months, observed oral cleanliness	Toothache by parental the past 12 months. Oral cleanliness by plaque index (Silness & Low-1964).	School performance	Score in mathematics	Children aged 11-12 with toothache had a lower school performance than their peers. Children aged 10–11 years with a toothache in the past 12 months had significantly lower school performance than their peers. For children aged 6-7 years, IT WAS NOT SIGNIFICANT. The presence of substantial plaque was significantly associated with child's school performance at; 6–7 years and 10–11 years
Milgrom – 1998 Cross-sectional	Caries	From school dental screening data	School time lost due to OH problems	Questionnaire by mother	Poor OH is associated with school absence and reduced school performance
Muirhead & Locker – 2006 Ecological	% of children in need of urgent treatment (severe trauma, large cavities, acute	From school dental screening data	School performance	Ontario's educational assessment organisation	School performance was a significant prophet of children in need of dental treatment, especially of urgency

	gingival swelling, infection or pain)				
Muirhead & Marcenes – 2004 Ecological	Caries	BASCD OH survey of 5 years old children	School performance	English, mathematics and literacy tests	Low school attainment, free meals at school, schoolchildren's addresses were good indicators for 5 years children OH.
Naavaal – 2018 Cross-sectional	Acute/unplanned dental care (past 6 months)	Parents reporting	School hours missed	Parents reporting	Emergency/unplanned dental care accounted for 34 million school-hours loss annually.
Nasuuna – 2016 Cohort	Oral health	Perceived by the parents	School performance	Scores (numeracy and reading ≤ national minimum standard)	Dental conditions determined poor reading skills. Developmental delay, epilepsy, dental problems, speech, intellectual disabilities and LBW were linked with poor reading scores than those without these conditions (P<0.05) and had a higher OR of being at (OR: 1.3) or below (OR: 3.7) the national minimum standard for reading).
Neves – 2016 Cross-sectional	Caries, trauma, MO	ICDAS, TDI MO=increased overbite (>2 mm), increased overjet (>2 mm), anterior open bite, anterior crossbite and posterior crossbite.	School days lost because of dental problems	Reported by the parents	Dental caries is associated with absenteeism only. The prevalence rate of preschool absenteeism due to oral problems was 8.4 %.
Pau – 2008 Cross-sectional	Dental pain (the past month only)	Dental pain questionnaire, Child-OIDP.	Attending school, learning, homework	Child-OIDP (oral impact on daily performance)	Students who stated difficulties with playing, relaxing or sleeping, going to school and speaking or pronouncing were more likely to visit a dentist because their 139/500 students had dental pain in the past month. 45 (32.4%) reported impacts of pain on going to school and learning in class compared to 94 (67.6%), in whom it did not impact their school tasks. (45 / 500 x 100 = 9% students with dental pain that reported impacts of dental pain on school attendance and performance
Paula – 2016 Case-Control	Caries, BoP	WHO, DMFT/dmft, BoP	School performance	Cumulative grades at the end of the year	Caries, even if treated, were risk indicators of poor school performance
Petersen – 2008 Cross-sectional	Oral health	Self-reported	School performance	Self-reported	The students with low academic attainments reported: periodic dental visits, sugar

					consumption, smoking, alcohol, watching Tv for a long time, and playing on the computer.
Petridou – 1996 Cross-sectional	Caries	DMFT – DMFS	School performance	Objectively measured grades on a 10-grade scale	Good school performance is associated with better OH. Teeth filling was not significantly associated with school performance. Children achieved better by 1 grade, had a lower prevalence of DMFT by 0.2 and DMFS by 0.6)
Piovesan - 2012	Oral health, trauma, caries	Self-perceived & DMFT (clinically evaluated) (prevalence of untreated caries (corresponding to a nonzero D or d component in DMFT index and evidence of dental trauma)	School performance and school attendance	School reports: score in Portuguese language and number of school days missed in the last 3 months.	Children with DMFT had lower mean school performance, but the difference was not significant. Low household income ($P<0.05$), higher mean CPQ score ($P<0.05$) and higher school days missed ($P<0.001$) were individual determinants for lower school performance. Dental caries was not associated with Brazilian language skills or school days missed. Psychological and SES conditions determined children's academic performance. Being a girl was associated with higher school performance ($P < 0.05$)
Pongpichit – 2008 Longitudinal	Oral pain Caries	Parents perception	Absenteeism	School attendance records	159 missing school hours among children because of dental reasons (117 for dental appointments, 42 for dental pain). Low but considerable
Seirawan - 2012 Ecological Cross-sectional	Oral health (caries, dental pain, presence of dental caries and treatment needs)	Caries clinically: cavitated caries = minimum of 0.5mm discontinuity of enamel and white spot lesions, nonactivated = demineralisation, colour and translucency of the tooth surface. Pain by parent survey. Treatment: (1) "urgent" for immediate care involving pain, infection, swelling, extensive carious lesions, advanced periodontal conditions, or cuspidors soft tissue lesions; (2) "early" for care needed within 15 days to treat dental caries, mild gingivitis, and minimal calculus; or (3) "routine" for dental care within 6 months for prevention.	school performance (School performance and attendance) Proficiency levels from 1 to 5 where 1 = "far below basic", and 5 = "advanced" 2="below basic 3="basic and 4="provident,"	Objectively measured school attendance a GPA The LA Unified School District (LAUSD) office DATA and accountability. Tests scores: English language, arts and mathematics, and grade point averages, number of absent days from the school register	Childen with toothache 4 times more likely to performe low GPA, and 6 times more likely to miss school days. Objective OH have no significnat reltaions
Shaikh – 2016 Cross-sectional	Toothache (past 6 months)	Subjectively measured dental pain	School Attendance	The school attendance (school record for 6 months (form was used to specify reasons for absence)	Attendance was related to acute unplanned dental care. The prevalence of absenteeism due to toothache =18%)

Appendix 6. Summary of the confounders in the included studies

Agaku – 2015 Cross-sectional	8	1- Gender. 2- Age. 3-Ethnicity. 4- Health insurance coverage. 5- Poverty level. 6- Presence of a co-morbid condition. 7- Ever repeated a grade. 8-Presence of smokers in the household.	The mean number of school's missing days related to illness/injury was significantly higher among females than males (β = 0.11; p b 0.001), those aged ≥15 years compared to ≤9-year-olds (β = 0.10; p = 0.001), those with any health insurance coverage compared to those with none (β=0.24; p b 0.001), those with a co-morbidity compared to those with none (β=0.59; p b 0.001), those that had ever repeated a grade compared to those that had not (β=0.09; p = 0.020), and among those living with a smoker (β =0.21; p b 0.001).
Astrom & Okull – 2003 Cross-sectional	5	It is adjusted for 1-Age. 2-Hender. 3-Place of residence (urban / ruler). 4-Religious affiliation. 5-Parental education.	After adjusting for socio-demographics, non-clinical and clinical variables, place of residence did not sustain its statistically significant association. Non-clinical and clinical variables mediated Even its effect. No statistically significant relationship effect between missing teeth and social and behavioural variables.
Bernabe - 2007 a Cross-sectional	0	1- Sex. 2- Age. 3-Education level (Primary school vs high school) of child	Only education level has significantly influenced the prevalence of self-perceived malocclusion and intensity of the impacts associated with self-perceived malocclusion.
Bernabe - 2007 b Cross-sectional	0	0	"Further studies are needed to explore how oral impacts vary by socio-demographic characteristics, such as gender, age or socio-economic status".
Blumenshine – 2008 Ecological	9	Controlling for 1-sex. 2-race. 3-parental education. 4-Medicaid insurance. 5-Public versus private school. 6-Presence of medical. 7-Presence of mental and behavioural conditions. 8-Learning disability. 9-school days missed >2 weeks.	Male (OR) = 1.86, 95% (CI) = 1.34, 2.60], African-American (OR = 1.50, 95$ CI = 1.03, 2.08), had public or no insurance (OR = 1.72, 95% CI = 1.17, 2.53), parents with high school education or less (OR = 3.66, 95 percent CI = 2.35, 5.69) were more likely to have parentally reported poor school performance, mental disorder (OR = 2.68, 95%CI = 1.58, 4.54), diagnosis of behavioural conditions (OR = 3.98, 95% CI = 2.50, 6.34), and diagnosis of a learning disability (OR = 4.97, 95% CI = 3.10, 7.97) significantly linked to poor school performance. Children with both poor oral and poor general health were 2.3 times more likely to report poor school achievement than those with both good oral and general health (OR of 2.34 (95 % CI = 1.07, 5.67)
Butani – 2009 Cross-sectional	2	1-Age. 2-Gender	Adjusting for age and gender: children from special education classes were 2.4 times as likely to have a parental perception that their oral health was less favourable (good/fair/poor) (p = .001, 95% CI 1.54, 3.67).
Colares & Feitosa – 2003 Cross-sectional	0	0	0
David – 2006 Cross-sectional	4	1- Gender. 2-Place of residence. 3-SES. 4-Bleeding gums. 5-Bad breath 6-Toothache. 6-Food impaction. 7 - Dental visits. 8-Satisfied with the appearance of teeth 9-Oral health knowledge. 10-Caries experience 11- OHI 12-Anterior teeth fracture.	"This analysis showed that the initial results of unadjusted analyses were left essentially unchanged when cluster effects were taken into account".
Detty and Oza-Frank – 2014 Cross-sectional	1	School-based dental sealant program (SBSP)	The prevalence of untreated caries and academic performance at schools without an SBSP (P = 0.001) was significant determinants, but not at schools with an SBSP (P = 0.833) after adjusting for other school characteristics.
Egri & Gunai – 2004 Ecological			
El-Sayed – 2015 Cross-sectional	0	0	0

Feitosa – 2005 Cross-sectional	0	0	0
Freire – 2008 Cross-sectional			
Garg – 2012 Cross-sectional	0	0	0
Gherunpong – 200486 Cross-sectional	0	0	0
Gift – 1992 Ecological	0	0	0
Gradella – 2011 Cross-sectional	5	Adjusted for 1-Gender. 2-Age. 3-Mother education. 4-House ownership. 5-Household overcrowding.	
Guarnizo-Herreno and Wehby – 2012 Cross-sectional	19	Adjusted: 1-child's age. 2-Gender. 3-Ethnicity. 4-country of birth (the US vs others). 5-Birth order. 6-Numbers of people in the household. 7-Maternal age. 8-Marital status. 9-Maternal educational. 10-household poverty-level. 11-Household employment status. 12-Child's health insurance coverage. 13-learning disability, attention deficit disorder or attention deficit hyperactive disorder. 14-behavioral or conduct problems. 15-autism. 16-developmental delay. 17-speech problems. 18-and hearing problems. 19-State-level	
Jackson – 2011 Cross-sectional	11	1- Gender. 2-Race. 3- school grade. 4-Paternal education level. 5- Ethnicity. 6-Health insurance. 7-Special health care need. 8-OHS. 9-General health status. 10- Days for school absence for routine dental care. 11-School absence caused by dental pain	
Jiang – 2005 Cross-sectional	0	0	Multivariate analysis of perceived dental health: significant variables were gender, age, general hygiene practices, visiting a dentist, alcohol habits, oral hygiene practices, family income, attitudes towards dental health and parents' education. Finally, the most significant factors for experiencing dental symptoms: gender, age, general hygiene practices, visiting a physician, visiting a dentist, alcohol habits, consumption of sugary foods and drinks, and lifestyle of parents.

Jurgensen & Petersen – 2009 Cross-sectional	0	0	0
Kaewkamnerdpong - 2018	14		
Krisdapong - 2013	8	1-Current level of study. 2-Area of residence. 3-School type. 4-dental care in the current semester. 5- DMFT. 6- Severe untreated caries. 7-Intensity of oral impacts. 8- Toothache as a perceived cause of oral impacts.	Multivariate analyses adjusted both age groups: lower grade of 12-15-year-old children were 2 times (95% CI: 1.2, 3.6) and 3.5 times (95% CI: 1.1, 11.0), respectively, more likely to miss school. Children who received dental care during the semester of the study were significantly more likely to miss school than those who did not. The intensity of overall OHRQoL impacts was also significantly associated with school absence in 12 years. Children with severe/moderate intensity OHRQoL were significantly 3 times more likely to miss school compared with those with no or minimal intensity impacts. The likelihood of absenteeism for children with OHRQoL impact at little intensity increased but was not significantly higher than those with no or minimal intensity impacts. Unadjusted models for both age groups: children with severe DMFT were 3 times more likely to missed school, whereas children with toothache were 2 times more likely to miss school. The relations between absence and severe caries and toothache were not significant in adjusted models.
Maharani – 2017 Cross-sectional;	0	0	0
Milgrom – 1998 Cross-sectional	0	0	0
Muirhead & Locker – 2006 Ecological	2	Educational and deprivation confounders (1-the % of grade3 ESL learners and 2- median family income)	
Muirhead & Marcenes – 2004 Ecological	0	0	
Naavaal – 2018 Cross-sectional	7	1-Gender. 2-Age. 3-Ethnicity. 4-Parental education. 5-Family income. 6-OHS. 7- Dental care.	Multivariate models 1: children with high family incomes (≥$75,000) were less likely to need critical dental care in contrast to those in low-income families (OR = 0.69; 95% CI (0.51-0.92)) (Table 3). Model 2: Children with good OH were 1.6 times, and those with fair/poor OH were 2.7 times more likely to lose one or more hours compared to those with very good OH.
Nasuuna – 2016 Cohort	6		
Neves – 2016 Cross-sectional	4	1-child's gender, 2-child's age, 3-mother education4-household income	No association was found with the outcome.
Pau – 2008 Cross-sectional	0	0	0
Paula – 2015 Cross-sectional	5	Multivariate logistic model, Remains statistically significant when linked with adolescents' poor school performance in the final model:1- a number of individuals living in the	

		household, 2- overcrowding, 3-parental perceptions about their children's OH, 4-Carious lesions and a 5-Question from CPQ11-14 (difficulty in paying attention in class because of their teeth, lips, jaws or mouth).	
Paula – 2016 Case-Control	6	1-Caries lesions with no treatment 2011 2-Monthly household income. 3-Mother education. 4- Overcrowding. 5-Children living with both biological parents.	
Petersen – 2008 Cross-sectional	8	1-Gender. 2- Age. 3- Parental education level. 4-Family income. 5-Performance. 6-Peer relationship. 7-Attitudes towards OH. 8-Knowledge about prevention of dental disease.	
Petridou – 1996 Cross-sectional	4	1- Age. 2- Gender. 3- OH. 4. SES	Better DMFT among male students with high SES, brushing at least once per day, & better academic performance.
Piovesan - 2012	7	1-Gender. 2- Ethnicity. 3- Household income. 4- CPQ. 5- School Absenteeism. 6-School level average income. 7-Number of professors at school. (2&7 were not significant in the full model)	The a significant relationship between performance and neighbourhood income (b = 0.03).
Pongpichit – 2008 Longitudinal	0	0	0
Seirawan - 2012 Ecological Cross-sectional	3	Logistic regression model adjusted the 1-a type of school, 2- gender, and 3-Ethnicity when needed.	High school perform less than elementary school students in math P< .001). High school boys had a lower GPA than did high school girls (P= .002). Asian students performed statistically significantly better than did other ethnicities {P< .001), were the only ethnicity to achieve an average GPA >3, & advanced in English language arts. The average missing days of 6 for elementary school, compared with 2.6 among high school. Asian students had fewer absent days per school year than did all others (2.1) {P<,001).
Shaikh – 2016 Cross-sectional	0	0	The prevalence of absenteeism because of toothache was higher in 16 & 18-year-old female students ($P \leq 0.05$)

Appendix 7. Search strategies to update evidence related to the impacts of OHCs on children's and adolescent's school performance and attendance

1. Search date

From 2018-July 2021

2.Database

Scopus, MEDLINE, and PubMed

3.Mesh terms

"children" or "adolescence" or "adolescent" and "oral health" or "dental health" or "oral conditions" or "dental conditions" or "dental problems" or "oral problems" or "dental needs" or "dental care" or "dental treatment" or "dental pain" or "dental decay" or "caries" or "oral infections" or "dmft" and "school performance" or "academic performance "or "school attendance" or "school absence" or "school absenteeism"

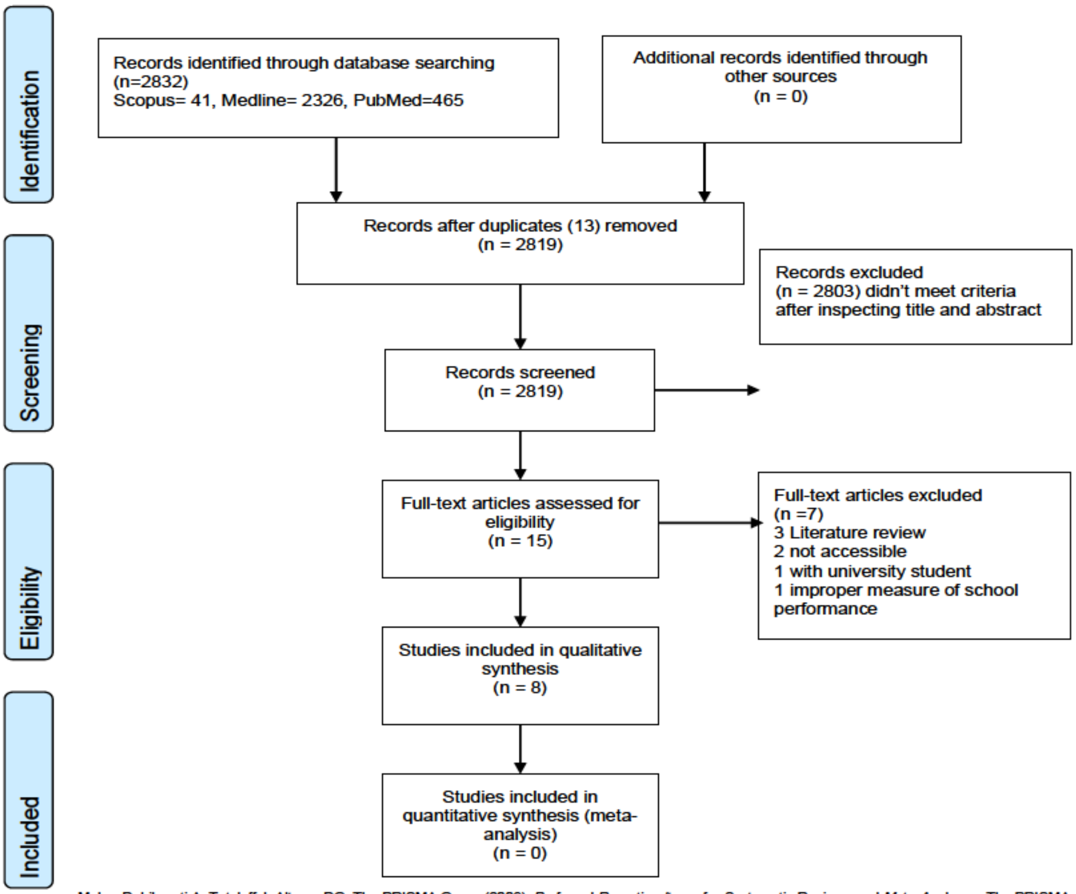
4.Eligibility

- Studies involving participants aged 19years
- Epidemiologic studies: Clinical trials and observational (cohort, case-control and cross-sectional) studies published in English
- Studies that examined assessed OHCs (clinical-self-reported)
- Available information regard school performance and/or school attendance

5.Results

Figure 1 illustrates the results of the electronic database search using the PRISMA flow chart (Moher et al., 2009). The electronic search recognised 2819 articles after removing duplicates. Two thousand eight hundred three articles did not meet eligibility criteria after screening title and abstract. Eight new articles were found that examined the relationship between school performance and attendance in children and adolescents. Details of included and excluded studies are found below

Figure 1 Prisma flow chart for identifying systematic reviews on the association between OHCs, and school achievement and attendance in children and adolescents (2018-2021)



Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097
For more information, visit www.prisma-statement.org.

5.1 Complete bibliographic details for excluded studies

1. Quadri, M.F.A. and Ahmad, B. (2019). Is there evidence for the impact of poor oral health on school performance? *BMC Oral Health.* **19**(1), pp.143-143.
   Literature Review for Maharani et al., 2017

2. Brignardello-Petersen, R. (2019). Children and adolescents with poor oral health are more likely to also have poor school performance and attendance, but there is no evidence that oral health is 1 of the causes. *J Am Dent Assoc.* **150**(5), pp.e51-e51.
   Literature Review for Rebelo et al., 2019

3. Groenewald, C.B., Giles, M. and Palermo, T.M. (2019). School Absence Associated With Childhood Pain in the United States. *Clinical Journal of Pain.* **35**(6), pp.525-531.
   Not accessible

4. Karam, S.A., Costa, F.d.S., Schwendicke, F., Correa, M.B. and Demarco, F.F. (2021). Oral health and academic performance or absenteeism: Findings from a University in Southern Brazil. *Community Dent Oral Epidemiol.* **49**(3), pp.267-274.
   The sample was University students, not children

5. Martin, M.A. (2019). Oral health problems are associated with worse academic performance. *J Pediatr.* **214**, pp.238-241.
   Evidence-based review by Martin of a different article by Guarnizo-Herre~no

6. Neves É, T.B., Granville-Garcia, A.F., Dutra, L.D.C., Baccin Bendo, C., Ferreira, F.M., Paiva, S.M. and Horowitz, A.M. (2021). Association of Oral Health Literacy and School Factors with Untreated Dental Caries among 12-Year-Olds: A Multilevel Approach. *Caries Res.* **55**(2), pp.144-152.
   Not accessible

7. da Franca Bandeira Ferreira Santos, C., Godoy, F., Menezes, V.A., Colares, V., Zarzar, P.M., Ferreira, R.C. and Kawachi, I. (2020). School academic climate and oral health (tooth loss) in adolescents. *PLoS One.* **15**(5), pp.e0233505-e0233505.
   School climate as performance evaluated on the national, not individual level

5.2 Complete bibliographic details for included studies

1. Almeida, R.F., Leal, S.C., Medonca, J.G.A., Hilgert, L.A. and Ribeiro, A.P.D. (2018). Oral health and school performance in a group of schoolchildren from the Federal District, Brazil: Oral health and its relationship with school performance of schoolchildren from Brazil. *Journal of public health dentistry.* **78**(4), pp.306-312.

2. Gopalan, T., Asokan, S., John, J. and Geetha Priya, P. (2018). School absenteeism, academic performance, and self-esteem as proxy measures of oral health status: A cross-sectional study. *Journal of the Indian Society of Pedodontics and Preventive Dentistry.* **36**(4), pp.339-346.

3. Guarnizo-Herreno, C.C., Lyu, W. and Wehby, G.L. (2019). Children's Oral Health and Academic Performance: Evidence of a Persisting Relationship Over the Last Decade in the United States. *Journal of Pediatrics.* **209**, pp.183-+.

4. Karki, S., Päkkilä, J., Laitala, M.L., Humagain, M. and Anttonen, V. (2019). Influence of dental caries on oral health‐related quality of life, school absenteeism and school performance among Nepalese schoolchildren. *Community Dent Oral Epidemiol.* **47**(6), pp.461-469.

5. Cunha, I.P.d., Pereira, A.C., Meneghim, M.d.C., Frias, A.C. and Mialhe, F.L. (2019). Association between social conditions and oral health in school failure. *Rev Saude Publica.* **53**, pp.108-108.

6. Quadros, L.N., Rebelo, M.A.B., de Queiroz, A.C., Pereira, J.V., Vettore, M.V. and Rebelo Vieira, J.M. (2020). Clinical consequences of untreated dental caries and school performance in low-income adolescents. *Int J Paediatr Dent.* **31**(5), pp. 619-626

7. Darley, R.M., Karam, S.A., Costa, F.D.S., Correa, M.B. and Demarco, F.F. (2021). Association between dental pain, use of dental services and school absenteeism: 2015 National School Health Survey, Brazil. *Epidemiol Serv Saude.* **30**(1), pp.e2020108-e2020108.

8. Ortiz, F.R., Ardenghi, T.M., Paiva, S.M., Maroneze, M.C. and Pordeus, I.A. (2021). Impact of Oral Conditions and Subjective Factors on Academic Performance. *Pesquisa Brasileira Em Odontopediatria E Clinica Integrada.* **21,** pp. e0233

Appendix 8. Muharraq's schools quality rating (2018-2019)

http://www.bqa.gov.bh/En/Reports/SchoolsReports/Pages/default.aspx

Muharraq HR1 MALE	Total Grade 2 Students	Outstanding 1	Good 2	Satisfactory 3	Inadequate 4	Number of classes
1 Abu Obaid primary boys - not exist	**75**	**1**				**3**
2 Abu Firas alhamadani primary boys' school	**97**	**1**				**3**
3 Al- hidd primary boys' school	**147**				**1**	**4**
4 Al- khawarizmi primary boys' school	**76**	**1**				**3**
5 Al-busaiteen primary boys' school	**123**			**1**		**4**
6 Al-dair primary boys' school	**128**			**1**		**4**
7 Abu alala maári primary boys' school	**64**		**1**			**2**
8 Arad primary boys school	**65**			**1**		**3**
9 Hassan bin Thabit primary boys school	**165**		**1**			**6**
10 Omar bin Abdul Aziz primary boys school	**81**			**1**		**3**
11 Qalali primary boys school	**87**			**1**		**3**
12 Samaheej primary intermediate	**87**				**1**	**3**
13 Sh. Mohamed bin Isa al-Khalifa primary boys school	**0**		**1**			**0**
	1195					**41**
Muharraq HR1 FEMALE	Total Grade 2 Students	Outstanding 1	Good 2	Satisfactory 3	Inadequate 4	Number of classes
14 Al-busaiteen primary girls' school	**160**		**1**			**5**
15 Al-dair primary, an intermediate girls' school	**101**		**1**			**3**
16 Al-muharraq primary girls' school	**150**	**1**				**5**
17 Al-orouba primary girls' school	**96**	**1**				**3**
18 Aminah bint Wahab primary girls school	**198**	**1**				**6**
19 Arad primary girls school	**83**	**1**				**3**
20 Asma that alnetaqain primary girls' school	**160**		**1**			**5**
21 Ruqaya primary girls school	**145**			**1**		**5**
22 Zubaidah primary girls school	**96**	**1**				**3**
23 Mariam Bent Omran	**96**	**1**				**3**
	1285					**41**

Appendix 9. Participant Information Sheet and consent form

The Effects of Oral Health Conditions on Children's Academic Performance and School Attendance

Appendix 2 Participant Information Sheet

You are invited to participate in a research project. Before deciding to or not to participate, kindly read the following information to understand why the study is being done, and why your participation is essential. Please take your time and discuss the information with others if you like. If there is anything not clear, do not hesitate to contact me.

Thank you

1. What is the project's purpose?

This research is requirement of a PhD project which aims to investigate how oral health and other social and environmental variables might restrict children's academic potentials over time. This will be conducted twice in September 2019, and September 2020.

2. Why have I been chosen?

You have been chosen because you live in Muharraq governorate, and your child in grade 2 attending one of Muharraq primary school. I will be asking around 500 parent-child pairs to participate as well.

3. Do I have to take part?

It is entirely up to you to participate. If you decide to take part, then will ask you to sign a consent, and you can withdraw at any time without the need for justification. This will not affect you and children at any time.

4. What will happen to me if I take part? What do I have to do?

If you decide to take part, then we will conduct oral health examination, body weight and height measurement and interview for your child at school, similarly to the one done by a dental hygienist in a regular basis. We will obtain your child birth weight and gestational age from the health records. We will ask you about his academic score and attendance. Then will ask you as a parent to fill out a questionnaire regarding the life course of your child. The questionnaire might take 30 minutes to fill. However, you can have a week to fill it and send it back with your child to school in a sealed envelop.

5. What are the possible disadvantages and risks of taking part?

There are no risks expected from this study. We assured you that your name would never be in any report, we will write about the project. Every answer by you is our priority to keep it confidential, so you do not need to worry about others knowing your answers.

6. What are the possible benefits of taking part?

While there are no immediate benefits for you as a participant in this study, however, the information retrieved might support promotional and interventions directed for children in the future.

7. Will my taking part in this project be kept confidential?

All information collected about you and your family will be kept confidential, and out of reach only for the researcher. The questionnaire, will keep saving in a locked cabinet at the University of Bahrain for three years then will be terminated, and the other information will be saved without names at University of Sheffield google drive. The report of this project will not mention any name for any participants.

8. What will happen when the research project ends?

We will collect the information and analyse the result. We can send you a copy if you wish to know.

9. Who is organising and funding the research?

The research is organised by Seham Mohamed, who is currently a PhD student at the School of Clinical Dentistry at the University of Sheffield. The project funded by the University of Sheffield at the United Kingdom and Bahrain University. A team of supervisors maintains the study, Professor Sarah Baker, Head Academic Unit of oral health, Dentistry and Society of the School of Clinical Dentistry, University of Sheffield, Dr Mario Vettore, Senior Lecturer in the School of Clinical Dentistry, University of Sheffield, and Professor Chris Deer, Dean School of Clinical Dentistry at University of Sheffield.

10. What if something goes wrong and I wish to complain about the research?

If you feel unhappy or if you have any concerns regard the project, I will be happy to talk to you about it at any time. You can contact me using the below details, or contact the Patient Advice and Liaison Service at the hospital on Tel: (0114)2712450

11. Who has reviewed the study?

The Research Ethics Committee has reviewed the research proposal at the University of Sheffield and the Ministry of Health and Ministry of Education in Bahrain.

12. Contact for further information

There are three two senior members of staff involved besides me, and they are willing to help if you need any further information you need;

The Effects of Oral Health Conditions on Children's Academic

Performance and School Attendance

Name and details
Seham Mohamed PhD student at the School of Clinical Dentistry University of Sheffield Dental Public Health Department 19 Claremont Crescent on whats up: 0097339070805 alternatively, by email: samohammed1@sheffield.ac.uk
Mario V Vettore Adjunct Professor Dental School, Federal University of Minas Gerais R. Prof. Moacir Gomes de Freitas, 688 - Pampulha, Belo Horizonte - MG Brazil CEP: 31270-901 Telephone: +55 (31) 32455940 Email: mariovettore@gmail.com
Professor Sarah R Baker Professor of Psychology as applied to Dentistry School of Clinical Dentistry Claremont Crescent Sheffield S10 2TA Telephone: +44 (0) 114 2159312 Email: s.r.baker@sheffield.ac.uk
Professor Chris Deery Dean School of Clinical Dentistry School of Clinical Dentistry Claremont Crescent Sheffield S10 2TA Telephone: +44 (0) 114 2159415 Email: c.deery@sheffield.ac.uk

Please note that there is a consent form needed to be signed if you agree that you and your child participate in this project. If so, please sing it within the sealed enveloped attached in, and send it back with your child to school.

Thank you very much for taking time reading the information sheet.

The Effects of Oral Health Conditions on Children's Academic Performance and School Attendance

Participant Consent Form

Researcher Name: Seham Mohamed

Please tick the appropriate boxes	**Yes**	**No**
Taking Part in the Project		
I have read and understood the study information sheet dated 05/09/2019. I had an appropriate time to consider participation, and the study has been explained well to me.		
I have been given the time and the chance to ask questions about the study.		
I agree to take part in the project. I understand that taking part in the project will include oral examination for my child, retrieve his birth weight, gestational age from ministry of health records, school score and attendance from us as the child guardians. I agree to answer the questionnaire.		
I understand that my taking part is voluntary and that I can withdraw from the study at any time without justification.		
I understand my personal details such as name, and phone number will remain confidential, and will be stored, and will not be exposed only to the main researcher. This information will be permanently deleted from the records three years after publication of this study.		
I agree to participate with my child at this study.		
I would like to receive a copy of the study results.		

Name of Researcher_____________________ Date______________________ Signature________________

Name of Parent_________________________ Date______________________ Signature________________

Name of Student___________________________ Bahrain Personal Number___________________________

Please sign one copy and return it in the given envelope along with this consent, and return it with your child to school, and keep one copy for your record

Contact

Seham Mohamed, PhD candidates in University of Sheffield, Faculty in Bahrain University
WhatsApp 0097339070805

Email: samohammed1@sheffield.ac.uk, sehamdh@hotmail.com

School of Clinical Dentistry. Claremont Crescent. Sheffield. S10 2TA.

Appendix 10. Parent's questionnaire (English)

The University Of Sheffield.

Parent's Questionnaire

جامعة البحرين
University of Bahrain

The Effects of Oral Health Conditions on Children's Academic Performance and School Attendance

The study number of the student: ______________	**Student's personal number:** _______________

Dear parents/ guardians of the participating students in this research. Thank you very much for taking the time and efforts to fill this questionnaire — a step that reflects your interest in better education and academic performances for all your children.

Please read every question in this questionnaire carefully and make sure to use only one choice if the question has multiple choices or you write the correspondent answer in the blank space if necessary.

Make sure to attempt all the questions, and then send this answered questionnaire in the sealed envelope attached for you with this questionnaire and return it with the student to the school.

Seham Mohamed
PHD candidates in University of Sheffield
Faculty in Bahrain University

Parent Questionnaire

1. Telephone contact: ___________________________	2. Mobile: ---
3. Age of mother: -----------------	4. Age of father: ----------------------------

5. Child Age (In completed years)
Day -------\ Month ---------------\ Year -----------\

6. Child Gender O Male O Female

7. Place of Birth: ______________________________

8. Ethnicity
O Bahraini O Gulf Cooperation Countries O Arab O Asian O African O European O Others

9. Area of residence

O Muharraq governorate
O The capital governorate
O The central governorate
O The southern governorate
O The northern governorate

Section 1 FAMILY STRUCTURE and SOCIOECONOMIC STATUS NOW

TO BE ANSWERED BY THE FATHER OR THE MOTHER OF THE CHILD

10. What type of a family does the child lives in?

O Nuclear family (i.e. the parents and the children live together).
O Extended Family (i.e. the parents and the child/children live with one or more of the grandparents, uncles, aunts and cousins)
O Single parent family (i.e. Only one parent and the child/children live together)

11. What is the current marital status of the parents?
O Married O Divorced O one of them widowed

12. How many brothers and sisters do this child have in total excluding him/her?_____

13. What is the current mother's level of education?

O Not educated
O Primary school education (1 - 6 years)
O Intermediate school education (7 – 9 years)
O Secondary school education (10 – 12 years)
O College/ University
O Post college

14. What was the total number of educational years completed by the mother?
____

15. What is the current employment status of the mother?

O Unemployed
O Self-employed
O Employed in the private sector
O Military
O Retired
O Government employee on the salary scale for public jobs
O Government employee on the salary schedule for specialized jobs
O Government employee on the salary scales for judges' jobs
O Government employee on the salary schedule for executive jobs
O Government employee on the salary scale of academic jobs
O Government employee on the salary scale of diplomatic jobs

16. If you are an employee please type your job title _____________________

17. What is the current father's level of education?

O Not educated
O Primary school education (1 - 6 years)
O Intermediate school education (7 – 9 years)
O Secondary school education (10 – 12 years)
O College/ University, how many by years……………………………………………….
O Post college, how many by years……………………………………………….

18. What was the total number of educational years completed by the father?
____

19. What is the current employment status of the father?

- O Unemployed
- O Self-employed
- O Employed in the private sector
- O Military
- O Retired
- O Government employee on the salary scale for public jobs
- O Government employee on the salary schedule for specialized jobs
- O Government employee on the salary scales for judges jobs
- O Government employee on the salary schedule for executive jobs
- O Government employee on the salary scale of academic jobs
- O Government employee on the salary scale of diplomatic jobs

20. If you are an employee please type your job title ______________________

21. At your best estimate, any of the following will appropriately describe the monthly income of your family in Bahraini dinars.

- O BD<200
- O BD 200-399,
- O BD 400-599
- O BD 600-799
- O BD 800-999
- O BD ≥ 1000

22. How can you describe your home ownership right now?

- O Owned house
- O Rented house
- O Owned flat
- O Rented flat
- O Others (please specify ______________________)

23. How many rooms do your home contain now, excluding your kitchen and bathrooms?
____

24. How many people lives in this house?
____

Section 2 PARENTS and CHILD ORAL HEALTH BAHAVIOURS NOW

Statement	Never	Once a day	Twice a day	> 2 a day	Weekly
Teeth Cleaning					
25. How often does the MOTHER brush her teeth					
26. How often does the MOTHER floss her teeth					
27. How often does the MOTHER use mouth wash					
28. How often does the FATHER brush his teeth					
29. How often does the FATHER floss his teeth					
30. How often does the FATHER use mouth wash					
31. How often does the CHILD brush his/her teeth					
32. How often does the CHILD floss his/her teeth					
33. How often does the CHILD use mouth wash					
Sugar Consumption					
34. How often does the MOTHER eat sweet snacks					
35. How often does the FATHER eat sweet snacks					
36. How often does the CHILD eat sweet snacks					

Self-perception of health and oral health					
	1 Excellent	2 Good	3 Average	4 Fair	5 Poor
37. How would the MOTHER rate her oral health generally					
38. How would the MOTHER rate her health generally					
39. How would the FATHER rate his oral health generally					
40. How would the FATHER rate his health generally					
41. How you would rate your CHILD oral health generally					
42. How you would rate your CHILD health generally					

43. If parents use a toothpaste, please determine the level of fluoride? Or write the toothpaste name..................

O 500 O 1000 O 1350-1450 O ≥ 5000 O Other -----------------------

44. If child use a toothpaste, please determine the level of fluoride?

O 500 O 1000 O 1350-1450 O ≥ 5000 O Other -----------------------

45. Does the child rinse with water, or only spit the toothpaste after brushing?
O Rinse with water
O Rinse with mouth wash
O Spit the toothpaste only without rinsing with water
O I don't know

46. Does the MOTHER visit the dentist?
O Yes
O No

47. Does the FATHER visit the dentist?
O Yes
O No

48. Why does the mother visit the dentist in general?
O Emergency
O Regular checkup
O Don't know

49. Why does the father visit the dentist in general?
O Emergency
O Regular checkup
O Don't know

50. If it's for checks up, how often does the MOTHER go?
O Every 6 months
O Once a year
O Once every two years
O Less often
O I can't remember

51. If it's for checks up, how often does the FATHER go?
O Every 6 months
O Once a year
O Once every two years
O Less often
O I can't remember

52. Does the MOTHER smoke?
O Yes
O No
54. If yes, what type?
O Cigarettes, HOW many per day___________
O Pipe
O Others ______________

53. Does the FATHER smoke?
O Yes
O No
55. If yes, what type?
O Cigarettes, HOW many per day ___________
O Pipe
O Others ______________

56. Does the child have any chronic disease from below?

O Asthma	O Iron deficiency	O Sickle cell diseases	O Epilepsy	O Cerebral palsy
O Thalassemia	O Type I diabetic Mellitus	O Disabilities; hearing, mental, visual, speech	O Autism	O (ADHD)

57. Does the child currently taking any medication? If yes, please specify

O Yes ____________________________ O No

Section 3 Kindly note that this section of the questions looks alike at the first instant with the previous, however, it asks about the situation when the child BORN.
FAMILY STRUCTURE and SOCIOECONOMIC STATUS WHEN THE CHILD BORN

58. What was the type of family when the baby was born?

O Nuclear family (i.e. the parents and the children live together).
O Extended Family (i.e. the parents and the child/children live with one or more of the grandparents, uncles, aunts and cousins)
O Single parent family (i.e. Only one parent and the child/children live together)

59. What was the marital status of the parents?

O Married **O Divorced** **O one of them widowed**

60. How many brothers and sisters did this child had in total at birth except for him/her?
____

61. What was the birth order of this child compared to his/her siblings?

O First **O Other, specify_____________________**
O Second

62. What was the level of mother's education when the child was born??

O Not educated
O Primary school education (1 - 6 years)
O Intermediate school education (7 – 9 years)
O Secondary school education (10 – 12 years)
O College/ University
O Post college

63. What was the mother's job when the baby was born??

O Unemployed
O Self-employed
O Employed in the private sector
O Military
O Retired
O Government employee on the salary scale for public jobs
O Government employee on the salary schedule for specialized jobs
O Government employee on the salary scales for judges' jobs
O Government employee on the salary schedule for executive jobs
O Government employee on the salary scale of academic jobs
O Government employee on the salary scale of diplomatic jobs

64. Please type the job title if there was any ______________________

65. What was the father's level of education at the time when the child was born?

O Not educated
O Primary school education (1 - 6 years)
O Intermediate school education (7 – 9 years)
O Secondary school education (10 – 12 years)
O College/ University, how many by years………………………………………….
O Post college, how many by years…………………………………………….

66. What was the employment status of the father at the time when the child was born?

O Unemployed
O Self-employed
O Employed in the private sector
O Military
O Retired
O Government employee on the salary scale for public jobs
O Government employee on the salary schedule for specialized jobs
O Government employee on the salary scales for judges jobs
O Government employee on the salary schedule for executive jobs
O Government employee on the salary scale of academic jobs
O Government employee on the salary scale of diplomatic jobs

67. Please type the job title if there was any ______________________

68. At your best estimate, any of the following would appropriately describe the monthly income of your family in Bahraini dinars when the child was born.
O BD<200
O BD 200-399,
O BD 400-599
O BD 600-799
O BD 800-999
O BD ≥ 1000
69. How can you describe the ownership of the house when the child was born?
O Owned house
O Rented house
O Owned flat
O Rented flat
O Others (please specify ________________________)
70. How many rooms were in your house at that time, except for the kitchen and the bathrooms? ____
Mother Status at Pregnancy and at The Child Birth
71. How old was the mother at the time of the birth of this child? (In completed years)
Day -------\ Month ---------------\ Year -----------\
72. Did the mother suffer from diabetes mellitus during pregnancy with this child?
O Yes O No
73. Did the mother suffer from hypertension during pregnancy with this child?
O Yes O No
74. Did the mother suffer from any other condition during pregnancy with this child please specify?
----
75. Was the mother an active smoker (i.e. using cigarettes or shisha) at the time of this child pregnancy?
O Yes O No
76. How did you give birth for this child?
O Caesarean section O Normal birth
77. Did you suffer from the postnatal depression after having this baby?
O Yes O No
BIOLOGY AND BEHAVIOR OF THE CHILD AT THE AGE OF TWO YEARS
78. How long have you been pregnant with this baby (gestational age)?
O Normal (i.e. equal to or more than 37 weeks) **O Pre-term birth (i.e. less than 37 weeks)**
79. What was the weight of the child at birth??
O Normal (i.e. equal to or more than 2500 g) **O Low-birth-weight (i.e. less than 2500 g)**
80. Was the child breastfeed only by mother for the first six months of his life?? (i.e. without other supplemental food)
O Yes O No
81. If the child relied on breastfeeding only, for how long that was ?
O Less than two years **O Equal or more than two years**
82. Did the child rely on drinking a bottle of formula milk before or during his night sleep?
O Yes O No
83. Did the child use to have sweetened drinks other than milk in his feeding bottle?
O Yes (i.e. equal to or more than one time per day), SPECIFY please ____________________________________ **O No (i.e. less than one time per day**

84. Did your child use a pacifier?

O Yes O No

85. If the answer to the previous question (yes), when did the child start using a pacifier?
____

86. How long did he use it? ___________________________?

CHILD BIOLOGY AND BEHAVIOR FROM 3-6 -YEARS OLD

87. When did the child start regular teeth brushing?

O At equal to or less than one year
O At more than one year

88. Was the child brushing his teeth under the supervision of an adult until he reached the age of six years??

O Always
O Mostly
O Occasionally
O Never

89. Did the child visit the dentist on a regular basis?

O Yes
O Never visited the dentist
O No, except in emergencies (in case of a toothache)

90. Did the child suffer from dental pain before entering school?

O Yes O No

91. Did the child suffer from decay in his primary teeth before entering the school?

O Yes O No

92. If the answer to previous question was (Yes), did the tooth decay require a dentist treatment?

O Yes O No

93. Did the child enrolled in a kindergarten before school?

O Yes O No

94. If the answer to the previous question is yes, how many years did your child study in kindergarten?

O One year
O Two years
O Three years

SECTION 4 THE ACADEMIC PERFORMANCE OF THE CHILD AT 6-YEARS OLD

95. What was the overall academic performance obtained by the child at the end of the last year in his school certificate?

O Excellent	O Very good	O Good	O Average	O Acceptable	O Failed

96. How many school days did your child missed the last year?

O No absent O Absents day from 1-5 days O Absents day from 6-9 days O Absents days ≥10

97. Had your child been absent from school because of oral, facial and dental problems?

O Yes O No

98. If the previous question was yes, please mention the reasons?

....

SECTION 5 PARENTING STYLE, PLEASE TICK ONE BOX

Statement	Never	Rarely	Sometimes	Very often	Always
Mother Parenting Style					
99. I am responsiveness for my chil's feelings and needs					
100. I take my child's wishes into consideration before I ask him/her to do something					
101. I explain to my child how I feel about his/her good/bad behaviour					
102. I encourage my child to talk about his/her feelings and problems					
103. I encourage my child to freely "speak his/her mind", even if he/she disagrees with me					
104. I explain to my child my expectations from him					
105. I provide my child reasons for the expectations I have for him/her					
106. I compliment my child					
107. I consider my child's preferences when I make plans for the family (e.g., weekends away and holidays					
108. I respect my child's opinion and encourage him/her to express them					
109. I allow my child to give input into our family rules					
110.I explain to my child the consequences of his behaviour					
111.I give my child reasons why rules should be obeyed					
112. I provide comfort and understanding when my child is upset					
113. I have warm and intimate times together with my child:					
114. When my child asks me why he/she must do something, I tell him/her is because I said it, and I am your Mother					
115. I punish my child by taking privileges away from him/her (e.g., TV, games, visiting friends)					
116. I yell when I disapprove of my child's behaviour					
117. I explode in anger towards my child					
118. I spank my child when I don't like what he/she does or says					
119. I use criticism to make my child improve his/her behaviour					
120. use threats as a form of punishment with little or no justification					
121. I punish my child by withholding emotional expressions (e.g., kisses and cuddles					
122. I openly criticise my child when his/her behaviour does not meet my expectations					
123. I feel the need to point out my child's past behavioural problems to make sure he/she will not do them again					
124. I remind my child that I am his/her parent					
125. I remind my child of all the things I am doing and I have done for him/her					
126. I find it difficult to discipline my child					
127. I give into my child when he/she causes a commotion about something					

128. I spoil my child					
129. I ignore my child's bad behaviour					
130. I threatened my child with punishment more often than giving it					
Statement	Never	Rarely	Sometimes	Very often	Always
Father Parenting Style					
131. I am responsiveness for my chil's feelings and needs					
132. I take my child's wishes into consideration before I ask him/her to do something					
133. I explain to my child how I feel about his/her good/bad behaviour					
134. I encourage my child to talk about his/her feelings and problems					
135. I encourage my child to freely "speak his/her mind", even if he/she disagrees with me					
136. I explain the reasons behind my expectations					
137. I provide comfort and understanding when my child is upset					
138. I compliment my child					
139. I consider my child's preferences when I make plans for the family (e.g., weekends away and holidays					
140. I respect my child's opinion and encourage him/her to express them					
141. I allow my child to give input into our family rules					
142. I explain to my child the consequences of his behaviour					
143. I give my child reasons why rules should be obeyed					
144. I provide my child reasons for the expectations I have for him/her					
145. I have warm and intimate times together with my child:					
146. When my child asks me why he/she must do something, I tell him/her is because I said it, and I am your Father					
147. I punish my child by taking privileges away from him/her (e.g., TV, games, visiting friends)					
148. I yell when I disapprove of my child's behaviour					
149. I explode in anger towards my child					
150. I spank my child when I don't like what he/she does or says					
151. I use criticism to make my child improve his/her behaviour					
152. use threats as a form of punishment with little or no justification					
153. I punish my child by withholding emotional expressions (e.g., kisses and cuddles					
154. I openly criticise my child when his/her behaviour does not meet my expectations					
155. I feel the need to point out my child's past behavioural problems to make sure he/she will not do them again					
156. I remind my child that I am his/her parent					
157. I remind my child of all the things I am doing, and I have done for him/her					
158. I find it difficult to discipline my child					

159. I give into my child when he/she causes a commotion about something					
160. I spoil my child					
161. I ignore my child's bad behaviour					
162. I threatened my child with punishment more often than giving it.					
PARENTS SCHOOL SUPPORT					
Statement	Never	Rarely	Sometimes	Very often	**Always**
Mother Academic Support					
163. I attend parent teacher meeting at my child school					
164. I discuss my child school progress with his teacher					
165. I attend school events and activities					
166. I make sure my child does his homework					
167. I motivate my child to work harder when he gets poor grade					
168. I volunteer at my child school					
169. I talk with my child regarding my expectations for him/her school work					
Statement	Never	Rarely	Sometimes	Very often	**Always**
Father Academic Support					
170 I attend parent teacher meeting at my child school					
171. I discuss my child school progress with his teacher					
172. I attend school events and activities					
173. I make sure my child does his homework					
174. I motivate my child to work harder when he gets poor grade					
175. I volunteer at your school					
176. I talk with my child regarding my expectations for him/her school work					

Appendix 11. Children's face-face questionnaire

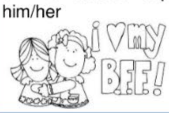
The University Of Sheffield.

جامعة البحرين
University of Bahrain

Children Face-Face Questionnaire

Student ID: ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ **Site ID:** ___ ___ ________________________

Interviewer Number: ___ ___ ______________

Statement Teacher Perceived Support	Yes	Sometimes	No
1. My teacher is nice and friendly 			
2. My teacher likes me 			
3. When I need extra help, my teacher gives it to me  			
Classmate Perceived Support			
4. The student in my class enjoy being together 			
5. Most of the student in my class are kind and helpful 			
6. When a student upset, another student comfort him/her  			

The University Of Sheffield.

جامعة البحرين
University of Bahrain

Modified Pediatric Oral Quality Of Life (POQL)
Child Self-Report

	Excellent	Good	Average	Fair	Poor
1. How would rate your oral health?					
2. How would you rate your general health?					

In the Past 3 months……………….

	How often did this happen?				How bothered were you?				
	All the time	Some of the times	Once in a while	Did not happe n	Very	someti mes	A little bite	never	Did not happen
1. Did you have pain because of your teeth or mouth?									
2. Did you have trouble eating any foods (hard/hot/cold) because of your teeth or mouth?									
3. Did you have trouble being attentive in school because of your teeth and mouth?									
4. Did you miss school days because of your teeth or mouth?									
5. Did not want to laugh or smile around others because of your teeth or mouth?									
6. Did you worry that you were not a good looking to others because of your teeth or mouth?									
7. Were you unhappy with the way you looked because of your teeth or mouth?									
8. Were you angry or upset because of your teeth or mouth?									
9. Did you feel worried because of your teeth or mouth?									
10. Did you cry because of your teeth or mouth?									
Total									
	The sume/70x100								

Appendix 12. Dental examination form

Participant study number.. Examiner/Recorder...

School Code... Date............................/Septemper/2019.......

Examination Form

1- Occlusion For Anetrior teeth

☐ Lip Competent: Yes/ No ☐ Overjet: .... ☐ Ovebite: ....

☐ Anterior Openbite: Yes / No/ NA ☐ Anterior Crossbite: Yes/ No/ NA

2- Dental trauma index (PERMANENT INCISOR)

12	11	21	22
42	**41**	**31**	**32**

3- Dental biofilm

S1	S2	S3
S6	**S5**	**S4**

3- ICDAS , PUFA/pufs and EDD

	17	16	15	14	13	12	11		21	22	23	24	25	26	27
D								M							
O								O							
M								D							
B								B							
L								L							
PUFA															
EDD															

	55	54	53	52	51		61	62	63	64	65
D						M					
O						O					
M						D					
B						B					
L						L					
pufa											
EDD											

	47	46	45	44	43	42	41		31	32	33	34	35	36	37
D								M							
O								O							
M								D							
B								B							
L								L							
PUFA															
EDD															

	85	84	83	82	81		71	72	73	74	75
D						M					
O						O					
M						D					
B						B					
L						L					
pufa											
EDD											

Appendix 13. Weight and Height form

Examiner………………………………………………… School/Class n …………………………………… Date……………………………………………

Grade 2 Weight and Height

	Student Number	Student Name	Weight KG	Height CM
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
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33.				
34.				

Appendix 14. University of Sheffield ethical approval

The University Of Sheffield.

Downloaded: 28/05/2019
Approved: 28/05/2019

Seham Mohamed
Registration number: 180129258
School of Clinical Dentistry
Programme: Standard PhD in the School of Clinical Dentistry

Dear Seham

PROJECT TITLE: The Effects of Oral Health Conditions on Childrens Academic Performance and School Attendance Using A Life Course Ap-proach: Longitudinal Study in the Kingdom of Bahrain
APPLICATION: Reference Number 026444

On behalf of the University ethics reviewers who reviewed your project, I am pleased to inform you that on 28/05/2019 the above-named project was **approved** on ethics grounds, on the basis that you will adhere to the following documentation that you submitted for ethics review:

- University research ethics application form 026444 (dated 08/05/2019).
- Participant information sheet 1061375 version 1 (07/05/2019).
- Participant consent form 1061376 version 1 (07/05/2019).

The following optional amendments were suggested:

1. Place version numbers of the documents and date as footnotes 2. Make sure participants get clean versions minus track changes 3. Amend questions to children to make them simpler for example instead of 'how would you rate your oral health' for children why not do you think your teeth and mouth are healthy? 4. Give the name of someone at the school who would be willing to talk to parents if they are upset

If during the course of the project you need to deviate significantly from the above-approved documentation please inform me since written approval will be required.

Yours sincerely

Janine Owens
Ethics Administrator
School of Clinical Dentistry

Appendix 15. Bahrain's Ministry of Education ethical approval

KINGDOM OF BAHRAIN
Ministry of Education

Number: 03/04/tmb2019

Date: 16 May 2019

[emblem: 2019, 100 years of formal education in the Kingdom of Bahrain]

Dear Respected Teacher Seham Abdulla Saleh

Warm regards,

RE: Approval of the application of research tools by the Primary Education Directorate

With reference to your application on 15/04/2019 regarding the use of research tools entitled, 'The Relationship of Oral Diseases to the Academic Performance of Students: Using the Human Life Cycle Approach' - I am pleased to inform you that the application for research tools to the Primary Education Directorate has been approved.

The use of these tools should be carried out in accordance with the following instructions and conditions:

1. Adherence to the use of the approved tool(s), without addition to, or omission of such tools.

2. During the use of research tools, it must be ensured that the educational process and achievement of students is not harmed.

3. The information gathered must be protected and used only for the purpose of scientific research.

4. Upon its completion, a copy of the research must be provided to the Department of Public Libraries at the Ministry of Education.

5. The researcher must bear responsibility for all procedures and steps necessary to implement the use of the research tools. They are not entitled to rely upon the Ministry staff to fulfil this task.

With our best wishes for your success, please accept our sincerest regards.

[signature]

Dr. Farzana Abdulla Al Maraghi

Principal of the Department of Scientific Research

atc ASSOCIATION OF TRANSLATION COMPANIES
Certified Translation produced by translatemydoc
Member No. T29

Scientific Research Directorate at the Secretariat-General of the Higher Education Council
Tel : (00903) 17873061 – Fax : (00973) 17680168 P.O. Box : 43 Kingdom of Bahrain

2030 BAHRAIN

Appendix 16. Bahrain's Ministry of Health ethical approval

Kingdom of Bahrain
Ministry of Health
Office of Asst. Undersecretary
For Human Resources & Services

مملكة البحرين
وزارة الصحة
مكتب الوكيل المساعد
للموارد البشرية والخدمات

No: AURS/ 402 /2019
Date: 22nd July 2019

To: Seham Mohamed
School of Clinical Dentistry
University of Sheffield

Subject: Letter of Approval for Research Proposal:

"The Effects of Oral Health Conditions on Children's Academic Performance and School Attendance Using A Life Course Approach: Longitudinal Study in the Kingdom of Bahrain"

Dear Mrs. Seham,

Thank you for submitting your research proposal documents, which have been considered by members of the Research Technical Support Team (RTST) on 29th May 2019.

We would like to inform you that the team found no major ethical issues or methodological problems that would hinder the conduct of this survey. We are thus pleased to approve the above application.

This approval is subject to the following conditions:

1. We expect that the study will begin within 6 months of the date of this approval.
2. Approval from an MOH Research Committee does not automatically imply that the researcher is granted access to data, medical records or biological samples from MOH healthcare facilities. Researchers must seek permission and follow procedures as dictated by the concerned departments after presenting them with a valid MOH approval letter.
3. Any significant change, which occurs in connection with this study and/or which may alter its ethical consideration, must be reported immediately to the RTST.
4. This approval is valid for up to **1 year** from the date of approval. If the study extends beyond this date, a progress report must be sent to the RTST to renew the approval.
5. The RTST must be informed when the research has been completed and a copy of the final research report must be submitted for our records.

We wish you all the best in this study.

Yours sincerely,

[redacted]

For **Fatima A. Wahid Al Ahmed**
Assistant Undersecretary for Resources and Services

CC: Team file

Appendix 17. University of Sheffield ethical amendments

The University Of Sheffield.

School Of Clinical Dentistry.

16th December 2020

Ms Seham Mohammed
School of Clinical Dentistry
Claremont Crescent
Sheffield
S10 2TA

Professor Chris Deery
Dean
School of Clinical Dentistry
Claremont Crescent
Sheffield
S10 2TA

Telephone: +44 (0) 114 222 2076
Email: hesdenreshub@sheffield.ac.uk

Dear Seham

Application No:	**026444**
Project Title:	**The Effects of Oral Health Conditions on Children's Academic Performance and School Attendance Using A Life Course Approach**

I am writing to confirm approval of your request for minor amendments to your ethics submission Number 026444, detailed in the Notice of Amendments Form submitted on 16th December 2020.

Yours sincerely

[redacted]

Professor Paul Hatton
Acting Ethics Lead

Appendix 18. MOE ethical approval for schoolchildren attendance

The ethical approval to obtain children attendance from school records was done via emails between the researcher Mrs Mariam Al-Othman; She is an Educational Specialist in Scientific Research Directorate in Secretariat-General of the Higher Education Council. She sent an email as indicated below in the Arabic language, and the translation is below.

From: sehamdh@hotmail.com

To: Mariam Hasan Ahmed Alothman; Cc & Bcc

Re: OBTAINED STUDENT ATTENDANCE

From: Mariam Hasan Ahmed Alothman <mariam.alothman@moe.gov.bh>
Sent: Monday, October 12, 2020 5:45:50 AM
To: seham mohammed <sehamdh@hotmail.com>
Subject: Re: OBTAINED STUDENT ATTENDANCE

الاستاذة الفاضلة سهام محمد المحترمة
تحية طيبة وبعد

عطفاً على بريدكم الالكتروني أدناه، يمكنكم مراجعة مكتب الإرشاد الإجتماعي في المدارس التي تم فيها فحص الطلبة لتزويدكم بحضور وغياب الطلبة للفترة من سبتمبر 2019-فبراير 2020، على أن تزودوا مكتب الإرشاد بأسماء الطلبة اللذين لديهم موافقة من اولياء أمورهم بعرض الموافقات المعتمدة- وفي حال عدم تعاون أي مدرسة بتزويدكم بالبيانات يمكنكم التواصل معنا على 17896948.

تحيتي
مريم العثمان

From: seham mohammed <sehamdh@hotmail.com>
Sent: Sunday, October 11, 2020 2:49 PM
To: Mariam Hasan Ahmed Alothman <mariam.alothman@moe.gov.bh>
Subject: Re: OBTAINED STUDENT ATTENDANCE

الفاضله إستاذه مريم
الموافقه كانت ورقية، وإنشاءالله في المرفق بتحصلين نماااذج أبوي.
٤٤ طالب وطالبه تمت إزالتهم من الدراسه تماما لانه ماوافقوا أوا مارجعوا الأوراق...

The email said:

The respectable Mrs Seham Mohamed

Due and respects

In response to your email below, you can check with the Social Guidance Office in schools where students have been screened to provide you with the presence and absence of students for the period from September 2019 to February 2020, providing the Guidance Office with the names of students who have the consent of their parents to offer approved approvals - and if no school cooperates with providing you with data, you can contact us on 17896948.

Regards

Mariam Al – Othman

Appendix 19. Summary of data screening

<u>Missing values patterns and percentage</u>

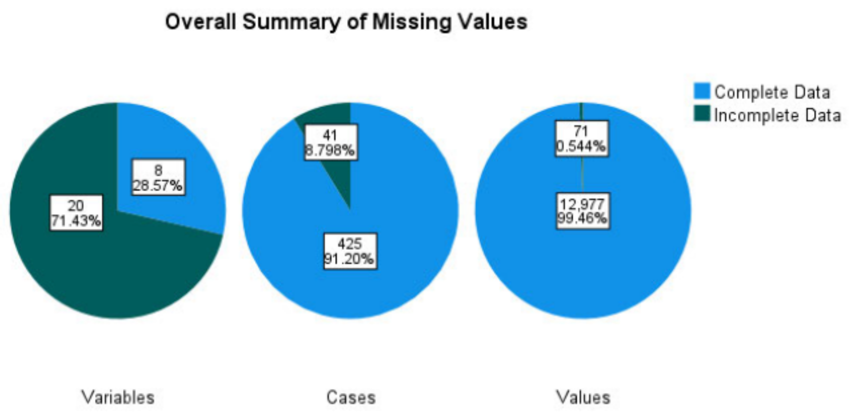


Table 1 Summary of variables with missing values

	Missing N	Missing %	Valid N
1. Academic performance G2	16	3.4%	450
2. Father parenting style	16	3.4%	450
3. Mother parenting style	10	2.1%	456
4. Father’s level of education at birth	3	0.6%	463
5. Mother use of mouth wash	3	0.6%	463
6. Mother flossing	3	0.6%	463
7. Mother teeth brushing	3	0.6%	463
8. Mother's employment at birth	2	0.4%	464
9. Mother's level education at birth	2	0.4%	464
10. Current household income	2	0.4%	464
11. Current mother’s level of education	2	0.4%	464
12. Exclusive breast feeding	1	0.2%	465
13. Birth weight	1	0.2%	465
14. Gestational age	1	0.2%	465
15. Maternal postnatal depression	1	0.2%	465
16. Maternal health conditions	1	0.2%	465
17. Maternal hypertension	1	0.2%	465
18. Maternal diabetes mellitus	1	0.2%	465
19. Family income at birth	1	0.2%	465
20. Current father’s level of education	1	0.2%	465

Little's MCAR test

EM Estimated Statistics

EM Means[a,b]

ChCweight	ChCheight	CHBMIP	MAge	FAge	ChAge	ChGender	Ethnicity	AOR	CFT	CMS	NSiblings	CMEL	CMEY	CMEM	CFEL
25.149	120.619	59.92	35.80	41.21	7.09	1.38	1.59	1.04	2.80	2.94	3.17	3.75	1.25	2.06	4.14

a. Little's MCAR test: Chi-Square = 517.370, DF = 19504, Sig. = 1.000

b. The EM algorithm failed to converge in 25 iterations.

Double-cl
activa

Table 2 Results of the univariate analysis

Number of observations with a Z score of below or above 3.29	Variable
7 cases	Absent days
6 cases	School performance
7 cases	Treated primary teeth
9 cases	Enamel caries
4 cases	Dentine caries

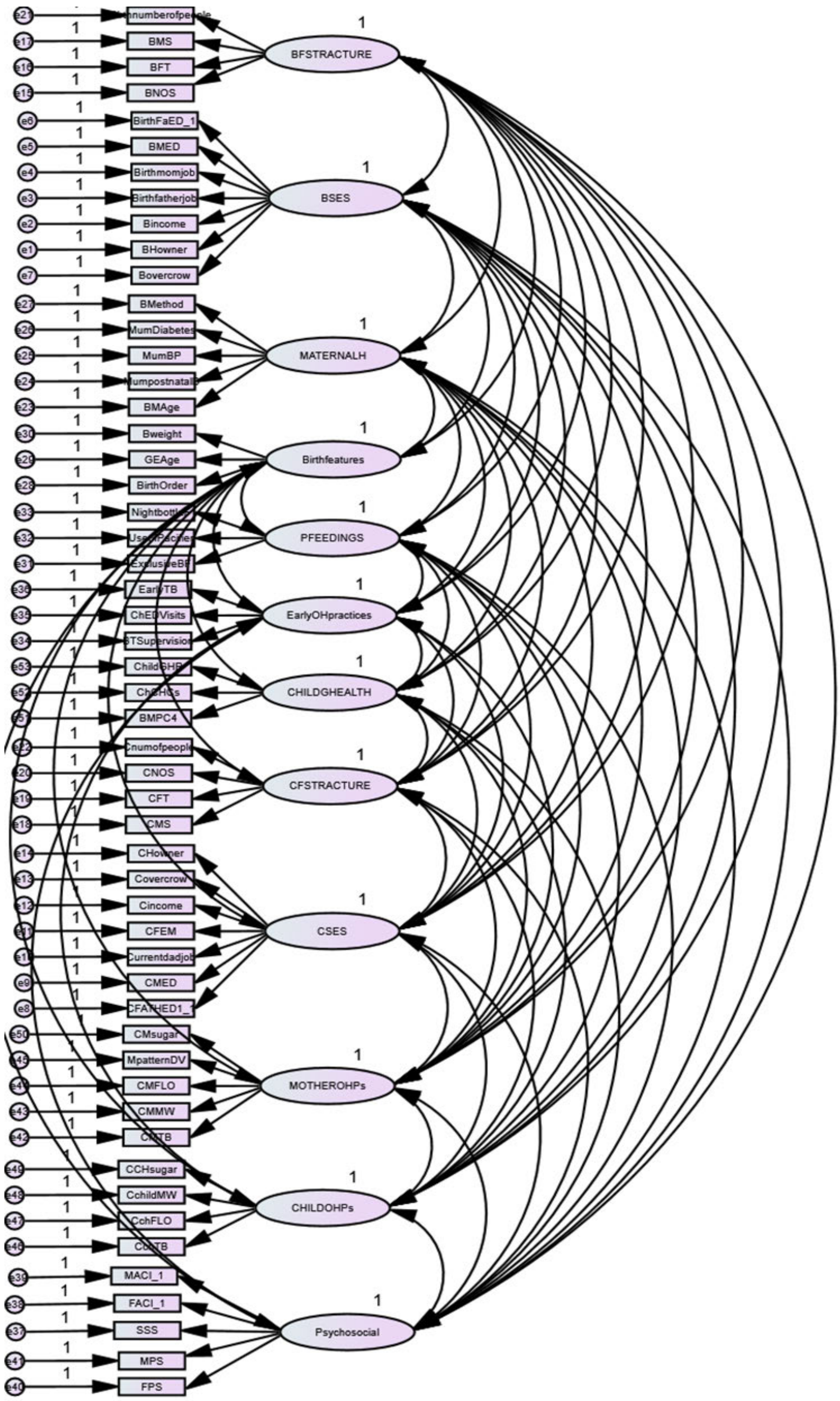
Table 3 Results of the multivariate analysis

	Observation number	Mahalanobis d-squared	P1	P2
1.	77	137.967	.000	.000
2.	380	122.966	.000	.000
3.	20	106.742	.000	.000
4.	440	106.090	.000	.000
5.	49	98.472	.000	.000
6.	117	96.752	.000	.000
7.	419	95.786	.000	.000
8.	121	94.324	.000	.000
9.	324	88.567	.000	.000
10.	275	83.425	.000	.000
11.	7	80.280	.000	.000
12.	34	79.227	.000	.000
13.	432	77.526	.000	.000
14.	332	77.092	.000	.000
15.	142	76.606	.000	.000
16.	217	75.263	.000	.000
17.	104	73.871	.000	.000
18.	364	73.548	.000	.000
19.	233	72.606	.000	.000
20.	89	72.174	.000	.000
21.	16	71.549	.000	.000
22.	452	69.341	.000	.000
23.	71	68.482	.000	.000
24.	157	67.386	.000	.000
25.	351	65.942	.000	.000
26.	463	65.904	.000	.000
27.	189	65.853	.000	.000
28.	387	65.671	.000	.000
29.	192	65.114	.000	.000

Table 4 Test of normality

Variable	Min	Max	Skew	Critical ratio	Kurtosis	Critical ratio
Plaque	.000	100.000	-.671	-5.911	-1.083	-4.774
EDD	.000	1.000	7.974	70.275	61.587	271.378
Maternal CHCs	1.000	2.000	-1.286	-11.331	-.347	-1.528
Treated teeth	.000	25.000	2.156	19.004	5.407	23.825
ds_4_6	.000	68.000	.817	7.202	.677	2.983
Supervised TB	1.000	2.000	-.731	-6.443	-1.465	-6.457
Absent days	.000	22.000	3.970	34.988	23.299	102.667
pufa	1.000	2.000	1.175	10.352	-.620	-2.733
ds_2_3	.000	11.000	1.655	14.581	2.925	12.888
Exclusive breast feeding	.000	1.000	.986	8.686	-1.028	-4.532
School performance	65.000	100.000	-1.656	-14.596	2.977	13.118
Current dental pain	.000	1.000	.495	4.364	-1.755	-7.732
Birth weight	1.000	2.000	-2.467	-21.743	4.087	18.010
Gestational age	1.000	2.000	-2.502	-22.050	4.260	18.772
Birth order	1.000	2.000	-1.202	-10.590	-.556	-2.450
income at birth	1.000	3.000	.020	.176	-.680	-2.998
Mother academic involvement	8.000	28.000	-.471	-4.151	-.502	-2.214
Father parenting style	1.000	3.000	-3.418	-30.125	10.256	45.193
Mother parenting style	1.000	3.000	-4.338	-38.229	17.813	78.492
Child's teeth brushing	.000	2.000	.138	1.212	3.553	15.655
Child's flossing	.000	2.000	3.017	26.588	8.930	39.348
Child's use of MW	.000	2.000	1.943	17.125	2.886	12.718
Child's sugar consumption	.000	2.000	-.038	-.333	-.280	-1.235
Mother's teeth brushing	.000	2.000	.547	4.824	.408	1.797
Mother's teeth brushing	.000	2.000	.736	6.485	-.502	-2.212
Mother's flossing	.000	2.000	1.408	12.411	1.019	4.489
Current income	1.000	3.000	-.124	-1.095	-.763	-3.361
Current father's level of education	.000	2.000	-1.821	-16.052	2.447	10.784
Current mother's level of education	.000	2.000	-1.251	-11.027	.388	1.711
Mother job at birth	1.000	3.000	1.443	12.719	.299	1.318
Mother's level of education at birth time	.000	2.000	-1.202	-10.593	.226	.997
father's level of education at birth time	.000	2.000	-1.769	-15.586	2.280	10.047

Appendix 20. The initial CFA model



Appendix 21. Standardised Regression Weights, total, direct and indirect effects, BC 95% CI, and SE for full model

Parameter			Estimate	Lower	Upper	P	Total effect	Direct effect	P/direct	Indirect effect	P/indirect	Bootstrap-SE	BC 95% CI
MCHCs	<---	BSES	-.001	-.121	.116	.970	-.001	-.001	.970			.061	-.121/.116
CSES	<---	BSES	.986	.957	1.005	.003	.986**	.986**	.003			.12	.957/1.005
C mother education	<---	BSES					.636**			.636**	.002	.063	.514/.758
C father education	<---	BSES					.464**			.464**	.003	.068	.321/.585
C family income	<---	BSES					.458**			.458**	.001	.071	.323/.599
MOHPs	<---	BSES					-.036			-.036	.589	.073	-.178/.112
C mother flossing	<---	BSES					-.011			-.011	.559	.022	-.055/.035
C mother mouth wash	<---	BSES					-.028			-.028	.574	.058	-.147/.079
C mother brushing	<---	BSES					-.007			-.007	.497	.016	-.039/-.015
Parent's characteristics	<---	BSES					.438			.438**	.006	.148	.165/.727
Mother parenting S	<---	BSES					.293			.293**	.002	.073	.149/.432
Father parenting S	<---	BSES					.231			.231**	.001	.066	.108/.354
Mother academic involvement	<---	BSES					.151			.151**	.004	.098	.041/.396
Birth outcomes	<---	BSES	-.034	-.211	.184	.752	-.034	-.034	.752			.096	-.022/.021
Birth order	<---	BSES					-.007			-.007	.611	.020	-.048/.034.
Gestation age	<---	BSES					-.030			-.030	.781	.065	-.194/.137
Birth weight	<---	BSES					-.022			-.022	.681	.085	-.137/.124
Supervised TB	<---	BSES	.163	.034	.268	.007	.163**	.163**	.007			.059	.034/.268
Child OHPs	<---	BSES					-.190			-.190**	.004	.068	-.328/.057
Child sugar	<---	BSES					.036			.036**	.002	.019	.008/.080
Child MW	<---	BSES					-.161			-.161**	.003	.056	-.274/-.050
Child flossing	<---	BSES					-.092			-.092**	.002	.036	-.169/-.030
Child TB	<---	BSES					-.044			-.044**	.001	.019	-.089/-.015
Plaque	<---	BSES					-.006			-0.006	.704	.016	-.042/.023
Breastfeeding	<---	BSES	.078	-.032	.193	.163	.078	.078	.163			.057	-.032/.193
Dentine caries	<---	BSES	-.248	-.356	-.121	.002	-.249**	-.248**	.002	-.001	.949	.057	-.356/-.121
Enamel caries	<---	BSES	.089	-.041	.193	.181	.066	.089	.181	-.023	.149	.059	-.041/.193
pufa	<---	BSES	.018	-.131	.135	.844	-.005	.018	.844	-.022	.162	.066	-.131/.135
Dental pain	<---	BSES					-.039			-.039**	.002	.015	-.075/-.014
Treated teeth	<---	BSES	.021	-.101	.133	.830	.003	.021	.830	-.017	.257	.062	-.101/.133
B father education	<---	BSES	.497	.318	.623	.003	.497**	.497**				.075	.318/.623
B mother education	<---	BSES	.665	.530	.789	.003	.665**	.665**				.065	.530/.789
B mother job	<---	BSES	.481	.377	.658	.000	.481**	.481**	.000			.066	.377/.658
B family income	<---	BSES	.413	.267	.575	.001	.413**	.413**	.001			.078	.267/.575
Birth outcomes	<---	MCHCs	.159	.040	.304	.012	.159*	.159*	.012			.068	.040/.304

Parameter			Estimate	Lower	Upper	P	Total effect	Direct effect	P/direct	Indirect effect	P/indirect	Bootstrap-SE	BC 95% CI
Birth weight	<---	MCHCs					.102			.102*	.018	.052	.012/.212
Gestational age	<---	MCHCs					.137			.137*	.019	.058	.026/.249
Birth order	<---	MCHCs					.032			.032*	.010	.020	.005/.092
EDD	<---	MCHCs					-.002			-.002	.593	.008	-.024/.009
pufa	<---	MCHCs					.002			.002	.768	.009	-.019/.020
Dentine caries	<---	MCHCs					-.012			-.012*	.044	.010	-.042/000
Dental pain	<---	MCHCs					-.002			-.002	.059	.002	-.008/.000
Enamel caries	<---	MCHCs					.008			.008	.169	.008	-.004/.031
EDD	<---	Birth outcomes	-.014	-.140	.054	.735	-.014	-.014	.735			.050	-.140/.054
Plaque	<---	Birth outcomes					-.001			-.001	.622	.003	-.010/.004
Treated teeth	<---	Birth outcomes				.	-.001			-.001	475	.005	-.003/.015
Dentine caries	<---	Birth outcomes	-.077	-.169	.008	.072	-.076	-.077	.072	.001	.705	.004	-.169/.008
Enamel caries	<---	Birth outcomes	.048	-.046	.128	.284	.048	.048	.284			.003	-.046/.128
Dental pain	<---	Birth outcomes				.	-.011			-.011	082	.009	-.037/.001
pufa	<---	Birth outcomes	.010	-.145	.092	.959	.010	.010	.959			.057	-.145/.092
Birth order	<---	Birth outcomes	.199	.064	.338	.002	.199**	.199**	.002			.070	.064/.338
Gestational age	<---	Birth outcomes	.860	.544	1.630	.002	.860**	.860**	.002			.252	.544/1.630
Birth weight	<---	Birth outcomes	.642	.316	.932	.004	.642**	.642**	.004			.184	.316/.932
Enamel caries	<---	EDD	.000	-.075	.105	.952	.005	.000	.952	.005	.065	.045	-.075/.105
Dentine caries	<---	EDD	-.090	-.146	-.030	.002	-.069**	-.090**	.002	.021	.090	.029	-.146/-.030
pufa	<---	EDD	-.032	-.087	.067	.528	-.033	-.032	.528	-.001	.687	.039	-.087/.067
Treated teeth	<---	EDD	.085	-.046	.213	.177	.092	.085	.177	.007	.052	.062/.005	-.046/.213
Dental pain	<---	EDD					-.014			-.014	.062	.062	-.033/.017
Plaque	<---	EDD	.058	-.017	.110	.098	.058	.058	.098			.030	-.017/.110
Dentine caries	<---	Breastfeeding	.026	-.050	.113	.489	.026	.026	.489			.042	-.050/.113
pufa	<---	Breastfeeding	.019	-.071	.117	.683	.019	.019	.683			.047	-.071/.117
Treated teeth	<---	Brest feeding	-.011	-.085	.081	.894	-.011	-.011	.894			.043	-.085/.081
Enamel caries	<---	Brest feeding	-.019	-.100	.082	.756	-.019	-.019	.756			.046	-.100/.082
Dental pain	<---	Breastfeeding					.005			.005	.412	.008	-.008/.023
Child OHPs	<--	Supervised TB	.025	-.070	.118	.592	.025	.025	.592			.046	-.070/.118
Child TB	<---	Supervised TB					.006			.006	.507	.011	-.015/.032
Child flossing	<---	Supervised TB					.012			.012	.565	.022	-.035/.056
Child MW	<---	Supervised TB					.021			.021	.584	.038	-.056/.098
Child sugar	<---	Supervised TB					-.005			-.005	.482	.009	-.026/.012
Plaque	<---	Supervised TB	-.011	-.103	.087	.825	-.011	-.011	.825			.048	-.103/.087
Enamel caries	<---	Supervised TB	-.061	-.157	.039	.229	-.060	-.061	.229			.051	-.157/.039
Dentine caries	<---	Supervised TB	-.061	-.153	.024	.172	-.066	-.061	.172	-.005	.807	.045	-.153/.024
pufa	<---	Supervised TB	-.041	-.146	.045	.331	-.038	-.041	.331	.002	.468	.047	-.146/.045
Treated teeth	<---	Supervised TB	-.063	-.160	.049	.229	-.063	-.063	.229	-.001	.882	.051	-.160/.049

Parameter			Estimate	Lower	Upper	P	Total effect	Direct effect	P/direct	Indirect effect	P/indirect	Bootstrap-SE	BC 95% CI
Dental pain	<---	Supervised TB					-.012			-.012	.129	.009	-.033/.001
MOHPs	<---	CSES	-.037	-.181	.114	.585	-.037	-.037	.585			.074	-.181/.114
Mother TB	<---	CSES					-.008					.016	-.040/.022
Mother MW	<---	CSES					-.028					.058	-.149/.079
Mother flossing	<---	CSES					-.011					.023	-.056/.036
Parent's characteristics	<---	CSES	.444	.167	.733	.006	.444**	.444**	.006			.150	.167/.733
Mother academic involvement	<---	CSES					.153					.099	.042/.401
Father parenting S	<---	CSES					.234					.067	.109/.358
Mother parenting S	<---	CSES					.297					.074	.153/.438
Child OHPs	<---	CSES	-.109	-.284	.129	.238	-.197	-.109	.238			.112	-.284/.129
Child TB	<---	CSES					-.046					.019	-.090/-.015
Child flossing	<---	CSES					-.095					.037	-.175/-.032
Child MW	<---	CSES					-.166					.058	-.281/-.049
Child sugar	<---	CSES					.036					.019	-.026/.085
Plaque	<---	CSES					-.004			-0.004	.690	.013	-.038/.018
pufa	<---	CSES					-.018					.014	-.035/.002
Dentine caries	<---	CSES					.005					.012	-.016/.038
Enamel caries	<---	CSES					-.010					.013	-.046/.008
Treated teeth	<---	CSES					-.006					.012	-.035/.014
C mother education	<---	CSES	.645	.521	.770	.002	.645**	.645**	.002			.064	.521/.770
C father education	<---	CSES	.470	.323	.596	.003	.470**	.470**	.003			.071	.323/.596
C family income	<---	CSES	.464	.333	.607	.001	.464**	.464**	.001			.070	.333/.607
Child OHPs	<---	Parent's characteristics	-.132	-.381	.082	.258	-.132	-.132	.258			.129	-.381/.082
Child TB	<---	Parent's characteristics					-.031			-.031	.507	.032	-.104/.015
Child flossing	<---	Parent's characteristics					-.064			-.064	.565	.065	-.201/.038
Child MW	<---	Parent's characteristics					-.112			-.112	.584	.109	-.315/.072
Child sugar	<---	Parent's characteristics					.025			.025	.482	.028	-.012/.096
Plaque	<---	Parent's characteristics					-.003			-.003	.561	.012	-.041/.014
Treated teeth	<---	Parent's characteristics					-.004			-.004	.425	.012	-.035/.010
pufa	<---	Parent's characteristics					-.012			-.012	.213	.017	-.063/.005
Dentine caries	<---	Parent's characteristics					.003			.003	.449	.011	-.010/.041

Parameter			Estimate	Lower	Upper	P	Total effect	Direct effect	P/direct	Indirect effect	P/indirect	Bootstrap-SE	BC 95% CI
Enamel caries	<---	Parent's characteristics				.	-.007			-.007	236	.012	-.049/.006
Mother parenting S	<---	Parent's characteristics	.669	.318	.907	.002	.669**	.669**	.002			.154	.318/.907
Father parenting S	<---	Parent's characteristics	.527	.225	.699	.001	.527**	.527**	.001			.127	.225/.699
Mother academic involvement	<---	Parent's characteristics	.345	.176	.579	.003	.345**	.345**	.003			.103	.176/.579
Plaque	<---	MOHPs					.015			.015	.719	.046	-.076/.111
Treated teeth	<---	MOHPs					.025			.025	.611	.043	-.054/.109
pufa	<---	MOHPS					.070			.070	.119	.049	-.016/.178
Dentine caries	<---	MOHPs					-.020			-.020	.631	.043	-.109/..060
Dental pain	<---	MOHPs					.001			.001	.948	.009	-.017/.018
Enamel caries	<---	MOHPs					.041			.041	.257	.043	-.037/.133
Child OHPs	<---	MOHPs	.784	.560	.940	.003	.784**	.784**	.003			.089	.560/.940
Child TB	<---	MOHPs					.183			.183**	.001	.057	.083/.304
Child flossing	<---	MOHPs					.377			.377**	.003	.082	.186/.534
Child MW	<---	MOHPs					.662			.662**	.003	.085	.456/.810
Child sugar	<---	MOHPs					-.148			-.148**	.002	.046	-.243/-.060
Mother flossing	<---	MOHPs	.302	.146	.425	.004	.302**	.302**	.004			.069	.146/.425
Mother MW	<---	MOHPs	.778	.641	1.028	.002	.778**	.778**	.002			.100	.641/1.028
Mother TB	<---	MOHPs	.206	.081	.308	.003	.206**	.206**	.003			.057	.081/.308
Plaque	<---	Child OHPs	.020	-.099	.136	.735	.020	.020	.735			.058	-.099/.136
Treated teeth	<---	Child OHPs	.030	-.071	.134	.653	.032	.030	.653	.002	.604	.054	-.011/.021
pufa	<---	Child OHPs	.090	-.024	.206	.138	.089	.090	.138			.060	-.024/.206
Dentine caries	<---	Child OHPs	-.033	-.138	.058	.454	-.025	-.033	.454	.007	.731	.050	-.138/.058
Dentine caries	<---	Child OHPs	.050	-.049	.170	.287	.052	.050	.287	.002	.568	.056	-.049/.170
Dental pain	<---	Child OHPs					.001			.001	.952	.011	-.022/.023
Child sugar	<---	Child OHPs	-.189	-.292	-.070	.003	-.189**	-.189**	.003			.055	-.292/-.070
Child MW	<---	Child OHPs	.845	.724	.967	.002	.845**	.845**	.002			.059	.724/.967
Child sugar	<---	Child OHPs	.481	.320	.608	.003	.481**	.481**	.003			.072	.320/.608
Child TB	<---	Child OHPs	.233	.110	.353	.002	.233**	.233**	.002			.061	.110/.353
pufa	<---	Plaque	-.011	-.111	.084	.803	-.011	-.011	.803			.051	-.111/.084
Treated teeth	<---	Plaque	.116	.019	.192	.013	.116*	.116*	.013			.044	.019 /.192
Dentine caries	<---	Plaque	.370	.293	.442	.002	.370**	.370**	.002			.038	.293/.442
Enamel caries	<---	Plaque	.094	.006	.181	.033	.094*	.094*	.033			.044	.006/.181
Dental pain	<---	Plaque					.055**			.055	.002	.020	.019/.098
Dental pain	<---	Dentine caries	.155	.063	.244	.002		.155**	.002			.047	.063/.244
Dental pain	<---	pufa	.061	-.031	.155	.203	.061	.061	.203			.047	.000/.000

Parameter			Estimate	Lower	Upper	P	Total effect	Direct effect	P/direct	Indirect effect	P/indirect	Bootstrap-SE	BC 95% CI
Dental pain	<---	Treated teeth	-.011	-.100	.078	.791	-.011	-.011	.791			.045	-.100/.078
Absent days	<---	BSES					-.025			-.025	.433	.039	-.118/.035
Absent days	<---	CSES					-.022					.042	-.131/.030
Absent days	<---	MCHCs					.001			.001	.896	.008	-.016/.016
Absent days	<---	Supervised TB					.001			.001		.006	-.011/.014
Absent days	<---	Birth outcomes					.005	.006	.946			.048	-.014/.008
Absent days	<---	MOHPS					-.002			-.002	.482	.005	-.014.006
Absent days	<---	Child OHPs					-.003			-.003	.522	.006	-.018/.009
Absent days	<---	Dental pain	-.045	-.122	.034	.293		-.045	.293			.041	-.122/.034
Absent days	<---	Parent's characteristics	-.051	-.202	.078	.497	-.051	-.051	.497			.075	-.202/.078
Absent days	<---	Enamel caries	-.017	-.082	.066	.678		-.017	.678			.037	-.082/.066
Absent days	<---	Dentine caries	.013	-.069	.098	.753		.013	.753			.042	-.069/.098
Absent days	<---	pufa	-.018	-.096	.066	.620	-.021	-.018	.620			.042	-.096/.066
Absent days	<---	Treated teeth	.000	-.108	.115	.949		.000	.949	.001	.499	.057	-.108/.115
Absent days	<---	Birth outcomes	.006	-.103	.090	.946		.006	.946	-.002	.433	.056	-.103/.090
School performance	<---	Absent days	-.074	-.162	.013	.082	-.074	-.074	.082			.045	-.162/.013
School performance	<---	Dental pain	-.010	-.103	.080	.848	-.007	-.010	.848	.003	.173	.047	-.103/.080
School performance	<---	Parent's characteristics	.213	.060	.376	.004	.216**	.213**	.004	.003	.497	.081	.060/.376
School performance	<---	Enamel caries	.024	-.052	.103	.496	.025	.024	.496	.001	.422	.040	-.052/.103
School performance	<---	Dentine caries	-.154	-.258	-.055	.006	-.156**	-.154**	.006	-.002	.736	.052	-.258/-.055
School performance	<---	pufa	-.018	-.110	.074	.751	-.017	-.018	.751	.001	.743	.047	-.110/.074
School performance	<---	Plaque					-.043			-.043*	.026	.021	-.089/
School performance	<---	Treated teeth	.102	.031	.174	.011	.102*	.102*	.011			.038	.031/.174
School performance	<---	EDD				.	.021			.021*	033	.010	.002/.044
School performance	<---	Birth outcomes	-.018	-.128	.094	.728	-.006	-.018	.728	-.012	.142	.010	-.128/.094
School performance		CSES					.095					.066	.016/.255
School performance	<---	BSES					.137			.137**	.004	.062	.050/.281
School performance	<---	MCHCs					-.001			-.001	.817	.009	-.023/.014
School performance	<---	Supervised TB					.003			.003	.711	.011	-.015/.027
School performance	<---	MOHPs					.006			.006	.473	.009	-.011/.026
School performance	<---	Child OHPs					.007			.007	.470	.012	-.014/.032
School performance	<---	Breastfeeding					-.006			-.006	.412	.008	-.023/.009

The full model from AMOS