Obesity and Dental Caries in Children in Scotland: Trends, Inequalities, and the Reach and Impact of the Childsmile Programme

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Abstract

Background

Childhood dental caries and obesity are global public health non-communicable disease challenges. Despite recent improvements, caries experience remains highly prevalent among Scotland's children with wide inequalities, with one half of children from the poorest areas suffer caries by 5-years-old, with extraction of teeth under general anaesthetic being the most common reason children are electively admitted to hospital. Ten percent of Primary 1 children (typically aged 5-years-old) in Scotland have obesity, with higher rates seen in more deprived areas. Caries and obesity share socioeconomic determinants that underpin these large inequalities, with sugar consumption being one of the key causative factors for both conditions. Both conditions are among the first observable outcomes of poor health in the early years and markers of poor health in adulthood. There may be opportunities within the Childsmile programme (Scotland's national oral health improvement programme) to intervene to tackle common risk factors of caries and obesity, however, as of yet it is unclear what relationship exists between the two conditions in childhood. Furthermore, it is unknown to what extent the problem is for children with co-existing caries and obesity and if inequalities exist in this group.

Aims

To examine the interrelationship between obesity and dental caries in Primary 1 schoolchildren in Scotland over time (2011 to 2018). To measure socioeconomic inequalities in childhood obesity and dental caries, separately and together. To explore the reach and impact of the national child oral health improvement programme for Scotland, Childsmile, in preventing childhood obesity and caries.

Methods

Population-level repeated cross-sectional data linkage and secondary analysis of pseudonymised, individual-level National Health Service data on caries experience and obesity, from multiple cohorts of Primary 1 children in Scotland, between 2011/12 and 2017/18 and a measure of area-based deprivation (Scottish Index of Multiple Deprivation) from the child's home postcode have been used. The thesis compares access to school-based dental inspections; primary care prevention; and Childsmile interventions between children with the co-existing conditions and their peers with neither condition adjusted by area-based socioeconomic deprivation, school year, sex, and age.

Results

The prevalence of caries experience in Primary 1 children has been reducing overall in Scotland from 32.9% in 2011/12 to 29.5% in 2017/18, although absolute inequalities remain large and consistent, with the difference in prevalence between the most and least deprived being 37.5% in 2011/12 and 34.1% in 2017/18. The prevalence of obesity has plateaued overall (9.8% in 2011/12; 10.1% in 2017/18), however, this has masked a small but steady rise is prevalence in the 10% most deprived areas (11.8% in 2011/12; 12.9% in 2017/18). Prevalence of co-existing obesity and caries was 3.4% over the study period with large, persistent inequalities. In children from the 20% most deprived areas, 5.6% had co-existing conditions in contrast with 1.4% from the 20% least deprived areas (adjusted odds ratio=6.63; 95% confidence interval=[6.16 to 7.14]). Children with co-existing conditions were less likely to attend primary dental-care than their peers, and in those who attended dental practice, were less likely to receive prevention (fluoride varnish, toothbrushing instruction, or dietary advice). Childsmile nursery-supervised toothbrushing access among children with co-existing conditions was similar to children with neither condition and children with co-existing conditions were more likely to be

referred to a Childsmile Dental Health Support Worker, but less likely to be contacted by a DHSW and have the intervention delivered.

Conclusions

Inequalities have been identified in young children with caries experience, obesity, and co-existing caries and obesity in Scotland, compounded by reduced and variable access to preventive dental services in children with co-existing conditions. Further efforts are needed to develop and improve preventive care, adopting a common risk factor approach, and the pathways for children with co-existing caries and obesity and integrate oral health to wider healthcare systems for these children to mitigate against health inequalities. Upstream, midstream, and downstream interventions must be considered to maximise the impact and reduce prevalence and inequalities.

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To Granda

I didn't know you, but you knew me

Author's Declaration

Parts of the research work, or work during the PhD, included in this thesis have been published or presented in international and national conferences.

Publications

Trends in socioeconomic inequalities in underweight and obesity in 5-year-old children, 2011-2018: a population-based, repeated cross-sectional study
Stewart, R and Reilly, JJ and Hughes, A and Kelly, LA and Conway, DI and Young, D and Sherriff, A
BMJ Open, 2021

Child oral health and preventive dental service access among children with intellectual disabilities, autism and other educational additional support needs: A population-based record linkage cohort study
Sherriff, A and Stewart, R and Macpherson, LMD and Kidd, JBR and Henderson, A and Cairns, D and Conway, DI
Community Dentistry and Oral Epidemiology, 2022

National Conferences

Glasgow Paediatric Research Day, 5nd November 2021, Glasgow, UK
Oral presentation title: Obesity and dental caries in children in Scotland: population-based data linkage analysis

Scottish Oral Health Research Collaboration, 20th November 2022, Online
Oral presentation title: Obesity and dental caries in children in Scotland: population-based data linkage analysis

International Conferences

International Centre for Oral Health Inequalities Research and Policy, 18th February 2020, Online

Oral presentation title: Obesity and dental caries in children in Scotland: trends, inequalities and the impact of the Childsmile programme

25th Congress of the European Association of Dental Public Health, 2nd to 4th September 2021, Online

Oral presentation title: Obesity and dental caries in children in Scotland: population-based data linkage analysis

101st General Session and Exhibition of the International Association for Dental Research, 21st to 24th June 2023, Bogotá, Colombia

Obesity and dental caries in children in Scotland: population-based data linkage analysis

27th Congress of the European Association of Dental Public Health, 14th to 16th September 2023, Riga, Latvia

Exploring Childsmiles Role in Reaching Children with Co-existing Caries and Obesity

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

Ryan Stewart

Glasgow - November 2023

Abbreviations

ALSPAC Avon Longitudinal Study of Parents and Children

aOR adjusted odds ratio

aORs adjusted odds ratios

aRR adjusted risk ratio

aRRs adjusted risk ratios

BASCD British Association for the Study of Community Dentistry

BMI body mass index

CHI Community Health Index

CHSP Child Health Surveillance Programme

CHSP 6-8wk Child Health Surveillance Programme 6 to 8 weeks

CHSP-S Child Health Systems Programme - School

CI confidence interval

CIs confidence intervals

CSV Comma-separated Values

DEXA Dual energy X-ray absorptiometry

Df Degrees of Freedom

DHSW Dental Health Support Worker

DMFS Decayed, Missing, Filled Surfaces

DMFT Decayed, Missing, Filled Tooth (permanent dentition)

dmft decayed, missing, filled tooth (primary dentition)

EDDNs Extended Duty Dental Nurses

eDRIS electronic Data Research and Innovation Service

EPCC Edinburgh Parallel Computing Centre

FVA Fluoride Varnish Application

GDPR General Data Protection Regulation

GDS General Dental Services

HIC Health Informatics Centre

ICDAS International Caries Detection and Assessment System

IMD Index of Multiple Deprivation

ISD Information Services Division

IT Information Technology

LD Least Deprived

MD Most Deprived

MI Motivational Interviewing

MIDAS Management Information & Dental Account System

NCDs non-communicable diseases

NDIP National Dental Inspection Programme

NHS National Health Service

NRS National Records Scotland

NSS National Services Scotland

NSTB Nursery Supervised Toothbrushing

OR odds ratio

ORs odds ratios

PBPP Public Benefit & Privacy Panel

PDS Public Dental Services

PHS Public Health Scotland

PSD Practitioner Services Division

RII Relative Index of Inequality

RQ research question

RR risk ratio

RRs risk ratios

SDR Statement of Dental Remuneration

SDS Standard Deviation Scores

SFTP Secure File Transfer Protocol

SII Slope Index of Inequality

SIMD Scottish Index of Multiple Deprivation

SSBs sugar sweetened beverages

UI uncertainty interval

UK United Kingdom

USA United States of America

VAT Value-Added Tax

VPN Virtual Private Network

WC Waist circumference

WHO World Health Organization

Chapter 1

Introduction

Untreated dental caries (tooth decay) in permanent teeth is the most common health condition according to the Global Burden of Disease 2019. The neglect of dental care and health is of concern, given that roughly half of the world's population is affected by some form of oral disease (Kassebaum et al., 2017). Most recent estimates state 3.5 billion people worldwide suffer from oral diseases, with 514 million children suffering from dental caries in primary dentition with oral diseases disproportionally affecting socioeconomically deprived individuals (WHO, 2022). "The mouth really is a marker of social position and future disease risk" were the words from Richard Watt, Professor and Chair of Dental Public Health at University College London, in a profile from The Lancet (Davies, 2019). Oral diseases are driven by the social and commercial determinants of health, but in theory with the right policies, preventive services/programmes and resources these diseases can be prevented.

1.1 Literature Search Strategy

Ovid Medline and Embase were searched for relevant literature using MeSH (Medical Subject Headings) terms such as 'children', 'Dietary sugars', 'Health Behaviour', 'Health Promotion', 'Dental Caries', 'Oral Health', 'Obesity', and 'Body Weight'. Terms were used in different combinations relevant to specific topic of interest. A full search strategy can be found in Appendix A. In addition, PubMed was also searched.

Bibliographies of relevant papers were hand searched to identify additional papers that may have initially been missed. Google and other sites, such as OpenGrey, were used to identify any grey literature and government policy documents. Further discussions were held in person with other Childsmile programme staff to identify reports and audits that were both publicly and not publicly available. Findings for the search are reported through Chapter 1.

1.2 Non-communicable Diseases

Non-communicable diseases (NCDs) are likely to have a long duration and are a consequence of a combination of genetic, physiological, behavioural, environmental, social, and economical factors. NCDs are responsible for 71% (41 million) of the worlds deaths annually with 15 million of these classed as "premature" (under 70-years-old). This makes NCDs the leading cause of deaths in the world. The majority of deaths, including premature deaths, occur in low- and- middle-income countries, where exposure to harmful products, such as tobacco, is higher (WHO, 2018a). Cardiovascular diseases, cancers, respiratory diseases and diabetes account for circa 80% of deaths (WHO, 2018a). While NCDs are driven by socioeconomic factors, the rise in NCDs is predicted to also impact back on poverty in low-income countries as the cost to treat NCDs deplete household resources (WHO, 2018a). Worldwide cumulative economic loss has been estimated at US$ 7 trillion between 2013 and 2028 due to premature deaths caused by NCDs (WHO, 2013). Environmental factors faced in childhood often influence occurrence of NCDs in adulthood. Children who experience caries and obesity at a young age are at an increased risk of developing other NCDs and health conditions later in life, such as cardiovascular diseases, diabetes, and acute and chronic infections (Botelho et al., 2022; Weihrauch-Blüher et al., 2018).

1.3 Dental Caries

Dental caries, also known as dental or tooth decay, happens when bacteria in the dental plaque biofilm metabolize sugars which produces acids that demineralise the enamel and dentine layers of a tooth. Children and adolescents are most at risk of caries, however, the disease is progressive, so most cases are found in adults (WHO, 2017). An estimated 5-10% of high-income countries health care budgets are spent on treating caries, making it one of the most expensive diseases to treat (WHO, 2017). The direct costs (i.e., costs completely contributed to the service) of caries worldwide in 2010 was an estimated US$ 298 billion, with a further US$ 144 billion on indirect costs (e.g., attributed economic losses) (WHO, 2017), making caries the third highest health expenditure in Europe after diabetes and cardiovascular disease (Peres et al., 2019).

1.3.1 Measuring dental caries experience

Dental caries experience can be measured using the Decayed, Missing, Filled Tooth (permanent dentition) (upper case DMFT) Index or decayed, missing, filled tooth (primary dentition) (lower case dmft). This measure has been used for nearly 80 years and was originally intended to describe both dental status and treatment needed in primary school children (Larmas, 2010). The World Health Organization (WHO) has standardised the DMFT Index for use in surveys to describe past and present caries experience in both adults and children (Larmas, 2010). Unerupted teeth, congenitally missing teeth, or supernumerary teeth, teeth assumed to be removed for reasons other than dental caries are not counted for calculation of the DMFT/dmft. When a carious lesion is present, the tooth is marked as a 'D'. A tooth that has been extracted is marked as an 'M' and with an 'F' if there is a permanent or temporary filling present in the tooth (Broadbent et al., 2005). If every tooth was affected by caries, a maximum score of 32 would be recorded for permanent dentition and 20 for primary dentition. Obvious caries experience is when the disease process clinically appears to have penetrated the dentine of the tooth. This is recognised internationally as caries at the D_3/d_3 level. An adult/child with no obvious caries experience has $D_3MFT/d_3mft=0$. This definition of caries is in accordance with the British Association for the Study of Community Dentistry (BASCD) (BASCD, 2023) guidelines and international epidemiological conventions. This is different from diagnostic levels used by many dentists during a dental clinical examinations (Macpherson et al., 2018). In addition to the severity of caries measured by DMFT/dmft, in dental health surveys, the prevalence of caries experience is measured by the percentage with obvious caries experience (percentage $D_3MFT/d_3mft>0$).

An alternative to the D_3MFT/d_3mft is the International Caries Detection and Assessment System (ICDAS) (ICDAS, 2023) which was developed to obtain a more detailed level of caries diagnosis. This is an evidence-based system for detection and classification of caries in dental education, clinical practice, dental research and dental public health. ICDAS has three levels of diagnosis full, modified, and merged for varying degrees of detail. The 'full' ICDAS ranges from 0 to 6, where 0 is no evidence of caries and 6 for extensive distinct cavity with visible dentine. The primary requirement for applying the ICDAS system is that the teeth are clean and dry. A dry tooth is essential for detecting non-cavitated lesions because water can clog the pores in carious teeth, amongst other reasons such as, water can obscure detection of early white spot lesions (Gugnani et al., 2011). There are some limitations with the usage in dental epidemiology surveys. Even though it can report caries at the enamel as well as dentine level, it usually reports at the dentinal level which, as per DMFT, is a recognised level of clinical significance and severity. In addition, due to the cleaning and drying of the teeth, measuring ICDAS on a large scale can become difficult, time consuming and costly, so DMFT/dmft is generally used in all large epidemiological surveys in the United Kingdom (UK), such as the detailed inspection in the National Dental Inspection Programme (NDIP) used in Scotland to measure caries in school children (Macpherson et al., 2018) or the National Dental Epidemiology Programme in England (Office for Health Improvement & Disparities, 2023). In the case of NDIP, a basic inspection at a national level is conducted to measure caries experience at the dentine level as a proxy for dmft.

1.3.2 Descriptive epidemiology of dental caries in children globally

It was estimated by the Global Burden of Diseases in 2019 that the total number of people with new cases untreated caries in permanent teeth was 3.09 billion (95% uncertainty interval (UI): 2.76bn to 3.39bn), and a further 2.03 billion (95% UI: 1.77bn to 2.33bn) already prevalent cases (Qin et al., 2022). There were 1.15bn (95% UI: 0.79bn to 1.52bn) new cases of caries in deciduous teeth adding to the already exists 0.52bn (95% UI: 0.41bn to 0.63bn) existing cases (Qin et al., 2022). These total population estimates have increased greatly since 1990, however, demographic changes (e.g., population growth and ageing) are likely to have played a large role in this increase. The report notes some limitations were that data were limited in some geographical areas and so values were estimated instead of measured (Qin et al., 2022). In 1990, the population was estimated at 5.29 billion rising to 7.74 billion in 2019 (The World Bank, 2023).

In 1980, the WHO Oral Health Collaborating Centre in Malmo estimated the global weighted mean (weighted for population size of the country) DMFT for 12-year-olds was 2.43, however, it is unknown how many countries provided data for this (Malmo University, 2020). By 2001, the estimate was at 1.74 for 183 countries, rising up 1.86 (209 countries) in 2015 and then 1.90 (205 countries) in 2018 (Malmo University, 2020). Out of the WHO Regions (WHO, 2023b), South-East Asia region had the highest mean DMFT in 2015, scoring 2.97. The Americas had the second highest mean (2.08), whereas, Western Pacific had the lowest at 1.05, followed closely by Africa at 1.06. In Europe the mean DMFT for 12-year-old children was 1.81 (Malmo University, 2020). Traditionally, it was observed that caries prevalence was higher in higher income countries (Petersen et al., 2005), which was associated with access to foods with high sugar content. However, caries is rising in low- and- middle-income countries linked to both economic growth and changes in diets. This transitional change is observed across NCDs.

1.3.3 Descriptive epidemiology of dental caries in children United Kingdom

The Childrens Dental Health Survey collects data every 10 years for countries in the UK (excluding Scotland since 2013). The surveys included a dental examination and a self-completion questionnaire completed by the parent or guardian of the child. The 2003 version of the survey was opt-out consent for 5-year-olds meaning all children received an inspection as standard unless consent was withdrawn, however, in 2013 the survey required written opt-in consent from the parents/carers and the child could also opt-out on the day. The 2013 survey had an initial sample size of 5,069 5-year-old children. After removing non-participating schools and pupils which were ineligible for other reasons 2,193 from England, 800 from Wales, and 674 from Northern Ireland were selected for sampling. After the removal of children due to reasons mainly from lack of consent, a total of 2,549 observations were collected. The latest survey from 2013 found 31% of 5-year-old children had obvious caries experience in their deciduous teeth (Children's Dental Health Survey, 2015). The 2003 survey reported 41% of 5-year-old children had obvious caries experience. The 2003 survey examined 10,381 children from the UK (including Scotland). Results solely from Scotland found prevalence of caries at 55% for the same age group in 2003 and 33% in 2012 (no data published in 2013) (Macpherson et al., 2020). It is difficult to directly compare the results from the 2003 and 2013 reports due to Scotland being included in the first and the change in consent, however it appears that the prevalence of caries has reduced between 2003 and 2013.

1.3.4 Descriptive epidemiology of dental caries in children Scotland

The National Dental Inspection Programme (NDIP) is a statutory programme, based on statutory requirement for children to have dental examinations, that provides dental inspections to all children attending mainstream and some special schools in Scotland (UK Government, 1978, 1980). The programme is designed to assess children's oral health and identify any dental problems they may have, with the aim of preventing future dental issues and ensuring that children receive any necessary follow-up care with the outcome of the inspection fed back to the parents/carers of the child (UK Government, 1978, 1980). The NDIP is an important preventive dental service, helping to ensure that children receive the care they need to maintain good oral health. By identifying and treating dental issues early, the programme can help to prevent more serious dental problems from developing later on. Overall, the NDIP plays an important role in promoting oral health and improving the health and well-being of children in Scotland. The NDIP publishes data annually on children's oral health in Scotland, with a basic dental inspection on both Primary 1 (typically aged 5-years-old) and Primary 7 (typically aged 11-years-old) children attending primary schools being conducted each year. The basic inspection is performed within the schools on all children attending and accepting the dental inspection. Consent is on an opt-out basis, either from the parent/carer of the child or the child themselves on the day.

Additionally, the programme also involves a more detailed inspection of the teeth on a sample of children in the two age groups from local authorities on alternate years. The NDIP collects data from all 14 regional National Health Service (NHS) Health Boards in Scotland. Each NHS Health Board is required to identify the number of schools required to obtain a representative sample of their size of population per age group for the detailed inspection. Once the required number is found, the schools are stratified by Scottish Index of Multiple Deprivation to avoid sample skew. Whole classes are randomly selected within each health board, to simplify the process, until the quoted number of observations is obtained. From an estimated total of 61,715 Primary 1 children in Scotland in the school year 2017/18, 16,814 (27.2%) of these were selected for a detailed inspection.

The 2018 NDIP report (for the school year 2017/18) showed that 28.9% of Primary 1 children in Scotland had obvious caries experience, i.e., $d_3$mft>0, a 26.5% improvement from the 55.4% prevalence when the NDIP began collecting data in 2003 (Macpherson et al., 2018). Since the introduction of the NDIP in 2003, there has been an improvement in percentage of Primary 1 children with obvious caries experience in every report. From the programme 2017/18, 23% of Primary 1 children in Scotland had untreated caries. It was also reported that the mean $d_3$mft score for primary school children in Scotland was 1.14, which is a greater than 50% reduction since 2003. However, of those that had a $d_3$mft>0, the mean score was 3.94, which is only a 20% ($d_3$mft 1.04) improvement since 2003. Although overall caries experience is improving within Scotland, of those that do develop caries, the level of caries is not improving as steadily. Since the national introduction of the Childsmile programme (Section 1.9) in 2011, caries prevalence has reduced from 33.0% to 28.9%, with a steady reduction year on year (Macpherson et al., 2018).

1.3.5 Risk factors of dental caries

As defined in a dictionary of epidemiology (Feinleib, 2001), risk factors are "an aspect of personal behaviour or lifestyle, an environmental exposure, or an inborn or inherited characteristic, that, on the basis of epidemiological evidence, is known to be associated with health-related condition(s) considered important to prevent". Risk factors for dental caries have been extensively researched systematically by Harris et al. (2004)

and Kirthiga et al. (2019). Early work on risk factors was conducted by Harris et al. (2004). This systematic review was conducted on risk factors for dental caries in deciduous teeth of children aged six years and under. Due to the large body of literature this review was limited to studies found through computerised searching, with only published material being within the scope. Only the PubMed database was used to gather papers, searching for studies between 1996 and April 2002. Initially 1,029 papers were identified but only 260 papers were marked as potentially meeting the inclusion criteria, with the rest being excluded for either being reviews, "subjects too old", or "outcome of the study was not caries" (Harris et al., 2004). After a more in-depth check of full papers, further exclusion of papers resulted in a total of 73 studies for the review. These papers were assessed for bias. For cross sectional and case control studies, four questions on the bias of paper (e.g., selection bias acceptable?) were set out. If the answer was "yes", the paper was given a score of one, with a maximum of 4 if all questions were positively answered. For cohort studies there was an additional question, giving a maximum score of 5. Interventional studies were tested with another set of questions deemed appropriate for interventional studies. This had a maximum score of 5. Only 1 paper scored 0 whereas 8 studies scored 1, 16 scored 2, 32 scored 3, and 15 studies and one study scored 4 and 5, respectively. Harris et al. (2004) found 106 significant risk factors related to the prevalence or incidence of caries. The review splits the risk factors into 6 categories: sociodemographic, dietary, oral hygiene, factors related to breast/bottle feeding, oral bacteria flora, and other factors (such as child time sleeping and parents dental health). The review highlighted acquiring *Streptococcus mutans* (Section 1.3.5.5) at a young age, less than daily toothbrushing, and a high cariogenic diet as important risk factors, but notes that these factors may interact and create a balance of positive and negative behaviours to control the risk of caries.

The updated systematic review by Kirthiga et al. (2019), which cites Harris et al. (2004), aimed to assess current evidence for association between various risk factors and the prevalence or incidence of early childhood caries of children from birth to six years old. Using a search strategy which scanned Medline, Embase, Cochrane Central Database, Cochrane Oral Health Groups Specialised Register, CINAHL, LILACS, and IndMED for studies initially up to June 2016, then update to January 2019. Hand searching was completed for studies published between 2005 to January 2019. Kirthiga et al.

(2019) made use of Harris et al. (2004) earlier work, using the hand search completed in the earlier review. Any study which focused on children up to 6-years-old, except those with special health care needs, of which early childhood caries was the outcome were included in the review. No method of assessment for the outcome was specified. The computerised and hand search found 7,034 studies, which reduced to 5,819 once duplicates were removed. After removing studies which had an improper study design or outcome, 209 studies were assessed completely with 120 studies removed at this stage for unsuitable study designs including reviews, cross-sectional or interventional based studies. Eighty-nine studies, giving 1,352,097 participants, were deemed suitable for this review. Kirthiga et al. (2019) found 123 significant risk factors associated with early childhood caries. These risk factors were split into the same six subgroups by Harris et al. (2004).

The collective findings of these two reviews are reported below in Sections 1.3.5.1 to 1.3.5.6.

1.3.5.1 Sociodemographic risk factors

Sociodemographic risk factors are those which are based on a persons characteristics, e.g., socioeconomic status, gender, or ethnicity. Both reviews cited in the previous section found that sociodemographic risk factors of increased caries included, but not limited to, the gender of the child (males more at risk), low family income, ethnicity (non-Hispanic White and Asian from separate studies), low parental and maternal education, higher number of children per family, low maternal occupation, rural or urban domicile (identified as risk factors in different cohorts), and being first born. In addition, Harris et al. (2004) found that those attending mainstream schools were more likely to have caries in childhood compare to those who attend independent schools. Kirthiga et al. (2019), in addition, identified low socioeconomic status as a risk factor of caries.

1.3.5.2 Dietary risk factors

Dietary risk factors relate to a persons diet, with dietary sugars previously noted as a pivotal factor in the risk of caries experience (Sheiham et al., 2015). Harris et al. (2004) and Kirthiga et al. (2019) both identified high frequency of high sugar foods per day, high number of sugary snacks between meals, no set time for snacks, food before sleeping, cariogenic food consumption, frequency of consumption of sugar-sweetened beverages, and daily sucrose intake were all significant risk factors in a childs risk of caries. Others included low levels of Vitamin D and calcium during the mothers pregnancy (Kirthiga et al., 2019).

The association between caries and sugar intake has long been reported, however, there is a desired need for meaningful research on this association which also addresses the financial conflicts of interest between the sugar industry and research (Kearns et al., 2019). Many research organisations display partnerships with companies who have confectionery brands, yet also sell products to improve oral health. There has been some evidence to suggest that the sugar industry has had some influence on research agendas by using their financial power to push research to focus on their own products (such as toothpaste or sugar-free gum) to help battle caries whilst moving research away from studying product which could cause or increase risk of caries (Fabbri et al., 2018; Odierna et al., 2013). Kearns et al. (2019) has highlighted the need for openness and honesty in regarding the funding and payments from organisations who have a stake in the outcome and to prohibit or end relationships with industry that are only interested in financial gain or saving reputation. This work highlights the important role of "commercial determinants" in oral health (Peres et al., 2019).

1.3.5.3 Oral hygiene risk factors

Oral hygiene risk factors include lack of use of fluoride toothpaste, the age toothbrushing started, if the child has visible plaque, adults not being involved in brushing, and not brushing daily (Harris et al., 2004; Kirthiga et al., 2019). Not having teeth cleaned at bedtime was a risk factor found by Harris et al. (2004). During the night, the mouth stops producing saliva meaning any bacteria left in the mouth can work away at the tooth and cause demineralisation. The NHS recommends brushing your teeth twice a day, making sure one brush is at night before bed, and then one other part of the day (National Health Service, 2020b). Furthermore, T. Walsh et al. (2019) in a systematic review highlighted an increased concentration of fluoride (1,450ppm) slightly reduced the risk of caries experience in the primary dentition compared to lower concentrations (440ppm).

1.3.5.4 Factors related to breast/bottle feeding

Risks of developing caries in childhood begin from birth. Those who are bottle fed instead of breast fed are more likely to develop early childhood caries, with other factors including sleeping with the bottle, nocturnal bottle feeding, feeding to help sleep, formula in bottle at night, feeding associated with nap times, and feeding on demand identified as additional risk factors (Harris et al., 2004; Kirthiga et al., 2019). Even though breast feeding reduces the risk of caries, those who are breast fed for less than 6 months are more likely to develop early childhood caries as well as those who are breast fed longer than 12 months (Kirthiga et al., 2019). Nocturnal breast feeding and using a bottle at night have both been positively associated with childhood caries (Harris et al., 2004; Kirthiga et al., 2019), which goes with the principal of night time brushing from Section 1.3.5.3. Adding sugar to the bottle increases a childs risk of caries (Kirthiga et al., 2019).

1.3.5.5 Oral bacteria

The presence of microbial biofilms on the tooth surface is essential for the development of caries. The *Streptococcus mutans* group of bacteria has been emphasised as playing a role in the caries process. Animal studies have demonstrated the high cariogenicity as these bacteria can produce and tolerate an acidic environment. Consequently, presence of *Streptococcus mutans* (Harris et al., 2004; Kirthiga et al., 2019) and the count of the bacteria (Harris et al., 2004) has been associated with childhood caries. The bacteria Lactobacilli, members of the lactic acid group, are “friendly” bacteria which normally live in the humans digestive, urinary, and genital systems but are also found in some fermented foods. Lactobacilli were treated as the leading candidate in the causation of dental caries prior to the 1950s, until *Streptococcus mutans* took over (Badet et al., 2008). Lactobacilli creates a low pH environment, which they can tolerate, but is inhabitable for other competing microbes. Due to the bacteria lowering the pH when present in the mouth, it has been associated with promoting caries (Harris et al., 2004; Kirthiga et al., 2019). Recent focus has shifted away from single organisms to microbiome, however, research remains limited.

1.3.5.6 Other risk factors

Other risk factors presented in Harris et al. (2004) and Kirthiga et al. (2019) related largely to the mother and father of the child. Risk of caries increases if the mother has herself poor brushing habits (Harris et al., 2004), the mother has high mean decayed teeth (Harris et al., 2004), and parental smoking (Kirthiga et al., 2019). Others include the child going to bed late (Kirthiga et al., 2019) or getting few hours' sleep (Harris et al., 2004), the length of time the child gets to watch television (Harris et al., 2004), if the child used a dummy soother for 2 years or longer (Harris et al., 2004), if the child had a lack of paediatric check-ups (Harris et al., 2004), and low birth weight (Kirthiga et al., 2019).

1.4 Childhood Obesity

The WHO defines obesity as "abnormal or excessive fat accumulation that presents a risk to health", with fat accumulating when a person consistently consumes more calories than they expend through physical activity (WHO, 2021). The term for obesity is used in many different ways, including 'obese', 'with obesity', 'having obesity', 'at risk of obesity', and 'very overweight'. Regardless of the terminology used, the measure is the same in most cases. The author has chosen to use the terminology 'with obesity' to treat the condition as a disease and as such the terminology may be changed from the original version from studies where appropriate (i.e., when the measure is the same). Many countries are facing an urgent and serious challenge of childhood obesity (WHO, 2021). Prevalence of childhood obesity is rising around the world, and while there are suggestions that some rates are plateauing in places such as the USA (Dietz, 2016), there are no countries which have reversed the rise. Children who are at least moderately overweight before puberty have significantly higher chances of type 2 diabetes and cardiovascular disease in midlife (Weihrauch-Blüher et al., 2018). Baird et al. (2005) reviewed 24 studies which "assessed the relationship between infant size or growth during the first two years of life and subsequent obesity". They found that infants who were at the highest end of the distribution for weight or BMI were more likely to develop obesity in adolescence or early adulthood than other infants across the distribution. The review notes that less than half of the studies took confounding factors into account and most studies had a medium level of bias (measured using a checklist approved by the Centre for Reviews and Dissemination (University of York, 2023)).

The Scottish Government tried to estimate the direct costs of obesity to the NHS Scotland in 2015. This used the estimation from Walker (2003) where 60% of obesity costs came from prescribed medication, 30% from hospital care, and the remaining 10% from General Practitioner consultations. In this estimate the costs were £171m annually (£223m in 2015 after adjusting for inflation). Using calculations which considered inflation and the change in prevalence of obesity, it was estimated in 2015 that the direct costs of obesity to NHS Scotland could be as much as £600m annually. Calculating total economic losses can be difficult due to obesity being a risk factor for many conditions, however, it has been estimated that the total economic cost of obesity to Scotland ranges from £0.9bn to £4.6bn per year (Castle, 2015).

Obesity in children has previously been linked to numerous conditions later in life, including obesity in adulthood which can lead to severe health risks (Simmonds et al., 2016). Having obesity also increases the risk of heart disease, stroke, high blood pressure, diabetes, and some cancers (Reilly et al., 2003). As well as these physical illnesses, childhood obesity has been linked to mental health issues, lower self-esteem, as well as social problems such as bullying and stigma within childhood and adulthood (Beck, 2016; Halfon et al., 2012; Morrison et al., 2015). Children with obesity are more likely to suffer from breathing difficulties, hypertension, insulin resistance, and early markers of cardiovascular disease in childhood (WHO, 2021).

1.4.1 Measuring obesity

Many methods for measuring or quantifying obesity exist, however, there is no universally recommended method. Dual energy X-ray absorptiometry (DXA or DEXA as per NHS definition) is a popular method to measure body composition which is accurate and easy to perform (Bazzocchi et al., 2016). A DEXA scan passes X-rays through a persons body at two different levels (high and low). Some radiation is absorbed by the bone and soft tissues and some travels through the body. Detectors in the scanner measure how much radiation has passed through the bones and the information is sent to a computer. The measurements collected are then compared with the bone density of a young healthy adult or an adult matched with the persons gender, age, and ethnicity (National Health Service, 2020a). On an epidemiological scale it is difficult to justify the use of DEXA due to the, albeit low, radiation exposure to the subject, the cost of the screening, and time taken to obtain measurements.

Another method of measuring body composition is hydrostatic weighing. To complete this, the subject must fully submerge themselves underwater where their gross underwater mass is measured (Gibby et al., 2017). This would be difficult for general and large numbers of measurements of weight due to the large amount of subjects having to be immersed in the water, the staff required to complete this, and the subjects then having to dry themselves.

body mass index (BMI) is a simple method used to measure the amount of tissue mass (i.e., muscle, fat, and bone) in an individual. This is calculated by taking a persons weight in kilograms (kg) and dividing it by the square of their height in metres (m^2), giving a score in kg/m^2. To develop the BMI formula used today, it was realised that a persons weight would depend on their height. Initially, it was suggested that tall people were merely scaled-up versions of short people, however, this theory was rebutted as tall people tend to be more narrowly built. After further research it was found that the best approach to calculating BMI was to divide weight by height raised to the power of 1.6 (Benn, 1971). This was deemed inconvenient for population-based studies thus it was determined that raising height to the power of 2 was appropriate. Table 1.1 shows the standard BMI weight classifications as defined by the NHS for adults. Limitations of BMI include it not being able to distinguish the difference between fat,

Table 1.1: Classification of body mass index for adults

Weight classification	BMI (kg/m^2)
Underweight	< 18.5
Healthy Weight	18.5 24.9
Overweight	25.0 29.9
Obesity	30.0 39.9

Information extracted from National Health Service (2023)
BMI - body mass index; kg - kilograms; m - metres

muscle and bone. This means very muscular adults and athletes may be classed as having "overweight" or "obesity" even though they have low body fat.

When it comes to children, BMI changes significantly with age and sex, rising steeply in infancy, dropping during primary school years, and then rising again in adulthood. Due to this, it had been suggested that age related reference curves were required to calculate BMI in children. Cole et al. (1995) updated the reference curves for BMI in UK children, presented as nine percentiles covering birth to 23-years-old. These percentiles were referenced from data from 1990. The LMS method summarises the distribution of BMI at each age by its median (M), coefficient of variation (S), plus a measure of skewness based on the Box-Cox power (L) which is required to transform the data to normality. These three measurements depend on age and sex of the child. These can then be used to calculate a Standard Deviation Scores (SDS) for the child using Equation 1.1, where $L(t)$, $M(t)$ and $S(t)$ are the values of L, M and S where t is the value appropriate to the childs age and sex. The SDS can then be converted to a centile, using normal distribution tables. The cut-offs for obesity in children as suggested for population monitoring from these calculations is presented in Table 1.2. Children at the extreme centiles should be viewed with caution, and only seen as clinically important if the trend continues into the second and third year of measurements. This measure is still currently in use within the UK, however, for children aged up to 4 years these reference curves have been replaced by the WHO reference curves (WHO, 2023a).

$$SDS = \frac{[BMI/M(t)]^{\mathrm{L(t)}} - 1}{L(t)S(t)} \tag{1.1}$$

Table 1.2: Classification of weight for children

Weight classification	Centile
Underweight	2nd
Overweight	85th
Obesity	95th

Information extracted from Information Services Division Scotland (2018)

Waist circumference (WC) can be used instead of BMI because a predominantly abdominal fat distribution is deemed worse for health than if the fat is more evenly spread throughout the body (WHO, 2000). To measure WC, a measuring tape should be wrapped round a subject's waist, roughly at navel height. Reilly et al. (2010) conducted a cohort study to compare WC percentiles versus BMI percentiles. This study took a BMI and WC measurement from 809 boys and 913 girls with a mean age of 9.9-years-old for both sexes. These scores were then standardised and compared to their DEXA measurement, which was used to show "true positives". This study found that it is unlikely that WC offers an improved diagnosis of high fat mass over that already provided by BMI in children. However, the Scottish Government have previously linked BMI and WC as this helps to remove healthy individuals with a high percentage of lean muscle mass but low body fat from the overweight category (Scottish Government, 2011b), although it is not currently measured nationally.

1.4.2 Descriptive epidemiology of obesity in children globally

Between 1980 and 2013, global overweight and obesity rates increased by 27.5% in adults and 47.1% in children (Ng et al., 2014). In 2016, 1.9bn adults had overweight, with 650m of these people classed as having obesity. Worldwide, 41m children under 5-years-old had overweight (WHO, 2021). It has been predicted by the WHO that, if the current trend continues, 70 million children will have overweight or obesity by 2025 (WHO, 2019). Within Europe, an estimated 41 million children aged between 5- and- 19-years-old had overweight or obesity, a 12% rise in prevalence since 2010 (WHO, 2018b). The biggest rise in prevalence can be seen in the Western Pacific, where there has been a 43% rise, giving a total estimate of 84 million children having overweight or obesity (WHO, 2018b). In the Americas an estimated total of 75 million children are classed as having overweight or obesity, while 43, 47, and 42 million are in Africa, South-East Asia, and Eastern Mediterranean, respectively (WHO, 2018b).

1.4.3 Descriptive epidemiology of obesity in children United Kingdom

Within the UK, obesity in all ages has the second largest economic impact on public health, after smoking, with an estimated annual cost of £44.7bn (Dobbs et al., 2014). In all ages in 2018/19 there were 876,000 hospital admissions in total England alone where obesity was a factor, an 23% increase on 2017/18 (National Health Service, 2020c). There were 11,117 hospital admissions which could be directly attributed to obesity in 2018/19, a 4% increase from the 2017/18 estimate (National Health Service, 2020c). In the same period, 9.7% of 4 to 5-year-old children had obesity, with the rate growing to 20.2% for 10- to- 11-year-old children, with the prevalence of obesity being more than double in children from the most deprived areas compared to those from the least deprived areas in England for both age groups (National Health Service, 2020c).

1.4.4 Descriptive epidemiology of obesity in children Scotland

Public Health Scotland (PHS), formally Information Services Division (ISD) of NHS National Services Scotland (NSS), publishes reports annually on BMI for Primary 1 children in Scotland by school year. The 2017/18 report showed that 76.5% of Primary 1 children in Scotland had a BMI in the healthy weight range. For the same school year, 12.3% of Primary 1 children had overweight, with a further 10.1% had obesity. Prevalence of underweight was 1.0%. These rates have somewhat plateaued over the years (since 2001), however, the rates still remain high. Obesity levels in Scotland are reported and vary with sex (higher prevalence in males) and area-based deprivation (higher prevalence in children from the most deprived areas) (Information Services Division Scotland, 2018a).

1.4.5 Risk factors of obesity

A scoping review by Chi et al. (2017), aimed to find risk factors of childhood obesity. PubMed and Embase were searched to find relevant studies, with only English-language publications being included. Initially, 2,572 studies were found and after exclusion of duplicates and relevance checks the number was reduced to 260. A further 80 studies were excluded after full text reviews, leaving 180 papers for this scoping review. The search included papers up to June 2016 with no further restriction on dates. This review found 38 significant risk factors, split into two categories (modifiable and non-modifiable) and then into a further seven sub-categories: Biological and Developmental, Sociodemographic and Household, Cultural, Community, Behavioural, Psychosocial, and Medical. The review did not calculate any risk scores for the factors. The behavioural factors associated with obesity included low physical activity, mainly lack of daily exercise, limited outdoor playtime, and low activity during breaks at school. Diet was also included as a significant risk factor. Diet included shorter duration breastfeeding, formula and bottle use, total energy intake, early introduction to solid food, and intake of sugar sweetened beverages (SSBs) and sweets. Also included were meals and snacking and mealtime and eating behaviours. In other words, children who had fewer than three to four meals per day, those who did not eat meals together as a family, and those with a strong appetite were at higher risk of childhood obesity. It is mentioned that increasing protein and carbohydrates are both independently associated with childhood obesity, while preferring fatty foods and having a low fruit and vegetable intake are also associated. This review did not take into account any possible bias within the studies so this could affect some of the results.

The review by Chi et al. (2017) benefited from the amount of research completed in risk factors for obesity on the back of the study by Reilly et al. (2005), with many research studies conducted after 2005. Reilly et al. (2005) created a prospective cohort study which looked at risk factors in early life (up to 3 years of age) for obesity in children in the UK. Obesity was defined as a body mass index equal or greater than the 95th centile, equivalent to a standard deviation score of 1.64 or more, where the standard deviation scores being calculated as per Cole et al. (1995). The cohort study by Reilly et al. (2005) identified 8,234 children aged 7-years-old from the Avon Longitudinal Study of Parents and Children (ALSPAC) (Golding et al., 2001). Of these 8,234 children, 909 children were randomly selected as a sub-sample to receive full and regular health check-ups. Binary logistic regression models were used to carry out multivariable analysis for obesity according to numerous putative (i.e., commonly regarded) risk factors. Putative risk factors were identified from previous reported associations with obesity; in total, 31 were identified. From the cohort, measurements were only available for 21 of these factors, however, a further four potential risk factors (relating to growth in infancy and early childhood) were identified through the sub-sample. It was found that eight early life risk factors for obesity in childhood were significantly related to risk of obesity. This study was one of the first of its kind completed and due to the lack of research in this area, many potential risk factors may have been missed out, such as physical activity and parental control over feeding. Some of the significant risk factors presented were: maternal smoking (between 28- and 32-weeks gestation); birth weight; not breast feeding; parental obesity. Interestingly, diet (obtained through a food frequency questionnaire at 38 months measured using principal component analysis scores in quartiles: junk, healthy, traditional, fussy, or snack) was identified as having an independent association, however, when adjusted for other potential risk factors, no association was found, however potential confounding with other risk factors may be a reason for this exclusion. All models were adjusted for maternal education (as a proxy for socioeconomic status) but the results of this measure were not reported.

1.4.5.1 Biological and developmental risk factors of obesity

Studies have previously reported on finding genes and epigenetic factors which are associated with obesity in childhood (Lee et al., 2015; Mejía-Benítez et al., 2015; Wang et al., 2013). One study highlights it was not usually the gene itself which causes obesity, rather an interaction with some other behaviour, for example, a higher intake of sodium (Lee et al., 2015). Mejía-Benítez et al. (2015) reports that the presence of gene *AMY1* copy number can reduce the risk of obesity given it aids the production of salivary amylase which promotes the digestion of dietary starch and thus increases metabolism. The gene *FTO* has been reported to increase the risk of obesity through controlling feeding behaviour and energy expenditure (Wang et al., 2013). In addition to genes, development coordination problems are also more likely to increase the risk of obesity compared to children who develop at an expected rate (McCurdy et al., 2014), and two studies have found that females who enter puberty early have increased risk of obesity (Ho et al., 2013; Patterson et al., 1997).

1.4.5.2 Sociodemographic and household risk factors of obesity

Many studies have reported on the association between overweight/obesity and race and ethnicity. Data from the Millennium Cohort Study (CLS, 2023) have reported this association within the UK, with children of Black ethnicity at more risk than children of White ethnicity, whereas children of Indian ethnicity had a lower risk (Hawkins et al., 2009). A further study using these data identified that children of Asian ethnicity and African ethnicity were more at risk of obesity than children of White/European ethnicity (Brophy et al., 2009). Ethnicity plays a role in inequalities for obesity, specifically in England where Black male and female children (aged 3- to-17-years-old) are more likely to have obesity or overweight than White or Asian children, while in the United States, Mexican American male children and Non-Hispanic Black female children have highest rates of obesity (OECD, 2010).

Income and socioeconomic status have been reported to affect risk of obesity. Multiple studies have reported low income as a risk factor of childhood obesity (Brophy et al., 2009; McCurdy et al., 2014; Twarog et al., 2015). Brophy et al. (2009) reported an increase risk of obesity in low-income families, regardless of ethnic background of the family, although Hawkins et al. (2009) found no association despite the studies being conducted on the same cohort. The difference in these studies is Brophy et al. (2009) focused on 5-year-old children whereas Hawkins et al. (2009) focused on 3-year-old children. This suggests that inequalities in income and risk of obesity begin increasing at an early age. Other studies have reported high income as a risk factor of obesity, although all of these studies were conducted in Asia (Baygi et al., 2012; J. Chen et al., 2005; Firestone et al., 2011).

The Organisation for Economic Co-operation and Development found a linear relationship between the number of years spent in full-time education and the probability of obesity in Australia, Canada, England, and Korea (OECD, 2010). In Australia, Canada, and England, obesity rates reduced the longer a person has been in education for both males and females. This was also the case for Korean females, however, not Korean males. Surprisingly, the more years of education a Korean male had the higher the obesity rate. In France, of those 20-year-olds classed as having obesity, 48% had been in education for over 12 years, compared to the 62% of those without obesity at 20-years-old (OECD, 2010).

Other household factors such as parental unemployment, maternal age (both younger and older identified), lower parental education, being first born, parity, household size (smaller and larger identified), and parents in separate households before birth were found to be risk factors of obesity (Chi et al., 2017).

A previous study using data from 10,736 children, with a mean age of 14.3-years-old from the UK Millennium Cohort Study identified inequalities in prevalence of obesity between those living in poverty and those not living in poverty, with children living in poverty having a higher prevalence. (Noonan, 2018). Furthermore, poor diet, high consumption of fast food and sugar sweetened beverages, and low consumption of fruit and vegetables was most prevalent in children living in poverty. This study has identified pathways between poverty and obesity in adolescents, although further work would be required to identify how physical activity would affect this. Noonan (2018) note that interventions to reduce obesity must consider poverty in the design and implementation.

1.4.5.3 Cultural risk factors of obesity

Children from acculturated families (families who integrate into another culture) have previously reported to have an increased risk of obesity (Chi et al., 2017). An example of this is Latino children in the USA who speak Spanish at home versus speaking English have higher risk of obesity (Wojcicki et al., 2012) or higher risk in children in the USA who spoke English as a second language (Hu et al., 2007) The risk of obesity was found in one study conducted in Cameroon to differ with religion, although once adjusted for other factors such as country, no association was found (Tchoubi et al., 2015) suggesting that differences in risk would be between countries and not necessarily religions.

1.4.5.4 Community risk factors of obesity

Community risk factors of obesity reported in the review by Chi et al. (2017) that children from urban areas rather than rural/remote areas were at increased risk of obesity. The racial make-up of the neighbourhood was also reported to affect the risk of childhood obesity.

1.4.5.5 Behavioural risk factors of obesity

Behavioural risk factors of childhood obesity can begin from birth. Various studies have reported on the risk of obesity for each feeding type. Hawkins et al. (2009) has reported that children who were not breastfed had a higher risk of obesity than children who were breastfed for any amount of time. Other studies have reported that long duration of breastfeeding will reduce the risk of obesity (Danielzik et al., 2004; S. Robinson et al., 2014). Formula and bottle use were also associated with increased risk of obesity with the type of formula and age at using bottle both risk factors (Chi et al., 2017). It should be noted that none of these studies accounted for the association between socioeconomic status and breast feeding, which has shown that women from lower socioeconomic status are less likely to breastfeed (Oakley et al., 2013).

A study conducted in the United States of America (USA) reported that a risk factor of obesity is the consumption of sugar sweetened beverages (SSBs) (Pan et al., 2014). Any consumption of SSBs within the first year of life was found to be associated with an increased risk of obesity when compared to those who never consumed. Similar findings were reported in further studies conducted in the USA (Flores et al., 2013; Welch et al., 2008).

Chi et al. (2017) identified multiple risk factors relating to food, including total energy intake, time introduced to solid food, nutrients, foods, serum biomarkers (molecules produced by cells), meals, snacking, and mealtime and eating behaviours. Increased energy intake was associated with childhood obesity and reported in multiple studies (Hui et al., 2003; Jingxiong et al., 2009). A faster eating speed, stronger appetite, and habit overeating were reported to be risk factors of childhood obesity (Chi et al., 2017). Various mealtime behaviours such as eating fewer family meals, watching television while eating, and less importance of family mealtimes were also associated with childhood obesity.

Low physical activity has been reported to be a risk factor of obesity. Lack of daily exercise, irregular vigorous activity, low activity during breaks at schools or on weekdays and weekends, limited outdoor playtime, and non-participation in organised sporting activities all increase the child's risk of obesity (Chi et al., 2017). Other risk factors of obesity relating to physical activity occur in sedentary lifestyles. Children with a sedentary lifestyle have a higher risk of obesity (Grigorakis et al., 2016), including number of hours spent studying during the week and access to electronic communication and entertainment devices (Farajian et al., 2014). In addition having any screen time, watching television, and using computers and playing video games also increased the risk of obesity (Bingham et al., 2013).

Parental weight increases a child's obesity risk, with either parent's obesity amplifying it (Baygi et al., 2012; Danielzik et al., 2004; Hawkins et al., 2009; Jingxiong et al., 2009; Ness, 2004; Reilly et al., 2005). Additionally, increased birth weight raises obesity risk in childhood, categorised as low, middle, and high (Danielzik et al., 2004), as well as in five weight categories (<2,500g, 2,500-4,000g, 4,000-5,500g, >5,500g) (Tchoubi et al., 2015), and across the entire birth weight spectrum (rounded to the nearest 100g) (Ness, 2004).

1.4.5.6 Psychosocial risk factors of obesity

Various psychosocial risk factors have been identified by Chi et al. (2017). Maternal stress is likely to increase risk of obesity (Dancause et al., 2012). Children from families with no strict behavioural rules were at an increased risk of obesity, so too children with more complex family issues such as domestic violence, maternal substance abuse, food insecurity, and maternal depression (Suglia et al., 2012).

Parenting practices are likely to affect the risk of obesity. Chi et al. (2017) found evidence to show that single parenting, restrictive parenting, and children cared for by grandparents were at a higher risk of obesity. Children with low self control, high emotionality, and poor effective responsiveness had an increased risk of obesity (Bergmeier et al., 2014).

1.4.5.7 Medical risk factors of obesity

Chi et al. (2017) reported family medical history as a risk factor of obesity, mainly having a close relative with type 2 diabetes. The review adds gestational hypertension or diabetes, gestational weight gain, and low maternal vitamin D as risk factors of obesity. The review also notes parental smoking and exposure to second half smoke as risk factors of obesity. No confounding effect of socioeconomic status was considered.

The child's health plays an important role in obesity, with children being born by Caesarean section, children exposed to antibiotics in utero and during first year of life, and not taking regular multivitamins were risk factors of obesity (Chi et al., 2017). One study notes that children who did not use health care services had a higher risk of obesity (Hassanzadeh-Rostami et al., 2016). Shorter sleeping time was also found to be a risk factor (Ness, 2004; Reilly et al., 2005; Suglia et al., 2012).

1.4.6 Confounding of risk factors

Many studies which have reported on the risk factors of obesity have tended to fail to report on the potential confounding effects on socioeconomic status. It is possible that many of the risk factors identified for obesity (or higher BMI) are proxy measures of socioeconomic status. For example, parental smoking was found to be a risk factor of obesity. It is well documented that socioeconomic status is both associated with smoking (Office for National Statistics, 2023; Scottish Government, 2022c) as well as obesity (Chi et al., 2017), so without fully accounting for socioeconomic status the true relationship between the outcome and risk factor will not be understood.

1.5 Common Risk Factors

A common risk factor approach, first defined by Sheiham et al. (2000), aims to address risk factors which are common to many NCDs within the context of the wider social environment. The review mentioned in the previous section by Chi et al. (2017) used the identified risk factors of obesity and looked at how this could be applied to developing interventions aimed at preventing obesity and dental caries in children. Chi et al. (2017) took all the obesity risk factors and searched dental literature to determine if there was any evidence of them also being related to caries. This provided a theoretical model on common risk factors for obesity and dental caries. These risk factors were split into two categories (modifiable and non-modifiable) and then a further five sub-categories: Biological and Developmental; Sociodemographic and Household; Cultural; Behavioural; Psychosocial. Some of the modifiable common risk factors were: sugar-sweetened beverage intake; increased energy intake; increased stress; duration of breastfeeding. The authors noted that there may be non-overlapping risk factors which are equally important, such as fluoride varnish application and increasing physical activity to reduce the intake of SSBs (Chi et al., 2017).

Uerlich et al. (2021) has published information on common determinants of caries and overweight or obesity in children using longitudinal data from the Born in Bradford cohort study (Born in Bradford, 2017). The study utilised three datasets to identify caries experience at 5-years-old in 2014/15 as well as BMI status. Overall, there were 171 children included in the study, although missing data existed in 9 out the 15 variables, of which 8 were included in the final analysis. Multiple imputation was used to create complete data. The author noted that the method used is considered 'adequate' in social research. In the study caries was measured using dmft and treated on a continuous scale. BMI was categorised in five groups: severe thinness; thinness; normal weight; overweight; obese. Six variables in total were linked to both caries experience and overweight/obesity separately (Uerlich et al., 2021). Higher BMI and more caries were affected by higher frequency of SSBs, emotional and behavioural difficulties of the child, and being male. An inverse association (higher BMI, less caries) was associated with uninvolved parenting style and indulgent feeding style. In addition to this no alcohol consumption by the mother after birth (ever/never) was identified as a risk factor for higher caries and BMI independently. Uerlich et al. (2021) notes that the cohort had a higher percentage of Pakistani participants compared to most other studies, and the Pakistani ethnic group have the highest reported percentage of non-alcohol drinkers. Socioeconomic status, measured in five groups (least deprived and most educated, employed and not materially deprived, employed but no access to money, receiving benefits but coping, most deprived) was linked to lower BMI and more caries, a result which the author notes is different to common reporting of the association and suggests confounding of ethnicity as an explanation of this finding.

1.5.1 Sugar consumption as a common risk factor of caries and obesity

Free sugars include all monosaccharides (including glucose) and disaccharides (including fructose) added to foods and drinks by the manufacturer, cook or consumer, and sugars naturally present in honey, syrups, fruit juices, and fruit concentrates, as per the WHO Guidelines (WHO, 2017). The term free sugars does not include sugars found naturally in dairy products along with sugars naturally present in whole fruits, vegetables and grains. Sugar consumption worldwide has tripled in since the 1960s (BDJ Team, 2017), with this increase expected to keep growing while nutritious foods have become relatively more expensive than foods high in sugar (Wiggins et al., 2015). Global sugar consumption was estimated at 173.7 million tonnes in 2021/22 and forecast as 174.7 million tonnes in 2022/23, a 0.6% increase, with production expected to increase at the higher rate of 2.6% between 2021/22 and 2022/23 (FAO, 2022). This equates to an annual per capita intake of 22.0kg (circa 60g per day) in 2021/21 and 21.9kg in 2022/23. Free sugars has potential for abuse, with numerous studies examining the dependence-producing properties of sugar in humans (Garber et al., 2011). More specifically, sugars can promote the hormone ghrelin, which signals hunger to the brain and it can also interfere with the hormone leptin which helps produce the feeling of satiety (Garber et al., 2011; Lustig, 2010). Importantly, sugars can induce all the diseases associated with metabolic syndrome (Lustig, 2010; Tappy et al., 2010).

Lustig et al. (2012) suggested that sugar consumption is linked to a rise in NCDs and furthermore, free sugars intake has shown to be a causation of dental caries, as caries does not occur in the absence of free sugars in a diet. Evidence within this field has resulted in the WHO recommending limiting free sugars intake to less than 10% of total energy intake, but ideally less than 5%, as this minimises the risk of dental caries throughout the life course (WHO, 2017)

Anderson et al. (2009) conducted a systematic review which aimed to assess the "relationship between quantity and pattern of sucrose use and dental caries". Sucrose, which is the scientific name for table sugar, is a combination of 50% glucose and 50% fructose, found naturally in many fruits, but added to foods such as, ice-cream, breakfast cereals, and other sugar-sweetened beverages. The review conducted superficial hand searching of papers published between 1856 and 1940, detailed hand searching for publications between 1940 and 1966 and then electronic for 1966 to 2007, using MEDLINE and Embase. The review excluded studies which looked at subjects over 35-years-old as the authors stated that most caries at this age would be recurrent caries. The inclusion criteria consisted of 23 questions covering the population, outcome, the journal it was published in, and diagnostic criteria. Papers were then graded against the selection criteria and those papers which fulfilled less than 11 questions of the selection criteria were excluded. No suitable papers were found before 1940, with only 5 from the 23 papers from 1940 to 1966 deemed suitable for inclusion. There were 49 papers, from an initial 113, published between 1966 and 2007 that met the inclusion criteria. Papers which focused on early childhood caries were removed as they believed caries diagnosis in young children had issues and that dietary assessments were untrustworthy, which left 95 papers. Papers were graded as part of the selection criteria. It was deemed that if a paper met all 23 criterion then it was graded "A". A paper was graded "B1" if at least 19 (but not all) of the criteria were filled, "B2" if between 12 and 18, and "C" if 11 or less were marked. All papers which received a "B2" or "C" were removed, leaving 31 papers, of which only 1 was graded "A" and the rest (30 papers) graded "B1". Of the papers which measured association between amount of sugar and caries, 6 of the 15 found a significant relationship, whereas 19 of the 31 papers found a significant relationship between dental caries and frequency of sugar consumption. Pastry food was seen to have the highest odds of caries (OR: 3.02; 95% CI: 1.51 to 6.05) while consumption of ice-cream, cakes, and sliced bread also showed a positive association with caries, however, no odds ratios were provided for these. The one paper which was graded "A" did not look at the relationship with total sugar consumption, however, it found a significant relationship between dental caries and frequency of sugar consumption. Unfortunately, there was no meta-analysis conducted for this review. This suggests that dental caries is more affected by the frequency of sugar than the quantity.

A review of systematic reviews by Keller et al. (2015) looked at a population of children and adolescents aged 6-months-old to 19-years-old with the aim of providing an up-to-date synthesis of recent evidence regarding the association between SSBs consumption and weight gain. PubMed, Medline, CINAHL, and Web of Knowledge were used to search for reviews published from 1990 till August 2013. The criteria for inclusion were that the exposure was SSBs, the outcome was weight gain, overweight or obese. The mean age range for this population was 9.4-years-old. Many of the reviews within this review mention they were limited to small sample sizes so these results could be unrepresentative of the population. The quality of the reviews were assessed using the Assessment of Multiple SysTemAtic Reviews measurement tool (Shea et al., 2007). For each question answered "yes", a score of 1 was given, with a maximum of 11 for meta-analyses and 10 for reviews. Reviews scored between 0 and 4 were low quality, 5 and 8 moderate and 9 and 11 were classed as high quality. The review found that 9 of the 13 papers reviewed found a direct association between SSBs and weight gain in children and adolescents, while 2 found no association and 2 getting inconclusive results. Of those papers which gave effect sizes, the effect of increasing consumption of SSBs was between 0.03 and 0.14 BMI unit change (standardised mean difference) per serving of SSBs. Two reviews were graded 9, the highest score given, one of which found a positive association and the other proving to be inconclusive. Both these reviews were meta-analysis and review published in 2013. The positive review had a population of children from USA and Singapore, whereas the inconclusive review focused solely on a population from the USA.

SSBs have also demonstrated putative effects on diabetes, metabolic syndrome, cardiovascular diseases, certain types of cancers, and premature death (Hruby et al., 2016). It has also been argued that fructose, found in free sugars in SSBs, exerts similar toxic effects on the liver as alcohol (Lustig, 2010). A systematic review and meta-analysis by Malik et al. (2013) aimed to summarise evidence of weight gain in children and adults from consumption of SSBs. PubMed (since 1966), Embase (since 1947), and the Cochrane library (since 1951) were used to find papers from the index date up till March 2013. This found 9,833 unique papers, from which 9,773 were excluded for non-relevance and other exposures. A further 5 papers were found from the reference list of the 60 papers. After full-text review, 20 papers were included for the meta-analysis in children. These papers included an age range of 2- to- 16-years-old, with the number of participants from 141 to 11,703. The review found evidence that consumption of SSBs promotes weight gain in children and adults. It was estimated that for every 12oz serving of SSBs per day, BMI increased by 0.07 (95% CI: 0.01 to 0.12) during the time period specified in each study. Over a one-year period, it was estimated that BMI increased by 0.06 (95% CI: 0.02 to 0.10) for the same daily dose of SSBs.

In Scotland a longitudinal cohort study by A. Macintyre et al. (2018) reported that there was a positive association between consumption of SSBs between 1 and 6 times per week at 4- to- 5-years-old and having obesity and 7- to- 8-years-old compared to children who consumed SSBs less than once a week/never (aOR: 1.65; 95% CI: 1.12 to 2.44). Interestingly, there was no increased odds of obesity in children who consumed SSBs a least once a day (aOR: 1.19; 95% CI: 0.85 to 1.65) (A. Macintyre et al., 2018). This study used data from a nationally representative sample of 2,986 children from the Growing Up in Scotland study, a longitudinal study of three cohorts of children born in Scotland (GUS, 2023). A. Macintyre et al. (2018) note that they were limited in the information available regarding the volume of SSBs consumed, only if it was consumed. Furthermore, confounding may have been present with the inclusion of information regarding total energy intake and diet quality. A further study using data from the Growing Up in Scotland study surveyed parents/carers of 3,770 children aged 10-months born between June 2004 and May 2005 (Skafida et al., 2017). Child were surveyed annually until their 5th birthday when self-reported dental caries (parent/carer noted child's tooth had fillings, tooth had been extracted, or lots of decay) was recorded. Children who consumed SSBs several times a month had higher odds of caries at 5-years-old than children who consumed SSBs less than once a month or never (aOR: 1.26; 95% CI: 1.01 to 1.55) (Skafida et al., 2017). Furthermore, children who consumed sweets or chocolates once a day or more had higher odds of caries than children who consumed these less than once a day (aOR: 1.53; 95% CI: 1.24 to 1.89). These findings included adjusting for oral health behaviours including frequency of attendance at general dental services and toothbrushing (use of toothbrush and if brushing at bedtime) (Skafida et al., 2017). The authors note that while this is a representative sample of children in Scotland, all oral health and dietary variables were self-reported and could not be validated against gold standard methods.

A narrative review by Poti et al. (2018) has identified an association between ultra-processed foods and obesity. Ultra-processed foods tend to be energy dense, with high sugar and fat content. Consumption of these products may increase energy intake given the density of the calories, with research suggesting that high consumption of ultra-processed foods can lead to over-eating and addictive eating (Carter et al., 2016; Pan American Health Organization, 2015b; Schulte et al., 2015). Furthermore, the consumption of ultra-processed food have been linked to dental caries in children and adolescents in a meta-analysis of 42 studies (Cascaes et al., 2023). This analysis found that consumption of ultra-processed foods increased risk of dental caries with a pooled risk ratio of 1.71 (95% CI: 1.31 to 2.24) from a sample size of 5,068 children from seven cohort studies and one non-randomised trial. A pooled odds ratio was estimated from a sample of 35,427 children from one-case control study and 18 cross-section studies. This found that the pooled odds of caries increased by 1.55 (95% CI: 1.37 to 1.55) in children who consumed ultra-processed foods. While these studies have been conducted on caries and obesity separate, it is possible further research could identify consumption of ultra-processed foods as a common risk factor.

1.6 Associations Between Dental Caries and Obesity in Children

Hayden et al. (2013) conducted a meta-analysis on the association between obesity and dental caries in children under 18-years-old, using BMI and DMFT/dmft for the respective measures. A systematic search was conducted in Embase, Medline, ScienceDirect, Ovid, and PsychInfo for papers published between 1980 and 2010 which addressed childhood obesity and dental caries. Only studies which were published in English and were fully accessible were included. The initial literature search identified 212 potential papers, where 70 duplicates were excluded as well as 97 papers which did not satisfy inclusion criteria. Of the 45 papers left, 7 were excluded after abstract checks. Of the 38 papers for which full text was appraised, only 14 papers met the inclusion criteria, which checked the studied population, outcome, and design. The studies were scrutinised for quality using an appraisal checklist developed by the University of Wales. This checklist assessed the studies on 12 criteria including bias, follow up and appropriate use of statistical methods. A total score of 12 was available which was for the highest quality of papers. This was completed by two of the authors for all the papers selected and then assessed for agreement. A funnel plot was then used to assess the publication bias, which confirmed a low level of bias. The review was interested in papers which had outcome measures of weight and caries experience in a population of children under 18-years-old. From a synthesis of results, a significant relationship between childhood obesity and dental caries was found (effect size (standard difference in means): 0.104, 95% CI: 0.001 to 0.206; p=0.049). This effect size can be interpreted in terms that an effect size of 0.104 means that the score of the mean in the experimental group is 0.104 standard deviations above the mean score in the control group. This review found that different results were derived dependent on which measure was used to assess the childs weight status. Positive relationships were found in studies which used standardised measures for measuring childhood obesity, such as, BMI for age centiles (effect size: 0.189, 95% CI: 0.060 to 0.218; p=0.004) and the International Obesity Task Force cut offs (Cole et al., 2000, 2012) (effect size: 0.104, 95% CI: 0.060 to 0.180; p=0.008). Those studies which used Z-scores and non-standardised scales provided insufficient evidence to suggest an association between childhood obesity and dental caries (effect size: -0.147, 95% CI: -0.396 to 0.102; p=0.248, effect size: -0.030, 95% CI: -0.436 to 0.375, p=0.884 respectively). The effect size, standardised mean difference, denotes the size of the intervention effect in the relationship relative to the standard deviation in that study. In studies where the difference of means is the same proportion to the standard deviation will provide an effect size of one. The negative effect size means the mean of those in the experimental group were 0.147 standard deviations lower than the control group. Hayden et al. (2013) state that a main limitation of their review was the studies included used varying definitions of dental caries, with some using DMFT, where others used Decayed, Missing, Filled Surfaces (DMFS), dft, or a combination.

A systematic review by Hooley et al. (2012) searched for literature published between 2004 and 2011 inclusive. They used Medline, Web of Science (ISI), Cochrane, Scopus, Global Health, and CINAHL databases for papers that “tested associations between body mass index and dental caries in child and adolescent populations (aged 0- to- 18-years)”. The criteria for papers were that they measured caries rates (either DMFT/dmft or papers which categorised teeth conditions), measured some form of weight-to-height ratio to estimate body fat, and assessed the relationship between obesity and dental caries in children and adolescents up to 18-years-old. Studies were also assessed for representativeness of the sample. This was marked by a grading score of 1 (highest) to 4 (lowest), where 1 was "sample involved forms of stratification or cluster sampling" and 4 being "sample of convenience without random selection". The scores for each criterium were added up and a grading system was used to mark studies between "A" and "D". Initially 757 records were found, 612 after removal of duplicates. A further 503 were excluded as they did not meet inclusion criteria, with 39 more excluded after abstract checks and 21 after full text checks for the same reason. Two papers were removed as full text was unavailable. This left 47 papers which met the selection criteria. However, two papers reported on the same data and were combined for this review, while two other papers reported findings of two separate studies, therefore, a total of 48 papers were included in this review. Out of these papers, 5 met the criteria to be graded A, while 20 were graded B. The review found that 23 studies found no association between BMI and dental caries, 17 found a positive relationship and 9 found a negative relationship. The mean DMFT/dmft score for the positive associations was 2.13 (high caries, high BMI), with a mean score of 4.96 and 3.04 for the negative (low caries, high BMI) and no associations papers, respectively. The studies which found positive associations were mainly from the USA and Europe, while the negative association studies came mainly from Asia and South America. From this review there is evidence to suggest that caries is associated with both high and low BMI, giving a U-shaped pattern, however, there remains significant disagreements about the association between obesity and dental caries, and its direction.

An umbrella systematic review was registered with PROSPERO (an international database of prospectively registered systematic reviews) and published by Carson et al. (2017). This aims to answer the question "does the available evidence support a relationship between dental caries experience and body weight in the child population?". At time of publication, this review has not yet been completed. The review will focus on the quality of literature around this topic for children under 18-years-old, with no limitations around geographic location or cultural factors (Carson et al., 2017). The review will include systematic reviews and/or meta-analyses of observational, cross-sectional, case series, cohort, aetiology, and case-control studies.

D. Chen et al. (2018) published results of a review focused on observational studies which compared BMI and dental caries. This review identified 43,860 children under 18-years-old (53% males; 47% females) from fourteen studies found across PubMed, Embase, and the Cochrane Library of Systematic Reviews. The quality of the included studies were assessed using a version of the Agency for Healthcare Research and Quality checklist for cross-sectional studies (AHRQ, 2023). Only two of the fourteen studies included were of high quality. Eight studies were medium quality and four low quality. Five studies identified no association between BMI and caries, five found a positive association, three found an inverse association, and one identified a U-shaped relationship with dmft higher in underweight children compared to healthy weight (D. Chen et al., 2018). The study which identified this U-shaped curve was conducted in India in 2011 on children aged 6- to- 15-years-old (Subramaniam et al., 2011). The authors provide reasons for this association such as the environmental roles of dietary patterns in developing countries and the cohort consisted of more underweight children from lower socioeconomic status where nutrition is worse.

Alshihri et al. (2019) published a narrative review on the association between dental caries and obesity. The authors conducted a search of PubMed, Medline, ScienceDirect, Scopus, and Google scholar for research published between January 2015 and May 2018. A total of 26 studies were included in the review, of which eight studies focused on primary dentition, nine permanent dentition, and nine on both primary and permanent dentition. Of the 26 studies, 22 were cross-sectional designs and 3 were longitudinal, all of which focused on permanent dentition, and one study a case-control design. From the eight studies which focused on primary dentition only one study identified a positive association (high caries, high BMI). This case-control study was conducted in Canada on children aged 2- to- 6-years-old. Four studies found an inverse relationship (high caries, lower BMI or low caries, high BMI), although none of these studies were conducted in Europe or North America, with 2 studies from Asia (China and Iran), 1 from South Africa, and 1 one from Brazil. Two studies conducted in Europe (Netherlands and UK) did not find an association between caries and BMI. Alshihri et al. (2019) notes that possible explanations for a positive association is the role of diet (such as poor food choices, dietary habits, frequency and high consumption of fermentable carbohydrates, consumption of sweetened junk food, and high calorie diets), biological indicators (such as lower saliva production and differing microbial profiles), and lifestyle (such as reduced physical activity, higher consumption of snacks, and time spent watching TV or using electronics). The role of diet was crucial in studies with an inverse relationship too (Alshihri et al., 2019). Fatty and fried food and unrefined carbohydrates may be involved in this type of association between caries and obesity. Dietary limitations, such as saliva production, restricted diets for lengthy periods of time, mastication, and deficiency in vitamins A, D, and iron, may play a part in an inverse association. Alshihri et al. (2019) reports another reason for higher caries and lower BMI could be from children who have good nutrition but untreated caries, with reports than children who were underweight gained weight after having caries treated (Bafti et al., 2015). Socioeconomic status may have played a part, with children with underweight and caries more likely to be from more socioeconomically disadvantaged areas, however, there was a large amount of variation across different populations. Alshihri et al. (2019) comments on methodological difference as a reason for the differing results in the association between caries and obesity. Diversity of age, particularly studies with larger age ranges, can play a role in the association between caries and obesity, particularly given the fact that obesity and caries are both known to differ with age (Public Health England, 2015). The gender of the study samples could contribute given dietary behaviours and physical activity differs between genders. Most of the studies included in the review by Alshihri et al. (2019) recommended increased sample sizes, particularly to solve the problem of sub-grouping by BMI status. Alshihri et al. (2019) notes the different diagnosis methods of caries as a reason for conflicting results. Studies included in this review had a mix of methods for diagnosis. Methods for diagnosis of caries included dmft/DMFT, DMFS, dft, American Academy of Pediatric Dentistry, ICDAS, and the National Institute of Dental Research criteria. This could potentially lead to vast differences in caries prevalence across the studies dependent on the methods used. The measure of BMI across studies differed too. Methods used included WHO growth references, Centers for Disease Control and Prevention, and World Obesity/Policy and Prevention. Some studies also used waist circumstances as a measure of obesity. These could lead to different results across all studies and populations.

1.6.1 Summary of the findings relating to the association between caries and obesity

Across the studies described above, there is conflicting evidence of an association between caries and obesity. The measure of BMI was shown to affect the outcome of the association, with studies that used standardised measures of obesity more likely to find positive associations compared to studies which used Z-scores and non-standardised methods which will more likely to find no association. The definition of caries was different across studies included in the reviews, which may impact the association. Location is also likely to affect the association, with research conducted in the USA and Europe more likely to identify positive associations compared to Asia and South America which are more likely to identify negative associations. The U-shaped curve, which has been reported to make the relationship between caries and BMI non-linear, is when the risk of caries in children underweight and obesity are highest compared to healthy weight and overweight. Hooley et al. (2012) and Hayden et al. (2013) recommend further work into the associations through longitudinal studies, to "gauge the association between early childhood caries and health outcomes in adolescence and adulthood" and to also include data on children who are aged between 0- and-6-years-old. From a brief search of articles in PubMed which cited Hooley et al. (2012) and Hayden et al. (2013), there appears to be no longitudinal studies which cover children into adolescence, however, a more systematic search would be required.

Identifying an association between caries and obesity is important as both are prevalent public health problems which have both been linked to morbidity. Both NCDs are considered to have potentially lifelong impacts on the quality of life in young children (Hayden et al., 2013; Kassebaum et al., 2017; Maffeis et al., 2001). Identifying the association at a young age may help develop effective targeted public health policies and programmes which may prevent serious complications or chronic conditions from developing as the child gets older (Chi et al., 2017; Levine, 2012; Vann et al., 2005). In Scotland, the national child oral health improvement programme, Childsmile (Section 1.9), takes a common risk factor approach and may be able to tackle the prevalence of caries and obesity by providing appropriate support to families to adopt behaviour change relating to improved diets.

1.7 Inequalities in Health

Higher socioeconomic position correlates with longer life expectancy and improved health outcomes. In 2008, Prof Michael Marmot chaired an independent review, commissioned by the Secretary of State for Health, to propose evidence-based strategies for reducing health inequalities in England from 2010. This led to the creation of the "Fair Society, Healthy Lives: The Marmot Review" (Marmot et al., 2010). Prof Marmot emphasised that health inequalities, resulting from societal disparities in birth, work, living, and aging, have life and death implications.

Earlier, the 2008 WHO Commission on Social Determinants of Health (CSDH, 2008), which Prof Marmot also chaired, concluded that health inequalities arise due to inequalities of daily life, with power, money, and resources playing fundamental roles in strengthening inequalities. These social and economic inequalities support the range of interacting factors that shape health and well-being, which include: material circumstances; social environment; psychological factors; behaviours; biological factors. These factors are then influenced by social position, education, occupation, gender, income, ethnicity, and race. Focusing on the social determinants of health inequalities, it is easy to see how these inequalities still exist today. Inequalities persist across key domains: in early child development and education, employment and working conditions, housing and neighbourhood conditions, standards of living, and benefits of society. A central message from Marmot et al. (2010) is that action is required across all the social determinants of health, not just by the Government, but also the third and private sectors. Six policy recommendations are provided in the Marmot Review to take the first vital steps towards a more equal healthy world as quoted in the review:

- Give every child the best start in life.
- Enable all children, young people and adults to maximise their capabilities and have control over their lives.
- Create fair employment and good work for all.
- Ensure a healthy standard of living for all.
- Create and develop healthy and sustainable places and communities.
- Strengthen the role and impact of ill-health prevention.

A systematic review by Schwendicke et al. (2015) on socioeconomic inequalities and caries searched Medline, Embase, CINAHL, Web of Science, Cochrane Central Database, and Campbell Library for studies published between January 2000 and August 2013. Only published material was accepted, with grey literature and studies not published in English being excluded. The population of interest for this review was any adults or children with permanent or deciduous teeth. There was no specific necessity for the measurement of caries, however, estimates had to be adjusted for at least two possible co-founders. The search found 5,539 papers electronically, with 5,153 removed after screening of title and abstract. A hand search of bibliographies was conducted which found a possible 144 suitable papers, leaving a total of 530 papers to be screened full-text. After removal of papers, for reasons such as no multivariate analysis or no clinical assessment of caries, 170 papers were left with a further 15 duplicates excluded. This left 155 papers suitable for qualitative synthesis and 92 papers for meta-analysis. It was found that people with low own or parental educational, occupational background, or income were between 1.21 (95% CI: 1.03 to 1.41) and 1.48 (95% CI: 1.34 to 1.63) times more likely to have a DMFT/dmft score greater than 0. This review reported slight publication bias but claimed it did not significantly affect their estimates.

1.7.1 Health inequalities in Scotland

NHS Health Scotland categorises health inequalities as the "unfair and avoidable differences in peoples health across social groups and between different population groups" (NHS Health Scotland, 2016). As well as on a world scale, inequalities are evident within countries, cities and towns. In Glasgow there is a 17.6-year gap in the life expectancy of a male between the richest and poorest areas across 2015 to 2019, which is an increase of the 2001 to 2005 estimate of 15.3 years (Whyte et al., 2021) and life expectancy in Glasgow remains 4.8 years less for males and 4.0 years less for females than in Edinburgh (Whyte et al., 2021). Health inequalities are accountable for thousands of unnecessary premature deaths every year in Scotland. NHS Health Scotland proposes that health inequalities are caused by income, power, and wealth. A report by Christie (2011) suggested that around 40% of NHS Health Scotland's spending accounted for by interventions which could have been avoided by prioritising a preventative approach.

1.7.2 Inequalities in child oral health and obesity in Scotland

Child dental health inequalities in Scotland are persistent. In 2018, 56% of Primary 1 children from the most deprived areas in Scotland show no obvious caries experience compared to the 86% from the least deprived areas (Macpherson et al., 2018). The gap between deprivation levels has remained the same over the past decade. Inequalities have roughly stayed the same over time. In 2012 there was a 31% gap between the percentage of caries free children in the most (51% caries free) and least (81% caries free) deprived areas (Macpherson et al., 2012). In 2018, the gap was 30%, showing that although overall percentage of caries free children has improved, the gap has not (Macpherson et al., 2018). There is a clear social gradient between the percentage of Primary 1 children who show no obvious caries experience. This can be seen too in obesity levels for Primary 1 children. In the school year 2017/18, 26% of children from the most deprived areas were at risk of being overweight or obese, compared to the 17% from the least deprived areas, a difference of 9.0% (Information Services Division Scotland, 2018b), which was slightly higher than the 7% difference in 2011/12 (25% in children from the most deprived areas; 18% in children from the least deprived areas) (Information Services Division Scotland, 2013).

1.8 Tackling Inequalities

1.8.1 Proportionate universalism

Actions to reduce the social gradient in health must be universal but scaled and intensified to different levels of deprivation. This is known as "Proportionate Universalism" defined by Marmot et al. (2010). Individual, community, and population-wide interventions must be targeted proportionally across the socioeconomic gradient. More intensified action is required for communities or individuals with greater deprivation, however, action is still required in communities with less deprivation. Focusing effort and actions are required across all communities on the socioeconomic gradient. If a policy offers services to everyone across the social gradient equally then those less in need can take up more resources when they maybe do not need them. Those with access to the greatest resources have the advantage to get the most use out of the activities and messages to make changes to benefit their health so those at the lower side of the socioeconomic scale must have greater access. Proportionate Universalism treats everyone at the same time, but more intensely for those who need it most. Planning for proportionate universalism requires an assessment of the need and an understanding of socioeconomic inequalities on health outcomes. A knowledge of how to allocate resources per unit of additional need is essential (Marmot et al., 2010).

1.8.2 Upstream approaches

Building on the work of Marmot et al. (2010) and applying it to oral health, Watt (2007) sets out “From victim blaming to upstream action” as one of the “radical reorientations” needed to tackle inequalities. This approach aims to tackle the social determinants of health, instead of blaming individuals for the choices they have made. Watt highlights the causal pathways which link the biological, behavioural, psychosocial, environmental, and political factors to health outcomes and inequalities. Watt (2007) also provided examples, one of those is smoking. This highlighted the greater value and effectiveness of upstream fiscal policies and environmental regulations compared to those based on behavioural and clinical preventative measures. Furthermore, Watt provided examples of local and national upstream actions to promote oral health. Policies could be developed to focus on local levels, for example, nutrition policies in schools and nurseries, encourage community clinics to sell subsidised toothbrushes and toothpastes, encourage nurseries and schools to subsidise healthy snacks, or encouraging schools to become involved in the Health Promoting Schools Network. At a national level, policies could be to encourage tighter legislation on food labelling and claims, support the removal of VAT on oral hygiene products, support legislation of content and timing of television adverts promoting childrens foods and drinks, or encouraging greater availability of sugar-free paediatric medicines. Health professionals, as well as dentists, provide health advice on sugar reduction to the public, however, there has been minimal evidence showing this approach works (Macpherson et al., 2019a). Further emphasis has been placed on the need for more novel upstream methods by Watt et al. (2019). Upstream initiatives can be used to tackle diseases which share common risk factors. For example, the WHO recommended emphasising the limit on intake of free sugars as this could control caries and obesity (WHO, 2016). An example of this type of policy was the introduction of the 'Sugar Tax', which has been predicted to have a positive impact on a child's oral health and obesity (Briggs et al., 2017; Rogers et al., 2023b).

1.8.2.1 Taxation of sugar-sweetened beverages

A sugar tax was first adopted by Norway in 1981 and in 2018 a total of 36 nations and 8 US cities had adopted some form of sugar tax (World Cancer Research Fund International, 2018). It has been suggested that a minimum sugar tax of 10% has an effect on purchasing behaviour, however, a 20% sugar tax has been found to be the most effective rate for reducing consumption of SSBs (Backholer et al., 2016, 2017; Pan American Health Organization, 2015a; A. Wright et al., 2017).

Mexico introduced a 10% sugar tax in 2014. Preliminary results from this showed an average of 6% reduction in purchases of SSBs in 2014 compared to 2013, with a 7% increase being recorded in purchases of non-taxed beverages. During this period, sales of mineral water increased nearly 4%, showing the tax has a significant impact on consumer purchasing behaviour (Pan American Health Organization, 2015a). It has been noted that more time is required to be able to understand the full impact of this sugar tax on the country's health, but initial reports suggests the tax is a powerful tool to protect public health (Pan American Health Organization, 2015a). However, analyses of Mexico's sugar tax acted as a tipping point for the sugar tax roll out across the world.

The UK Government launched a Soft Drink Industry Levy, dubbed the 'Sugar Tax', in April 2018. Since the announcement in March 2016, over 50% of manufacturers reduced the sugar content of drinks, even before the launch date. This resulted in removing 45 million kg of sugar every year from SSBs (HM Treasury, 2018). The money raised from this tax was expected to add extra resources to primary schools, mainly in healthy breakfast clubs and sports equipment. The UK's version of the sugar tax implicates a 24p per litre charge on drinks with more than 8g of sugar per 100ml and 18p per litre charge on drinks with 5-8g of sugar per 100ml. Research on healthy eating found only 38% of the Scottish population would be deterred by the sugar tax (Mintel Press Office, 2018). It remains to be seen the full impact that sugar tax will have on the UK.

Initial reports on sugar intake since this sugar tax has found a 3.5% reduction is the sales weighted average total sugar per 100g in items for consumption at home between 2015 and 2020 (Office for Health Improvement & Disparities, 2022). This reduction was much smaller (0.2%) in out of home purchasing between 2017 and 2020. There have been reductions in purchasing for consumption at home in yogurts and fromage frais (13.5%), breakfast cereals (14.9%), ice cream, lollies, and sorbets (7.2%), sweet spreads and sauces (10.1%), puddings (2.3%), cakes (3.2%), morning goods (4.9%), and chocolate confectionery (0.9%). The reduction in product was not so clear in outside of home consumption. There was a reduction is cakes (8.2%) and morning goods (8.2%), however ice cream, lollies, and sorbets (0.5%), puddings (0.3%), and biscuits (0.3%) all increased (Office for Health Improvement & Disparities, 2022). The other food categories from the at home consumption were not included in the out of home analysis as there was a lack of quality data to compare. This analysis has suggested that at home consumption of sugar has decreased although there is no clear change in consumption outside of the home.

The first evidence of the impact of the sugar tax in the UK has reported that the tax may have prevented over 5,000 incidences of obesity in girls aged 10- to- 11-years-old in England, an 8% relative reduction (Rogers et al., 2023b). This reduction was largest in girls from the 40% most deprived areas. The interrupted time series analysis tracked prevalence of obesity in England between 2014 and 2020 using surveillance data from the National Child Measurement Programme. No association was found in boys of same age or children aged 4- to- 5-years-old (Rogers et al., 2023b). The authors state a potential reason for no difference in the younger age group is due to young children not yet consuming SSBs. A further interrupted time series analysis by Rogers et al. (2023) reported the effect of the sugar tax on childhood hospitalisations for carious tooth extraction under general anaesthetic as a proxy for child oral health. Using data from Hospital Episodes Statistics, it was found that the incidence rate for admissions fell from 31.0 admissions per 100,000 people per month (between January 2014 and March 2018) to 28.5 after the introduction of the sugar tax (April 2018 to February 2020), which based on population estimates is a reduction of 5638 admissions. The reduction in admissions was largest in children aged 0- to- 4-years-old with a relative reduction of 28.6% (95% CI: 21.5% to 35.6%), followed by a 5.5% (95% CI: 0.5% to 10.5%) relative reduction in children aged 5- to- 9-years-old. No overall reduction was identified in children aged 10- to- 14-years-old and 15- to- 18-years-old (Rogers et al., 2023a). These improvements were not only seen in age, but also in socioeconomic status, with all fifths of Index of Multiple Deprivation (IMD) showing a reduction in admissions, except IMD 3 (middle deprived areas). Those from IMD 2 (second most deprived fifth) had the greatest relative reduction (16.8%; 95% CI: 22.4% to 11.3%).

1.8.3 Midstream approach

Midstream approaches as defined by Watt (2007) refers to community levels action it attempts to equip at-risk communities with the right tools and knowledge to protect them against social and environmental factors they face on a daily basis. This attempts to mitigate against the effects of structural determinants of health which influence social position and circumstances through empowering communities. Historically, professionals developed strategies and policies with little or no consultation with the targeted populations. Midstream policies engage those who the policies are designed for. The communities can take part in planning, designing, governing, and the delivery of the services through many forms, such as forums and volunteering (OMara-Eves et al., 2013). These approaches have been gaining increasing support, but it is critical to consider if and under what situations these strategies are effective. There is a lack of robust synthesis of research which focuses on the effectiveness and cost efficiency of community based action. However, more recent work has found community-based interventions to be valuable to improving health outcomes (Brunton et al., 2015, 2014; OMara-Eves et al., 2013). OMara-Eves et al. (2013) note that it is difficult to determine which particular model of community engagement is best or more likely to be effective, and that much greater emphasis should be put on the long-term outcomes for direct and indirect beneficiaries, evaluation, and reporting costs and resources.

1.8.3.1 Community engagement in health

Blair et al. (2006) demonstrated how working in the socioeconomically disadvantaged communities can have benefits on oral health outcomes. The study aimed to develop an oral health promotion programme to improve the dental health of children under 5-years-old in two socioeconomically disadvantages areas in Glasgow. Using voluntary programmes and actions groups, these partnerships have the potential to support families through advice and learning new skills required to improve oral health in the home, through areas such as self-empowerment, resilience, and debt management. Community-based approaches provide a local network of support, in which those who need help can help each other. Oral health can be integrated into other existing health services such as ante-natal classes. This work was a fore-runner to Childsmile (Section 1.9).

Public Health England set out a toolkit of examples of ways to promote oral health in communities through community action (Public Health England, 2014). Split into four themes - Supportive environment, Strengthening community actions, Supporting consistent evidence informed information, and Community-based preventative services - interventions can take the form of supervised tooth brushing in targeted settings, oral health training in the wider workforce, targeted community-based fluoride varnish applications, or targeted provision of toothbrushes and toothpastes. Additionally, the toolkit identified initiatives which involved healthy food and drink policies in local childcare settings with, with a common risk factor approach, could help benefit other NCDs such as obesity.

1.8.4 Downstream approach

Downstream interventions are delivered at a micro level, usually one-to-one and in clinical settings. These interventions are focused on behaviour change or support for individuals. Downstream interventions are generally for those who actively seek support, which has led to suggestions that these interventions do not reduce inequalities, but may in fact increase inequalities, although no conclusive evidence has been presented on this (Lorenc et al., 2013). Those who need the interventions most are generally less likely to engage with the services, which could widen these inequalities. In addition, downstream interventions can be costly, time consuming, and ineffective. However, in oral health improvement prevention approaches in clinical settings have an important place. The literature review was recently comprehensively reviewed in 'Delivering Better Oral Health' (UK Government, 2021) with strong evidence from fluoride based one-to-one prevention, but more limited for dietary interventions.

1.8.4.1 Food banks

Food banks are an example of a downstream intervention, where those who are already experiencing socioeconomic issues rely on immediate help from these services. Food bank use is on the rise in Scotland and the UK (The Trussell Trust, 2023a). Food banks can help those in need, but they must be accessible to those who need them most. If a family is unable to access the food bank, this downstream intervention is unlikely to work and potentially widen inequalities between them and those that can access the services.

1.9 Childsmile

Scotland has a very poor record on oral health. Because of this the Scottish Government created *An Action Plan for Improving Oral Health and Modernising NHS Dental Services in Scotland* (Scottish Government, 2005). This action plan set targets on improving oral health across Scotland from birth no matter of a person's social standing. This was the first step towards the creation of Childsmile, the national child oral health improvement programme (Childsmile, 2020). The programme is designed to improve the oral health of children in Scotland and reduce inequalities both in dental health and access to dental services, at upstream, midstream, and downstream levels, combining universal and targeted elements aiming to achieve a proportionate universal approach in the population. Childsmile aims to provide every child with a tailored programme of care within Primary Care Dental Services, free daily-supervised toothbrushing in nursery, fluoride varnish application in nursery and school, free dental packs to support toothbrushing at home, and Dental Health Support Workers in community settings. Childsmile is a Scottish Government funded project, which since 2011 has been delivered in all health board areas throughout Scotland. The programme adopts a multifaceted, multisetting approach.

1.9.1 The founding principles of Childsmile

The national child oral health improvement programme for Scotland, Childsmile, was launched as demonstration projects in the West and East of Scotland, in response to the Action Plan in 2006 (Macpherson et al., 2010a; Turner et al., 2010). Childsmile was built on a foundation of public health principles aimed at reducing health inequalities as outlined in the Ottawa Charter (WHO, 1986), as well as the latest evidence from systematic reviews and clinical guidelines from the Scottish Intercollegiate Guidelines Network in 2005 (SIGN, 2014).

1.9.2 Evidence based preventive interventions

Childsmile was developed using the knowledge acquired from previous oral health interventions implemented in Scotland. These interventions consisted of clinical procedures administered in dental clinics (Donaldson et al., 1986), community-based initiatives that involved collaborating with the local populace, improving community knowledge and skills, providing fluoride toothbrushes and toothpaste (Blair et al., 2006, 2004), and the identification of high-risk children by health visitors who offered oral health guidance (Ballantyne-Macritchie, 2000). Interventions are based on evidence-based interventions identified in clinical guidelines (SDCEP, 2010; SIGN, 2014).

1.9.3 Theory-based development

Childsmile's creation and evaluation followed evidence- and theory-based approaches (Macpherson et al., 2019b). This development strategy defined the change mechanisms at the beginning of the programme, namely the Childsmile interventions, and the context in which they would be implemented (Blamey et al., 2007). The approach entailed involving a wide range of stakeholders, which aided in identifying evidence-backed interventions that could generate long-term positive impacts on child oral health outcomes (Macpherson et al., 2019b).

By utilising an evidence- and theory-based approach, a multi-service and multi-agency programme was designed that incorporated health visitors, schools and nurseries, community support workers and agencies, and dental services adopting upstream, midstream, and downstream principles (Macpherson et al., 2010a). The programme also adopts a Proportionate Universalism approach (Section 1.8.1).

1.9.4 Aims of Childsmile

Childsmile's main objectives were not only to enhance the oral health of children living in Scotland, but also to combat the observed inequalities in Scotland's oral health outcomes and access to general dental services (Macpherson et al., 2010a). This entailed shifting the focus of dental services toward preventive care and engaging with children from an early age (W. Wright et al., 2015), operating within and collaborating with communities, and implementing clinical prevention and oral health promotion initiatives in nurseries and schools (Turner et al., 2010). The Childsmile interventions are a mix of targeted interventions (aimed at children predicted to be at a higher risk of dental caries) and universal interventions available to all children. However, the intervention intensity can be tailored to meet the specific needs of each child, which is known as Proportionate Universalism (Section 1.8.1). Shaw et al. (2009) acknowledged that although Childsmile could anticipate which children might suffer the burden of health inequalities, Childsmile alone could not address the social determinants of these inequalities. A much broader social and political transformation would be necessary: "reform attempts to reduce health inequalities must be intersectoral and not only focused on the traditional health sector" (Shaw et al., 2009).

1.9.5 Childsmile components

Childsmile is a comprehensive intervention with multiple sectors that employs public health principles, including the common risk factor approach, upstream, midstream, and downstream initiatives, and proportionate universalism, as recommended by the WHO (1986). Since its national roll out in 2011, Childsmile has continually been developed to draw on evidence from systematic reviews (Brunton et al., 2015, 2014; OMara-Eves et al., 2013) and clinical guidelines (SIGN, 2014). The intervention is split into two parts: Universal and Targeted. Universal components are delivered to all children whereas Targeted components are aimed at those who need them most. The intervention consists of four main components: a targeted community-based intervention involving Dental Health Support Worker (Section 1.9.5.1); a universal dental primary care component where dental team members provide preventive clinical treatment and tailored dietary and toothbrushing advice (Section 1.9.5.2); a supervised toothbrushing programme offering free daily supervised toothbrushing in nurseries (universal) and schools (targeted) (Section 1.9.5.3); and the targeted application of fluoride varnish to the teeth of children in nurseries and schools (Section 1.9.5.4) in areas with high levels of socioeconomic deprivation (Macpherson et al., 2019b).

In 2006, two demonstration projects were launched in the East and West of Scotland, and after a successful trial period, the Childsmile components were rolled out across all fourteen regional NHS Health Boards in Scotland by 2011 (Macpherson et al., 2019b). The Childsmile oral health pathway (Figure 1.1) begins when the child is six- to- eight-weeks-old, with different components being introduced at various stages of their pre-school years, leading up to a dental inspection at the age of five, when they are in the first year of primary school (Primary 1). Some children continue to receive supervised toothbrushing and fluoride varnish applications in targeted primary schools, and advice and clinical prevention in dental primary care should continue throughout childhood up to 18-years-old.

Childsmile also supports policy change at the national level, with representatives of the programme participating in a multidisciplinary group that successfully developed healthy eating regulations for schools (Scottish Government, 2008). Childsmile has also been incorporated into the universal Child Health Surveillance Programme in Scotland and has contributed to the reorientation of the NHS primary care contract to pay the General Dental Servicess to delivered Childsmile interventions (oral health instruction, dietary advice, fluoride varnish application), exemplifying upstream activity.

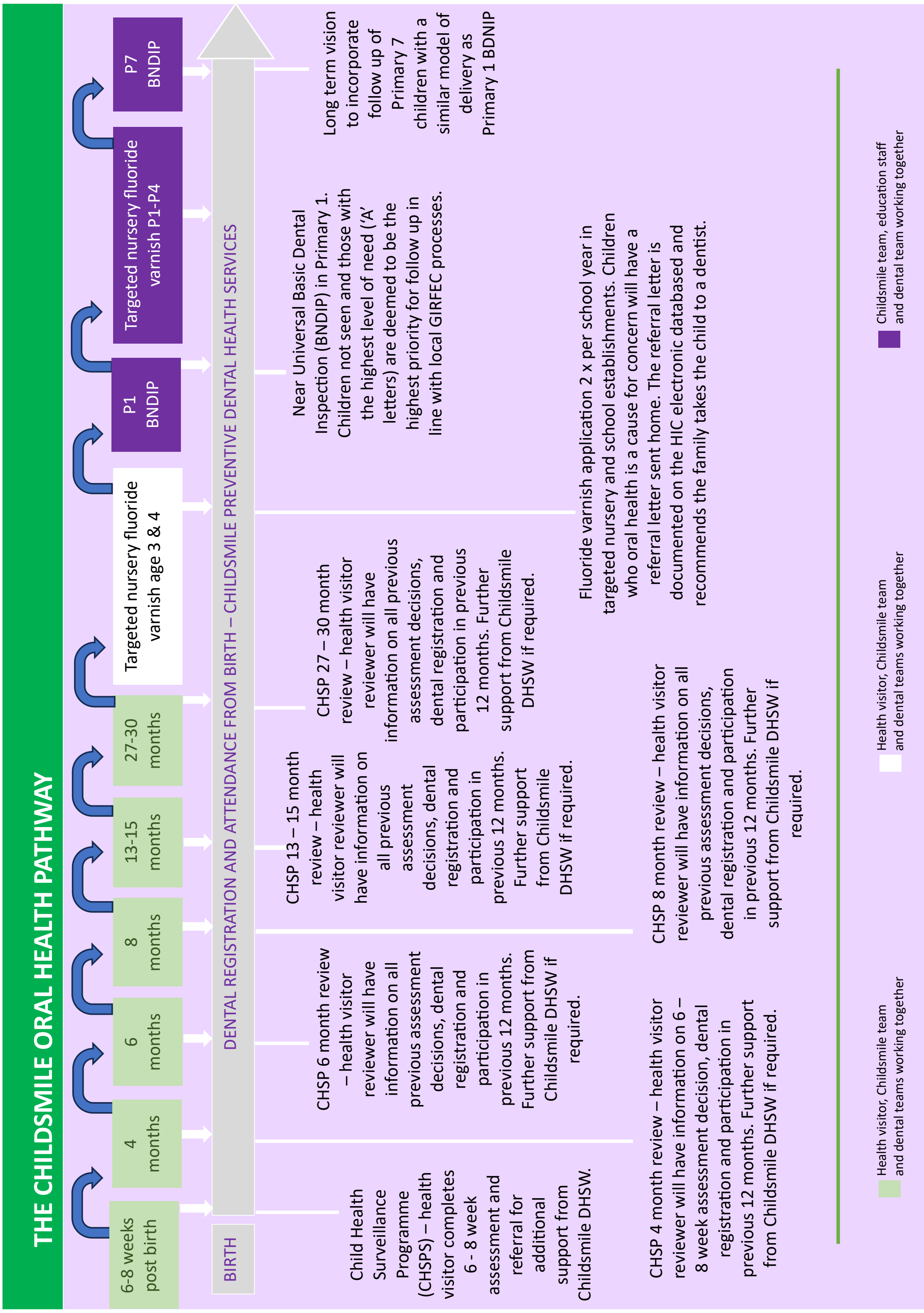

Figure 1.1: Childsmile Oral Health Pathway

Extracted from Macpherson et al. (2015) and updated from personal communication with King, P, Childsmile Programme Manager

CHSP - Child Health Surveillance Programme; DHSW - Dental Health Support Worker;

GIRFEC - Getting it Right for Every Child

1.9.5.1 Dental health support workers

The advantages of using Health Visitors, who are specifically trained nurses that visit parents with newborns throughout Scotland, to identify children at higher risk of dental caries have been previously established (Ballantyne-Macritchie, 2000). Additionally, training members of communities in areas of high deprivation in Scotland to provide oral health advice, toothbrushes, and fluoride toothpaste has shown positive outcomes (Blair et al., 2006, 2004). Based on this research, Childsmile has integrated every child in Scotland into its programme via the Child Health Surveillance Programme (CHSP) as part of the Universal Health Visitor Early Years Pathway (Scottish Government, 2015). Health Visitors regularly contact families from the time their child is 6- to- 8-weeks-old until they are 5-years-old to monitor the child's health and development, offer health advice, and refer them to various services (Scottish Government, 2015). Health Visitors have access to specific guidance on appropriate dental advice based on the child's age. Dental Packs containing toothbrushes and fluoride toothpaste are available, and children are encouraged to attend dental practices from a young age (Macpherson et al., 2019b). Health Visitors also identify families who may require additional support in relation to their child's oral health and refer them to local community-based Dental Health Support Workers (Turner et al., 2010).

Childsmile funded community-based para-professionals known as Dental Health Support Workers (DHSWs) provide support to targeted families with young children, particularly more so in areas of high deprivation as these families are usually more in need, both in the family home and at community clinics (Hodgins et al., 2018; Macpherson et al., 2019b). They offer age appropriate oral health interventions, such as providing dietary and toothbrushing advice and distributing dental packs with toothbrushes and fluoride toothpaste. DHSWs also assist in facilitating attendance at an NHS dental practice or Public Dental Services clinic, delivering Childsmile interventions tailored to the individual needs of each family (Kidd, 2012). Additionally, they can assess if a family/child requires additional support and visit them more than once if necessary. Furthermore, DHSWs work with local community agencies and third sector organisations that may help mitigate the impact of inequalities associated with wider social determinants (financial support/relationships) and signpost and facilitate engagement with local supportive organisations (Macpherson et al., 2019b).

1.9.5.2 Childsmile dental practice

Between July 2006 and September 2009, dental practices in the West of Scotland participating in the Childsmile pilot programme received remuneration directly from Childsmile for their involvement. However, in October 2011, Childsmile was incorporated into mainstream NHS Scotland dental services, and remuneration payments began to be made through the Statement of Dental Remuneration, the contract used to pay NHS dentists for their services (Scottish Government, 2011a). This change made Childsmile available in every NHS dental practice in Scotland that offers paediatric services, and led to a shift in primary dental care towards a greater focus on prevention.

Children, accompanied by their parents or carers, are encouraged to attend a dental practice every six months from their first year of life to receive age appropriate oral health interventions that are tailored to their individual needs. The specific interventions that now attract an NHS fee include: twice yearly fluoride varnish application from the age of two; toothbrushing advice; and dietary advice. Any member of the dental team who is trained and competent in these activities, including Extended Duty Dental Nurses, can deliver these interventions. The focus has shifted from standardised health education messages to more tailored messages. Action plans should be developed jointly by the dental team member and the family, taking into account social and commercial determinants that may act as barriers to implementing preventive approaches at home. The dental team should also be aware of local organisations and groups that can provide additional support beyond the scope of their care (Watt et al., 2014). If families fail to attend, or if the dental practice identifies the need, the dental professional is able to refer the family back to a DHSW for further intervention.

1.9.5.3 Supervised toothbrushing in nursery and school

In the latter part of the 20th century, nursery toothbrushing programs were implemented in various parts of Scotland. In 2001, the Scottish Executive established a standardised national toothbrushing programme, which provided toothbrushes and toothpaste through a national procurement contract. In 2006, this programme was integrated into the broader Childsmile programme (Macpherson et al., 2013a). National standards were developed, and local dental teams trained nursery staff to comply with these standards (SDCEP, 2010). This programme is now available to every three- and four-year-old (and some eligible two-year-olds) child attending nursery, whether in a mainstream or independent establishment. As of 2007, 95% of nurseries in Scotland were participating (Anopa et al., 2015). In addition, supervised toothbrushing is available in targeted primary schools using the same method of targeting as the fluoride varnish programme (Section 1.9.5.4) (Macpherson et al., 2019b). In both nurseries and participating primary schools, children are given the opportunity to brush their teeth for a minimum of two minutes per day, using 1,000 parts per million (ppm) fluoride toothpaste (1,450 ppm since Autumn 2016), under the supervision of nursery or school staff. Children also receive a home pack containing a toothbrush and fluoride toothpaste on at least four occasions while at nursery, with the aim of promoting toothbrushing at home (Macpherson et al., 2019b).

1.9.5.4 Fluoride varnish applications in nursery and school

Fluoride varnish applications were first piloted in the East of Scotland and are currently targeted towards children aged three to eight who attend nurseries and schools located in the most deprived areas of each of the fourteen regional Scottish NHS Health Boards (Humphris et al., 2014). At least 20% of children residing in each health board are eligible for this intervention, with nurseries and schools prioritised based on the highest proportion of children living in the most deprived Scottish Index of Multiple Deprivation (SIMD) fifth within each health board. An evaluation of the programme by Brewster et al. (2013) indicated that to ensure the inclusion of children from the most deprived SIMD areas, nursery schools located in the three most deprived SIMD fifths must be included in the programme. The intervention involves the application of fluoride varnish to the teeth twice per year by Extended Duty Dental Nurses who are trained in its application (Macpherson et al., 2019b). This process also facilitates the identification of children who require further dental care within a dental practice. All Extended Duty Dental Nurses, operating in both primary dental care and the nursery or school setting, receive formal training from NHS Education for Scotland.

1.9.5.5 Dietary interventions as part of Childsmile

Dietary advice is involved in multiple components of the Childsmile programme. General dental services are paid to provide dietary advice to all parents/carers of children aged 0- to- 5-years-old who attend the dental practice. DHSWs delivered dietary support to families who receive an intervention. In addition to this support, DHSWs aim to signpost families who need further help to food/diet related community/voluntary organisations.

1.9.6 Childsmile logic model

A 'theory-based approach' was used to conceive and evaluate Childsmile. This involved creating a logic model (Figure 1.2) that incorporated evidence-based health improvement activities and approaches, and linked these to outputs, interim outcomes, and long-term outcomes, including measures of oral health and oral health inequalities (Macpherson et al., 2019b). In addition to this, stakeholders identified obesity as a potential health outcome of the Childsmile programme. The logic model was developed with input from multiple stakeholders and serves as a guide for programme development, delivery, and evaluation. Routine monitoring of the programme is used to measure if the activities are being delivered as intended and to identify potential barriers and facilitators (Central Evaluation & Research Team, 2018). If necessary, theory-based qualitative work can be undertaken to inform amendments to the programme's delivery. This 'Theory of Change' approach enables the evaluation of both short-term and long-term outcomes of the programme.

1.9.7 The evaluation of Childsmile

As well as the delivery of intervention and prevention components, Childsmile is embedded with a theory-based research and evaluation arm, led by University of Glasgow (Ross et al., 2023). Childsmile is a complex intervention articulated through a series of logic models. There are two key areas to the evaluation of the programme: a process evaluation and outcome evaluation.

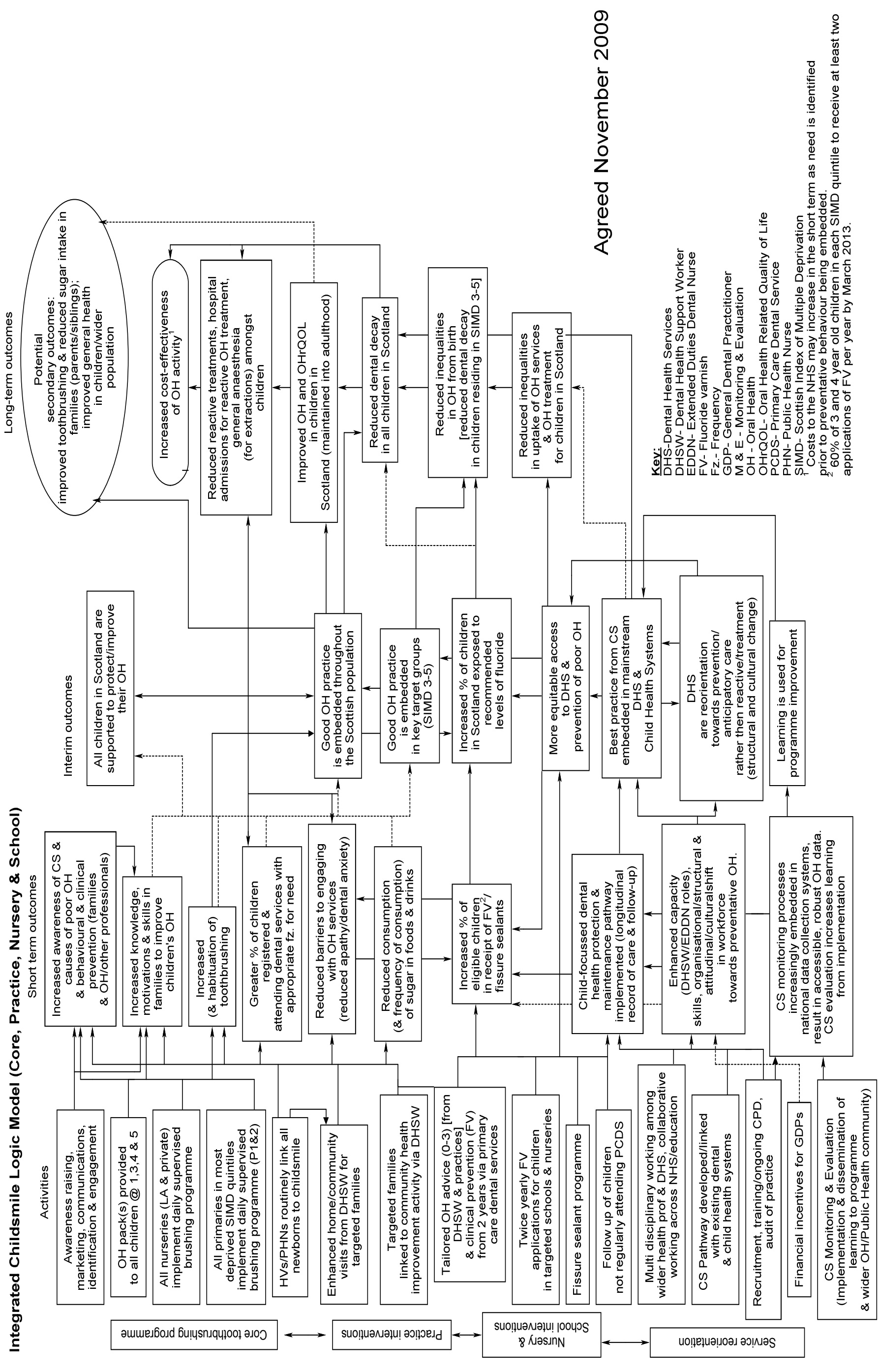

Figure 1.2: Childsmile Logic Model. Extracted from Childsmile (2010)

The use of data linkage provides a unique opportunity to analyse the outcomes of Childsmile at a population level. Safe Havens (Section 2.3.2) are useful tools that provide a secure environment for research, and by identifying and linking appropriate datasets, multiple outcomes can be analysed efficiently and effectively (Fleming et al., 2012). This approach is a cost-effective use of resources. The Safe Haven ensures that research using multiple sets of population-level administrative and health data can be effectively linked.

1.9.7.1 Process evaluation

Process evaluations are crucial to understand not only if the intervention is working but to understand why (Moore et al., 2015). The process evaluation is a mixed method approach which examines routine monitoring data which looks at the reach and participation in each component of Childsmile and assesses how closely the programme is being delivered as to how it was envisaged, supporting the continual refinement of the programme. The process evaluation covers the reach of application of fluoride varnish in education establishments and in the general dental services, participation in supervised nursery toothbrushing, and the activities of the DHSW (Macpherson et al., 2019b). The Central Evaluation and Research Team publish annual headline monitoring reports of the Childsmile programme (Central Evaluation & Research Team, 2018) and PHS publish reports on NHS dental participation (Public Health Scotland, 2023a). An example of this approach is using multiple routinely collect administrative datasets to assess the reach of the Childsmile components to children across the socioeconomic scale (Kidd et al., 2020) or using qualitative data understand the role of the DHSW and the difficulties they face day to day (Young, 2017).

1.9.7.2 Outcome evaluation

Outcome evaluations evaluate how multiple interventions of Childsmile interact with different health and education outcomes (Ross et al., 2023). Usually these will involve a data linkage analysis to combine multiple routine population-based administrative data sets to create a birth cohort. These will take a pragmatic approach, using standard operating procedures to check, managed and clean the data, as well as, epidemiological methods to address appropriate research questions.

An example of an outcome evaluation was exemplified for child dental caries, where a cost analysis of the Childsmile supervised nursery toothbrushing (Section 1.9.5.3), saw NHS Health Scotlands estimated dental intervention in children costs reduce from £8,766,297 in 2001/02 to £4,035,200 in 2009/10 due to the supervised toothbrushing component used in the programme (Anopa et al., 2015).

Another example is the evaluation of the fluoride varnish in nursery component of the Childsmile programme (McMahon et al., 2020). In this randomised controlled trial the effect of fluoride varnish application has on caries prevalence was considered. Children who did not receive the fluoride varnish application as part of the usual targeting were randomly allocated to either receive the fluoride varnish or continue with treatment as usual (i.e., no application). The children were then followed up for two years after the first application, with extra applications every six months. Findings from this evaluation suggest the fluoride varnish in nursery component of Childsmile is unlikely to be effective or cost-effective to the overall Childsmile programme (McMahon et al., 2020).

Kidd et al. (2020) conducted an evaluation of Childsmile using data linkage on routine administrative data sets in Scotland. A birth cohort was created of children who were Primary 1 in 2014/15. This study identified that participation with the different components of Childsmile were associated with reduced odds of caries experience. Participation in the supervised nursery toothbrushing and regular dental practice visits had the highest reduction of odds of caries with the supervised toothbrushing having the largest impact in children from the most deprived areas (Kidd et al., 2020). Given the Childsmile programme identified improving prevalence of obesity as a potential benefit of the programme, it is possible, using data linkage, to evaluate how Childsmile is doing at reaching children with co-existing caries and obesity and if the programme is having an impact on the prevalence.

1.10 Other UK interventions to tackle sugar related NCDs and inequalities

The UK Government has been trying to tackle sugar intake and obesity for many years. Change4life is Public Health Englands flagship programme for preventing childhood obesity, which was launched in 2009 (NSMC, 2023). The programme aims to improve health behaviours, such as: poor diet and lack of physical activity. Change4life gives suggestions to parents and children about recipes and activities they can both be involved in, as well as facts about food in general. The campaign has five main phases: reframing the issue; personalising the issue; rooting the behaviours; inspiring people to change; supporting families as they change (NSMC, 2023). In the programmes first year, the campaign reached 99% of its target population, with 413,466 families joining within the first 12 months and 44,833 participating after 6 months (NSMC, 2023). An informal evaluation of the programme reported that researchers noted that the embedding of the programme within wider policy benefited the programme, as well as the engagement of specialist suppliers and open source marketing to allow partners to create their own sub-brands (NSMC, 2023). The research note that in hindsight they would spend more time on developing the programme as well as developing more products for professionals, for example, teachers and doctors. A quasi-experimental evaluation of the impact of food purchasing behaviours after the ‘Smart Swaps’ campaign from Change4Life by Wrieden et al. (2016) identified short term success. The study found that the intervention group made more ‘smart swaps’ than the comparison group. A ‘smart swap’ could be considered as purchasing a lower sugar cereal or lower sugar drink. The authors note that further research would be required to evaluate longer term behaviours. A wider evaluation of programme using a cluster-randomised trial found that the materials results in greater awareness but had little impact on changing attitudes and behaviours, with low engagement being blamed (Croker et al., 2012).

Designed to Smile works with families and children aged 0- to- 7-years-old to improve children’s dental health in Wales (Designed to Smile, 2023). The programme provides guidance to families, provides toothbrushes and toothpaste, encourages a visit to the general dental services at an early age, and daily toothbrushing and twice yearly application of fluoride varnish in targeted schools and nurseries from more socioeconomically disadvantaged areas. The programme publishes annual monitoring reports with the latest version covering the school year 2021/22 which reported on the recovery from the COVID-19 pandemic in which the full programme was not able to be delivered (Dental Public Health Team, 2022). The monitoring report before the pandemic covered the school year 2018/19 and reported that 82% of eligible nurseries and schools were participating in the programme across Wales (Morgan et al., 2023). The fluoride varnish component of the programme was delivered in 89.9% of eligible establishments and 99.4% received toothbrushing visits and follow-ups.

1.11 Summarising the Gaps in the Literature

Dental caries and obesity are the most common NCDs in young children across the world (Kassebaum et al., 2017; WHO, 2023b). Obesity and oral diseases have been known to have an impact on a child's quality of life and are marked as early risk factors for other NCDs which may develop later in life, such as cardiovascular diseases, diabetes, and acute and chronic infections (Botelho et al., 2022; Weihrauch-Blüher et al., 2018). Caries and obesity are known to be public health problems within Scotland, with both conditions being unequally distributed across the socioeconomic scale (Information Services Division Scotland, 2018b; Macpherson et al., 2018). Although the magnitude of the caries and obesity problem has yet to be estimated and described.

Many studies have been conducted on the association between caries and obesity, however, no studies or reviews have been able to come to a conclusion regarding the direction and nature of the association (Alshihri et al., 2019; Hayden et al., 2013; Hooley et al., 2012). Identifying an association between caries and obesity is important given the prevalence of both conditions and the problem they may pose to current and future public health services. To the researcher's best knowledge, there have been no studies conducted so far on the association between caries and obesity using Scottish data. This research aims to fill this gap in the literature regarding the association in children in the first year of school. In addition, it aims to create a standard method for any future analysis of the association between caries and obesity in Scotland. This standardisation for Scottish data would be useful to future research given the amount of different results from using different methods of diagnosing for caries and obesity used across the world (Alshihri et al., 2019; Hayden et al., 2013; Hooley et al., 2012).

It has been suggested that dental caries and obesity may be more prevalent in individuals or populations due to the shared risk factors of excessive free sugar intake, socioeconomic deprivation, and wider social determinants (Alshihri et al., 2019; Hayden et al., 2013; Hooley et al., 2012). However, it is important to note that there are many other non-shared risk factors for these conditions. Obesity is influenced by various complex factors such as calorie intake, physical activity, genetics, and media exposure (Chi et al., 2017; Reilly et al., 2005). Similarly, dental caries can be influenced by exposure to fluoride, dietary composition, oral bacteria, salivary composition and flow rates, and tooth enamel structure, in addition to free sugar intake and socioeconomic deprivation (Harris et al., 2004). No study in Scotland has investigated the prevalence of co-existing caries and obesity in children in Scotland in relation to socioeconomic deprivation and other determinants such as age and sex.

The Childsmile programme in Scotland is a well-established programme within Scotland which has helped to successfully reduce the prevalence of caries in young children in Scotland. The programme has components which involved dietary support and advice. To utilise the common risk factor approach (Sheiham et al., 2000) it is beneficial to understand whether Childsmile currently reaches children with obesity and caries and to understand if the dietary components of the programme have an impact on reducing the risk of these conditions, but also to indicate potential opportunities where enhanced/improved interventions could be delivered to those with obesity and/or caries.

Data linkage presents a valuable chance to conduct a population-level analysis of Childsmile's outcomes. Safe Havens (Section 2.3.2) serve as an exceptional tool, creating a secure environment that supports research. By identifying and connecting relevant datasets, this approach enables the analysis of multiple outcomes rather than focusing solely on a single outcome (Fleming et al., 2012). Consequently, it optimises resource utilisation and proves to be an efficient and effective methodology.

1.12 Aims

The overarching aims of this thesis are:

(a) to measure the prevalence and socioeconomic inequalities in childhood dental caries experience and obesity in Primary 1 (circa 5-years-old) school children in Scotland, separately and together between 2011 and 2018.

(b) to examine the interrelationship between childhood dental caries experience and obesity.

(c) to measure the prevalence and socioeconomic inequalities in co-existing childhood dental caries experience and obesity between 2011 and 2018.

(d) to explore the reach and impact of the national child oral health improvement programme for Scotland, Childsmile, in preventing childhood dental caries experience and obesity between 2015 and 2018.

1.13 Overarching Research Questions

1. What are the trends in prevalence and socioeconomic inequalities in childhood dental caries experience in Primary 1 children in Scotland between 2011 and 2018?

2. What are the trends in prevalence and socioeconomic inequalities in childhood obesity in Primary 1 children in Scotland between 2011 and 2018?

3. What is the relationship between childhood obesity, as well as other categories of BMI, and dental caries experience in Primary 1 children in Scotland and has it changed between 2011 and 2018?

4. What are the trends in prevalence and socioeconomic inequalities in those children who have co-existing dental caries experience and obesity and have these changed between 2011 and 2018?

5. Have children with co-existing dental caries experience and obesity been reached by the Childsmile programme prevention in dental settings, community services, and educational settings by 5 years of age between 2015 and 2018?

6. Has the delivery of Childsmile dietary interventions by 5 years of age had an impact on the prevalence of co-existing dental caries experience and obesity between 2015 and 2018?

These research questions will be primarily addressed in the analysis in Chapters 3 to 7. Chapter 2 sets out the methodological aims and objectives with overarching purpose of obtaining and linking the population-level data that are required to answer the above research questions. Following the final analysis chapter (Chapter 7) the analyses will be summarised and discussed in detail, as well as future steps based on the results.

1.14 Thesis Outline

This introductory chapter has provided background information, has identified gaps in the literature, and stats the aims and research questions for the thesis. Chapter 2 will describe the data indexing, management, quality checks, and cleaning on the data, as well as overarching statistical methods. Chapter 3 will explore the trends and inequalities in the prevalence of caries experience in Primary 1 children in Scotland. Chapter 4 will follow this by exploring trends and inequalities in BMI status in the same population. Chapter 5 will explore the association between caries experience and BMI status before going onto explore the prevalence and inequalities of co-existing caries experience and obesity in Chapter 6. Chapter 7 will analyse if the Childsmile programme has reached children with co-existing caries and obesity and estimate if the dietary components of the programme have had an impact on the prevalence. Lastly, Chapter 8 will provide explanations for the results and provide recommendations for the future based on the results of the thesis.

Chapter 2

Methods

2.1 Overview

The aims of Chapter 2 are to describe the data indexing and management which form the base data for this thesis and also describe the quality checks on the data to ensure validity. The chapter will aim to cover the main statistical analyses used to answer the research questions. The chapter is split into three chronological sections: 'data indexing, management, and quality checks', 'data cleaning', and 'statistical methods'. A timeline of these activities are presented in Figure 2.1. This figure also notes whether tasks were completed by the author, the research team at the University of Glasgow, or in collaboration. Whilst the timeline ends at the point this thesis was submitted, the overall Childsmile evaluation continues through other projects.

The data indexing, management, and quality checks section describes the linked and anonymised child level databases, from many sources, that were linked together. The data management, quality, and completeness checks are detailed. The data cleaning section describes the inclusion criteria for each data set and the process involved in refining the data to ensure only accurate observations are retained. The statistical methods section details overarching statistical methods used to answer the research questions. More specific statistical methods relevant to research questions are included within each chapter. Relevant cohort assembly methods are within each chapter.

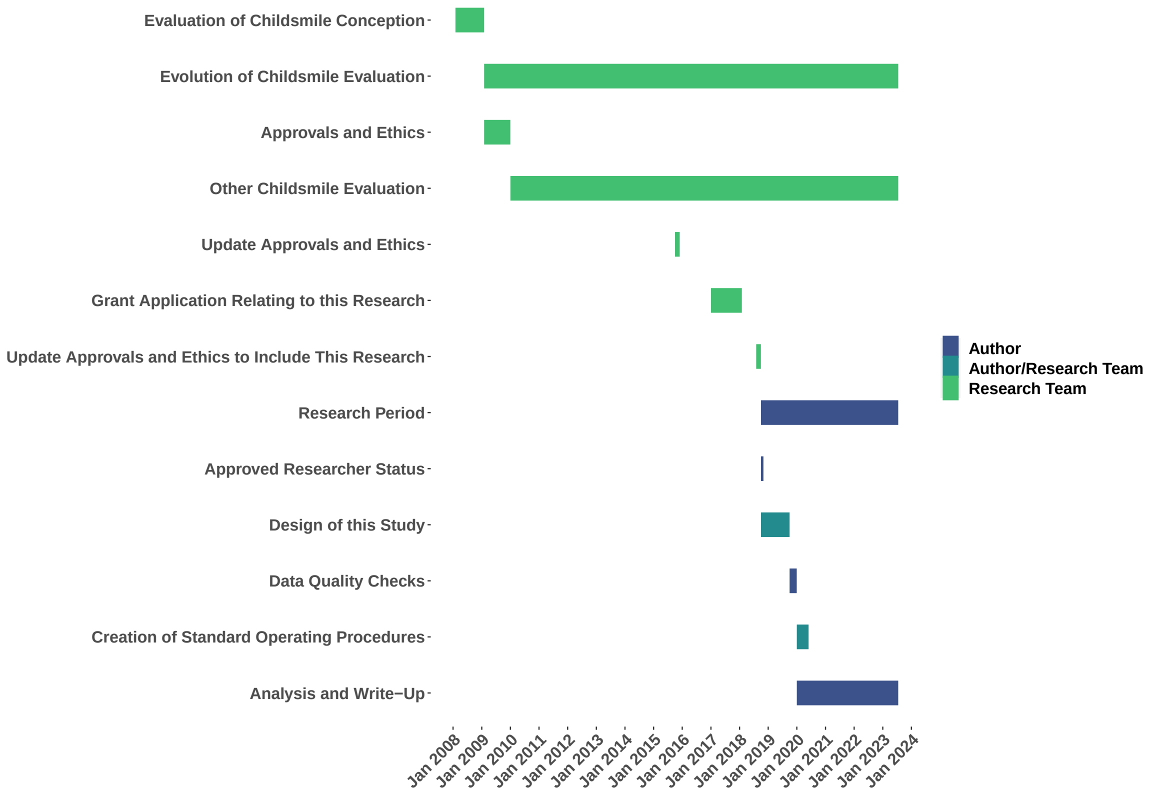

Figure 2.1: Timeline of the the research in context of the overall Childsmile evaluation

2.2 Chapter 2 Objectives

The objectives of chapter 2 are to:

1. describe the gaining of ethical and Information Governance approval to access and link multiple individual child level datasets within a Safe Haven environment.
2. specify the datasets and variables that are relevant to the analyses planned for this thesis.
3. describe the undertaking of quality and completeness assessments of the datasets that were uploaded to the Safe Haven.
4. create variables to be used to answer the research questions.
5. set out the overarching statistical analyses in this thesis.

2.3 Data Indexing, Management, and Quality Checks

This thesis utilises secondary data analysis from a series of population-based cross-sectional and longitudinal birth cohorts where data have been collected routinely from birth to Primary 1 (approx 5-years-old) of children living in Scotland. The data are sourced from routine administrative data and bespoke databases, collected at the individual level on the population by Public Health Scotland (PHS) and stored and analysed within the National Safe Haven (Section 2.3.2). Data were available for a number of years, however, each chapter uses specific years which have been detailed within each chapter.

2.3.1 Information governance approvals and ethics

The data linkage of routine administrative datasets to evaluate the reach and impact of the Childsmile programme was first proposed in 2008 by the Childsmile Evaluation board. This study, titled *Evaluation and development of Childsmile - the national oral health demonstration programme for Scotland*, aimed to evaluate the trends, inequalities, and the reach and effectiveness of the Childsmile programme on child health outcomes. Approval was granted by ethics committees which were in place at the time, and the initial application was updated over time. The following section describes the Information Governance Approvals in place for this thesis.

In October 2015, an application was submitted to Public Benefit & Privacy Panel (PBPP) for Health and Social Care (Public Benefit & Privacy Panel, 2015) by members of the Childsmile evaluation team at the University of Glasgow. The PBPP application covered multiple branches of the evaluation. The application also included:

- names of the users accessing the data and their current information governance training status,
- an overview of the study and why it was needed, along with the aims and objectives and the possible benefits to public health. An outline of the proposed

design was developed, which gave: data sources; inclusion/exclusion criteria; relevant date range; and the need for identifiable or potentially identifiable data,

- proposed duration of the study (given as 5 years in the first instance) and proposed requirements for updated data at regular intervals (given once during during the 5 years, expected around 2 to 3 years into the approval),
- details of ethical approvals,
- the Safe Haven that the requested data were to be accessed through,
- list of datasets and the variables that were required including the period they would cover (e.g., all CHSP-S inspections from 2008 to 2018) and whether the variables were required for processing only (e.g., child's postcode which was not required after Scottish Index of Multiple Deprivation (SIMD) had been attached to the data).

An amendment was made to the PBPP in October 2018 by the Childsmile evaluation team to request updated data up to and including the school year 2017/18 (initially 2014/15) and some fields within some datasets. This application update included relevant approvals in regards to this particular research project as part of the overall evaluation of Childsmile. This update was approved by the PBPP in November 2018 (Appendix B). An ethics application entitled "*Childsmile: the national oral health programme for Scotland; Evaluation and development project: Phase II*" was submitted to the University of Glasgow's College of Medical, Veterinary and Life Sciences Ethics Committee for Non-Clinical Research Involving Human Subject in January 2016. This was approved in the same month. These applications and amendments were in place for the author of this thesis beginning the PhD. Various extra amendments have been made to the PBPP application since the 2018 version, none which relate directly to this thesis except the extension up until 2025.

2.3.2 National Health Service National Services Scotland National Safe Haven

Between 2009 and 2012, the Scottish Government led consultations with public health and health service researchers in Scotland to create and publish strategies on their data linkage process, at a time where growing amounts of administrative datasets were being stored electronically. The aim of these strategies was to develop 'a culture where legal, ethical and secure data linkage is accepted and expected' as well as minimising the risks to privacy while enhancing transparency and to encourage the realisation of the benefits which can be achieved through data-linkage, maximising the value of administrative and survey data (Scottish Government, 2012a). The use of Safe Havens was deemed the best approach to implement these strategies.

The National Health Service (NHS) National Services Scotland (NSS) National Safe Haven was launched in November 2012. This provided researchers a safe and secure platform from which they could access, link, and analyse a wide range of administrative datasets including NHS owned. The National Safe Haven as it is now, is provided and run by the Edinburgh Parallel Computing Centre (EPCC). This launched in December 2015.

2.3.3 electronic Data Research and Innovation Service

The electronic Data Research and Innovation Service (eDRIS) was developed as a service to support national data linkage work. It was hosted within NHS NSS, now Public Health Scotland (PHS), and each project is provided with a named Research Coordinator to support access to the National Safe Haven. The Research Coordinator is there to provide support and guidance on the process of data linkage. This includes advice on the suitability of datasets and having appropriate consent and ethical approval to access and link the datasets required for the study. The Coordinator also provides support to the user to gain appropriate information governance training which is required before access to the data can be granted. Guidance is also given on how to access the Safe Haven through software installation and logon credentials. eDRIS review and disclose outputs that are requested by any researcher to ensure the outputs are non-identifiable and confidential. All requested outputs must be checked by an eDRIS research coordinator to ensure no table cells contain values less than five observations, or geographical tables with cells less than a count of ten, among other approvals. The researcher must complete a checklist before requesting disclosure (Appendix C).

2.3.4 Approvals to access National Health Service National Services Scotland National Safe Haven

All persons wishing to access and use the National Safe Haven have to be affiliated with an approved organisation, University of Glasgow in this instance. Furthermore, all persons had to read and sign the eDRIS 'User Agreement' and be named in the study's PBPP approval form. The author of this thesis completed an e-learning modules and quiz provided by the Medical Research Council titled *Research, GDPR and confidentiality* in September 2018 (Appendix D). The approvals from the e-learning modules lasted three years and were completed again in November 2020 (Appendix E) and June 2023 (Appendix F).

2.3.5 National Safe Haven installation and access to remote desktop

The Safe Haven can either be accessed within a physical secure access area in NHS buildings with workstations provided exclusively for working with data in the Safe Haven, or via a remotely accessed portal which provided approved users access to the National Safe Haven using a computer outside of the physical secure access area. Various hubs exist in which the Safe Haven can be physically accessed from secure locations, however, with the length and complexity of the study it was decided the best approach was access through a remote portal. Remote access to the National Safe Haven gave use of the datasets and also software packages within the portal.

A laptop was installed with a University of Glasgow Standard Staff Desktop which was linked to the National Safe Haven through a Virtual Private Network (VPN) using instructions provided by eDRIS. The VPN - Cisco Anyconnect Secure Mobility Client VPN - was installed by the Information Technology (IT) team within the College of Medical, Veterinary & Life Sciences at the University of Glasgow on to the laptop. This software was used to authenticate users when connecting to the National Safe Haven through a VPN. The next step was to install Citrix Receiver software. This allowed users to link their local computer to a virtual desktop. In this instance, the virtual desktop would be the same desktop as if they had logged onto the Safe Haven through a secure workstation within the National Safe Haven's physical secure access area.

The researcher provided the eDRIS Coordinator with a mobile phone number who in turn provided a username and password (username given by email and password given over the phone for security purposes) for access to the Safe Haven. The researcher received a document containing instructions and a link to the login page. Once on the login page, the researcher could enter their personal username. This then triggers a one-time use pin code to be sent to the user's phone. Once the pin is entered, the laptop connects to the Citrix Receiver. Access to the virtual desktop is then granted by entry of the personal/study username and password. Access to the Safe Haven is locked if left inactive for a period of time and the password would have to be re-entered. If the laptop lost connection the Cisco Anyconnect VPN, the full process to login the Safe Haven would begin again. Both passwords were to be changed monthly.

2.4 Data Linkage Process

The follow sections describe the data linkage process used to obtain the datasets for the thesis.

2.4.1 Transfer of linkable datasets into safe haven

The process involved in securely transferring the datasets from the providers into the NHS National Safe Haven is summarised in Figure 2.2. The processes are to ensure that potentially identifiable variables are kept anonymous. Potentially identifiable variables, such as DHSW name, were given anonymised codes to protect the identity of

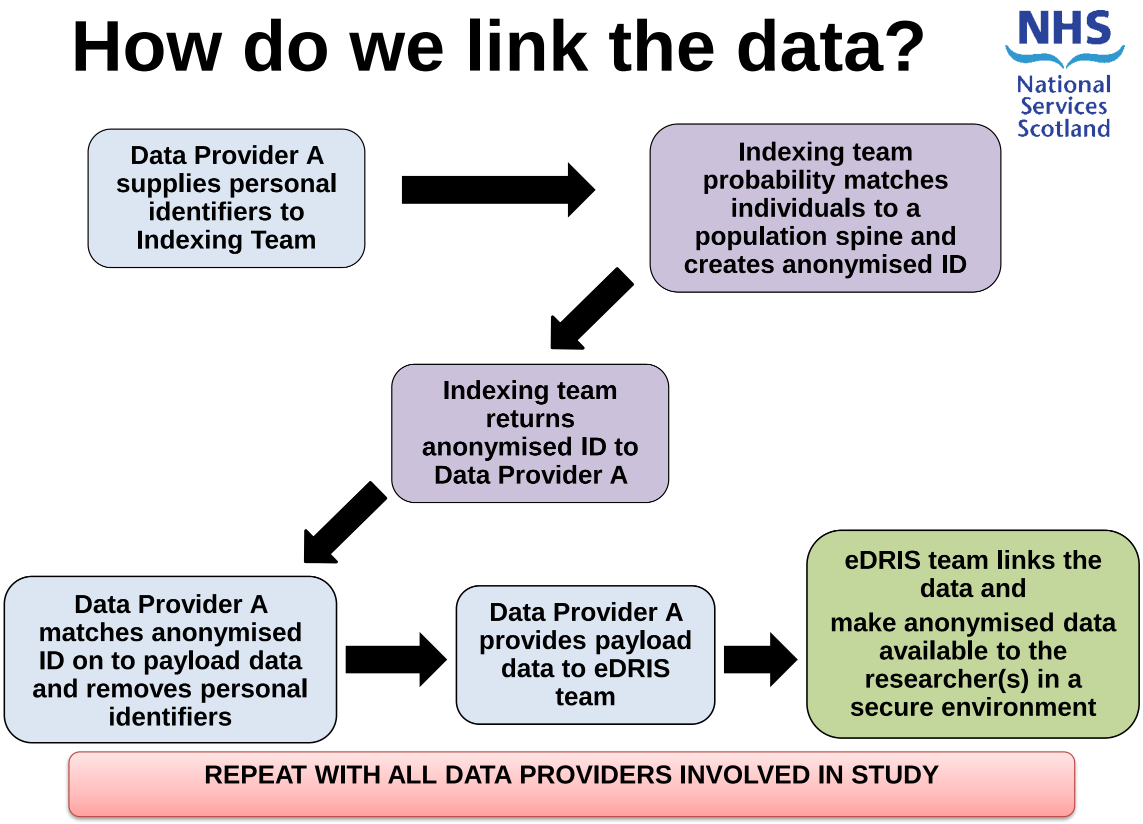

Figure 2.2: Linkage Process for NHS NSS Safe Haven

Extracted from Information Services Division Scotland (2010)

the individuals. PHS processed and provided all datasets, including the HIC datasets for the Safe Haven. The uploading of all datasets into the Safe Haven was completed in October 2019.

2.4.2 Indexing and transfer of datasets from indexing team back to data providers

The PHS Indexing Team processed each of the files and replaced the Community Health Index (CHI) number (Section 2.6.1) with a unique study person ID. This ID was unique to each child and in each dataset to ensure data could not be linked outwith the Safe Haven which could lead to breaches in confidentiality and protection. One of the main reasons for the Safe Haven is to protect and ensure confidentiality and for results to be released from the Safe Haven after disclosure checks have taken place. The disclosure checks ensure the confidentiality of individuals is upheld. If a child had more than one record within a dataset, the ID would remain the same within the individual dataset.

These files are then returned to the data providers through the Secure File Transfer Protocol (SFTP).

2.4.3 Transfer of datasets from data providers to linkage agent

For each dataset, a series of new datasets containing a unique local reference number along with the content data (data which contained variables of interest e.g. the health outcome) that had been approved by PHS for use in the Safe Haven were generated. The files returned from the Indexing Team were linked with the generated files. This appended the unique study person numbers on the content data and the unique local reference number was then removed from the files.

The updated files were sent to eDRIS via the SFTP and were processed directly by a Linkage Agent. The Linkage Agent automatically processes the files without any manual input.

2.4.4 Upload of linkable datasets into safe haven via linkage agent

The Indexing Team uploaded a ‘key’ to the linkage agent which contains a list of each unique study person’s ID and a corresponding index number (a linkage ID which was unique for each child with at least one record in any of the datasets being uploaded into the Safe Haven). The key was used to remove the unique study person index number, which was replaced with an index number. This index number allowed records to be matched and linked across datasets within the Safe Haven.

The Indexing Team uploaded a file into the Linkage Agent which contained a list of index numbers of records in the index datasets (Section 2.7). All datasets in the Safe Haven were then linked with this file. This meant that only children with records in CHSP 6-8wk (Section 2.8.1), NDIP Primary 1 Basic, and/or NDIP Primary 7 Basic (Section 2.8.2) were included in the datasets uploaded into the Safe Haven. This ensured that it was not possible for data providers to be able to identify which children were in the dataset from the original files.

Once this process was complete, the datasets were then securely uploaded into the Safe Haven. These datasets only included the index number and variables of interest. The index number allowed records from different data providers to be linked within the Safe Haven in order to complete the analysis required.

2.5 Linkage Methods

This section describes the principles and methods used to link datasets. The CHI number, is the basis of the data linkage. Data linkage is not 100% accurate so steps were taken to assess the validity of the linkage process to ensure the correct child's data were linked together. The data linkage process is explained previously (Sections 2.4.1 to 2.4.4).

The validation was completed by comparing all datasets to publications, where possible, but also comparing descriptive data across the datasets.

2.5.1 Data linkage principles

The Scottish Government has previously published information on upholding the principles of data linkage which emphasise the importance of privacy (Scottish Government, 2012b). The report notes that a balance is required between respect for privacy and the potential benefits to the general public through use of data for research purposes. However, methods for mitigating risks, for example, anonymisation and pseudonymisation, must be considered. The data controllers and researchers should make every reasonable step to minimise the risk of identification of any individuals from the data (Scottish Government, 2012b).

This thesis aims to look at data from multiple datasets and so requires a unique identifier for each child. However, the default position for data linkage is that the individual's name and direct identifiers should be removed. The main source of unique identifiers for health care in Scotland is the use of the CHI number. This number can be used to identify an individual as the number contains key information on the individual i.e. date of birth and sex. This led to the CHI numbers going through a process of pseudonymisation. Pseudonymisation is a procedure by which personal identifiable information within a dataset are replaced by an artificial identifier, essentially making the identifiers anonymous. However, pseudonymised data can be restored to its original values through the use of a linkage agent (Section 2.4.3), although this cannot be done by the researchers, only the approved data controllers.

2.6 Description of Datasets

The following sections describe the datasets (Table 2.1) that were identified for inclusion in this study. This includes information on: the purpose of the datasets, the history, who controls the data, any knowledge relating to the completeness of the data. An overview of the datasets can be found in Table 2.1.

All of the datasets at an individual child level had information collected on surname, forename, sex, home postcode and date of birth as standard, although, some of these, namely surname, forenames, and home postcode, were removed prior to the data being made available in the National Safe Haven for anonymity reasons.

All of the datasets described are controlled by PHS.

Table 2.1 highlights the timeline of each datasets used for this thesis i.e., the start date of the data to the end date of the data. The start date is the when the programme first began. The end date of the dataset does not mean the dataset has stopped being utilised, only that this date was the end of the data approved by the PBPP approval. In Table 2.1, datasets are split by their use in five categories: Heath outcome, Health visitor, Childsmile in dental practice, Childsmile by Dental Health Support Worker, and Childsmile in nursery school. Data available in the National Safe Haven began with children who were in Primary 1 in the school year 2008/09. At this time, not all programmes which the data were obtained from were launched. This issue is addressed where relevant to the analyses.

Table 2.1: Dataset description, purpose, time frame, and method of Community Health Index number linkage of the datasets used in the research

Dataset	Category	Purpose	What it Records	Time Frame	CHI Assignment
Primary 1 Basic National Dental Inspection Programme	Health outcome	To provide oral health assessment for every child in Scotland in Primary 1	Caries experience at Primary 1	1st July 2008 - 30th June 2018	Probability
Child Health Surveillance Programme 6 to 8 weeks	Health visitor	To assess children's health, development, and wider wellbeing alongside provision of health promotion advice and parenting support	If referred to Childsmile pathway	1st January 2003 - 30th June 2018	Pre-populated
Child Health Surveillance Programme - School	Health outcome	To provide height and weight assessment for every child in Scotland in Primary 1	Body mass index, sex, age, area-based deprivation in Primary 1	1st July 2008 - 30th June 2018	Pre-populated
Management Information & Dental Accounting System Participation	Childsmile in dental practices	To processes information on people registered with a NHS[1] dentist on a daily basis	Attended the general dental services	1st January 2009 - 30th June 2018	Probability
Management Information & Dental Accounting System Treatment	Childsmile in dental practices	To processes treatment delivered by a NHS[1] dentist on a daily basis	Treatment received at the general dental services, including Childsmile intervention prevention	1st January 2009 - 30th June 2018	Probability
Health Informatics Centre Dental Health Support Worker Diary Event	Childsmile by DHSW[2]	To process referrals to a DHSW[2] and subsequent contacts	If family was referred to a DHSW[2] and if the DHSW[2] contacted the family	1st July 2008 - 30th June 2018	Pre-populated
Health Informatics Centre Dental Health Support Worker Practice	Childsmile by DHSW[2]	To record information on the DHSW[2] intervention delivered	What happened during the DHSW[2] visit to the family	1st January 2011 - 30th June 2018	Pre-populated
Health Informatics Centre Fluoride Varnish Visit	Childsmile in nursery school	To records visits and application of fluoride varnish in nurseries and schools	Application of fluoride varnish to child's mouth in nursery or school	1st January 2006 - 30th June 2018	Probability
Health Informatics Centre Toothbrushing Consent	Childsmile in nursery school	To process consent to participate in nursery supervised toothbrushing	Consent to participate in nursery supervised toothbrushing	1st July 2006 - 30th June 2018	Probability

[1] NHS - National Health Service; [2] DHSW - Dental Health Support Worker

2.6.1 Community Health Index Number

The Community Health Index (CHI) database is an NHS Scotland population database that provides a unique ten-digit numeric identifier to each person living in Scotland. This is assigned to a person when they initially register with a NHS service (Information Services Division Scotland, 2020). The first 6 digits indicate the individuals date of the birth, followed by 2 random digits, the ninth digit indicates their sex - even for females, odd for males - and an arithmetical check digit finished the number. The CHI number is an identifiable data field, hence it is used in processing and linking data but it is then removed and pseudo-randomised after the process in complete. This makes the CHI number hidden from the researcher.

The CHI number was used in each dataset in this study. During data collection, the CHI was either pre-populated on the form or was added later through probability matching (Table 2.1). Probability matching methods link the child's name, sex, date of birth and postcode to the corresponding variables in with CHI database (Bhopal et al., 2010). This is a universally accepted method but it is not always accurate and errors can occur (Fleming, 2017). Previous work which validated the linkage of CHI numbers to child records in education datasets recorded that 99% of children were correctly matched to the CHI number (Clark, 2015; Wood et al., 2013).

The process of attaching CHI numbers to datasets is called chi-seeding, which assigns scoring points to matching identifiers called 'Match Weights'. Forename matches are assigned between 8 and 17 points; Surname 8 to 17 points; Date of Birth up to 15 points; Sex 1 points or minus 6 points; and Postcode up to 15 points. If there is no exact match found for the identifiers, probability is used to calculate the odds of records belonging to the same person. The odds are converted into a binit weight, where the odds ratios are expressed as a logarithm to base 2 (Kendrick et al., 1993). The higher the weight, the higher the probability that the records belongs to the same person. These weights are referred to as 'Match Weights' through out this thesis. Although, there is no guarantee that the records are from the same person, regardless of how high the weight is. PHS reported that <1% of records in the NDIP could not be assigned a CHI.

2.7 Index Datasets for Childsmile Evaluation

Child Health Surveillance Programme 6 to 8 weeks (CHSP 6-8wk) and National Dental Inspection Programme (NDIP) Primary 1 and Primary 7 Basic datasets were chosen as the baseline index datasets to be used as the inclusion criteria for records in all other datasets used in the evaluation of Childsmile (Section 2.3.1). In other words, all records which appear in a dataset used in this study must have been present in CHSP 6-8wk and/or NDIP Primary 1 Basic and/or NDIP Primary 7 Basic. The CHSP 6-8wk was chosen as this is normally the first contact with a health visitor after birth and where the CHI number is generated for most children, so no CHI seeding is required. The CHSP 6-8wk data fails to capture some children born in Scotland (more information provided in Section 2.8.1). In addition to the children missed out in the CHSP 6-8wk, the cohort would not include children who move into Scotland after birth. For this reason, the NDIP Primary 1 Basic dataset was used in an attempt to capture the children missed at the first contact. In addition to this, the NDIP Primary 7 Basic Inspection is the last opportunity for health services to nationally conduct inspections and so is used as an index data source to capture children who have entered Scotland after Primary 1 or missed both CHSP 6-8wk review and NDIP Primary 1 Basic. Using these three data sources allowed children to be captured prospectively and retrospectively between 2011/12 and 2017/18 for the study. A flow chart of the creation of the index cohort can be found in Figure 2.3.

A list of all CHI numbers in the baseline dataset was provided by NSS PHS Child Health Team to the PHS Indexing Team, a department within NSS PHS that processes CHI matching, with no other variables included. This list was then used to identify children to be included in this study. This list will be referred to as the Index Cohort.

Bespoke analyses for each research question were conducted using different cohorts of children. Each analytical cohort will be described in the Methods section of relevant Results chapters.

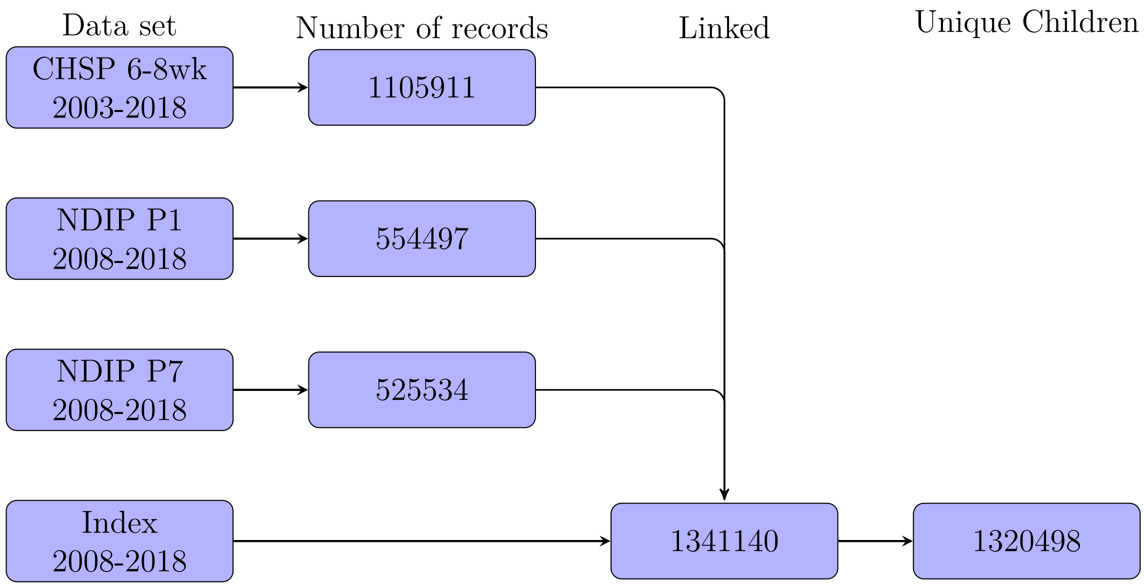

Figure 2.3: Flow chart of creation of Research Question 1 Cohort. CHSP 6-8wk - Child Health Surveillance Programme 6 to 8 weeks; NDIP - National Dental Inspection Programme; P1 - Primary 1; P7 - Primary 7

2.8 Health Outcome Datasets

2.8.1 Child Health Surveillance Programme 6 to 8 weeks

The Child Health Surveillance Programme 6 to 8 weeks (CHSP 6-8wk) assessment is generally completed by Health Visitors at around six to eight weeks after the birth of the child. It was established in 1991 by NHS Argyll and Clyde health board (now ceased to exist with the health board split between NHS Highland and NHS Greater Glasgow & Clyde), with most health boards having implemented the review by 2001, although some health boards implemented the review later (NHS Western Isles 2006, NHS Highland 2007, NHS Shetland 2008, NHS Grampian and NHS Orkney 2010) (Information Services Division Scotland, 2010b). A range of health, physical, and development information is collected on the child via the CHSP 6-8wk, such as concerns about feeding, growth, and sleep; breast feeding status; and length and weight. A copy of the form used during this review can viewed in Appendix G. In 2011, a section relating to the assessment of a child's dental health support requirement was added to the form. This recorded whether or not the child was referred to Childsmile Dental Health Support Worker (DHSW) by a health visitor.

When a child is due for a review, the CHSP system sends an invitation to the family and relevant electronic documents to the health visitors. During the review, the health visitor completes the form then provides a summary record of the discussion, findings, and actions required with the family which are automatically uploaded to the database. Copies of the form are provided to the family, the health visitor, and one to the local child health department.

The aim of CHSP 6-8wk is to review every child born in Scotland, however, an audit completed in 2010 suggested that 5.5% of children did not receive a review, which has been shown to be consistent over time (Wood et al., 2010). These figures are shown to be higher in more deprived areas, so children and families that most need support from a health visitor were less likely to be seen. It was stated that there are many possible reasons why a child may not have a review, for example, the child was in a special care baby unit or the family did not want to engage with the health visitor. It is also possible some records of reviews may get lost which would show as the child not receiving a review.

The CHSP 6-8wk dataset formed part of the 'source' dataset for the overarching Childsmile evaluation study (more information found in Section 2.7) as it is generally the first point of contact with a health visitor after birth.

2.8.2 National Dental Inspection Programme

The National Dental Inspection Programme (NDIP) is a series of annual dental inspections of school children that attend mainstream schools in Scotland and some independent education establishments. Some special schools or units, which support children with additional support needs, were included from the school year 2016/17. National Dental Inspection Programme dental inspections undertaken in schools are a statutory right for all children in public schools in Scotland; they are an important preventive dental service assessing children's oral health and ensuring primary dental care follow-up dependent on need since the outcome of the inspection is fed back to parents/carers via a letter (UK Government, 1978, 1980). The programme completes two types of inspections: Basic and Detailed. The first type, the Basic, is an annual inspection of every Primary 1 (typically aged 5- to- 6-years-old) child and Primary

7 (typically aged 11- to- 12-years-old). The second type, the Detailed; alternates a detailed inspection between Primary 1 and Primary 7 children. This takes a representative sample, roughly 20% of the population, and completes a detailed inspection of the child's mouth. Consent for both types of inspection is based on 'negative consent' (opt-out consent) i.e., children are automatically consented for the inspection and are only withdrawn if instructed by the parent/carer or if the child refuses on the day. The principle aim of the NDIP programme is to 'inform parents/carers of the oral health status of their children and, through appropriately pseudonymised, aggregated data, advise the Scottish Government, NHS Health Boards and other organisations concerned with children's health of oral disease prevalence at national and local levels' (Macpherson et al., 2018).

During the inspection, the data are recorded directly onto a laptop computer in the schools. When the laptop is connected to an NHS network point, the data are uploaded to the local health board server. Once the inspections are complete at the end of the school year, the local NHS Health Boards securely send all the information to PHS who, in collaboration with the University of Glasgow, then provide each regional NHS Health Boards with data quality and completion reports. NHS Health Boards can check any possible errors with the child's school before resubmitting the finalised data to PHS.

Prior to the inspection, the dental professionals are trained and calibrated over four mandatory courses. The training involves sessions on inspection procedure, tooth codes, and diagnostic criteria based on BASCD training (Macpherson et al., 2018). The dental professionals undergo clinical training sessions, which are followed by calibration sessions on another set of Primary 1 children. During the calibration sessions, each inspection team evaluate the same group of children. The course size usually ranges from 11 to 12 children. Inter-examiner agreement is evaluated at the patient level for $d_3$mft and separately for the d_3t, mt, and ft components, using both percentage agreement and Kappa statistics. For the Basic inspection standardisation training is conducted during examinations.

The Basic inspection is comprised of a simple examination of a child's teeth and is performed by a trained dental professional within the school setting. The dental professional completes a simple assessment of the child's mouth using a light, mirror,

Table 2.2: Basic Inspection letter definitions sent to parents/carers after inspection

Letter	2011/12 - 2014/15	2015/16	2016/17 - 2017/18
A	should seek immediate dental care on account of severe decay or abscess	should seek immediate dental care on account of severe decay or abscess	should arrange to see the dentist as soon as possible, if the child has not had a recent appointment, on account of severe decay or abscess
B	should seek dental care in the near future due to one or more of the following: history of tooth decay, a broken or damaged front tooth, tooth wear, poor oral hygiene or may require orthodontics	should seek dental care in the near future due to history of tooth decay	should arrange to see the dentist in the near future, if the child has not had a recent appointment, on account of evidence of current or previous decay
C	no obvious decay experience but should continue to see the family dentist on a regular basis	no obvious decay experience but should continue to see the family dentist on a regular basis	no obvious decay experience but should continue to see the family dentist on a regular basis

and ball-ended probe. The dental status is then categorised into one of three groups, A, B, or C, depending on the level of dental health and treatment required. The outcome of the Basic Inspection is then sent to the parents/carers of the child. The outcome is categorised into a letter which comprises of the state of dental health observed in the mouth at the time of inspection. The definitions on the letters was changed for the school year 2015/16 and then again for 2016/17 onwards. Table 2.2 states the definitions for each group.

Data from the Detailed Inspection are not used in this project due to the smaller number of records. This inspection is a more rigorous and comprehensive assessment using a light, mirror, and ball-ended probe in a school setting. It involves recording the status of every surface of each tooth. The goal of this is to create a representative survey of the levels of tooth decay at the population level in Scotland for each school year. Caries is measured as the disease process clinically appearing to have penetrated dentine on a tooth surface. The detailed inspection alternates between Primary 1 and Primary 7 every year, meaning there would only be data available every second year for Primary 1 schoolchildren.

The Basic Inspection is a good proxy for the detailed representative survey. The Basic Inspection has high population coverage, close to the population estimates (Table 2.3).

2.8.2.1 NDIP Primary 1 basic coding

The levels for each group in the NDIP Primary 1 Basic Inspection are presented in Table 2.4. The NDIP reports classify obvious caries experience as $d_3mft>0$ i.e., the

Table 2.3: Proportion of children eligible for a National Dental Inspection Programme review according to National Records Scotland who received an inspection

NDIP Year	Proportion (%)[1]
2008/09	84.9
2009/10	88.6
2010/11	85.6
2011/12	91.5
2012/13	91.4
2013/14	92.0
2014/15	88.4
2015/16	86.5
2016/17	88.7
2017/18	84.8

[1] Proportion of National Records Scotland population estimates

Table 2.4: NDIP Primary 1 Basic Inspection Group Levels

Letter	2011/12 - 2014/15	2015/16 - 2017/18
A	Abscess or infection Gross caries Obviously carious permanent tooth	Abscess or infection Gross caries Obviously carious permanent tooth
B	Obviously carious primary tooth Possibly carious permanent tooth Missing primary molar Evidence of restorations Poor oral hygiene	Obviously carious primary tooth Missing primary molar Evidence of restorations
C	No obvious caries experience	No obvious caries experience

sum of teeth which have decay into dentine, including teeth with fillings which require further treatment, filled teeth and teeth that are missing (extracted) due to decay. A hierarchy was used to ensure there was no double counting of teeth. In 2015/16, the coding was changed so obvious caries experience no longer included 'poor oral hygiene' and 'possibly carious permanent tooth', meaning only obvious caries experience was recorded as obvious caries experience which is the equivalent to $d_3$mft>0.

NDIP Primary 1 data relating to individual children are available in PHS from the 2008/09 school year onwards. The most current NDIP Primary 1 results available at the time of data extraction were for the 2017/18 school year, giving ten cohorts of data. The proportion of eligible children in Scotland according to National Records

Scotland (NRS) receiving a dental check in Primary 1 ranged from 84.9% in 2008/09 (Merrett et al., 2009) to 84.8% in 2017/18 (Macpherson et al., 2018) with a high of 92.0% in 2013/14 (Macpherson et al., 2014) and lowest coverage of 84.8% in 2017/18 (Table 2.3).

The NDIP Primary 1 Basic Inspection provides the largest coverage so is used as the primary source for caries experience at Primary 1.

2.8.3 Child Health Systems Programme - School

The aim of the Child Health Systems Programme - School (CHSP-S) is to promote the physical, mental and social well-being of children and to provide remedial action and support for pupils with health problems (Information Services Division Scotland, 2010b). As part of this each child has their body mass index (BMI) measured.

A CHSP-S review is offered to all Primary 1 schoolchildren in mainstream and special schools (although some children with complex special needs are not reviewed) at entry level to primary school with consent on an opt-out basis. Some independent (private) schools do take part. An estimated 1-2% of Primary 1 children in Scotland attend an independent school, and in 2017/18 only 12 of these schools took part (Information Services Division Scotland, 2018a). Measurements are conducted by health professionals in a school setting during any point of the school year. Children's height is measured in centimeters to one decimal place and their weight measured in kilograms to two decimal places (Royal College of Paediatrics & Child Health, 2009). No information was available to the author of the thesis regarding calibration or training conducted on health professionals. The health professionals record the results into the CHSP information system, for which PHS receive quarterly downloads. NHS Health Boards are responsible for working with Local Authorities to ensure that children who do not attend school have access to the care provided by CHSP. However, it is unlikely the measurements of the children would be included in the system.

The CHSP-S programme was first piloted in 1995 by NHS Borders. Other NHS Boards across Scotland adopted the system at different times, with most Health Boards using the programme by 2008 (except NHS Orkney 2010). However, in some Boards the system was only used in selected areas. The programme was then used in all parts of Scotland from 2011/12. PHS hold data from inception of the programme (i.e., 1995), although, coverage reports only began in 2001/02 when three Health Boards were using the programme. In 2001/02 the coverage was 21%, 94% in 2011/12, and 88% coverage in 2017/18 (Information Services Division Scotland, 2018a). Children's measurements are used to calculate a BMI which are standardised using growth reference data, more specifically UK 1990 references (Section 1.4.1). This gives Standard Deviation Scores (SDS) which can be categorised in underweight, healthy weight, overweight, and obesity groups using epidemiological cut-offs (Section 1.2).

The CHSP-S review provides the largest coverage of height and weight measurements so is used as the primary source for BMI at Primary 1.

2.9 Childsmile Intervention Datasets

The following sections describe the databases used to derived variables for attendance at the GDS, Childsmile prevention intervention at the GDS, Dental Health Support Worker visits, fluoride varnish application in nursery and school, and nursery supervised toothbrushing.

2.9.1 Management Information & Dental Account System

The Management Information & Dental Account System (MIDAS) is the system by which dentists in Scotland are paid for providing NHS dental treatments. The MIDAS Treatment dataset was one of the multiple datasets used to evaluate the Childsmile Programme. The system is a computerised system and processes information on people registered with an NHS dentist. Dentists use 'GP17 forms' to submit claims of treatment completed, financial reimbursement, and patient registrations. The completed form is submitted to the Practitioner Services Division (PSD) either electronically or by post. PSD are a division of NSS that ensure quality of provided dental treatment and also process payments to dental practitioners for the services they have provided and provide financial governance around this. MIDAS data are then stored within the

NSS data warehouse which is part controlled by PHS. Data quality is high for this dataset as the information must be recorded for the dentist to receive reimbursement for the treatment and for clinical governance purposes. PSD perform high level quality checks, which include financial and duplicate checks and checks to determine fraudulent claims (Information Services Division Scotland, 2019b). Errors made by practitioners in claiming for treatment are provided and identified by PSD's validation system which are then corrected by the dentist in the next available payment schedule (Information Services Division Scotland, 2019b). The list of treatment items available for claims are detailed in the Statement of Dental Remuneration (the primary care dental contract) (Scottish Government, 2020c). The number of treatments which are available for children's teeth are quite limited, however, in October 2011 Childsmile interventions were formally incorporated into the Statement of Dental Remuneration for the first time with itemized payments (Scottish Government, 2011a). Childsmile payments, during this thesis study period, included a basic fee for a basic oral health inspection on children aged 0- to- 5-years-old. There is an additional payment for the delivering of toothbrushing instruction, dietary advice, and fluoride varnish. This payment varies between children 0- to- 2-years-old and those 3- to- 5-years-old and also between Scottish Index of Multiple Deprivation fifths 1 to 3 and 4 to 5 (Scottish Government, 2020c). This payment system has been updated, however, this update took place after the time period for the data used in this thesis (Scottish Government, 2022b).

Dental practitioners record the start and end date of treatment, the type of treatment, count of the number of items that patient received, and the cost of treatment. The GP17 form records if the treatment was a one off, over the course of a period of time, or repeated treatment. The dental practitioner providing treatment, or who is responsible for the patient, records the surname, forename, date of birth, CHI number (Section 2.6.1), and postcode of the patient. The dental practitioner also provides the location that the treatment was given through a Location Code and a List Number, a unique ID number which is assigned to an individual dentist working at an individual practice. Dental practitioners who work at multiple practices have a separate list number for each dental practice they work. Individual dentists can be identified by a unique ID (based on their General Dental Council number) to ensure individuals can be identified.

For patient registration data, the dental practice records the date of registration on the GP17 form, or if they were already registered, the date of the most recent contact or treatment. The List Number of the dentist and Location Number of the practice are also provided.

Data for participation, treatments, and registrations for this study were provided as three separate datasets. The Childsmile interventions that are conducted in the dental practice and captured in MIDAS included the delivery of 'dietary advice', 'toothbrushing instruction', and 'application of topical fluoride' to children aged 0- to- 5-years-old. The MIDAS Participation dataset indicated every time there was a contact with a dental practice, meaning it was known if the individual attended but did not receive a claimable treatment.

2.9.2 Health Informatics Centre Childsmile IT System

Health Informatics Centre (HIC) provide database software for the electronic entry of Childsmile data relating to: Childsmile nursery and school supervised toothbrushing (2006 onwards) (Section 2.9.6), Childsmile fluoride varnish in Nursery and School (2006 onwards), and the DHSW component (2011 onwards). Childsmile staff (Dental Health Support Worker (DHSW) and Extended Duty Dental Nurses (EDDNs)) enter the data directly into the HIC databases, where quality checks are completed and made available to the regional Childsmile teams who can resolve any data issues.

The HIC IT system is a large single database which consists of the multiple smaller datasets explained in Sections 2.9.3 to 2.9.5. These are supplied to PHS by HIC every four months as part of the routine collection of Childsmile data by PHS. When the datasets have been uploaded in the NSS Safe Haven the datasets are partitioned back into the smaller datasets.

2.9.3 HIC DHSW Practice Diary Events

The DHSW Practice Diary Events data contains the information collected when a family is referred to a DHSW. This dataset, from 2010, records the first referral to and contact from the DHSW. This dataset includes:

- method of the referral ('health visitor referral' and location and code of health visitor if applicable, 'clinic', 'dentist', 'NHS', 'self', or 'other'),
- date of referral,
- the location of the health visitor,
- the contact type ('appointment', 'letter', 'telephone', 'text', 'unannounced visit', 'pre-arranged visit', and 'other'),
- the start and end date of the contact (interaction between DHSW and family).

2.9.4 HIC DHSW Practice Interventions

From January 2011 onwards, all DHSW child contacts as part of the Childsmile Practice community-based element of the programme were recorded on the HIC Childsmile IT system. This refers to the activities of the DHSW when a family have been referred to them. These data included:

- the name of the DHSW visiting the family,
- method of referral to the DHSW ('health visitor referral', 'clinic', or 'other'),
- type of visit ('clinic', 'home visit', 'telephone', or 'other'),
- result of visit ('declined', 'no entry', 'success', and the reason if the visit was declined,
- for the appointments which were a 'success', details of the oral health interventions delivered (such as toothbrushing instruction) were recorded along with outcomes such as the family being given a dental appointment, continued home sup-

port from the DHSW or signposting to nutritional related community/voluntary organisations,

- a series of actions determined by the result of the contact, for example, re-contacting and rescheduling appointments where the first visit was not a 'success', referral back to the health visitor, or if the family had made their own dental arrangements and no further support from DHSW was required.

2.9.5 HIC Fluoride Varnish Visit

The Fluoride Varnish Visit dataset is related to the application of fluoride varnish at educational establishments as part of the Childsmile Programme . The Fluoride Varnish is offered to the children twice within the school year at targeted nurseries and schools (Primary 1 to Primary 4). This involves the application of Fluoride Varnish by Extended Duty Dental Nurses (EDDNs) in a targeted nursery or school setting. Each child approaches the EDDNs with a name badge, which the EDDNs asks the child's name to check it matches to the name on the class list. Collected nationally from 2011, these data includes:

- consent information,
- date of intended application,
- whether or not the fluoride varnish was applied, and reason if varnish was not applied,
- the anonymised name of the EDDNs that applied the varnish,
- whether the parent/carer of the child was issued with a dental referral letter informing them that the child required additional dental needs and reason for the letter.

The data from this are entered manually at the time of application, directly into the HIC Childsmile IT system.

2.9.6 Toothbrushing Consent

The Toothbrushing Consent database included data relating to a child's consent for the supervised toothbrushing in the nursery component of the Childsmile programme. Data were collected between July 2006 and June 2018. A paper form was provided to parents/carers of children who attended participating establishments to provide signed opt-in consent for their child to participate in the toothbrushing component for that year. Completed consent forms were returned to local Childsmile staff via the nursery or school and the corresponding data were entered by Childsmile staff into the HIC Childsmile IT system.

2.10 Measure of Socioeconomic Deprivation

2.10.1 Scottish Index of Multiple Deprivation

The Scottish Index of Multiple Deprivation (SIMD) is an area-based measure of deprivation in Scotland (Scottish Government, 2016a). This study uses two versions of SIMD: 2012 and 2016. In 2012 and 2016, the population was split into 6,976 small areas, called data zones and based on home postcodes, which are of roughly equal population. Natural boundaries are generally used to create data zones which contain households with the same comparable social characteristics. Indicators are used to measure different sides of deprivations, such as, crime, unemployment, and time to travel to the GP (Scottish Government, 2016a). There are 38 different indicators of deprivations which are grouped into seven weighted domains (Scottish Government, 2016b):

- Income (7 indicators, 28% of total weighting)
- Employment (3 indicators, 28% of total weighting)
- Health (7 indicators, 14% of total weighting)
- Education, Skills and Training (5, indicators 14% of total weighting)
- Geographic Access to Services (8 indicators, 9% of total weighting)

- Crime (6 indicators, 5% of total weighting)
- Housing (2 indicators, 2% of total weighting)

The weight of each domain is used to calculate an overall deprivation score for each data zone. The data zone are then ranked from 1 (the most deprived) to 6,976 (the least deprived). These ranks can then be split into tenths (deciles) or fifths (quintiles), where SIMD 1 is the most deprived areas and SIMD 10 or 5 being the least deprived tenth and fifth, respectively.

The variables available for SIMD relate to national ranking, local ranking by health board, urban/rural rankings, and council area rankings. Routine administrative data can be linked to SIMD using the child's postcode at time of applicable intervention. All the datasets used in this study have both versions of SIMD attached to the dataset. The use of SIMD is discussed in Section 2.10.2.

2.10.2 SIMD version selection

SIMD is used in this thesis as a proxy for area-based deprivation. This measure is useful for identifying small areas of deprivation that could be missed using larger area measures, such as health board or council area. SIMD has the ability to highlight which areas are deprived but not which individuals are deprived. As all research questions were considered with an inequality lens, a measure of deprivation had to be used. The only routinely collected measure for routine data is SIMD. A review was published by PHS on *Deprivation Guidance for Analysts*. This review recommended that if the the analysis is to look at inequalities between the most and least deprived areas and whether this has changed over time then multiple releases of SIMD should be used (Information Services Division Scotland, 2017b). These analyses presented here aim to analyse the trends in inequalities over multiple years so two SIMD releases were used: SIMD 2012 (Scottish Government, 2012c) and SIMD 2016 (Scottish Government, 2016a). A disadvantage of using this approach is, with SIMD releases, methodology and indicators can change, so changes in the health outcome could be down to index changes rather than true changes. However, the advantages allow the most accurate estimates of health by SIMD at each point in time.

Table 2.5: SIMD version used for each school year

School Year	SIMD[1] Version
2011/12	2012
2012/13	2012
2013/14	2012
2014/15	2012
2015/16	2012
2016/17	2016
2017/18	2016

[1]SIMD - Scottish Index of Multiple Deprivation

SIMD was appended at the end of each data for each individual child. The SIMD was based on the child's home postcode at time of intervention. The SIMD used for each year was relevant to the CHSP-S (Information Services Division Scotland, 2018a) and NDIP Primary 1 (Macpherson et al., 2018) publications (Table 2.5). Both SIMD releases are appended to the end of each dataset. Due to CHSP-S dataset having a pre-populated CHI number, the measurement for area-based deprivation (SIMD) at time of inspection was also taken from dataset, although, it is possible a child may have moved to an area from a different deprivation level between inspections.

2.11 Data Management

The following sections refer to data management of the datasets included in the thesis.

2.11.1 Linkage validation

The quality of linkage was checked before any analysis was completed. To do this, all datasets were compared to the source datasets, CHSP 6-8wk and NDIP Primary 1. One of the essential checks for correct linkage is using the child's date of birth as this is a key criteria for the initial probability matching the link records to their CHI number (Kendrick et al., 1993). The results of this are presented in Table 2.6. This shows that all datasets had a high date of birth match compared to the source datasets, confirming the linkage was successful.

Table 2.6: Frequency of CHSP 6-8wk and NDIP Primary 1 records matching study datasets

Dataset	Total Records in Linked Dataset (a)	Unique Index Numbers in Linked Dataset (b)		Unique Index Numbers in Linked Dataset and 6-8wk[1] Assessment (c)		Unique Index Numbers with Matching DOB[2] in 6-8wk[1] Assessment (d)		Unique Index Numbers in Linked Dataset and NDIP P1[3] (e)		Unique Index Numbers with Matching DOB[2] in NDIP P1[3] (f)	
	n	n	% of a	n	% of b	n	% of c	n	% of b	n	% of e
CHSP 6-8wk[1]	1105911	1105911	100.0	-	-	-	-	433052	39.2	426483	98.5
NDIP P1[3]	554497	542851	97.9	433052	79.8	426483	98.5	-	-	-	-
CHSP-S[4]	660870	660870	100.0	549620	83.2	549620	100.0%	480756	72.7	473724	98.5
MIDAS[5] Registration	16747353	1180265	7.0	975902	82.7%	975897	>99.9	526474	44.6	518260	98.4
MIDAS[5] Participation	15661771	1184299	7.6	979201	82.7%	979197	>99.9	528165	44.6	519926	98.4
MIDAS[5] Treatments	13403362	1062770	7.9	877696	82.6	877692	>99.9	475106	44.7	467713	98.4
DHSW[6] Diary Event	277298	123258	44.4	115251	93.5	115246	>99.9	54149	43.9	53600	99.0
DHSW[6] Practice Intervention	166378	114912	69.1	107427	93.5	107422	>99.9	52068	45.3	51546	99.0
Toothbrushing Consent	712478	477350	67.0	388886	81.5	382008	98.2	393077	82.3	381817	97.1
Fluoride Varnish Visit	2398871	366704	15.3	301783	82.3	297842	98.7	265839	72.5	259473	97.6

[1] 6-8wk - Child Health Surveillance Programme 6 to 8 weeks; [2] DOB - date of birth; [3] NDIP P1 - National Dental Inspection Programme P1;
[4] CHSP-S - Child Health Systems Programme - School; [5] MIDAS - Management Information & Dental Account System; [6] DHSW - Dental Health Support Worker

Table 2.7: Frequency of CHSP 6-8wk records compared to NRS Scottish Birth Records

Year	NRS[1] Births Records (NRS)	CHSP 6-8wk	% of (NRS)
2002	51270	41002	80.0
2003	52432	42008	80.1
2004	53957	43541	80.7
2005	54386	43643	80.2
2006	55690	44758	80.4
2007	57781	47452	82.1
2008	60041	49821	83.0
2009	59046	49391	83.6
2010	58791	53464	90.9
2011	58590	55069	94.0
2012	58027	54566	94.0
2013	56014	52684	94.1
2014	56725	53239	93.9
2015	55098	50978	92.5
2016	54488	49652	91.1
2017	52861	49017	92.7
2018[2]	25648	16226	63.3
Total	**920845**	**796511**	**86.5**

[1] NRS - National Records Scotland
[2] 2018 estimate is from 01 Jan 2018 to 30 June 2018

2.11.2 CHSP 6-8wk completeness checks

To check the completeness of the CHSP 6-8wk dataset in the Safe Haven, the number of children born each year was compared to the annual Scottish Birth Data provided by NRS (National Records Scotland, 2019a). Table 2.7 indicates that between 2002 and June 2018, 86.5% of CHSP 6-8wk had a corresponding NRS birth record. The percentage of children missing is higher than 6% missing reported by Wood et al. (2010). The CHSP team were contacted about this issue via eDRIS who responded by stating that not all health boards were recording the CHSP 6-8wk review nationally until 2010. As evident in Table 2.7, in 2010 the percentage of children in CHSP 6-8wk increases to around the 6% missing mark. In 2018, it is possible that a proportion of children receiving a CHSP 6-8wk review were not in the CHSP system at the time of data extraction.

2.11.3 NDIP Basic Inspection Primary 1 completeness checks

To check the completeness of the NDIP Primary 1 dataset in the Safe Haven, the number of children inspected in each year was compared to the estimated number of children in mainstream Primary 1 and the number of Primary 1 children inspected in Scotland, taken from the annual NDIP reports (Macpherson et al., 2013b, 2014, 2011, 2012, 2010b, 2016, 2018, 2017; Merrett et al., 2009). The number of Primary 1 children in mainstream is estimated from NRS mid-year population estimates of 5-year-old children in Scotland at the time of each publication. These estimates may include children who do not attend mainstream schools and may attend independent schools. Data in Table 2.8 are presented by school year (1st July - 30th June).

Table 2.8 indicates that between 2008/09 and 2017/18, 97.0% of the total number of Primary 1 children in mainstream primary schools had a NDIP record uploaded to the Safe Haven. Compared to the publications, the data in the Safe Haven has a greater number of records. This is likely due to the published NDIP reports only include data on children who were present on the day and had a valid exam, however the data provided in the Safe Haven includes children who were absent on the day of inspection. When focusing on the proportion of A (‘seek immediate dental care’), B (‘seek dental care in the near future’), and C (‘continue to see family dentist on a regular basis’) letters distributed in Scotland, the data in the published reports and the safe haven match consistently across the ten years.

2.11.4 Child Health Systems Programme - School completeness checks

To check the completeness of the CHSP-S dataset in the Safe Haven, the number of children inspected in each year was compared to the estimated number of 5-year-old children in Scotland and the number of Primary 1 children inspected in Scotland, taken from the annual CHSP-S reports (Information Services Division Scotland, 2010a, 2012, 2013, 2014, 2015, 2016a,b, 2017a, 2018a). The population estimate is a NRS population estimate of 5-year-old children in Scotland at the time of publication. Table 2.9 indicates that between 2008/09 and 2017/18, 86.3% of the estimated 5-year-old

Table 2.8: Frequency of Primary 1 children with a NDIP Primary 1 inspection

School Year[1]	Total number of P1[2] children in Mainstream Schools (a)	Total number of P1[2] children inspected in Scotland (b)		Total number of P1[1] children inspected in uploaded NDIP[2] P1[1] dataset (c)			Proportion of Basic Inspection letters distributed in Scotland in Published Reports			Proportion of Basic Inspection letters distributed in uploaded NDIP[3] P1[1] dataset		
	n	n	% of a	n	% of a	% of b	A[4]	B[5]	C[6]	A[4]	B[5]	C[6]
2008/09	53135	45126	84.9	48496	91.3	>100	10.8	27.4	61.8	10.8	27.4	61.8
2009/10	54854	48606	88.6	52374	95.5	>100	9.8	27.2	63.0	9.8	27.2	63.0
2010/11	55763	47712	85.6	52573	94.3	>100	9.6	25.7	64.7	9.6	25.8	64.6
2011/12	54865	50204	91.5	55580	>100	>100	9.0	25.5	65.5	8.9	25.6	65.5
2012/13	56446	51573	91.4	56962	>100	>100	9.2	24.5	66.3	9.2	24.5	66.3
2013/14	57021	52439	92.0	58301	>100	>100	9.3	24.0	66.7	9.3	24.0	66.7
2014/15	59457	52579	88.4	57410	96.6	>100	8.0	22.4	69.5	8.0	22.5	69.5
2015/16	59796	51709	86.5	57322	95.9	>100	7.5	22.6	69.9	7.5	22.5	70.0
2016/17	58497	51899	88.7	57525	98.3	>100	7.3	21.8	70.9	7.3	21.8	70.9
2017/18	61695	52324	84.8	57954	93.9	>100	7.3	22.4	70.4	7.2	22.3	70.5
Total	**571529**	**504171**	**88.2**	**554497**	**97.0**	**>100**						

[1] School year runs from 1st July to 30th June; [2] P1 - Primary 1; [3] NDIP - National Dental Inspection Programme;
[4]Seek immediate dental care; [5]Seek dental care in the near future; [6]Continue to see the family dentist on a regular basis

Table 2.9: Total and percentage of children uploaded to the Safe Haven in the CHSP-S Cohort

School Year[1]	Population of 5-year-olds[2] (a)	Total number of P1[3] children reviewed by CHSP-S[4] (b)		Total number of CHSP-S[4] reviews uploaded in Safe Haven		
	n	n	% of a	n	% of a	% of b
2008/09	52681	34779	66.0	34869	65.8	>100
2009/10	54398	46354	85.2	45949	84.5	99.1
2010/11	55429	41590	75.0	41142	74.2	98.9
2011/12	55769	52972	95.0	52355	93.9	98.8
2012/13	57021	55004	96.5	54113	94.9	98.4
2013/14	59490	55494	93.3	54703	92.0	98.6
2014/15	59796	55492	92.8	54597	91.3	98.4
2015/16	58497	54165	92.6	53332	90.0	98.5
2016/17	61695	53626	86.9	52250	84.7	97.4
2017/18	60001	53016	88.4	52717	87.9	99.4
Total	**574777**	**502492**	**87.4**	**496027**	**86.3**	**98.7**

[1] School year runs from 1st July to 30th June;
[2] National Records Scotland population estimate of 5-year-old children living in Scotland;
[3] P1 - Primary 1;
[4] CHSP-S - Child Health Systems Programme - School

population had a NDIP record uploaded to the Safe Haven. Although, this was noticeably lower for 2008/09 to 2010/11. This is largely due to not all NHS Health Boards adopting the programme, while in NHS Greater Glasgow & Clyde only one council area was reviewed. Once all Health Boards were using the programme there is an increase in the percentage of population estimate, however, there is a slight reduction year on year after this. PHS have suggested that reasons for the decline in coverage include shortage of staff to conduct reviews and technical issues with recording review findings in the system (Information Services Division Scotland, 2018b). Compared to the national publications, the amount of observations when compared to population estimates are higher in the data provided in the Safe Haven. These small differences are likely to be caused by the data being derived from different sources with different base indexes which can cause different individuals to be included in the cohort.

2.11.5 MIDAS Treatment and Childsmile Dental Practice completeness checks

Whether or not the Childsmile interventions was delivered are captured within the MIDAS Treatment dataset. Therefore to calculate the total number of each three Childsmile Interventions (fluoride varnish, oral health instruction, dietary advice) in the Safe Haven data only applicable Fee Codes were selected.

The annual rates of Childsmile Interventions delivered in dental practices for the Safe Haven data were compared to published figures in the Childsmile National Headline Data reports (Central Evaluation & Research Team, 2013, 2014, 2015, 2016, 2017, 2018) to check for completeness of the MIDAS Childsmile Dental Practice data. These data are presented in Table 2.10 by financial year (1^{st} April to 31^{st} March). The data were restricted to ages between 0- and- 5-years-old, inclusive.

As evident in Table 2.10, there were more records of each intervention within the Safe Haven than published reports. Further contact with PHS found extra inclusion criteria were applied to the data that was not possible to do in the Safe Haven. In the published monitoring reports, claims where there was a delay in payment, records from Public Dental Services (PDS), and claims with missing practice health board were excluded. Around 10% of the Primary 1 population have attended a PDS, which could make up a large proportion of the difference. This estimate has been confirmed by an unpublished report.

There are no further data published on the number of each treatment. However, since the data for the Childsmile Interventions are valid, there is no reason to suggest the rest of the data would not be valid too.

2.11.6 DHSW completeness checks

The DHSW Practice Interventions dataset collects data on DHSW contacts with a child, therefore, this allowed calculating the total number of successful contacts in each year.

Table 2.10: Childsmile intervention rates in dental practices for children in Safe Haven data versus published reports

Financial Year	**Children receiving fluoride varnish in dental practice**			**Children receiving toothbrushing instruction in dental practice**			**Children receiving dietary advice in dental practice**		
	Published	Safe Haven		Published	Safe Haven		Published	Safe Haven	
	n	n	%	n	n	%	n	n	%
2008/09	341	258	75.7	5083	1570	30.9	5,482	1834	33.5
2009/10	2291	2908	>100.0	10816	11792	>100.0	11625	12951	>100.0
2010/11	8255	10312	>100.0	22335	27677	>100.0	23405	28996	>100.0
2011/12	36803	40876	>100.0	66352	75762	>100.0	68079	78055	>100.0
2012/13	61375	73603	>100.0	98137	117572	>100.0	98744	117342	>100.0
2013/14	70519	85030	>100.0	111616	133748	>100.0	111677	132928	>100.0
2014/15	75883	92644	>100.0	121072	145108	>100.0	120343	142657	>100.0
2015/16	78114	95714	>100.0	126127	149883	>100.0	125238	147178	>100.0
2016/17	78525	96351	>100.0	126385	151163	>100.0	125080	147685	>100.0
2017/18	85313	94359	>100.0	138220	149134	>100.0	136202	145605	>100.0
Total	**497419**	**592055**	**>100.0**	**826143**	**963,409**	**>100.0**	**825875**	**955231**	**>100.0**

Table 2.11: DHSW successful contacts in Safe Haven data versus published data

Financial Year	Published	Safe Haven	
	n	n	%
2008/09	4983	278	5.6
2009/10	12542	827	6.6
2010/11	17917	11146	62.2
2011/12	14201	14416	>100
2012/13	14557	15050	>100
2013/14	12721	12991	>100
2014/15	13671	13327	97.5
2015/16	14079	13445	95.5
2016/17	14501	13776	95.0
2017/18	14264	13479	94.5
Total	**133436**	**108735**	**81.5**

The annual rates of children having a successful contact with a DHSW were compared between data in the Safe Haven and figures published in the Childsmile National Headline Data reports (Central Evaluation & Research Team, 2013, 2014, 2015, 2016, 2017, 2018) to valid the DHSW Practice Interventions data. The values provided in Table 2.11 are presented by financial year (1st April to 31st March).

2.11.7 Fluoride varnish visit completeness checks

To validate the completeness of the Fluoride Varnish Visit dataset, the frequency of fluoride varnish applications in nursery and schools in the Safe Haven dataset were compared with the published rates in the Childsmile National Health Data Reports (Central Evaluation & Research Team, 2013, 2014, 2015, 2016, 2017, 2018). The total number of fluoride varnish in the Safe Haven data was 93.7% of that in published reports, however, this difference is reflected in the number of children in the index datasets (CHSP 6-8wk and NDIP Primary 1) in comparison to respective population estimates (Tables 2.7 and 2.8). This validates the completeness of the Fluoride Varnish Visit dataset with the Safe Haven in regards to the total number of applications.

Table 2.12: Fluoride varnish application rates for nursery and school children in Fluoride Varnish Dataset versus published data

School Year	Published	Dataset	
	n	n	%
2008/09	23276	21417	92.0
2009/10	43259	40215	93.0
2010/11	90242	82473	91.4
2011/12	138464	128674	92.9
2012/13	199074	187226	94.0
2013/14	241183	229368	95.1
2014/15	241062	238956	99.1
2015/16	267052	246223	92.2
2016/17	258209	240246	93.0
2017/18	254502	231105	90.8
Total	**1756323**	**1645903**	**93.7**

2.11.8 Toothbrushing Consent completeness checks

There are currently no published data available on toothbrushing consent rates in Scotland, hence it was not possible to validate the completeness of the Toothbrushing Consent dataset. Data are only published on the number of participating nurseries and not individuals. However, there are no issues with the other HIC provided datasets so there is no reason to suspect it would not be the case for this dataset.

2.11.9 NDIP Basic Inspection Primary 1 quality checks

The NDIP Primary 1 dataset was the only dataset where the the CHI was probability assigned which included an indexing match weight (Section 2.6.1). Due to date of birth contributing towards the match weight score, comparison of matching date of births within NDIP were compared to CHSP 6-8wk. CHSP 6-8wk was chosen as it is a pre-populated dataset for which the student's date of birth is provided before the review takes place. Table 2.13 shows that the majority of records with a match weight between 20 and 29.9 did not have a matching date of birth. However, the majority of records with match weights of 30 and above have a matching date of birth. Records with match weight of less than 20 had a high date of birth match, however, a match

Table 2.13: Number of successful date of birth matches in NDIP Primary 1 Basic Inspection and CHSP 6-8wk linked dataset 2008/09 to 2017/18

Match Weight	DOB Match: Yes		DOB[1] Match: No		Total
	n	%	n	%	
<20	61	62.2	37	37.8	98
20-24.9	50	14.4	297	85.6	347
25-29.9	313	35.6	566	64.4	879
30-34.9	3656	74.8	1230	25.2	4886
35-39.9	7752	69.8	3348	30.2	11100
40-44.9	11291	90.6	1171	9.4	12462
45-49.9	5812	97.9	125	2.1	5937
50-54.9	785	99.9	1	0.1	786
55-59.9	36	100.0	0	0.0	36
60-100	405086	100.0	13	0.0	405099
Total	**434842**	**98.5**	**6788**	**1.5**	**441630**

[1]DOB - Date of Birth

weight lower than 20 suggests that there are other matching issues, such as forename and surname.

To further investigate non-matching dates of birth between NDIP Primary 1 and CHSP 6-8wk, the date of birth were separated into three components: day of birth, month of birth, year of birth. This allowed a check on whether it was likely the date of birth was not a match due to data input errors. It was suggested that if two components of the date of birth matched then it was likely a data input error. If only one or zero components matched, then it was deemed to be an issue elsewhere. For match weights between 20 and 29.9, the majority of date of births had only one component matching (Table 2.14). For match weights greater than 30 only a very small number had only one component matching, with the majority having a full date of birth match.

Regardless of match weight, all records were provided in the Safe Haven. There is no gold standard cut-off for match weight for when a linkage is true or false. There must be a manual review of linked pairs to determine an acceptable cut-off value where values above the weight are categorised as successful links and those below the cut-off as failed links (Fleming et al., 2012). This threshold is chosen to maximise the number of true links and minimise false links. Moving the cut-off down increases sensitivity but increases the chances of false positives, which moving the cut-off up decreases sensitivity but decreases the chances of false positives (Fleming et al., 2012).

Table 2.14: Number of successful date of birth matches by components in NDIP Primary 1 Basic Inspection and CHSP 6-8wk linked dataset 2008/09 to 2017/18

Match Weight	All		Two		One		Zero	
	n	%	n	%	n	%	n	%
<20	61	62.2	1	1.0	36	36.7	0	0.0
20-24.9	50	14.4	26	7.5	271	78.1	0	0.0
25-29.9	313	35.6	120	13.7	444	50.5	2	0.0
30-34.9	3656	74.8	1073	22.0	157	3.2	0	0.0
35-39.9	7752	69.8	3331	30.0	17	0.2	0	0.0
40-44.9	11291	90.6	1,70	9.4	1	0.0	0	0.0
45-49.9	5812	97.9	125	2.1	0	0.0	0	0.0
50-54.9	785	99.9	1	0.1	0	0.0	0	0.0
55-59.9	36	100.0	0	0.0	0	0.0	0	0.0
60-100	405086	100.0	8	0.0	3	0.0	2	0.0
Total	**434842**	**98.5**	**5855**	**1.3**	**929**	**0.2**	**4**	**0.0**

Table 2.15: Number of children with match weight less than 30 in NDIP Primary 1 Basic Inspection Raw Dataset uploaded into the Safe Haven 2008/09 to 2017/18

School Year	MW≥30		MW[1]<30		Total
	n	%	n	%	
2008/09	48075	99.1	421	0.9	48496
2009/10	52104	99.5	270	0.5	52374
2010/11	52314	99.5	259	0.5	52573
2011/12	55328	99.5	252	0.5	55580
2012/13	56807	99.7	155	0.3	56962
2013/14	58162	99.8	139	0.2	58301
2014/15	57282	99.8	128	0.2	57410
2015/16	57242	99.9	80	0.1	57322
2016/17	57406	99.8	119	0.2	57525
2017/18	57882	99.9	72	0.1	57954
Total	**552602**	**99.7**	**1895**	**0.3**	**554497**

[1] MW - Match Weight

Excluding date of birth, all other variables used for chi-seeding were removed from the data before upload to the Safe Haven, so date of birth is the only variable available to suitable choose a cut-off level. From the data presented in Tables 2.13 and 2.14, it is evident that a match weight cut-off of 30 is more likely to indicate a true link between NDIP Primary 1 and the PHS CHI database. It was evident that there were fewer observations with a match weight less than 30 throughout the years, although there was a high proportion of observations in 2011/12 with a match weight greater or equal to 30 (Table 2.15). When the match weight was split into intervals of 5 (except for below 20 due to numbers in each interval and between 60 and 99 as there are no match weights in this intervals), it could be seen that the percentage of observation with matching NDIP date of birth and CHSP 6-8wk date of birth increased as the match weight increased, largely when the match weight increased above 30 (Table 2.13). When the date of birth was split into three components (year of birth, month of birth and day of birth), it was evident that a high percentage of observation with no matching date of birth and match weight above 30 had two matching components (Table 2.14), for which the non-matching component could possibly be put down to errors with data imputation. Therefore, a match weight of 29.9 or below was chosen as an appropriate cut-off. This decision is supported by previous data linkage studies (Kidd, 2019). However, it is possible that within this study there are still some false matches with match weight greater than or equal to 30.

The dates of birth with match weight greater than 30 with two matching components of date of birth were replaced with the date of birth from records in CHSP 6-8wk. Dates of birth for records in NDIP that did not have a matching record in CHSP 6-8wk were assumed to be correct as there were no further methods to validate these.

2.11.10 CHSP-S quality checks

From Table 2.6 it was evident that all the records from CHSP-S which were in CHSP 6-8wk had a matching date of birth. This is plausible to the due CHSP-S having a pre-populated class list before inspection. No further investigation was required for the date of births in CHSP-S.

Table 2.16: Date of Birth match between Intervention Datasets and CHSP 6-8wk

Dataset	Total Records (a)	Non Identical DOBs[1] (b)		Corrected DOBs[1] (c)	
	N	n	% of a	n	% of b
MIDAS Registration	13720225	64	<0.1	55	85.9
MIDAS Participation	12864705	43	<0.1	41	95.3
MIDAS Treatments	11356808	35	<0.1	35	100.0
DHSW Diary Event	258731	8	<0.1	3	37.5
DHSW Practice	155026	7	<0.1	4	57.1
Toothbrushing Consent	579980	9533	1.6	7469	78.3
Fluoride Varnish Visit	1950752	20572	1.1	16997	82.6

[1] DOBs - Dates of Birth; [2] MIDAS - Management Information & Dental Accounting System;
[3] DHSW - Dental Health Support Worker

2.11.11 Childsmile intervention datasets quality checks

The dates of birth in all other intervention datasets were compared to dates of birth in CHSP 6-8wk. If the date of birth was a full or partial match (all or 2 components of date of birth), then the date of birth in the intervention dataset was replaced by the date of birth from the CHSP 6-8wk dataset. Records which has zero or one matching component were marked as invalid, as findings from Section 2.11.9 suggest these are false matches. The number of matching and non-matching date of births are presented in Table 2.16.

2.11.12 Index numbers excluded from the analysis

The date of birth variable provided valuable information in ensuring the data was linked correctly. The linkage process would have been near impossible to validate without this information. Once the date of birth was altered, if required, indexes for which the date of intervention was on the same day or before the date of birth were excluded from analysis as it was deemed highly unlikely of this to be the case. Since it was not possible to determine if the intervention took place before the age cut-off, they were not included in the analysis. Records for which the date of birth was missing from the intervention data, or matched on zero or one of the components of date of birth were excluded from the intervention data. The total number of records remove for incorrect or missing date of birth or incorrect intervention date are presented in Table 2.17.

2.12 Data Processing within the National Safe Haven

Throughout this project, all linkage validation, completeness, cleaning and data linkage process were undertaken within the Safe Haven via R (R Core Team, 2023) by the author of this thesis.

2.12.1 Transfer of datasets from data providers to indexing team at Public Health Scotland

Each data provider (the controllers of the data) creates an extract from the original datasets which only contain the CHI number and a unique local reference number. These generated data are sent as separate files to the Indexing Team through a Secure File Transfer Protocol (SFTP), GlobalSCAPE, a NHS approved online data transfer service. eDRIS require specific requirements for the transferred data:

Table 2.17: Total Number of Indexes Excluded for Incorrect or Missing Date of Birth and Incorrect Intervention Date

Dataset	**Unique Index Numbers (a)**	**Unique Index Numbers Excluded for Incorrect or Missing DOB[1] (b)**		**Unique Index Numbers Excluded for Incorrect Intervention Date (c)**	
	N	n	% of a	n	% of a
MIDAS Registration	1180265	1	<0.1	140	<0.1
MIDAS Participation	1184299	0	0.0	96	<0.1
MIDAS Treatments	1062770	0	0.0	50	<0.1
DHSW Diary Event	123258	4	<0.1	651	0.5
DHSW Practice	114912	4	<0.1	628	0.5
Toothbrushing Consent	477350	1497	0.3	2152	0.5
Fluoride Varnish Visit	2398871	662	<0.1	3	<0.1

[1] DOB - Date of Birth; [2] MIDAS - Management Information & Dental Accounting System;
[3] DHSW - Dental Health Support Worker

1. each file must be in CSV format,
2. each variable had to have a fixed width with details of the width provided in a separate Microsoft Excel file,
3. files had to be sent delimited with details of the delimiter in a separate file, for example, columns separated by commas.

2.13 Overarching Cohort Description and Assembly

The following sections define the overarching cohort used for the analyses present in this thesis. Each results chapter has its own cohort and these are described in the relevant chapters.

Whilst data are available from 2008/09, only children in Primary 1 from 2011/12 were included in the overarching cohort. The main reason for this is the completeness of the CHSP-S data available within the Safe Haven (Table 2.9). Prior to 2011/12, the CHSP-S reviews were not conducted in all areas of NHS Health Board Greater Glasgow & Clyde. This NHS Health Board contains 36.3% of all areas in the 20% most deprived areas in Scotland according to SIMD 2020v2 (Scottish Government, 2020b). As this analysis focuses on inequalities, it was important that all areas of NHS Health Board Greater Glasgow & Clyde were included in the analyses. The CHSP-S programme began conducting reviews in all areas in 2011/12 and so this was selected as the baseline year for the overarching cohort. Some results chapter use a sub-cohort from this overarching cohort. This will be described in the relevant results chapter.

2.14 Cleaning of Safe Haven Datasets

The following section describes the data cleaning process and assembly of the cohorts described in Section 2.6.

2.14.1 Cleaning of the NDIP Primary 1 data

The NDIP Primary 1 data, relating to the basic inspection, provided by the data controllers was subject to data cleaning (Figure 2.4). The first step to remove those with a match weight less than 30 from analysis (as explained in Section 2.11.9). The next step of the data cleaning process was to remove those with a 'no exam' recorded. Due to the NDIP team being provided with a class list all those who do not receive an exam are marked as such in this column. Age calipers were applied thus if the child was younger than 4-years-old or older than 7-years-old they were removed from the analysis cohort as these children are outside the usual age range of children in Primary 1. As the socioeconomic inequalities were of key interest in this thesis, those with missing area-based deprivation measurements (Scottish Index of Multiple Deprivation (SIMD), Section 2.10.1) were excluded from analysis and children with no data on caries outcome were excluded. Due to calibration checks completed between the dental professionals completing the reviews, some children have multiple examinations, which are marked as a 'repeated exam'. The duplicate observations are marked as a repeat exam and hence removed from the analysis cohort so only the initial review was included in the analysis. The cohort was checked for duplicates using the index number in the cohort. If a duplicate was identified, which can happen for multiple reasons such as, calibration and training purposes, the child moved school during the school year and received another examination, or the child resat the school year. All duplicates were gathered and ordered by index number to ensure the duplicates were next to each other. If a duplicate index number was identified the following process was undertaken:

- If the match weights were different, the record with highest match weight was retained. If the match weights were equal then,
- The duplicates were checked for attendance. If one record had a valid caries record, and the other did not, the record with valid outcome was retained. If the outcome was the same then,
- The duplicate with the earliest exam date was retained. If exam dates were the same then,
- If the sex of the child was different, one record was kept as random since the sex

of the child would come from another dataset. If the sex of the child was the same then,

- One duplicate record was kept at random as there should be no significant differences between these records.

From the provided data of 401,054 observations, 10.8% (n=43,256) of records were removed from data cleaning (Figure 2.4), the majority (78.9%; n=34,129/43,256) through the child being absent or the parent/guardian opting out. This left 357,798 observations available for cross-sectional caries analysis which is described in detail in the relevant chapter (Chapter 3).

2.14.2 Cleaning of the CHSP-S data

To be included in the cohort for analysis (described in Chapter 4), the child must have a valid record. Firstly, each child must have a valid age i.e., between 4- and-7-years-old inclusive as these children are outside the usual age range of children in Primary 1. Only children with valid height and weight measurements were appropriate for analysis. This meant children with BMI SDS outwith the range of -6 and 6 were excluded as values outside this range can be seen as 'extreme' values (Information Services Division Scotland, 2018b). SDS were calculated for heights and weights of the children individually using UK 1990 reference curves (Section 1.4.1). The R package *childsds* (Vogel, 2022) was used to complete this. The same valid range between -6 and 6 SDS was applied. This range was used as SDS outwith this range can be seen as 'extreme' values (Information Services Division Scotland, 2018b). Children with missing area-based deprivation measurement (SIMD) were excluded due the thesis having a focus on socioeconomic inequalities. The initial dataset uploaded to the NSS National Safe Haven had 374,067 observation, which after data cleaning (Figure 2.5), 373,189 valid records remained, with 875 (0.2%) being lost through data cleaning.

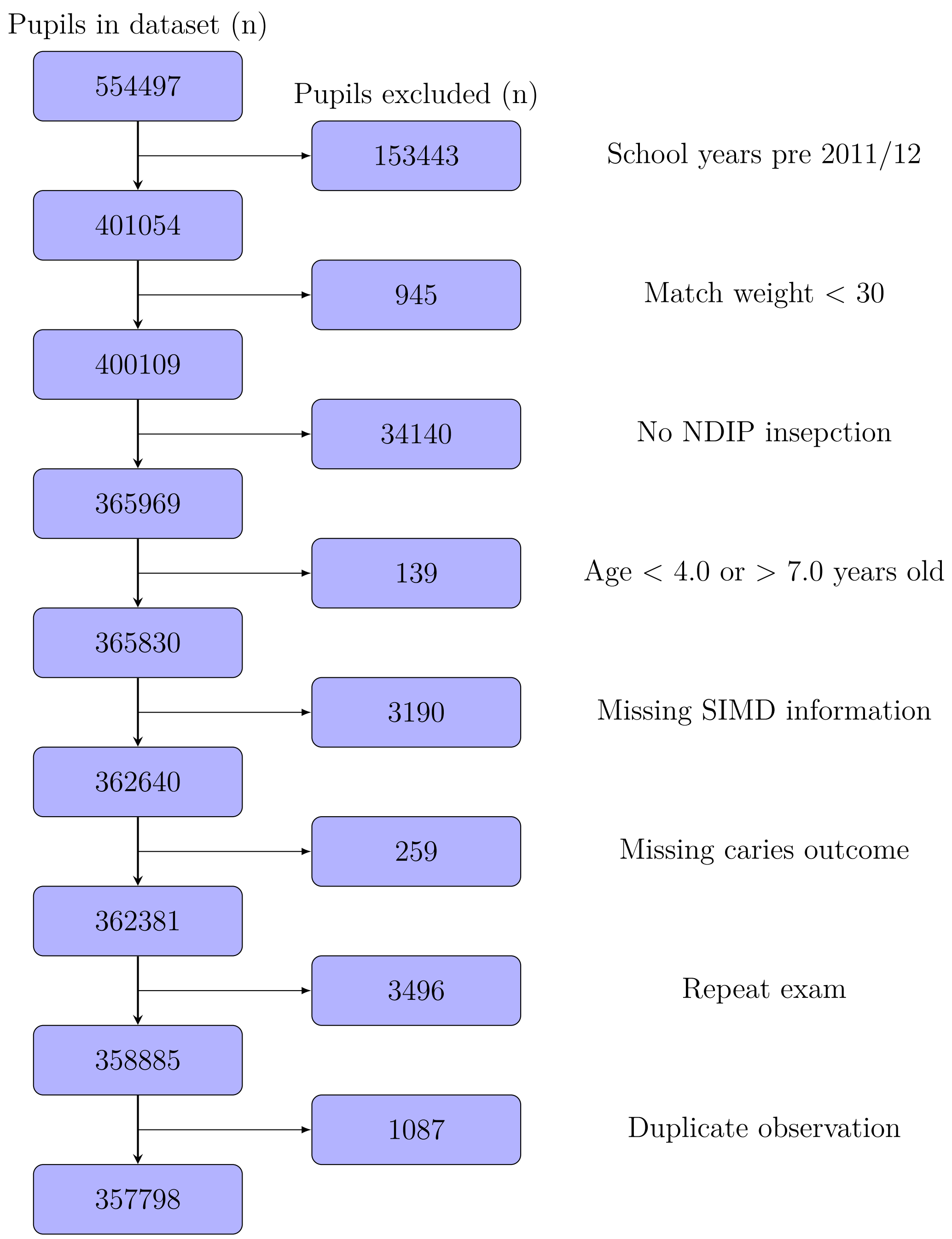

Figure 2.4: Flow chart of data cleaning of National Dental Inspection Programme Primary 1 Basic Inspection data in the National Safe Haven. NDIP - National Dental Inspection Programme; SIMD - Scottish Index of Multiple Deprivation

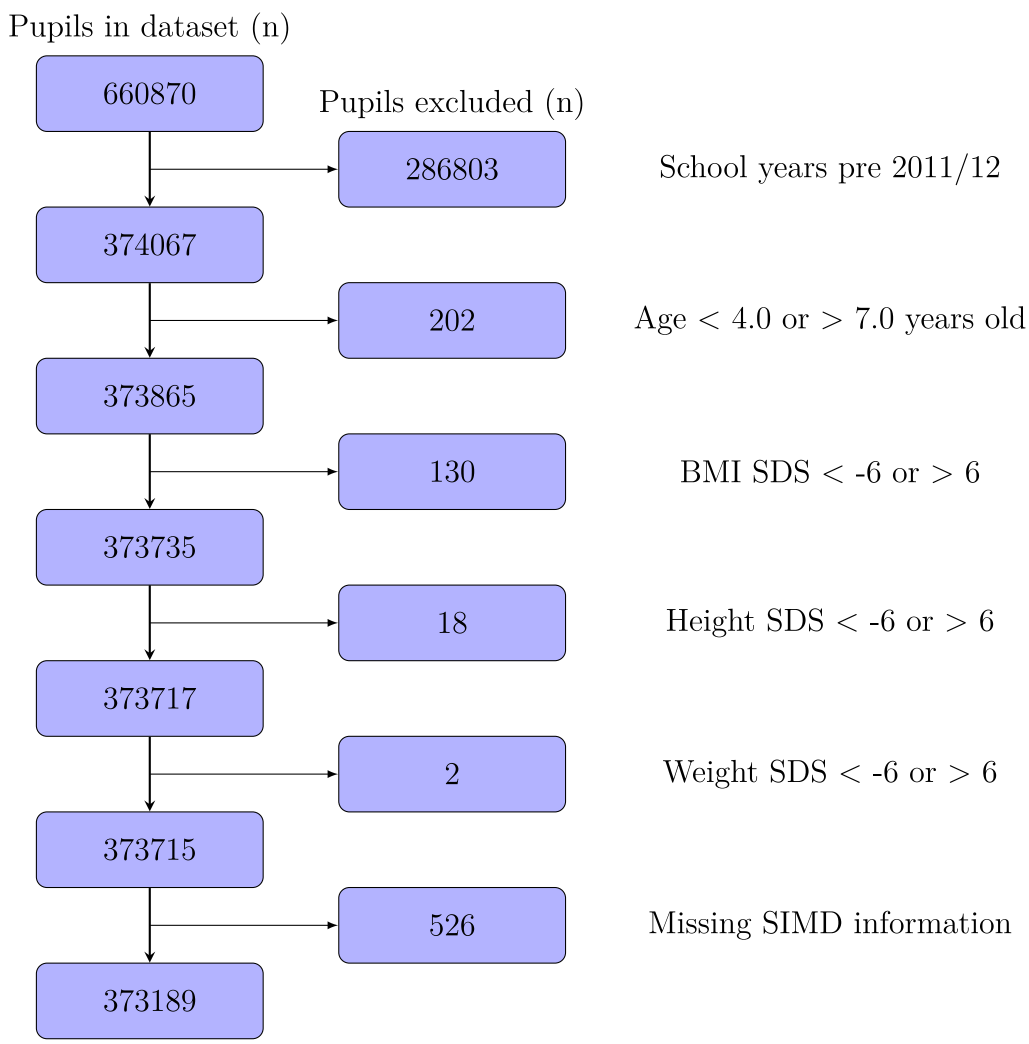

Figure 2.5: Flow chart of data cleaning of Child Health Systems Programme - School data in the National Safe Haven. BMI - body mass index; SDS - Standard Deviation Scores; SIMD - Scottish Index of Multiple Deprivation

2.15 Derivation of Outcome Variables

The following sections describes the derivation of outcome variable used in this thesis. The outcome variables were derived from variables included in the datasets. A full description of all the variables can be found in Appendices H to N.

2.15.1 Obvious caries experience

Obvious caries experience was defined as having one or more of the following:

- A1 - Abscess or infection
- A2 - Gross caries
- A3 - Obviously carious permanent tooth
- B1 - Obviously carious primary tooth
- B3 - Missing primary molar
- B4 - Evidence of restoration.

Thus, any child with one or more of the list would be classed as having *'obvious caries experience'*. If the child was marked as having none of the list about, and 'C - No obvious caries experience' was marked, then it was deemed that the child had *'no obvious caries experience'*. The categories 'B2 - Possible carious permanent tooth' and 'B5 - Poor oral hygiene' were not considered since the NDIP programme had removed these from their definition and recording of obvious caries experience (Section 2.8.2.1), but in the cases where only B2 or B5 were marked, then these children were defined as having *no obvious caries experience*.

2.15.2 Body mass index status

Different levels of BMI classification: underweight, healthy weight, overweight, and obesity, defined as BMI status collectively, were calculated using the BMI SDS centiles. The child's BMI was used to calculate a BMI SDS, which were then placed into centiles as described in Section 1.4.1. The centiles were used to derive the BMI status for each child by using epidemiological cut-offs first created by Cole et al. (1995):

- ≤2nd centile (BMI SDS circa ≤-2) were classed as having underweight
- >2nd centile and <85th centile (BMI SDS circa >-2 and <1.036) had healthy weight
- ≥85th centile and <95th centile (BMI SDS circa ≥1.036 and <1.645) had overweight
- ≥95th centile (BMI SDS circa ≥1.645) had obesity.

2.15.3 Co-existing conditions

The *co-existing conditions* variable was used to answer research questions 3 and 4 (Section 1.13). Using the Co-existing conditions cohort (Section 5.3.1), four groups were created: *'co-existing conditions'*, *'caries experience only'*, *'obesity only'*, and *'neither condition'*.

To be a member of the *'co-existing conditions'* group, the child must have both 'obvious caries experience' and 'obesity' in Primary 1. Children who formed the *'caries experience only'* were children who had 'obvious caries experience' and either 'underweight', 'healthy weight', or 'overweight'. Children in the *'obesity only'* group had 'obesity' and 'no obvious caries experience'. Lastly, children who formed the *'neither condition'* group had 'no obvious caries experience' and one of 'underweight', 'healthy weight', or 'overweight'.

2.16 Cleaning of Childsmile Intervention Datasets and Derivation of Intervention Variables

The following sections describe the data cleaning process for each of the Childsmile intervention datasets along with the process for determining the definition of each intervention variable, which will provide answers to research questions 5 and 6 (Section 1.13).

2.16.1 Cleaning of the Management Information & Dental Account System datasets

To create a complete MIDAS dataset, the MIDAS Participation was modified to retain only one record per child, per day. This was then linked to the MIDAS Treatment dataset. Records were checked against the CHSP 6-8wk for matching date of birth. In cases where 2 components of the date of birth matched (e.g., match of year and month, but not day), the date of birth was taken from the CHSP 6-8wk dataset. Duplicate records, defined when 'Index master', 'Start Date of Treatment', and 'Fee Code' were the same, were removed. Records up to and including the day before the child's 5th birthday were retained. This decision was made to allow all children an equal chance at receiving the interventions. If another date was selected, for example the NDIP Primary 1 Basic Inspection data, then there is a wide range of dates over the course of nearly a full year in which the intervention could take place. This would give some children extra time to potentially receive more Childsmile interventions than some of their counterparts.

The overall MIDAS dataset consisted of 97,916 records of children in Primary 1 between 2015/16 and 2017/18 after cleaning the data as per the requirements set out in Section 7.3.1 i.e., the child must be born on or after 1st January 2011.

2.16.1.1 Derivation of attendance at general dental service variable

A variable was devised to determine if the child had ever attended the General Dental Services (GDS) at least once in the first five years of life. This variable was called *Attendance at GDS*. This was simply if the child had attended the GDS, regardless of any intervention being provided. Furthermore, a variable was created to show how regular the child visited the GDS. Children were categorised as non-attenders, non-regular attenders (attended in one to three years of their first five years of life), and regular attenders (attended in four or five years of their first years of life). This was stored in the variable *Regular Attendance at the GDS*.

2.16.1.2 Derivation of Childsmile dental practice prevention intervention variable

The Childsmile dental practice prevention intervention variable was created to identify if a child had received a Childsmile oral health improvement intervention (dietary advice, oral health instruction, fluoride varnish application) during their visit to the GDS. The 'Fee Code' variable from the MIDAS datasets provided information on whether the child received one or more of dietary advice, oral health instruction, fluoride varnish application (available to children aged 2- to- 5-years-old). As the children who had never attended the GDS were accounted for in the variable *Attendance at GDS*, only children who had attended the GDS at least once in the first five years of life were included. The variable, *Childsmile Dental Practice Prevention Intervention Ever*, highlights the children who have received at least one dietary advice, oral health instruction, or fluoride varnish application in the GDS over the first five years of life.

2.16.1.3 Derivation of general dental service dietary advice variable

The dietary advice variable is a subset of the *Attendance at GDS* variable. As this intervention relates to diet, which is common risk factor of obesity and caries (Section 1.5), it was looked at in more detail than the other Childsmile Dental Practice interventions: oral health instruction and fluoride varnish application. In this case only records with a fee code corresponding to dietary advice were counted. It was of interest to know if the child had ever received dietary advice and so the variable *Dietary Advice at GDS* was created to show this. The variable *Total Number Dietary Advice at GDS* was created to show the total number of times a child received dietary advice in the GDS in their first five years of life. This variable was also created in a discrete nature to allow the comparison on each number of interventions to a baseline number. Only children who had attended the GDS within first five years of live were included.

2.16.2 Cleaning of the Dental Health Support Worker datasets

The DHSW component of Childsmile consists of providing toothbrushing and dietary advice, delivering a dental pack which contains a toothbrush and toothpaste, help with registration at the GDS, and signposting to external services and support. The delivery and intensity of each intervention is determined by the needs of the child and family, however, it is not possible from the data to determine the intensity, quality, or content of each intervention, only if the child received the intervention or not.

The first step of cleaning the data was to merge the DHSW Diary Event dataset with the HIC DHSW Practice dataset, retaining all records from both datasets but only retaining one record per child. Records were marked as invalid when the date of birth was missing, the date of birth did not match the date of birth from either CHSP 6-8wk or the NDIP Primary 1 datasets. When the date of birth matched on two of the three components then the date of birth was replaced with the corresponding date of birth from the CHSP 6-8wk or the NDIP Primary 1 datasets. Records were also marked as invalid when the date of referral was missing or was the same or before the child's date of birth. The sex of the child was also checked for a match with the CHSP 6-8wk or the NDIP Primary 1 datasets. Next was a check for true duplicates, defined as when 'Index Master', 'Date of Intervention', 'Type of Intervention', 'Result of Intervention', 'Signposted to Another Service', 'Dietary Advice Given', 'Toothbrushing Advice Given', and 'Continued Home Support' were all the identical. Records where the date of intervention was missing or on the same day or before the date of birth were marked invalid.

The dataset was filtered to only include interventions up to and including the day before the child's 5th birthday (Section 7.3.1), leaving 155,645 records. It is likely that the outcome would be measured after the child's 5th birthday. Invalid records where the same index had another valid record were removed from the data. This total number accounts for children who have received multiple DHSW contacts, for example, a child who had two contacts with a DHSW, they would have two records in the dataset.

2.16.3 Derivation of the referred to Dental Health Support Worker variable

Children who had a DHSW record in either of the datasets, regardless of successful or unsuccessful visit, were marked as 'Referred'. Being marked as 'Referred' did not mean the family was seen by a DHSW, only that they were initially referred to a DHSW. A family may be referred but never receive a successful contact for reasons such as the DHSW could not contact family or parental refusal. The variable *Referred to DHSW* highlights if a child was referred to a DHSW in their first five years of life regardless of the intervention being successfully delivered.

2.16.4 Derivation of the contact with Dental Health Support Worker variable

A DHSW contact was defined as a successful contact between a DHSW and the family, in which the DHSW had the opportunity to sit down and meet with the family. The variable *Contact with DHSW* was created to show if the family had ever had a successful intervention with a DHSW.

2.16.5 Derivation of the dietary advice from Dental Health Support Worker variable

Whilst many different types of interventions were provided by the DHSW, only interventions which could relate to both caries and obesity were considered. This included the dietary advice intervention. The dietary advice variable was marked when 'Dietary Advice Given' was marked as 'Yes' in the data. If a child received dietary advice within their first five years of life, the information was recorded in a variable called *Dietary Advice from DHSW*. Children must have first received a contact from a DHSW to be included. It is not possible to know the content or quality of the advice. The total number of times dietary advice was delivered by a DHSW was recorded under *Total Number Dietary Advice from DHSW*. This variable was also created in a categorical nature to allow the comparison on each number of interventions to a baseline number.

2.16.6 Derivation of the Dental Health Support Worker signposting to food/diet related community/voluntary organisations variable

The signposting to food/diet related community/voluntary organisation variable was defined as when the child was signposted to either 'Nutrition Child' or 'Nutrition Other'. There were other services that the child could be referred to, however, only nutrition child and nutrition other as these services related specifically to nutrition, which could affect both caries and obesity. It was not possible to know the exact type of services that the child was referred to. The variable *Signposting to Food/Diet Organisations from DHSW* was created to highlight if the child was signposted to a food/diet related community/voluntary organisation by a DHSW in their first five years of life. The total number of times a child was signposted was recorded in the variable *Total Number Signposting to Nutritional Services from DHSW*. This variable was also created in a discrete nature to allow the comparison on each number of interventions to a baseline number.

2.16.7 Cleaning of the nursery or school fluoride varnish application dataset

To generate the data required for fluoride varnish applications in nursery or school, data from the HIC system were cleaned to only retain records where the contact related to fluoride varnish consent or fluoride varnish application. Records were marked as invalid when the date of birth was missing, the date of birth did not match the date of birth from either CHSP 6-8wk or the NDIP Primary 1 datasets, when the date of birth matched on two of the three components then the date of birth was replaced with the corresponding date of birth from the CHSP 6-8wk or the NDIP Primary 1 datasets. Records were marked as invalid if the date the child was added to the HIC system was missing, or if children had missing date of visit, varnish applied flag, or reason for not receiving fluoride varnish. Furthermore, records where the date of visit was before the child's date of birth were marked invalid. Only fluoride varnish application conducted before the child's 5th birthday were included.

2.16.8 Derivation of the nursery and school fluoride varnish application variable

A variable that counted the total number of fluoride varnish applications each child received in nursery or school was created from the records where it was indicated that the child received fluoride varnish on the given date. If a child had received at least one application of fluoride varnish in nursery or school within their first five years of life, the variable *FVA Nursery/School* recorded this.

2.16.9 Cleaning of the nursery supervised toothbrushing dataset

To create the Toothbrushing dataset, records from the HIC system were retained where the contact was related to toothbrushing consent. Records were marked as invalid when the date of birth was missing, the date of birth did not match the date of birth from either CHSP 6-8wk or the NDIP Primary 1 datasets, when the date of birth matched on two of the three components then the date of birth was replaced with the corresponding date of birth from the CHSP 6-8wk or the NDIP Primary 1 datasets.

2.16.10 Derivation of the nursery supervised toothbrushing variable

Using the "date of contact" variable it was marked if the child was attending an establishment that participated in supervised toothbrushing in nursery. It was not possible to tell if the child actually took part, only that they attended an establishment that took part in the programme and that they had positive consent to take part. The variable *NSTB* was derived to indicate that a child had participated in supervised toothbrushing in at least one year in nursery. Children who attend more than one nursery may have more than one consent form. In this case the earliest consent date was included to identify when the child first consented to the programme.

2.17 Overarching Statistical Analyses

The following section describes the overarching statistical methods used. Chapter specific methods are described within each results chapter.

2.18 Software

Data cleaning and statistical analyses were completed using various versions (v3.5.2 to v4.1.2) of R (R Core Team, 2023), and multiple packages within the programme (Carstensen et al., 2022; Fox et al., 2019; Grolemund et al., 2011; D. Robinson et al., 2022; Venables et al., 2002; Vogel, 2022; Wickham et al., 2019; Zeileis, 2006; Zeileis et al., 2002, 2020).

2.19 Data Visualisation

Line graphs and bar charts were used to visualise trends in prevalence over time. Potential risk factors were cross tabulated with the outcome variable, dependent on the research question under consideration, to view the numbers of children within each grouping. Categorical variables were plotted using bar plots. Forest plots were used to view adjusted odds ratios from regression output.

2.20 Testing Trends Over Time

To test if a prevalence has a trend over time, the prevalence was modelled against year treated continuously. Trends were checked for any quadratic or cubic trends. If no quadratic or cubic trend appeared, the linear trend was used. The linear slope is reported, except where explicitly stated, alongside confidence intervals for the slope and the p-value. In the case of looking if different levels of factors, e.g., males and females from the factor sex, followed the same trend, the factor was tested for an interaction with the numeric year using the prevalence of the condition as the dependent variable. Quadratic and cubic terms for the numeric year were considered. The p-values for the interactions are reported and can be assumed to be linear unless stated.

2.21 Modelling Binary Outcomes

Binary logistic regression is a commonly used generalised linear model when the variable of interest is a Bernoulli variable i.e., binary (Zuur et al., 2009), which is a key difference between logistic regression and linear regression (Hosmer et al., 2013). Logistic regression is a vital part of any data analysis which aims to find a relationship between categorical response variable and one or more predictor variables, which will be appropriate for some of the research questions this thesis will answer. Logistic regression is able to handle multiple predictor variables, which can be measured differently, making it useful for many study types (Hosmer et al., 2013).

The logistic regression output can be understood through the use of odds ratios (ORs). For categorical covariates, ORs describe the odds of events in the exposed group divided by the odds of the event in the unexposed group, with odds of each event calculated by the number of events divided by the number of non-events. If the two outcomes are equally likely to occur the OR would be 1, whilst an OR of 2 would mean the exposed group has odds twice as high as the unexposed grouped.

For continuous covariates with OR of 2, the OR can be interpreted as for every unit increase of the continuous predictor variable, the odds of the dependent variable will increase by a factor of 2.

It is possible to determine the accuracy of the ORs by calculating 95% confidence intervals (CIs) from the standard error of the estimates. For a log estimate β_i the CI can calculated by

$$e^{\beta_i \pm z^{*}\text{standard error}(\beta_i)} \tag{2.1}$$

where z^* is the critical value, taken as 1.96 in this analysis to calculate a 95% CI. Taking the exponential of this converts interval from log scale to linear scale.

2.21.1 Diagnostics of a binary logistic model

The concordance statistic, more commonly known as ‘c-statistic’ or ‘c-index’, can be calculated to determine the predictive ability of the model. The value can take a range of 0 to 1, where a value below 0.5 indicates a poor model, a value of 0.5 indicates the model is no better at prediction than random chance, and values closer to 1 indicate the model is better at correctly predicting outcomes (Harrell Jr et al., 1996; Hosmer et al., 2013).

Deviance tests were carried out to obtain a value for deviance, which can be roughly approximated as χ^2. This value is the difference in difference in deviance between the fitted and null model. If the fitted model explains the data better than the null model then the deviance should be less in the fitted model. A p-value is calculated alongside this to check for statistically significant differences.

Residual deviance is a goodness-of-fit measure. The residual deviance is defined as the difference of likelihoods between a fitted model and the null model. For a perfect model, residual deviance would be 0 however, this is unlikely. Higher values of residual deviance suggest a less accurate model.

The degrees of freedom for the models are shown to display the number of independent values which have the freedom to vary.

2.22 Modelling Multinomial Outcomes

Binary logistic regression can be easily adapted to handle multinomial outcomes i.e., more than two categories in the dependent variable. Multinomial regression takes a reference category and the others levels of the dependent variable are compared to this reference.

Multinomial regression, similar to binary logistic regression, produces ORs and these can be interpreted in the same way as binary logistic regression (Section 2.21).

2.22.1 Diagnostics of a multinomial logistic model

In linear regression, R^2 is typically used to test the goodness-of-fit of the model. Multinomial regression does not have a direct equivalent, however, there are some estimates of this measures called Pseudo-R^2. McFadden's Pseudo-R^2 is treated as a measure of effect size. Contrary to linear regression, the R^2 value does not represent the amount of variance in the dependent variable explained by the independent variables. Higher values of Pseudo-R^2 indicate a better fit, however these should be interpreted with caution. Generally a value greater than 0.2 can be deemed as a good fit.

The Likelihood Ratio χ^2 test is an alternative goodness-of-fit test. This tests if the predictive ability of the fitted model is an improvement on the null model. These can be seen as a statistic which tells us which predictors significantly enable use to predict the outcome category, so higher values of χ^2 means higher predictive power. An associated p-value indicates the statistical significance of the improvement.

Standard errors for each each estimate were estimated using a *bootstrap* technique. The *bootstrap* technique is a re-sampling method for finding standard error. The idea is to imitate the process of randomly sampling from a population. This method essentially produces robust standard errors.

2.23 Modelling Count Outcomes

Another type of generalised linear model is the modified Poisson regression, which allows the use of count and binary variables. Over-inflation of the risk ratio is common when applying Poisson regression to binomial outcomes (Zocchetti et al., 1995), however, this problem can be overcome by using robust standard errors (Royall, 1986). This leads to a technique named as *Modified Poisson Regression*, coined by Zou (2004). Modified Poisson produces risk ratios (RRs), sometimes called relative risk. The risk ratio can be calculated using the equation

$$RR = \frac{\text{Incidence in Exposed}}{\text{Incidence in Unexposed}} \tag{2.2}$$

A RR of 1 indicates that there is no increase of risk between outcome one and outcome two. A RR of 2 indicates that outcome one is twice as likely to occur as outcome two. Confidence intervals can be calculated from the estimate in the same way as for ORs (Section 2.21) except using robust standard errors.

2.23.1 Diagnostics of a modified Poisson model

Modified Poisson regression model works best when the variance of a variable is equal to the mean. If the variance is greater than the mean this is known as over-dispersion, with under-dispersion presented when the variance is less than the mean. The dispersion parameter, which checks for under- and- over-dispersion can be estimated from the χ^2 statistic. If the dispersion parameter is equal to 1 then there is no dispersion. Values greater than 1 indicate over-dispersion, whilst values less than 1 indicate under-dispersion. If dispersion exists other models should be considered such as Quasi-Poisson and Negative Binomial regressions. If dispersion still exists, the simpler modified Poisson model is preferred. Zero-inflated models may also be considered in the outcome variable has many zeros.

The Likelihood Ratio χ^2 test is an alternative goodness-of-fit test. This tests if the predictive ability of the fitted model is an improvement on the null model. These can be seen as a statistic which tells us which predictors significantly enable us to predict the outcome category, so higher values of χ^2 means higher predictive power. An associated p-value indicates the statistical significance of the improvement.

2.24 Modelling Strategy for Research Questions 1 to 4

All regression models in Chapters 3 to 6 were tested with each potential risk factor in a univariable model to obtain unadjusted estimates specific to the model. All risk factors were then added to a multivariable model to fully assess the impact of each risk factor. Relevant diagnostics of models was completed to ascertain the quality of the models.

Any other strategy used that was analysis specific is described in the relevant chapter.

2.25 Measures of Inequality

Absolute and relative inequalities were calculated by the Slope Index of Inequality (SII) and the Relative Index of Inequality (RII), with 95% CI, for the prevalence of caries experience and obesity separately. The SII and RII were modelled using additive and multiplicative Poisson regression, respectively, using the rate of outcome, which varies chapter to chapter, as the dependent variable and the midpoint of the cumulative population for each tenth (or fifth in case of Chapter 6) of the socioeconomic scale (measured using SIMD). These are then ranked from the least deprived to most deprived and marked as the independent variable for each school year over the study period (Moreno-Betancur et al., 2015), using robust standard errors. The additive Poisson model can be described as

$$I = \beta_0 + \beta_1 \text{popmid} \tag{2.3}$$

where I is the incidence rate, β_0 is the intercept of the model, and β_1 is the estimate for the midpoint of the cumulative population for each tenth/fifth (popmid). The SII is estimated via

$$\widehat{SII} = \hat{\beta}_1 \tag{2.4}$$

where $\hat{\alpha}$ is obtained via the maximum likelihood from the additive Poisson regression model. The Slope Index of Inequality (SII) should be interpreted as the absolute inequality in caries experience or obesity between the top and bottom of the socioeconomic scale in terms of rate difference (Mackenbach et al., 1997). The multiplicative Poisson model can be described as

$$I = e^{(\beta_0 + \beta_1 \text{popmid})} \tag{2.5}$$

where I is the incidence rate, β_0 is the intercept, and β_1 is the regression coefficient for the midpoint of the cumulative population for each tenth/fifth (popmid). The RII can be estimated from

$$\widehat{RII} = \exp(\hat{\beta}_1) \tag{2.6}$$

where $\hat{\beta}$ is obtained by the maximum likelihood from a multiplicative Poisson regression model. The RII should be interpreted as the ratio of the outcome rates of those from the most deprived areas compared to those from the least deprived areas (Mackenbach et al., 1997). A large score on the SII and RII implies large differences between the most and least deprived on the socioeconomic scale. Linear regression models were used to test for an increasing or decreasing linear trend in the SII and RII estimates over time. The estimates were regressed against school year, which was treated as a continuous variable.

2.26 Chapter Summary

This chapter has outlined the overarching methods, data sources, and statistical analyses used to address the research questions. The overarching aim of this chapter was to detail the methods used to obtain and utilise relevant data sets to answer the proposed research questions. The chapter introduced the approach taken to index, manage, and clean the data as well as the quality checks conducted. The chapter also introduced the main statistical methods use for the analysis.

Chapter 3

Results

Trends in Prevalence and Inequalities in Obvious Caries Experience in Primary 1 Schoolchildren in Scotland, 2011 to 2018

3.1 Overview

This chapter provides the results of a cross-sectional analysis of dental caries experience data from children in Primary 1 between 2011 and 2018. Potentially associated factors are visualised and modelled against dental caries experience to help answer the aims and research questions for this chapter.

3.2 Aims

The overall aim of this chapter is to explore trends and inequalities in childhood dental caries experience of children in Primary 1 living in Scotland. To do this, the following research questions will be answered:

RQ1.1. What are the trends in prevalence and socioeconomic inequalities in childhood dental caries experience between 2011 and 2018?

RQ1.2. What is the relationship between childhood dental caries experience and (a) sex, (b) age, and (c) area-based deprivation (SIMD) and have these changed over time (2011-2018)?

RQ1.3. What factors in RQ 1.2 are independently associated with childhood dental caries experience?

3.3 Methods

3.3.1 Cohort assembly for Chapter 3

Research question 1 asks “what are the trends in prevalence and inequalities in dental caries experience - cross sectionally between 2011 and 2018?” (Section 1.13). This research question requires the NDIP Primary 1 dataset (Section 2.8.2), which is referred to as NDIP Primary 1 throughout this chapter.

The NDIP team are provided with a class list, which details personal identifiers (e.g. first name, second name, sex) of the children registered with the school. The CHI number of the child was then added at a later date using probability matching (Section 2.6.1). Due to possible errors in probability matching, the NDIP data were linked to the Child Health Surveillance Programme 6 to 8 weeks (CHSP 6-8wk) (Section 2.8.1) and Child Health Systems Programme - School (CHSP-S) (Section 2.8.3) datasets. The CHSP 6-8wk check is usually where the CHI number of the child is generated and, along with the CHSP-S, has a pre-populated list of CHI numbers. When the raw

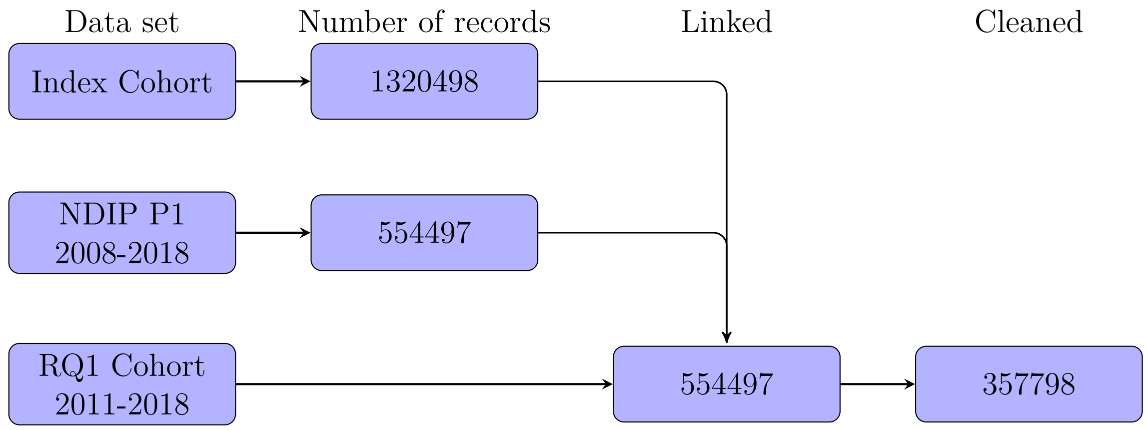

Figure 3.1: Flow chart of creation of Research Question 1 Cohort. NDIP P1 - National Dental Inspection Programme Primary 1; RQ - Research Question

NDIP Primary 1 dataset in the Safe Haven were linked to the CHSP 6-8wk there was a 98.5% success of matching dates of birth of the child and 99.1% success of matching sex of the child. For linking to the raw CHSP-S Cohort there was a 98.5% success on matching date of births and a 99.1% success on matching sex. Since the CHSP 6-8wk and CHSP-S are pre-populated, the sex and date of birth were taken from these datasets and used to answer RQ1. Where there was no record for either of the CHSP datasets, the original identifiers collected by the NDIP team were used.

All children who have a record in the Index Cohort (Section 2.7) were considered. However, only those records which had a valid NDIP Primary 1 Basic Inspection were included in the analysis to answer Research Question 1 (Figure 3.1). More information as to what constitutes as a valid review can be found in Section 2.14.1. Any children without a valid inspection were not included in this analysis.

The official definition for this cohort is children who were in Primary 1 between 2011/12 and 2017/18 who had a valid NDIP Primary 1 Basic Inspection and valid area-based deprivation (SIMD) measurement.

This cohort will be defined as Research Question 1 Cohort (RQ1 Cohort) throughout the thesis.

3.3.2 Study design, data sources, and definitions

This chapter is a repeated cross sectional analysis using large population based datasets. This chapter utilises the RQ1 Cohort. Dental caries experience (caries experience from now on), previously defined in Section 2.15.1, is when a child in Primary 1 (circa 5-years-old) has one or more of the following:

- Abscess or infection
- Gross caries
- Obviously carious permanent tooth
- Obviously carious primary tooth
- Missing primary molar
- Evidence of restoration.

3.3.3 Statistical analysis

This chapter uses line graphs to visualise the prevalence of caries experience over time (2011-2018) overall and for different factors which may be associated with caries experience: year; sex; age; and area-based deprivation (SIMD). Univariable and multivariable binary logistic regression are used to estimate odds ratios (ORs) and adjusted odds ratios (aORs), respectively, for the association between caries experience and other factors (sex, age, school year, and SIMD) using the methods and diagnostic criteria discussed in Section 2.21. Forest plots were used to visualise the aORs. The modelling strategy is discussed in Section 2.24. Slope Index of Inequality (SII) and Relative Index of Inequality (RII) are estimated to examine absolute and relative measures of inequalities in caries experience (Section 2.25).

3.4 Results

3.4.1 Description of the cohort

The NDIP Primary 1 data provided in the National Safe Haven (Section 2.14.1) had 87.7% of the population estimates overall for the seven years, however, the total in the the cleaned RQ1 Cohort was 98.6% of the total number of observations in the NDIP Primary 1 publications (Table 3.1). The difference between the population estimates and the number of valid reviews uploaded to the Safe Haven is likely due to do children not receiving a valid NDIP Primary 1 inspection.

The RQ1 Cohort had 357,798 observations, with 49,288 in 2011/12, 50,619 in 2012/13, 51,824 in 2013/14, 51,932 in 2014/15, 51,216 in 2015/16, 51,214 in 2016/17 and 51,705 in 2017/18 (Table 3.2). The cohort consisted of 51.0% (n=182,594/357,798) males and 49.0% (n=175,204/357,798) females, which was fairly consistent over the seven school years. There were more children from the 10% most deprived areas (SIMD 1) than from the 10% least deprived areas (SIMD 10) with 12.2% (n=43,747/357,798) and 8.8% (n=31,637/357,798) of children coming from these areas, respectively. This trend is consistent with NRS population estimates for area-based deprivation by age for SIMD 2016 (National Records Scotland, 2019b).

3.4.2 Trends in caries experience by cohort year (RQ1.1)

When exploring the trends in the prevalence of caries experience overall in Scotland, there was a reduction in prevalence over the study period where 32.9% (n=16,231/49,288) (Figure 3.2) of 5-year-old schoolchildren had caries experience in 2011/12, reducing to 29.5% (n=15,244/51,705) in 2017/18 (slope for trend=-0.007; 95% CI: -0.010 to -0.004; p=0.003). This reduction in prevalence has given a reduction in odds ratio for caries experience in each year. Compared to 2011/12, the odds of caries experience in 2012/13 was 0.98 (95% CI: 0.96 to 1.01) and 0.85 (95% CI: 0.83 to 0.87) in 2017/18 (Table 3.3).

Table 3.1: Total numbers and percentage of children's data uploaded to the Safe Haven in the Research Question 1 Cohort

School Year	Total number of P1[1] children in Local Authority schools (a)	Total number of children with valid inspections published in NDIP[2] reports (b)	Total number of NDIP[2] inspections uploaded in Safe Haven (c)	Total number of NDIP[2] inspections uploaded in Safe Haven with valid inspection			
	n	n	n	n	% of a	% of b	% of c
2011/12	54865	50204	55580	49288	89.9	98.2	88.7
2012/13	56446	51573	56962	50619	89.7	98.2	88.9
2013/14	57021	52439	58301	51824	90.9	98.8	88.9
2014/15	59457	52579	57401	51932	87.3	98.8	90.5
2015/16	59796	51709	57322	51216	85.7	99.0	89.3
2016/17	58497	51899	57525	51214	87.5	98.7	89.0
2017/18	61695[3]	52324	57954	51705	83.8	98.8	89.2
Total	**407777**	**362727**	**401045**	**357798**	**87.7**	**98.6**	**89.2**

[1] P1 - Primary 1; [2] NDIP - National Dental Inspection Programme;
[3] Estimate changed from estimated population in Mainstream Schools to National Records Scotland 2016 mid-year population estimate

Table 3.2: Characteristics of children by area-based deprivation, age, and sex in Research Question 1 Cohort

School	2011/12		2012/13		2013/14		2014/15		2015/16		2016/17		2017/18		Total	
Year	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
SIMD[1]																
1 (MD[2])	5959	12.1	6232	12.3	6438	12.4	6215	12.0	6199	12.1	6360	12.4	6344	12.3	43747	12.2
2	5465	11.1	5690	11.2	5853	11.3	5745	11.1	5897	11.5	5816	11.4	5877	11.4	40343	11.3
3	4973	10.1	5193	10.3	5250	10.1	5401	10.4	5335	10.4	5320	10.4	5387	10.4	36859	10.3
4	4895	9.9	5055	10.0	5123	9.9	5060	9.7	4992	9.7	5125	10.0	5115	9.9	35365	9.9
5	4697	9.5	4827	9.5	5195	10.0	4912	9.5	4781	9.3	4597	9.0	4706	9.1	33715	9.4
6	4689	9.5	4756	9.4	4819	9.3	4683	9.0	4586	9.0	4596	9.0	4743	9.2	32872	9.2
7	4933	10.0	5099	10.1	5131	9.9	4752	9.2	4729	9.2	4741	9.3	4759	9.2	34144	9.5
8	4854	9.8	4869	9.6	4891	9.4	5080	9.8	4892	9.6	4888	9.5	4927	9.5	34401	9.6
9	4616	9.4	4716	9.3	4867	9.4	5230	10.1	5123	10.0	5083	9.9	5080	938	34715	9.7
10 (LD[3])	4207	8.5	4182	8.3	4257	8.2	4854	9.3	4682	9.1	4688	9.2	4767	9.2	36137	8.8
Age																
4yo[4]	2768	5.6	2098	4.1	2460	4.7	2069	4.0	2165	4.2	2424	4.7	2369	4.6	16353	4.6
5yo[4]	41196	83.6	42613	84.2	43831	84.6	44015	84.8	43513	85.0	42760	83.5	42958	83.1	300886	84.1
6yo[4]	5324	10.8	5908	11.7	5533	10.7	5848	11.3	5538	10.8	6030	11.8	6378	12.3	40559	11.3
Sex																
Male	25222	51.2	25863	51.1	26328	50.8	26385	50.8	26066	50.9	26218	51.2	26512	51.3	182594	51.0
Female	24066	48.8	24756	48.9	25496	49.2	25547	49.2	25150	49.1	24996	48.8	25193	48.7	175204	49.0
Total	**49288**	**13.8**	**50619**	**14.1**	**51824**	**14.5**	**51932**	**14.5**	**51216**	**14.3**	**51214**	**14.3**	**51705**	**14.5**	**357798**	

[1]SIMD - Scottish Index of Multiple Deprivation; [2] MD - Most Deprived 10%; [3] LD - Least Deprived 10%; [4] yo - Years Old

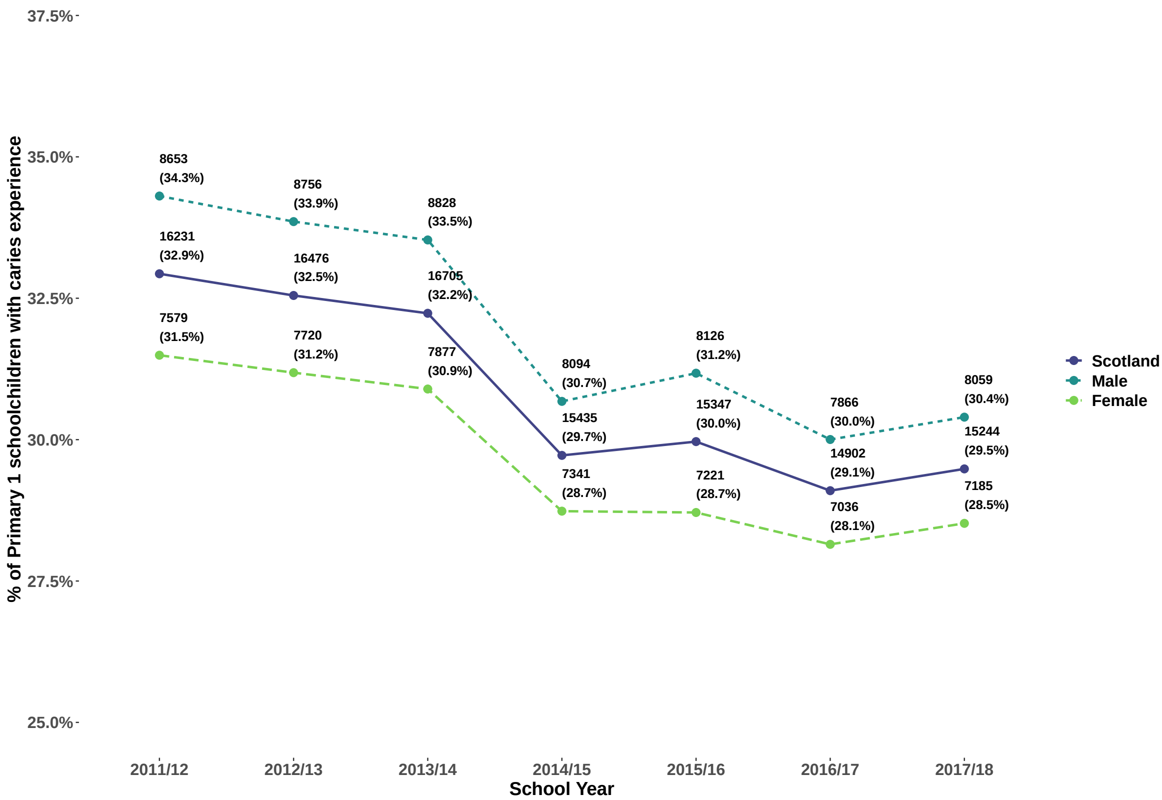

Figure 3.2: Prevalence of caries experience by sex (and overall) across the school years 2011/12 to 2017/18 in Primary 1 schoolchildren in Scotland (Appendix P)

Table 3.3: Unadjusted odds ratio and 95% confidence interval for caries experience according to school year based on a univariable logistic regression model

Year	Caries Experience		No Caries Experience		Total	OR[1]	95% CI[2]	p
	n	%	n	%				
2011	16231	32.9	33057	67.1	49288	-	Referent	-
2012	16476	32.5	34143	67.5	50619	0.98	[0.96,1.01]	0.20
2013	16705	32.2	35119	67.8	51824	0.97	[0.94,0.99]	0.018
2014	15435	29.7	36497	70.3	51932	0.86	[0.84,0.88]	<0.001
2015	15347	30.0	35869	70.0	51216	0.87	[0.85,0.89]	<0.001
2016	14902	29.1	36312	70.9	51214	0.84	[0.81,0.86]	<0.001
2017	15244	29.5	36461	70.5	51705	0.85	[0.83,0.87]	<0.001
Total	110340	30.8	247458	69.2	357798			

Logistic Regression Results					
Type 3 Results:	**Dev[3]**	**Df[4]**	**Res[5] Dev**	**p**	**C-statistic**
	383.2	6	441714	<0.001	0.52

[1]OR - odds ratio; [2]CI - confidence interval; [3]Dev - Deviance; [4]Df - degrees of freedom; [5] Res - Residual

Table 3.4: Unadjusted odds ratio and 95% confidence interval for caries experience according to sex based on a univariable logistic regression model

Sex	Caries Experience		No Caries Experience		Total	OR[1]	95% CI[2]	p
	n	%	n	%				
Female	51958	29.7	123246	70.3	175204	-	Referent	-
Male	58382	32.0	124212	68.0	182594	1.11	[1.10,1.13]	<0.001
Total	110340	30.8	247458	69.2	357798			

Logistic Regression Results					
Type 3 Results:	**Dev[3]**	**Df[4]**	**Res[5] Dev**	**p**	**C-statistic**
	225.3	1	441872	<0.001	0.51

[1]OR - odds ratio; [2]CI - confidence interval; [3]Dev - Deviance; [4]Df - degrees of freedom; [5] Res - Residual

3.4.3 Trends in caries experience by sex (2011-2018) (RQ1.2a)

The caries experience prevalence in both males and females has consistently reduced over the cohort period, although males have had a small but consistently higher prevalence than females (Figure 3.2). The prevalence of caries experience in males in the cohort was 32.0% (n=58,382/182,594) and 29.7% (n=51,958/175,204) in females (Table 3.4) There were small but statistically significant differences between sex (Table 3.4), although these differences did not change over the years (p for year/sex interaction=0.41), which allowed the cohort to be combined by sex for the further analyses.

3.4.4 Trends in caries experience by age (2011-2018) (RQ1.2b)

The prevalence of caries experience increased as age increased. Caries experience prevalence in 5-year-old children was 30.6% (n=92,038/208,848) prevalence of caries in 4-year-old children was 27.7% (n=4,531/11,822), which marked a lower prevalence than 5-year-old children (OR=0.87, 95% CI: 0.84 to 0.90) (Table 3.5). Prevalence of caries experience in children who were 6-year-old was 34.0% (n=13,771/40,559) which was a higher odds than 5-year-old children (OR=1.17, 95% CI: 1.14 to 1.19) (Table 3.5). The prevalence decreased for all ages over time, following a similar trend (p for year/age interaction=0.76), although the prevalence was consistently higher in 6-year-old children than the other ages, followed by 5-year-olds (Figure 3.3). The prevalence in children aged 4-years varied more over time than children aged 5- and 6-years due to the smaller sample size of children aged 4-years.

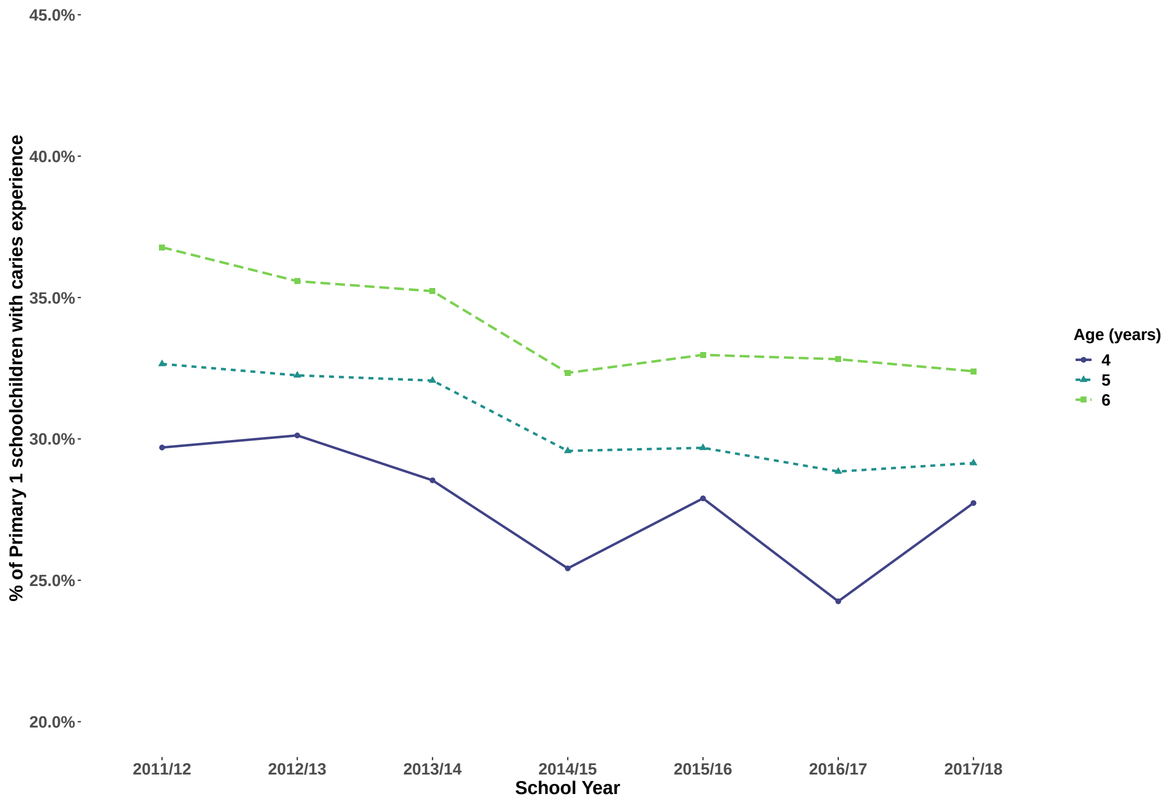

Figure 3.3: Prevalence of caries experience by age across the school years 2011/12 to 2017/18 in Primary 1 schoolchildren in Scotland

Table 3.5: Unadjusted odds ratio and 95% confidence interval for caries experience according to age based on a univariable logistic regression model

Age[1]	**Caries Experience**		**No Caries Experience**		**Total**	**OR**[2]	**95% CI**[3]	**p**
	n	%	n	%				
4	4531	27.7	11822	72.3	16353	0.87	[0.84,0.90]	<0.001
5	92038	30.6	208848	69.4	300886	-	Referent	-
6	13771	34.0	26788	66.0	40559	1.17	[1.14,1.19]	<0.001
Total	110340	30.8	247458	69.2	357798			

Logistic Regression Results					
Type 3 Results:	**Dev**[4]	**Df**[5]	**Res**[6] **Dev**	**p**	**C-statistic**
	266.7	2	441831	<0.001	0.51

[1]Age in years; [2]OR - odds ratio; [3]CI - confidence interval; [4]Dev - Deviance; [5]Df - degrees of freedom; [6] Res - Residual

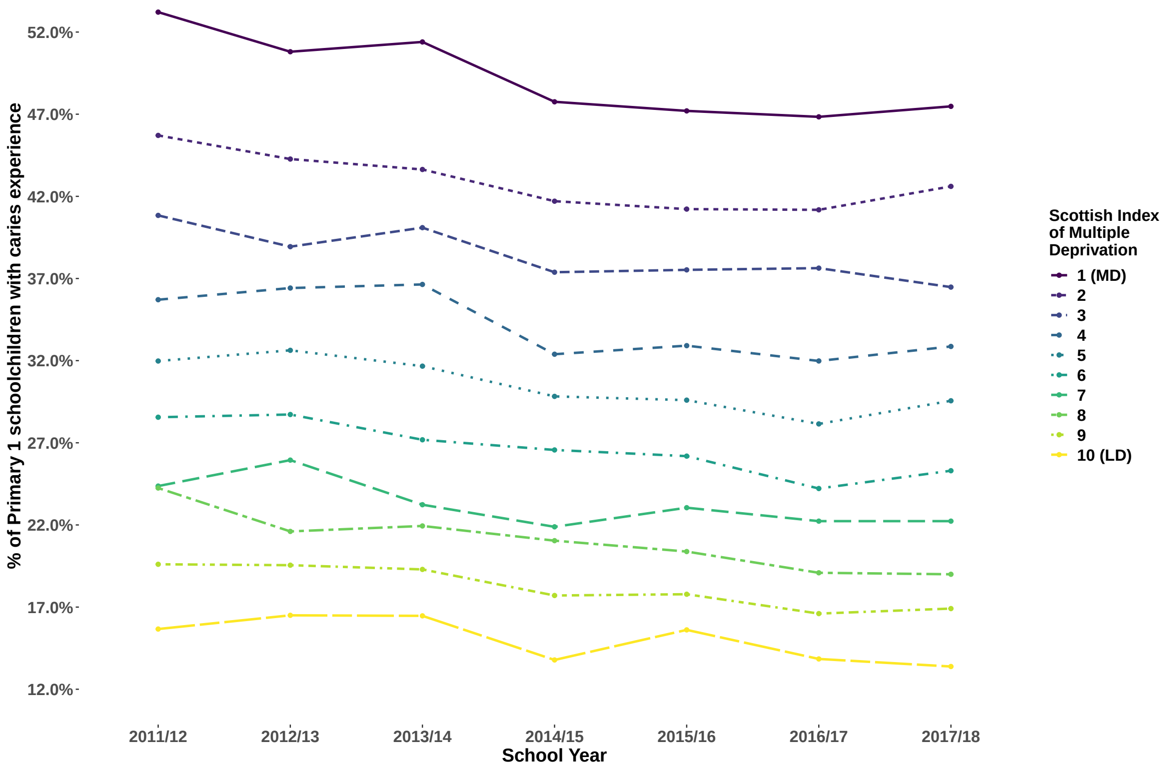

Figure 3.4: Prevalence of caries experience by area-based deprivation across the school years 2011/12 to 2017/18 in Primary 1 schoolchildren in Scotland (Appendix Q). MD - Most Deprived 10%; LD - Least Deprived 10%

3.4.5 Trends in caries experience by area-based deprivation (2011-2018) (RQ1.2c)

Caries experience prevalence has reduced in all tenths of the SIMD overtime, however, a clear social gradient is evident within each year (Figure 3.4). The prevalence within children from the 10% most deprived areas (SIMD 1) was 53.2% (n=3,171/5,959) in 2011/12, reducing to 47.5% (n=3,012/6,344) in 2017/18, a reduction of 5.7%. In the least deprived areas (SIMD 10), 15.7% (n=659/4,207) of children had caries experience in 2011/12 and 13.4% (n=638/4,767) in 2017/18, a reduction of 2.3%. Although there is a suggestion that greater improvements in caries prevalence have been observed in the least deprived groups, a formal test of interaction was not statistically significant (p for year/SIMD interaction=0.55), which suggests that the trends over time are similar for all tenths of SIMD. Despite this, overall children from the 10% most deprived areas in Scotland had odds of caries experience 5.50 (95% CI: 5.31 to 5.71) times higher than children from the 10% least deprived areas (Table 3.6).

Table 3.6: Unadjusted odds ratio and 95% confidence interval for caries experience according to area-based deprivation based on a univariable logistic regression model

SIMD[1]	Caries Experience		No Caries Experience		Total	OR[2]	95% CI[3]	p
	n	%	n	%				
1(MD)[4]	21531	49.2	22216	50.8	43747	5.50	[5.31,5.71]	<0.001
2	17297	42.9	23046	57.1	40343	4.26	[4.11,4.42]	<0.001
3	14146	38.4	22713	61.6	36859	3.54	[3.41,3.67]	<0.001
4	12068	34.1	23297	65.9	35365	2.94	[2.83,3.06]	<0.001
5	10287	30.5	23428	69.5	33715	2.49	[2.40,2.59]	<0.001
6	8773	26.7	24099	73.3	32872	2.07	[1.99,2.15]	<0.001
7	7959	23.3	26185	76.7	34144	1.73	[1.66,1.80]	<0.001
8	7236	21.0	27165	79.0	34401	1.51	[1.45,1.57]	<0.001
9	6306	18.2	28409	81.8	34715	1.26	[1.21,1.31]	<0.001
10(LD)[5]	4737	15.0	26900	85.0	31637	-	Referent	-
Total	110340	30.8	247458	69.2				

Logistic Regression Results					
Type 3 Results:	**Dev[6]**	**Df[7]**	**Res[8] Dev**	**p**	**C-statistic**
	20160.0	9	421938	<0.001	0.65

[1]SIMD - Scottish Index of Multiple Deprivation; [2]OR - odds ratio; [3] CI - confidence interval; [4]MD - Most deprived 10%; [5]LD - Least deprived 10%; [6]Dev - Deviance; [7] Df - degrees of freedom; [8] Res - Residual

3.4.6 Have measures of socioeconomic inequality changed over time (2011-2018)? (RQ1.2c)

There was no clear increasing or decreasing trend evident in the SII for caries experience in Scotland. The SII was estimated at 38.1% (95% CI: 34.8% to 41.5%) in 2011/12 and 36.9% (95% CI: 34.5% to 39.3%) in 2017/18, with slight fluctuation during the study period (Figure 3.5). The RII followed an upwards trend, with an estimated RII of 3.48 (95% CI: 3.15 to 3.85) in 2011/12 rising to 3.85 (95% CI: 3.47 to 4.26) in 2017/18. This suggests that absolute inequalities did not change during the study period, however, relative inequalities have increased due to the prevalence reducing equally in the most and least deprived groups (Figure 3.5).

Figure 3.5: Slope Index of Inequality and Relative Index of Inequality for children with caries experience (Appendix R). SII - Slope Index of Inequality; RII - Relative Index of Inequality

3.4.7 Modelling caries experience according to sex, age, SIMD, and school year (RQ1.3)

In a multivariable logistic regression model, sex, year, area-based deprivation, and age were associated with caries experience. From the deviance score it is evident that SIMD has the biggest effect on the model, followed by age (Table 3.7). The C-statistic of 0.65 suggests that the model has reasonable ability to predict caries experience, however from looking at the C-statistic from the univariable logistic regression models (Tables 3.3, 3.4, 3.5, 3.6), this ability is mainly due to SIMD.

Children from the 10% most deprived areas (SIMD 1) had adjusted odds of caries experience 5.60 (95% CI: 5.40 to 5.81) times higher than children from the 10% least deprived areas (SIMD 10) (Figure 3.6). The adjusted odds of caries experience increased as area-based deprivation increased. Children from the second least deprived areas (SIMD 9) had statistically significant higher odds of caries experience than children in SIMD 10. Males had higher odds of caries experience than females (aOR:

1.11; 95% CI: 1.10 to 1.13) and the odds of caries experience reduced going from 2012/13 to 2017/18 when compared to 2011/12 levels (Figure 3.6). When adjusted for other risk factors, the adjusted odds of caries in 4-year-old children was 0.79 (95% CI: 0.76 to 0.82), whilst the adjusted odds of caries in for 6-year-old children was 1.25 (95% CI: 1.23 to 1.28) when compared to 5-year-old children in the cohort (Table 3.7).

Table 3.7: Adjusted odds ratio and 95% confidence interval for caries experience based on a multivariable logistic regression model adjusted by area-based deprivation, sex, age, and school year

Variable	aOR[1]	95% CI[2]	p
Sex			
Female	-	Referent	-
Male	1.11	[1.10,1.13]	<0.001
Year			
2011	-	Referent	-
2012	0.97	[0.94,1.00]	0.025
2013	0.96	[0.93,0.98]	0.001
2014	0.86	[0.83,0.88]	<0.001
2015	0.86	[0.84,0.88]	<0.001
2016	0.82	[0.80,0.94]	<0.001
2017	0.84	[0.81,0.86]	<0.001
SIMD[3]			
1 (MD)[4]	5.60	[5.40,5.81]	<0.001
2	4.34	[4.18,4.50]	<0.001
3	3.59	[3.46,3.73]	<0.001
4	2.98	[2.87,3.09]	<0.001
5	2.52	[2.42,2.62]	<0.001
6	2.07	[1.99,2.16]	<0.001
7	1.72	[1.65,1.79]	<0.001
8	1.51	[1.45,1.58]	<0.001
9	1.27	[1.22,1.32]	<0.001
10 (LD)[5]	-	Referent	-
Age[6]			
4	0.79	[0.76,0.82]	<0.001
5	-	Ref	-
6	1.25	[1.23,1.28]	<0.001

Logistic Regression Results

Type 3 Results:	**Dev[7]**	**Df[8]**	**Res[9] Dev[7]**	**p**	**C-statistic**
Sex	225.3	1	441872	<0.001	0.65
Year	381.7	6	421316	<0.001	
SIMD[3]	20174.6	9	421698	<0.001	
Age	589.9	2	420726	<0.001	

[1]aOR - adjusted odds ratio; [2]CI - confidence interval; [3]SIMD - Scottish Index of Multiple Deprivation; [4]MD 10% - Most Deprived 10%; [5]LD 10% - Least Deprived 10%; [6] Age in years; [7] Dev - Deviance; [8]Df - Degrees of Freedom; [9]Res - Residual

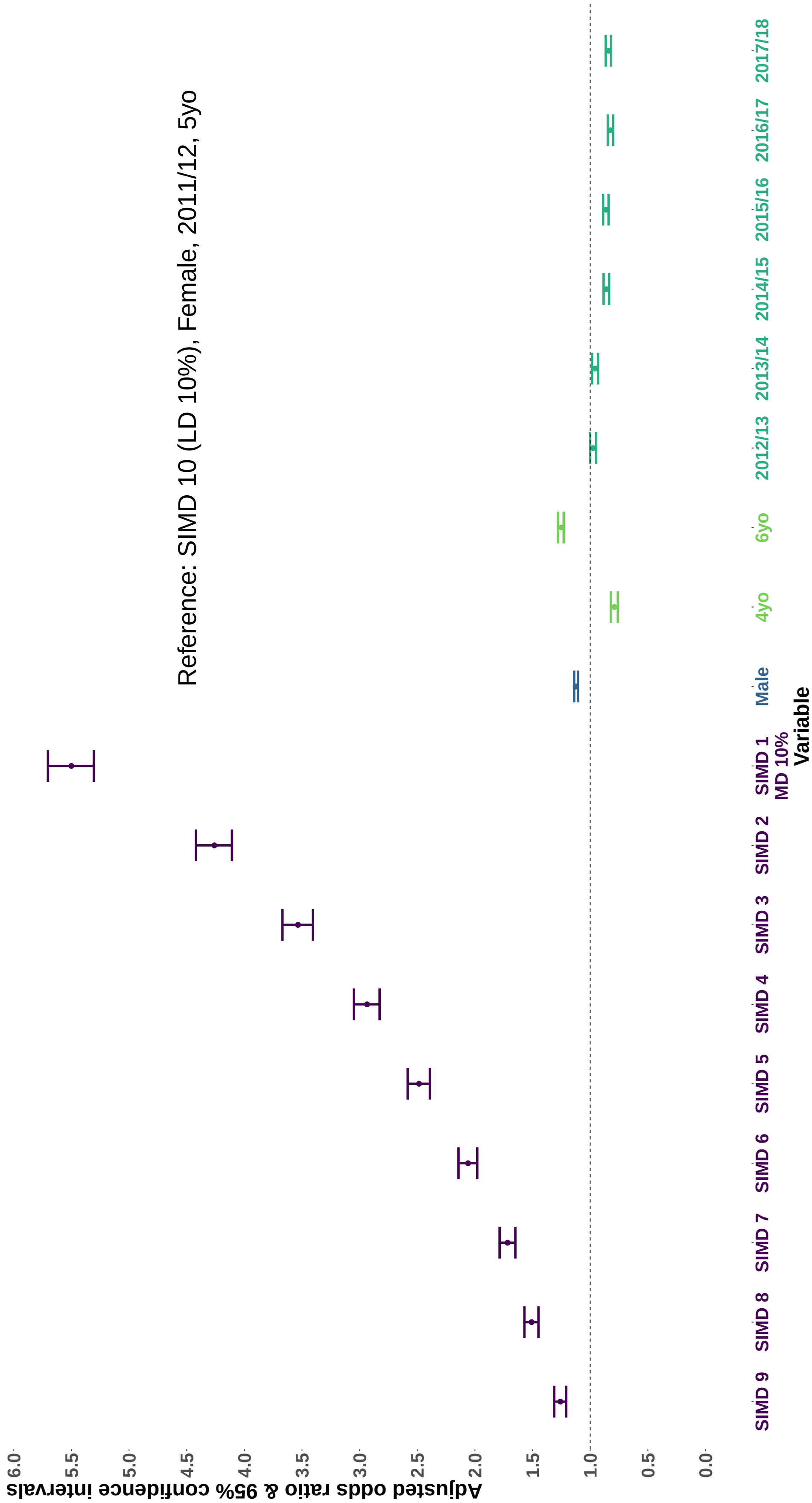

Figure 3.6: Adjusted odds ratios and 95% confidence interval for caries experience based on a multivariable logistic regression model according to year, age, sex, and Scottish Index of Multiple Deprivation. SIMD - Scottish Index of Multiple Deprivation; MD 10% - Most Deprived 10%; LD 10% - Least Deprived 10%; yo - years old

3.5 Chapter Summary

The aim of this chapter was to explore trends in prevalence of caries experience and inequalities in caries experience of children in Primary 1 living in Scotland. We used routinely collected data from NDIP over seven years to construct multiple cohorts (2011/12 to 2017/18) of children and examined trends in prevalence and inequalities over time.

This analysis has shown a reduction in caries prevalence overall within Scotland between 2011/12 and 2017/18. Prevalence of caries experience has followed a similar trend for males and females, although males have had a consistently higher prevalence over the cohort years albeit by a small amount. Older children have increased prevalence of caries experience, with the adjusted odds of caries experience compared to 5-year-old's reflecting this result.

Caries prevalence reduced over time in all tenths of SIMD, however there was a clear social gradient with large, stable absolute inequalities within this group. Due to the decreasing prevalence but stable absolute inequalities, relative inequalities have increased over the study period.

This analysis confirms that age, school year, sex, and area-based deprivation are independently associated with caries experience in Primary 1 children in Scotland, with SIMD having the strongest association with the highest predictive power.

Chapter 4

Results

Trends in Prevalence and Inequalities in BMI Status in Primary 1 Schoolchildren in Scotland, 2011 to 2018

4.1 Overview

This chapter provides the results of a cross-sectional analysis of BMI data from children in Primary 1 in Scotland between 2011 and 2018. Potentially associated factors are visualised and modelled against BMI to help address the aims and research questions for this chapter.

4.2 Aims

The overall aim of this chapter is to explore trends and inequalities in childhood BMI status in Primary 1 children living in Scotland. To do this the following research questions will be answered:

RQ2.1. What are the trends in prevalence and socioeconomic inequalities in childhood BMI status between 2011 and 2018?

RQ2.2. What is the relationship between childhood BMI status and (a) sex, (b) age, and (c) area-based deprivation (SIMD) and have these changed over time (2011-2018)?

RQ2.3. What factors in RQ 2.2 are independently associated with childhood BMI status?

4.3 Methods

4.3.1 Cohort assembly for Chapter 4

Research question 2 asks "what are the trends in prevalence and inequalities in obesity - cross sectionally between 2011 and 2018?" (Section 1.13). This research question requires the CHSP-S dataset (Section 2.8.3).

All children who have a record in the Index Cohort (Section 2.7) were considered. However, only those records which had a valid CHSP-S review between 2011/12 and 2017/18 were included in the analysis to answer Research Question 2 (Figure 4.1). More information as to what constitutes as a valid review can be found in Section 2.14.2. Any children without a valid CHSP-S review were not included in this analysis. Children must also have a valid area-based deprivation (SIMD) measurement.

This cohort will be defined as Research Question 2 Cohort (RQ2 Cohort) throughout the thesis.

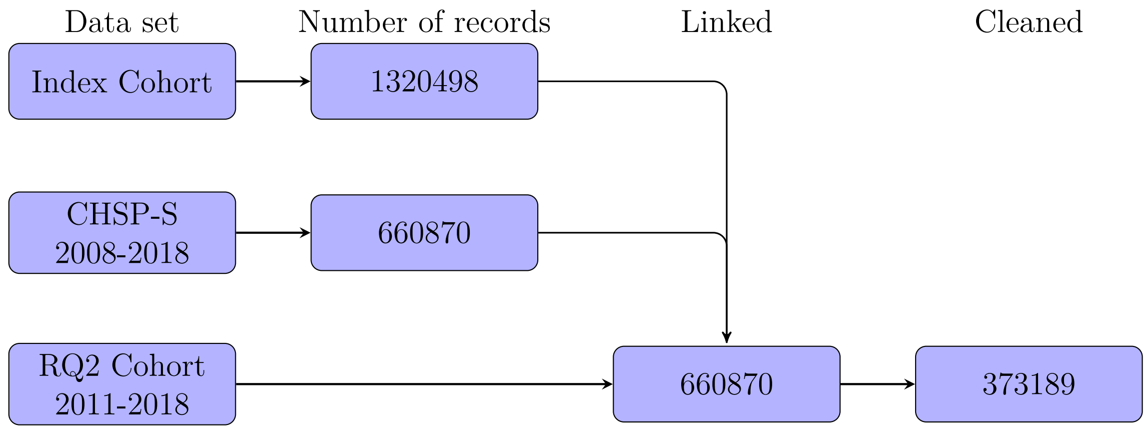

Figure 4.1: Flow chart of creation of Research Question 2 cohort. CHSP-S - Child Health Systems Programme - School; RQ - Research Question

4.3.2 Study design, data sources, and definitions

The following chapter is a repeated cross-sectional analysis using large population-based datasets. This chapter utilises the RQ2 Cohort. Different categories of BMI, previously defined in Section 2.15.2, are as follows:

- $\leq$2nd centile (BMI SDS circa $\leq$-2) were classed as having underweight
- $>$2nd centile and $<$85th centile (BMI SDS circa $>$-2 and $<$1.036) had healthy weight
- $\geq$85th centile and $<$95th centile (BMI SDS circa $\geq$1.036 and $<$1.645) had overweight
- $\geq$95th centile (BMI SDS circa $\geq$1.645) had obesity.

4.3.3 Statistical analysis

This chapter uses line graphs to visualise the prevalence of BMI status over time (2011-2018) overall and for different factors which may be associated with BMI status: year; sex; age; and area-based deprivation (SIMD). To test for difference in trend over time within each factor, binary logistic regression models were used with a year (treated numerically) and factor interaction, using BMI status as the outcome. A model was built for underweight, overweight, and obesity separately and compared to health weight.

Univariable and multivariable multinomial regression is used to estimate odds ratios (ORs) and adjusted odds ratios (aORs), respectively, for the association between BMI status and other factors (sex, age, school year, and SIMD) using the methods and diagnostic criteria discussed in Section 2.22. The modelling strategy is discussed in Section 2.24. Slope Index of Inequality (SII) and Relative Index of Inequality (RII) are estimated to examine absolute and relative measures of inequalities in BMI status (Section 2.25). To investigate whether the risk of underweight, overweight, and obesity had increased in 2017/2018 vs 2011/2012, modified Poisson regression models (Section 2.23) were used. Linear combination of regression parameters was used to provide point estimates the risk of underweight, overweight, and obesity in 2017/18 versus 2011/12 for each tenth of area-based deprivation (SIMD). RRs were calculated by taking the exponential of the sum of the estimate for 2017/2018 and the respective SIMD tenth and year interaction term, and robust standard errors were used to calculate 95% confidence intervals.

4.4 Results

4.4.1 Description of the cohort

The RQ2 Cohort had 90.5% (n=373,189/412,269) of the total NRS population estimates for the seven school years (Table 4.1). This reduced over the years from 93.6% in 2011/12 (n=51,173/55,769) to 87.7% (n=52,632/60,001) in 2017/18, with a low of 84.6% (n=52,164/61,695) in 2016/17 (Table 4.1). The drop in percentage of valid records of NRS population is in line with the CHSP-S publications (Information Services Division Scotland, 2018a). This suggests that the programme is not collecting data on the missing children and not that the data in Safe Haven is missing the records. Of the data uploaded to the Safe Haven there was a high proportion of children that had valid heights and weights recorded, with a 99.8% overall, which was consistent over the seven school years (Table 4.1).

The RQ2 Cohort had an overall sex split of 50.9% (n=190,100/373,189) males and 49.1% (n=183,089/373,189) females, which is consistent over the seven years (Table 4.2). There were more children from the most deprived tenth (12.2%; n=45,715/373,189;

SIMD 1) than any other tenth, with 8.7% (n=32,629/373,189) of children coming from the least deprived tenth (SIMD 10). This trend is consistent with NRS population estimates for area-based deprivation by age for SIMD 2016 (National Records Scotland, 2019b).

4.4.2 Trends and inequalities in healthy weight (2011-2018) (RQ2.1 & RQ2.2)

The prevalence of Primary 1 schoolchildren with healthy weight has plateaued between 2011/12 and 2017/18. In 2011/12 76.9% (n=40,112/52,173) children in Scotland had healthy weight with the equivalent estimate of 76.5% (n=40,257/52,632) in 2017/18 (Figure 4.2). There was no trend identified over time (slope for trend=-0.001; 95% CI: -0.003 to 0.001; p=0.20). Females consistently had slightly higher prevalence of healthy weight than males, with a 1.8% (females 77.8%, n=19,845/25,507; males 76.0%, n=20,267/26,666) higher prevalence in 2011/12 and 2.0% (females 77.5%, n=19,947/25,735; males 75.5%, n=20,310/26,897) in 2017/18 (Figure 4.2), however these slopes were not different over time (p for year/sex interaction=0.74).

Table 4.1: Total and percentage of children uploaded to the Safe Haven in the CHSP-S Cohort with valid height and weight

School Year	Total number of P1[1] children in Local Authority schools (a)	Total number of children with valid height and weight recorded in CHSP-S[2] reports (b)	Total number of CHSP-S[1] reviews uploaded in Safe Haven (c)	Total number of CHSP-S[1] reviews uploaded in Safe Haven with valid height and weight recorded			
	n	n	n	n	% of a	% of b	% of c
2011/12	55769	52445	52355	52173	93.6	99.5	99.7
2012/13	57021	54423	54113	53944	94.6	99.1	99.7
2013/14	59490	55003	54703	54556	91.7	99.2	99.7
2014/15	59796	54995	54597	54498	91.1	99.2	99.8
2015/16	58497	53720	53332	53222	91.0	99.1	99.8
2016/17	61695	52531	52250	52164	84.6	99.3	99.8
2017/18	60001	52534	52717	52632	87.7	>100	99.8
Total	**412269**	**375611**	**374067**	**373189**	**90.5**	**99.4**	**99.8**

[1]P1 - Primary 1; [2]CHSP-S - Child Health Systems Programme - School

Table 4.2: Characteristics of children by area-based deprivation, age, and sex in Research Question 2 Cohort

School	2011/12		2012/13		2013/14		2014/15		2015/16		2016/17		2017/18		Total	
Year	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
SIMD[1]																
1 (MD[2])	6355	12.2	6734	12.5	6822	12.5	6499	11.9	6471	12.2	6588	12.6	6246	11.9	45715	12.2
2	5792	11.1	6064	11.2	6169	11.3	6067	11.1	6094	11.5	6055	11.6	5869	11.2	42110	11.3
3	5242	10.0	5557	10.3	5497	10.1	5687	10.4	5558	10.4	5389	10.3	5497	10.4	38427	10.3
4	5219	10.0	5354	9.9	5342	9.8	5309	9.7	5180	9.7	5216	10.0	5197	9.9	36817	9.9
5	4938	9.5	5100	9.5	5428	9.9	5118	9.4	5045	9.5	4817	9.2	4822	9.2	35268	9.5
6	5000	9.6	5096	9.4	5057	9.3	4927	9.0	4809	9.0	4737	9.1	4868	9.2	34494	9.2
7	5238	10.0	5415	10.0	5454	10.0	5017	9.2	4982	9.4	4767	9.1	4892	9.3	35765	9.6
8	5050	9.7	5116	9.5	5141	9.4	5342	9.8	5129	9.6	5022	9.6	5111	9.7	35911	9.6
9	4900	9.4	5013	9.3	5139	9.4	5447	10.0	5224	9.8	5037	9.7	5293	10.1	36053	9.7
10 (LD[3])	4439	8.5	4495	8.3	4507	8.3	5085	9.3	4730	8.9	4536	8.7	4837	9.2	32629	8.7
Age																
4yo[4]	2698	5.2	2326	4.3	2556	4.7	3878	7.1	4124	7.4	3570	6.8	3551	6.7	22703	6.1
5yo[4]	43682	83.7	45024	83.5	44390	81.4	44503	81.7	42302	81.9	42219	80.9	42032	79.9	304152	81.5
6yo[4]	5793	11.1	6594	12.2	7610	13.9	6117	11.2	6796	13.2	6375	12.2	7049	13.4	46334	12.4
Sex																
Male	26666	51.1	27409	50.8	27797	51.0	27665	50.8	27035	50.8	26631	51.1	26897	51.1	190100	50.9
Female	25507	48.9	26535	49.2	26759	49.0	26833	49.2	26187	49.2	25533	48.9	25735	48.9	183089	49.1
Total	**52173**	**14.0**	**53944**	**14.5**	**54556**	**14.6**	**54498**	**14.6**	**53222**	**14.3**	**52164**	**14.0**	**52632**	**14.1**	**373189**	

[1]SIMD - Scottish Index of Multiple Deprivation; [2]MD - Most Deprived 10%; [3] LD - Least Deprived 10%; [4] yo - Years Old

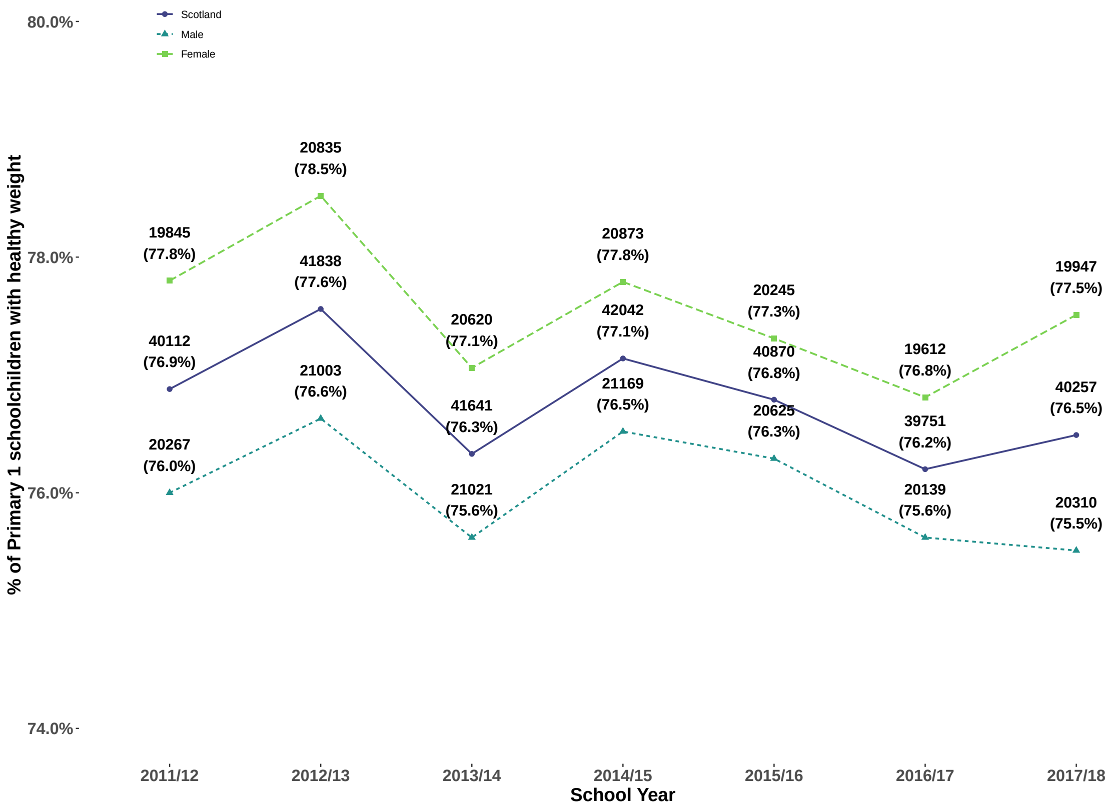

Figure 4.2: Prevalence of healthy weight in Primary 1 children in Scotland according to sex from 2011/12-2017/18 (Appendix S)

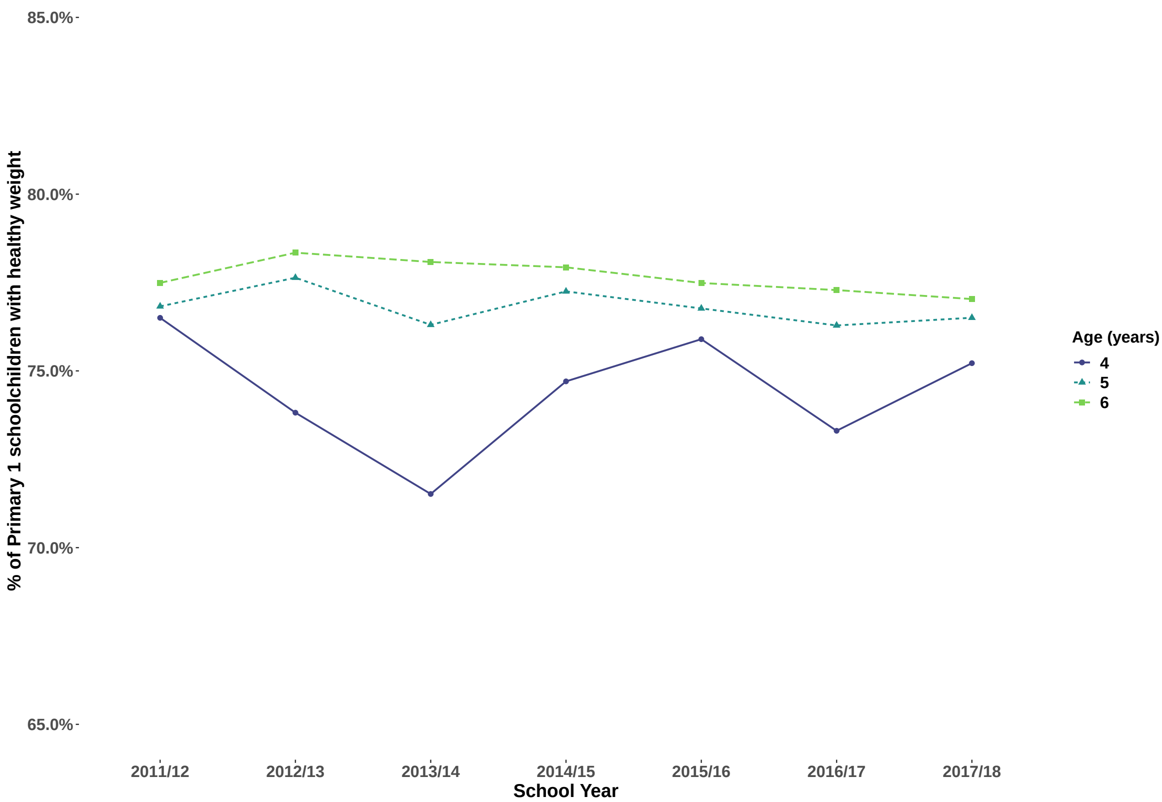

Figure 4.3: Prevalence of healthy weight in Primary 1 children in Scotland according to age between 2011/12 to 2017/18

Prevalence of healthy weight was stable in children aged 5- and- 6-years-old, showing very little changed across the seven cohort years (Figure 4.3). Prevalence of healthy weight in 5-year-old children was 76.8% (n=233,600/304,152) overall (Table 4.3), with similar values at both the start (2011/12 - 76.8%; n=33,559/43,682) and the end of the study period (2017/18 - 76.5%; n=32,156/42,032). This was similar to 6-year-old children with an overall prevalence of 77.7% (n=35,987/46,334) (Table 4.3), 77.5% (n=4,489/5,793) in 2011/12, and 77.0% (n=5,430/7,049) in 2017/18 (Figure 4.3). The prevalence of healthy weight in children aged 4-years had slight fluctuation from year to year, however there were smaller number 4-year-old children in this sample compared to the other age groups. Despite this fluctuation the prevalence of healthy weight in children aged 4-years was similar in 2011/12 (76.5%; n=2,064/2,698) and 2017/18 (75.2%; n=2,671/3,551) (Figure 4.3). The trends between ages did not differ over time (p for year/sex interaction=0.91).

4.4.2.1 Socioeconomic inequalities in healthy weight (2011-2018) (RQ2.2)

There was a clear social gradient, from least deprived to most deprived tenths of SIMD, present in the prevalence of healthy weight by area-based deprivation (Figure 4.4). Those from the 10% least deprived areas (SIMD 10) had the highest prevalence of healthy weight in 2011/12 (82.2%; n=3,648/4,439) and 2017/18 (82.9%; n=4,008/4,837). Those children from the most deprived areas (SIMD 1) had the lowest prevalence of healthy weight over study period with a prevalence of 73.7% (n=4,685/6,355) in 2011/12, reducing to 72.1% (n=4,503/6,246) in 2017/18 (Figure 4.4). The absolute difference in prevalence between most and least deprived was 8.5% in 2011/12 and 10.8% in 2017/18, suggesting inequalities are widening in the prevalence of healthy weight, with the least deprived areas improving and the most deprived areas worsening over the study period, however there was no difference in the trends statistically (p for year/SIMD interaction = 0.47).

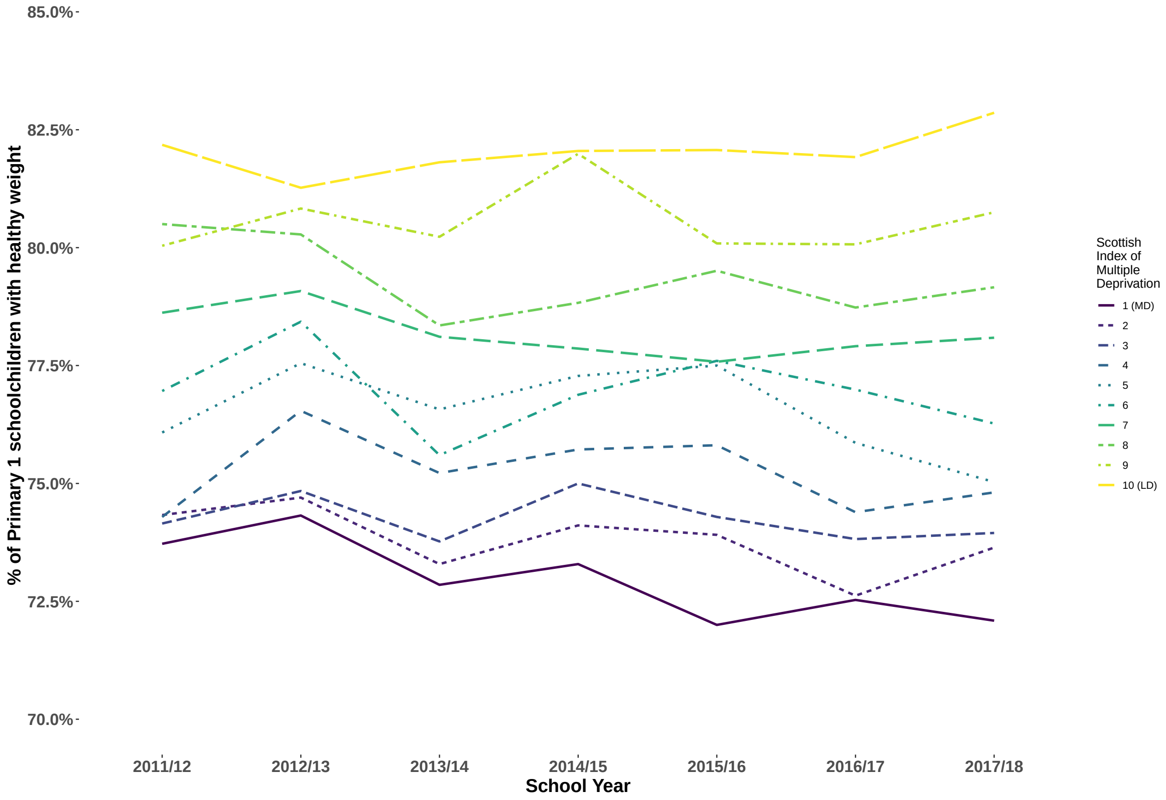

Figure 4.4: Prevalence of healthy weight by area-based deprivation and school year in Primary 1 children in Scotland (Appendix T). MD - Most Deprived 10%; LD - Least Deprived 10%

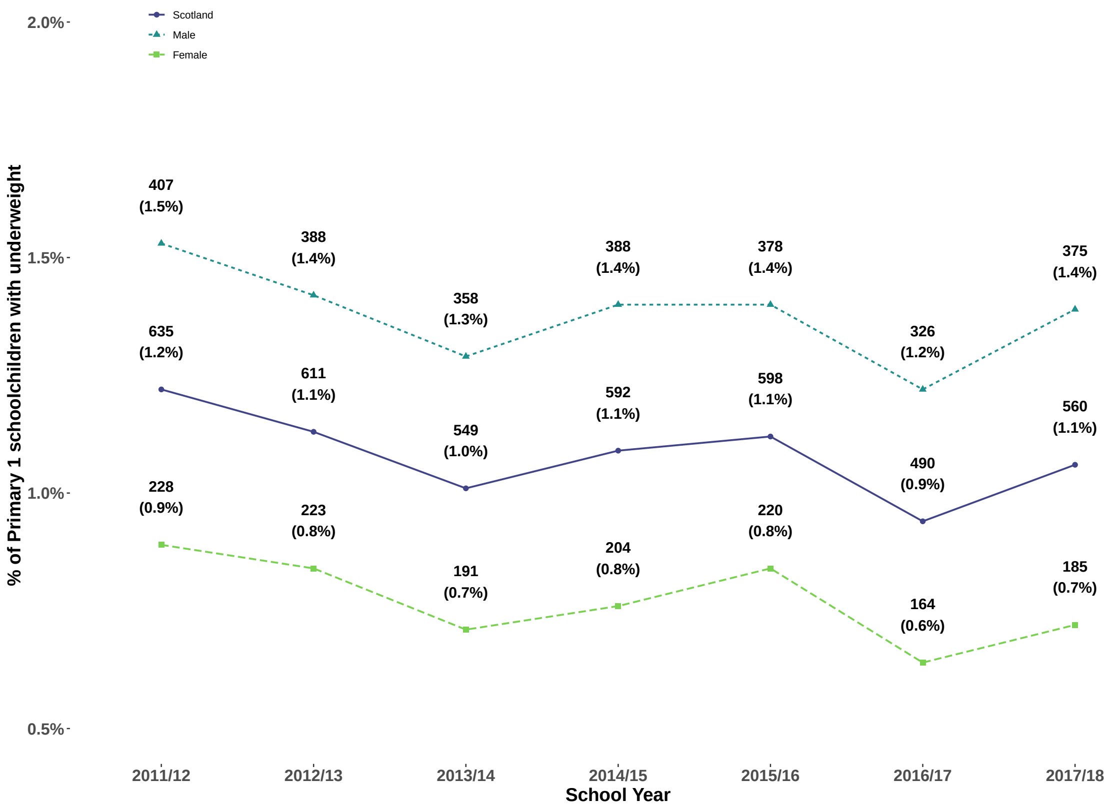

Figure 4.5: Prevalence of underweight by sex and Scotland overall and school year in Primary 1 children in Scotland (Appendix S)

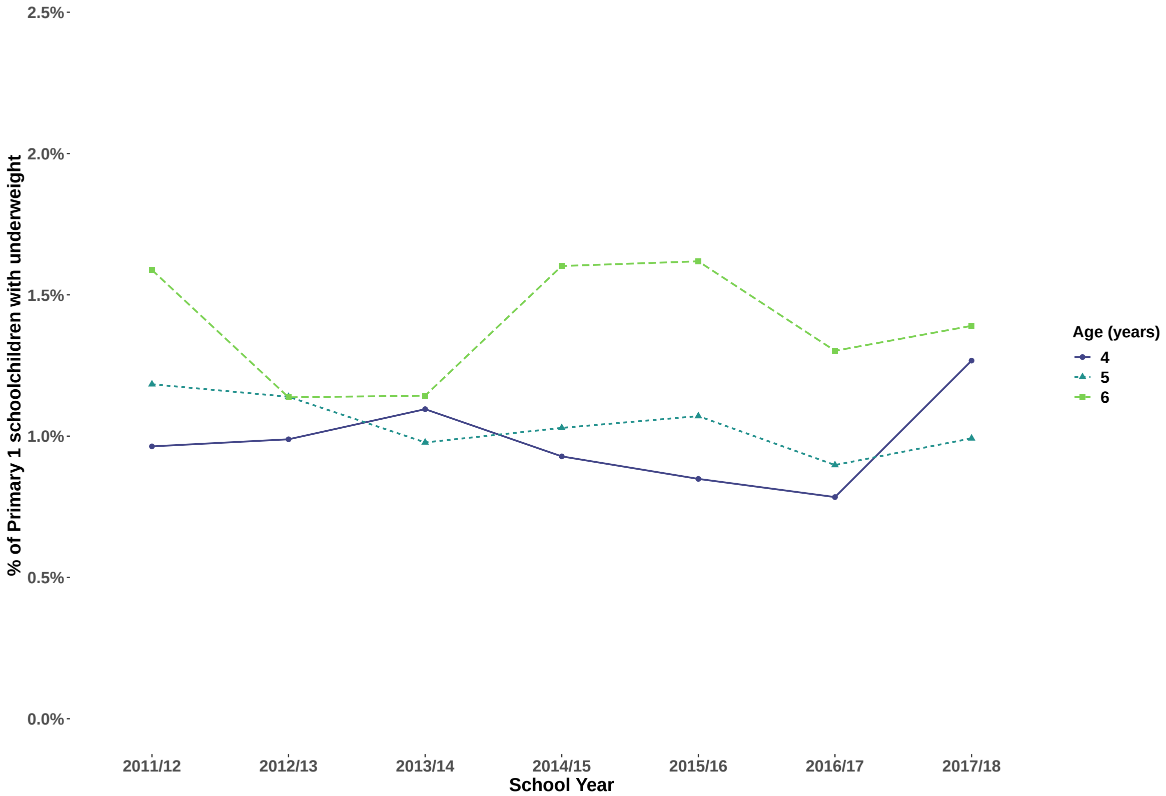

Figure 4.6: Prevalence of underweight in Primary 1 children in Scotland according to age between 2011/12 to 2017/18

4.4.3 Trends and inequalities in underweight (2011-2018) (RQ2.1 & RQ2.2)

Figure 4.5 shows the prevalence of underweight for males, females and all together over time (2011-2018). Overall, underweight prevalence ranged from 1.2% in 2011/12 (n=635/52,173) to 1.1% in 2017/18 (n=560/52,632), although no trend was identified (slope for trend=0.000; 95% CI: -0.001 to 0.000; p=0.12). Females had consistently lower prevalence over time than males but these differences were small. The gradients of the slopes of prevalence of underweight for males and females over time were not different (p for year/sex interaction=0.91).

There were fluctuations in the prevalence of underweight over the study period (Figure 4.6) although this is likely due to small sample sizes, particularly in those children aged 4- and- 6-years-old. The trend in prevalence of underweight across age groups followed a cubic trend over time (p for cubic year/age interaction=0.037). Prevalence of underweight in 4-year-old children was 1.0% (n=26/2,698) in 2011/12 and 1.3% (n=45/3,551) in 2017/18 (Figure 4.6). Prevalence of underweight in children aged

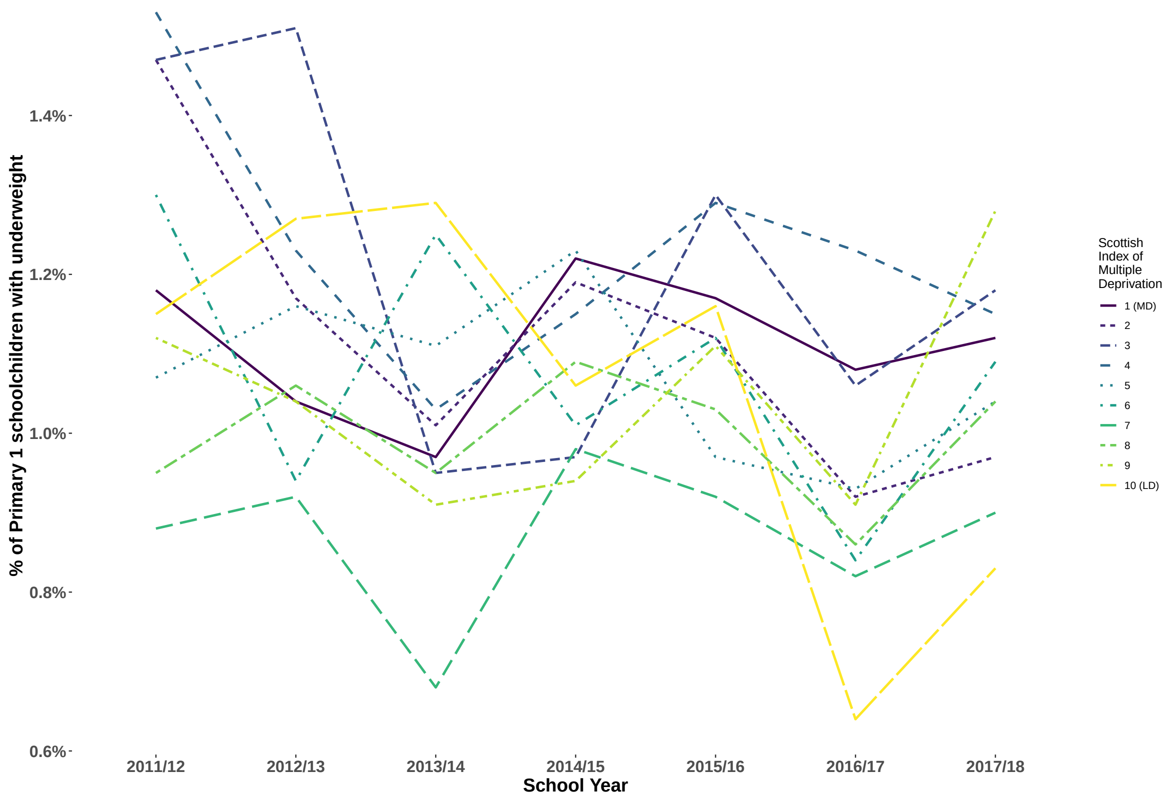

Figure 4.7: Prevalence of underweight by area-based deprivation and school year in Primary 1 children in Scotland (Appendix T). MD - Most Deprived 10%; LD - Least Deprived 10%

5-years saw a reduction in prevalence over the study period, with a prevalence of 1.2% (n=517/43,682) in 2011/12 and 1.0% (n=417/42,032) in 2017/18, whilst prevalence of underweight in 6-year-old children decreased from 1.6% (n=92/5,793) in 2011/12 to 1.4% (n=98/7,049) in 2017/18 (Figure 4.6).

4.4.3.1 Socioeconomic inequalities in underweight (2011-2018) (RQ2.2)

Patterns in inequalities over time were not clear for underweight children, possibly due to the small numbers (Figure 4.7) and there was no obvious social gradient observed. In 2011/12 the prevalence of underweight in the 10% most deprived areas (SIMD 1) was 1.2% (n=75/6,355), reducing to 1.1% (n=70/6,246) in 2017/18. The 10% least deprived areas (SIMD 10) prevalence of underweight reduced from 1.1% (n=51/4,439) in 2011/12 to 0.8% (n=40/4,837) in 2017/18. There was no differences in trend across SIMD tenths (p for year/SIMD interaction=0.17).

The risk of underweight in the most deprived children versus healthy in 2017/18 was

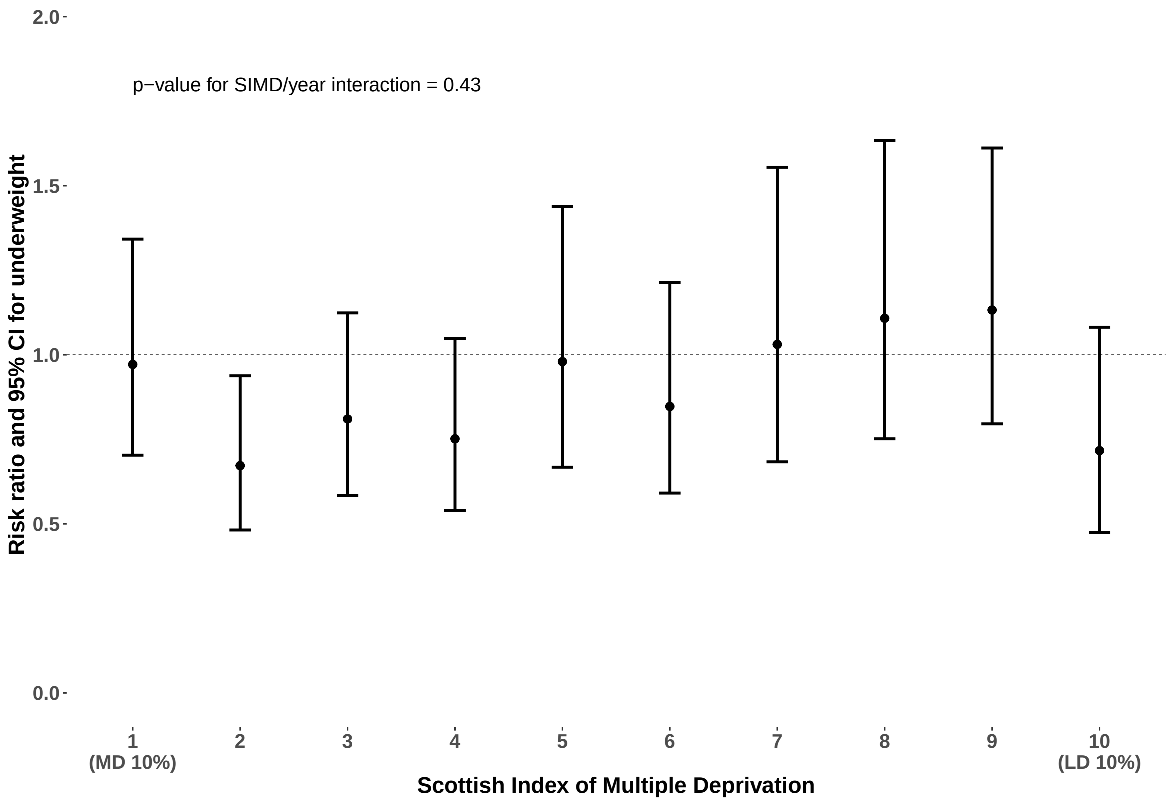

Figure 4.8: Risk ratios and 95% confidence intervals for the prevalence of underweight in 2017/18 compared to 2011/12 for each tenth of the Scottish Index of Multiple Deprivation. LD Least Deprived 10%; MD Most Deprived 10%

reduced by three percent compared to children in 2011/12 (RR=0.97; 95% CI 0.70 to 1.34; p=0.86) (Figure 4.8). The risk of underweight versus healthy weight reduced by 28% for children in the 10% least deprived in 2017/18 compared to 2011/12 (RR=0.72; 95% CI 0.47 to 1.08; p=0.11). The only change in risk of underweight versus healthy weight between 2011/2012 and 2017/2018 was evident in children from SIMD 2, where children in 2017/2018 had a lower risk of underweight than their counterparts in 2011/2012 (RR=0.67; 95% CI: 0.48 to 0.94; p=0.019). The prevalence of underweight is low in Scotland leading to a small sample sizes so confidence intervals were large.

4.4.3.2 Slope and relative indices for underweight (2011-2018) (RQ2.2)

In 2011/12 there was evidence to suggest that there were absolute and relative inequalities in the prevalence of underweight between the most and least deprived areas (SII=0.4; 95% CI: 0.1 to 0.8; RII=1.42; 95% CI: 1.06 to 1.90), followed by fluctuations in both SII and RII over the study period, with no systematic trend observed (Figure

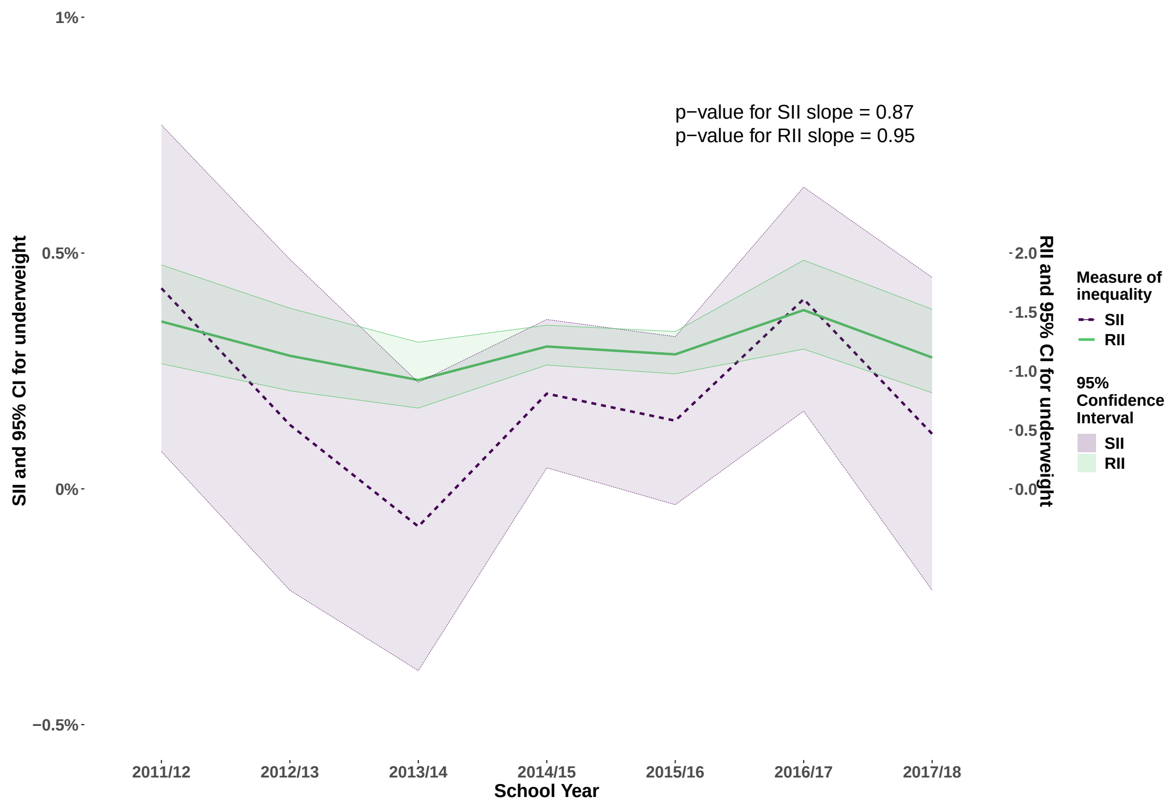

Figure 4.9: Slope and Relative Index of Inequality for underweight Primary 1 population in Scotland (Appendix U). SII - Slope Index of Inequality; RII - Relative Index of Inequality

4.9).

4.4.4 Factors independently associated with childhood underweight (RQ2.3)

Sex, school year, area-based deprivation, and age were all found to be significant risk factors of underweight compared to healthy weight. From the likelihood ratio χ^2 scores it is evident that SIMD has the biggest effect on the model, followed by sex (Table 4.3).

Male children had higher adjusted odds than females to have underweight with an adjusted odds ratio of 1.81 (95% CI: 1.69 to 1.93; p<0.001). The adjusted odds of underweight generally reduced as year increased when compared to 2011/12 with exception of 2012/13 and 2015/16 (Table 4.3). Children from the 10% most deprived areas had higher adjusted odds of having underweight than children from the 10% least deprived areas (aOR: 1.19; 95% CI: 1.03 to 1.37; p=0.015), although there was no difference in adjusted odds of underweight between SIMD 10 and SIMD 5, 6, 7, 8, and 9, suggesting that was no clear social gradient (Table 4.3). Children who were 4-years-old had no greater adjusted odds of having underweight than 5-year-old children (aOR: 0.98; 95% CI: 0.85 to 1.12; p=0.75) (Table 4.3). The adjusted odds having underweight was higher in 6-year-old children compared to 5-year-old children (aOR: 1.29; 95% CI: 1.18 to 1.40; p<0.001) (Table 4.3).

4.4.5 Trends and inequalities in overweight (2011-2018) (RQ2.1 & RQ2.2)

Prevalence of overweight is more unstable over the years than the prevalence of healthy weight (Figure 4.10). No trend for overweight was identified (slope for trend=0.000; 95% CI: 0.000 to 0.001; p=0.27). Prevalence of overweight in males was 12.4% in both 2011/12 (n=3,305/52,173) and 2017/18 (n=3,332/52,632). Prevalence of overweight in females rose from 11.8% (n=3,010/52,632) in 2011/12 to 12.2% (n=3,147/52,632) in 2017/18. The gradients of the slope for males and females over time were no different (p for year/sex interaction=0.13). Overall in the Scotland, 12.1% (n=6,315/52,173) Primary 1 children had overweight in 2011/12, compared to 12.3% (n=6,479/52,632) in 2017/18.

Children aged 4-years had a consistently higher prevalence of overweight than their 5- and- 6-year-old counterparts. Prevalence of overweight in 4-year-old children was 12.8% (n=344/2,698) in 2011/12 and 13.2% (n=469/3,551) in 2017/18 (Figure 4.11). There was very little change in prevalence of overweight in children aged 5-years, with a prevalence of 12.3% (n=5,352/43,682) in 2011/12 and 12.4% (n=5,192/42,032) in 2017/18 and the prevalence in 6-year-old children increased over the study period from 10.7% (n=619/5,793) in 2011/12 to 11.6% (n=818/7,049) in 2017/18 (Figure 4.11). There were no differences in trends between age groups (p for year/age interaction=0.82).

4.4.5.1 Socioeconomic inequalities in overweight (2011-2018) (RQ2.2)

Although there was no clear social gradient from most to least deprived areas, those in the 10% least deprived areas (SIMD 10) had consistently lower prevalence of overweight (Figure 4.12), although the trend is each SIMD tenth was similar over time (p for

Table 4.3: Adjusted odds ratios and 95% confidence intervals for underweight versus healthy weight based on multivariable multinomial regression model according to area-based deprivation, sex, age, and school year

Factor	Healthy Weight		Underweight		Total	OR[1]	95% CI[2]	p	aOR[3]	95% CI[2]	p
	n	%	n	%	n						
Sex											
Female	141977	77.5	1415	0.8	183089	-	Ref	-	-	Ref	-
Male	144534	76.0	2620	1.4	190100	1.82	[1.70,1.94]	<0.001	1.81	[1.69,1.93]	<0.001
Year											
2011	40112	76.9	635	1.2	52173	-	Ref	-	-	Ref	-
2012	41838	77.6	611	1.1	53944	0.92	[0.82,1.03]	0.16	0.92	[0.82,1.03]	0.14
2013	41641	76.3	549	1.0	54556	0.83	[0.74,0.93]	0.002	0.83	[0.74,0.93]	0.001
2014	42042	77.1	592	1.1	54498	0.89	[0.79,1.00]	0.042	0.89	[0.80,1.00]	0.045
2015	40870	76.8	598	1.1	53222	0.92	[0.83,1.03]	0.17	0.92	[0.82,1.03]	0.15
2016	39751	76.2	490	0.9	52164	0.78	[0.69,0.88]	<0.001	0.77	[0.69,0.87]	<0.001
2017	40257	76.5	560	1.1	52632	0.88	[0.78,0.99]	0.027	0.87	[0.78,0.98]	0.020
SIMD[4]											
1 (MD[5])	33363	73.0	507	1.1	45715	1.19	[1.03,1.36]	0.016	1.19	[1.04,1.37]	0.014
2	31075	73.8	471	1.1	42110	1.18	[1.03,1.36]	0.020	1.19	[1.04,1.37]	0.013
3	28538	74.3	462	1.2	38427	1.26	[1.10,1.45]	0.001	1.27	[1.11,1.46]	0.001
4	27708	75.3	453	1.2	36817	1.27	[1.11,1.47]	0.001	1.28	[1.11,1.48]	0.001
5	27005	76.6	379	1.1	35268	1.09	[0.94,1.27]	0.23	1.10	[0.95,1.28]	0.19
6	26548	77.0	373	1.1	34494	1.09	[0.94,1.27]	0.23	1.10	[0.95,1.28]	0.21
7	27965	78.2	311	0.9	35765	0.87	[0.74,1.01]	0.07	0.87	[0.74,1.01]	0.10
8	28489	79.3	358	1.0	35911	0.98	[0.84,1.14]	0.78	0.98	[0.84,1.14]	0.79
9	29054	80.6	377	1.1	36053	1.01	[0.87,1.17]	0.88	1.01	[0.87,1.17]	0.89
10 (LD[6])	26766	82.0	344	1.1	32629	-	Ref	-	-	Ref	-
Age[7]											
4	16924	74.5	221	1.0	22703	0.96	[0.84,1.10]	0.58	0.98	[0.85,1.12]	0.76
5	233600	76.8	3171	1.0	304152	-	Ref	-	-	Ref	-
6	35987	77.7	643	1.4	46334	1.32	[1.21,1.43]	<0.001	1.29	[1.18,1.40]	<0.001

Multivariable Multinomial Regression Results

Type 3 Results:	Factor	LR[8] χ^2	Df[9]	p	Res Dev[10]	$R^{2,11}$
	Sex	391.6	3	<0.001	547953.2	0.6%
	Year	86.3	18	<0.001		
	SIMD	2253.1	27	<0.001		
	Age	144.9	6	<0.001		

$n + n$ does not equal total as total includes those with overweight and obesity.

[1]OR - odds ratio; [2]CI - confidence interval; [3] aOR - adjusted odds ratio; [4]SIMD - Scottish Index of Multiple Deprivation; [5] MD - Most Deprived 10%; [6] LD - Least Deprived 10%; [7] Age in years; [8] LR - Likelihood ratio; [9] Res Dev - Residual Deviance; [10] df - degrees of freedom; [11] R^2 - McFadden's R^2

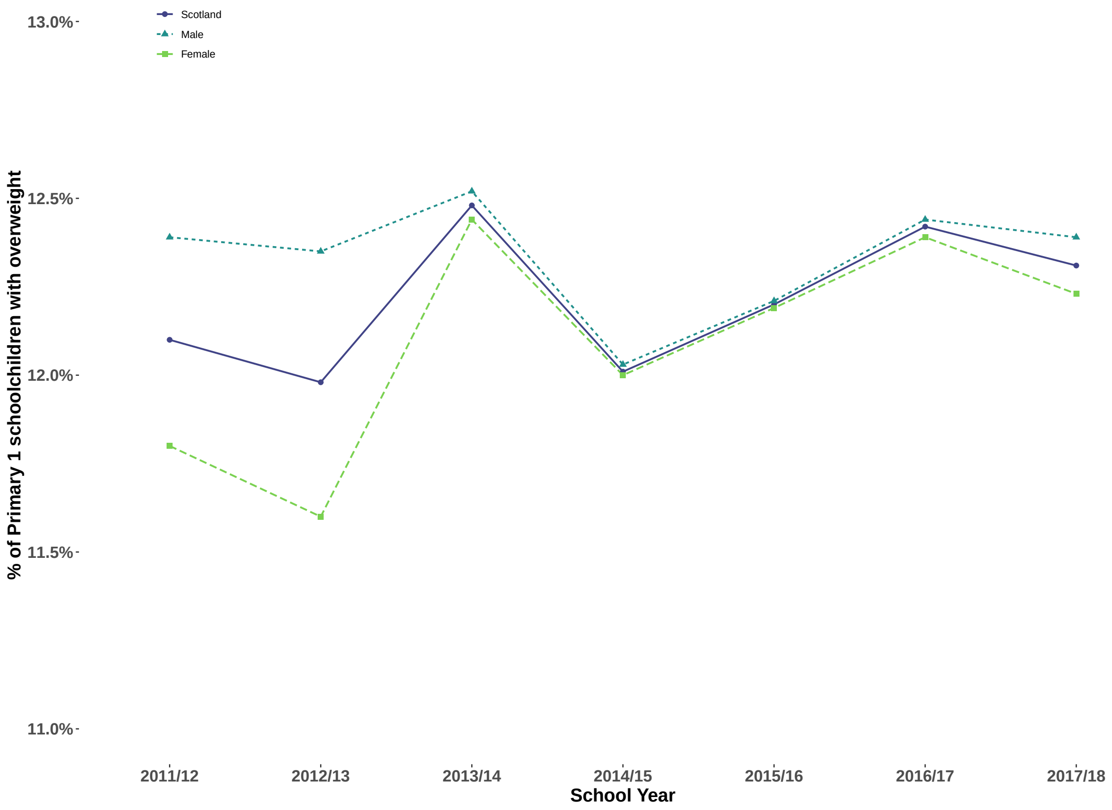

Figure 4.10: Prevalence of overweight overall and split by sex and school year in Primary 1 children in Scotland (Appendix S)

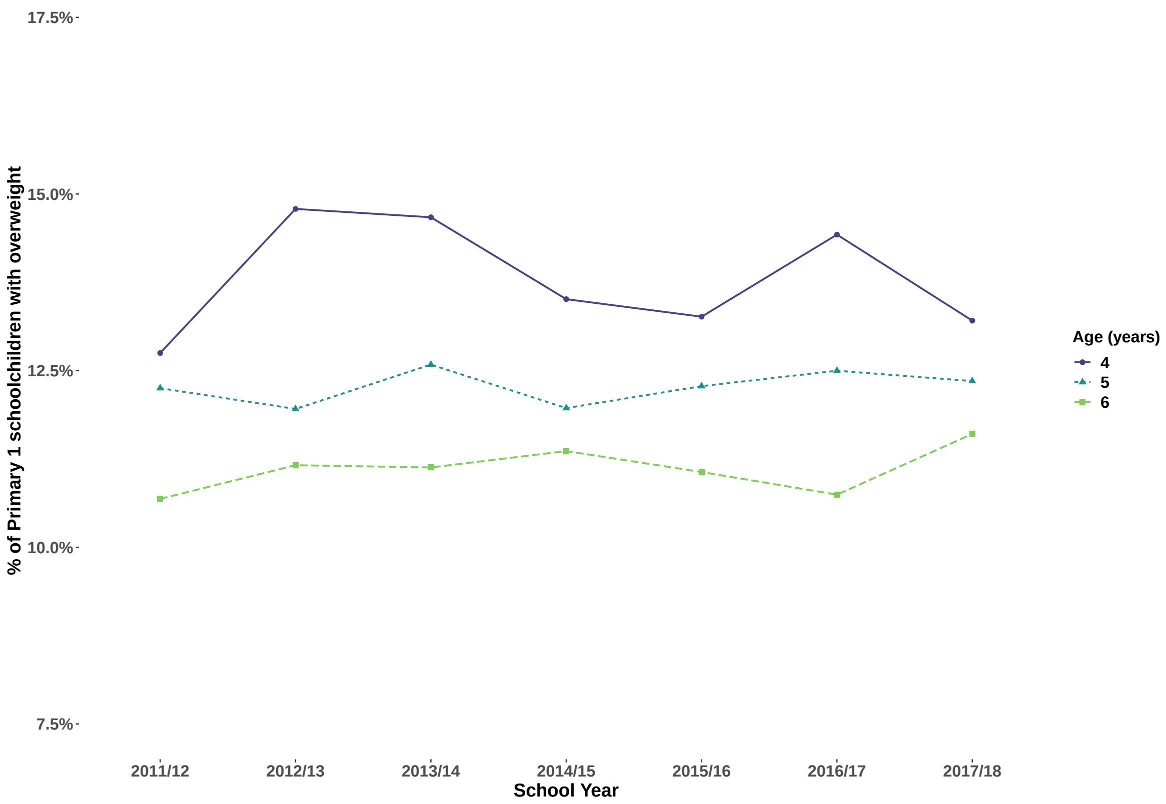

Figure 4.11: Prevalence of overweight in Primary 1 children in Scotland according to age between 2011/12 to 2017/18

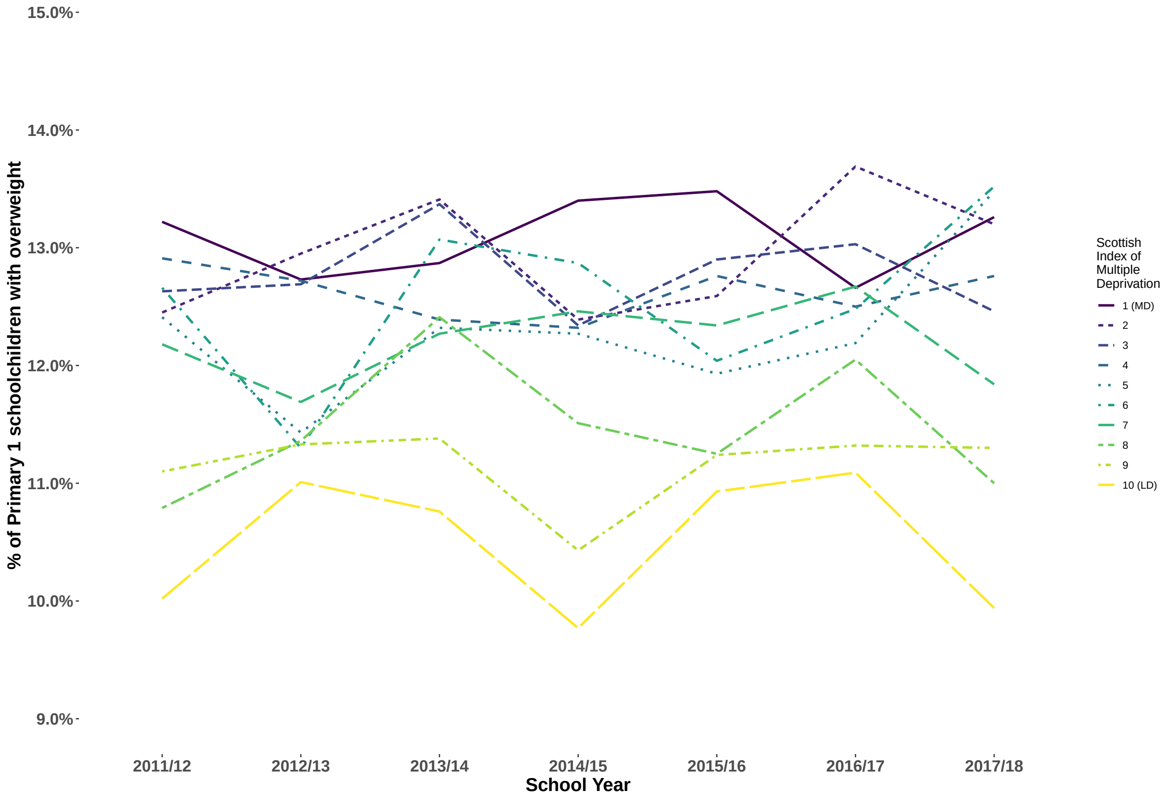

Figure 4.12: Prevalence of overweight by area-based deprivation and school year in Primary 1 children in Scotland (Appendix T). MD - Most Deprived 10%; LD - Least Deprived 10%

year/SIMD interaction=0.91). Children from these areas had prevalence of overweight of 10.0% (n=445/4,439) in 2011/12 and 9.9% (n=481/4,837) in 2017/18. In 2011/12 those from the most deprived areas (SIMD 1) had the highest prevalence of overweight (13.2%; n=840/6,355), however, due to a rise in prevalence in those from SIMD 5 (1.1% increase) and 6 (0.8% increase), those from the most deprived areas had the third highest prevalence of overweight in 2017/18 (13.3%; n=828/6,246). In those from SIMD 1 to 7 (70% most deprived areas), deprivation did not play much of an impact on prevalence.

There was no suggestion that any SIMD tenth had any change in risk of overweight between 2017/18 and 2011/12 than any other (Figure 4.13). This result suggests that overweight prevalence and risk has remained the same between 2011/12 and 2017/18.

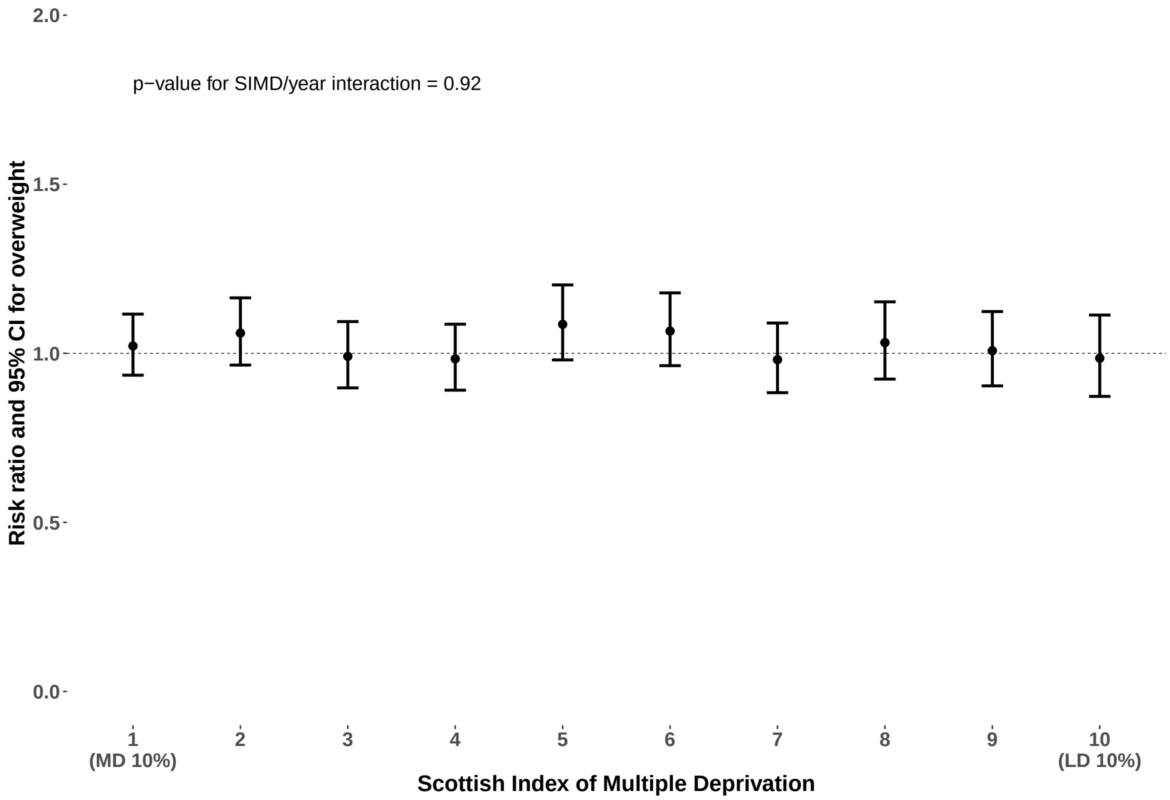

Figure 4.13: Risk ratios and 95% confidence intervals for the prevalence of overweight in 2017/18 compared to 2011/12 for each tenth of the Scottish Index of Multiple Deprivation. LD Least Deprived 10%; MD Most Deprived 10%

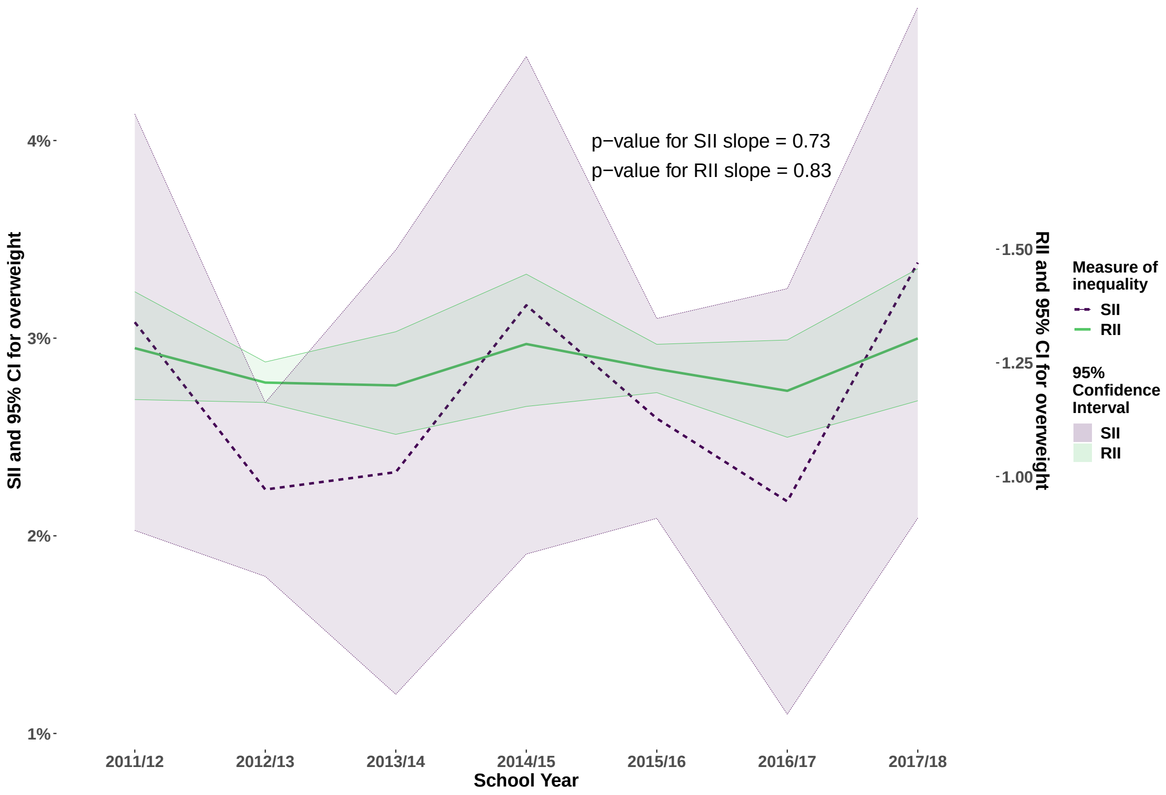

Figure 4.14: Slope and Relative Index of Inequality for overweight Primary 1 population in Scotland (Appendix U). SII - Slope Index of Inequality; RII - Relative Index of Inequality

4.4.5.2 Slope and relative indices for overweight (2011-2018) (RQ2.2)

Both the SII and RII slightly fluctuated over the years and no systematic trend was observed (Figure 4.14). The SII was estimated at 3.1% (95% CI: 2.0% to 4.1%) in 2011/12 and 3.4% CI: 2.1% to 4.7%) in 2017/18. The RII was estimated at 1.28 CI: 1.17 to 1.41) in 2011/12 and 1.30 CI: 1.17 to 1.46) in 2017/18 (Figure 4.14).

4.4.6 Factors independently associated with childhood overweight (RQ2.3)

Sex, school year, area-based deprivation, and age were all found to be significant risk factors of overweight compared to healthy weight. From the likelihood ratio χ^2 scores it is evident that SIMD has the biggest effect on the model, followed by sex (Table 4.4). Male children had higher odds than females to have overweight with an adjusted odds ratio of 1.05 (95% CI: 1.02 to 1.07; p<0.001). There was very little change in the

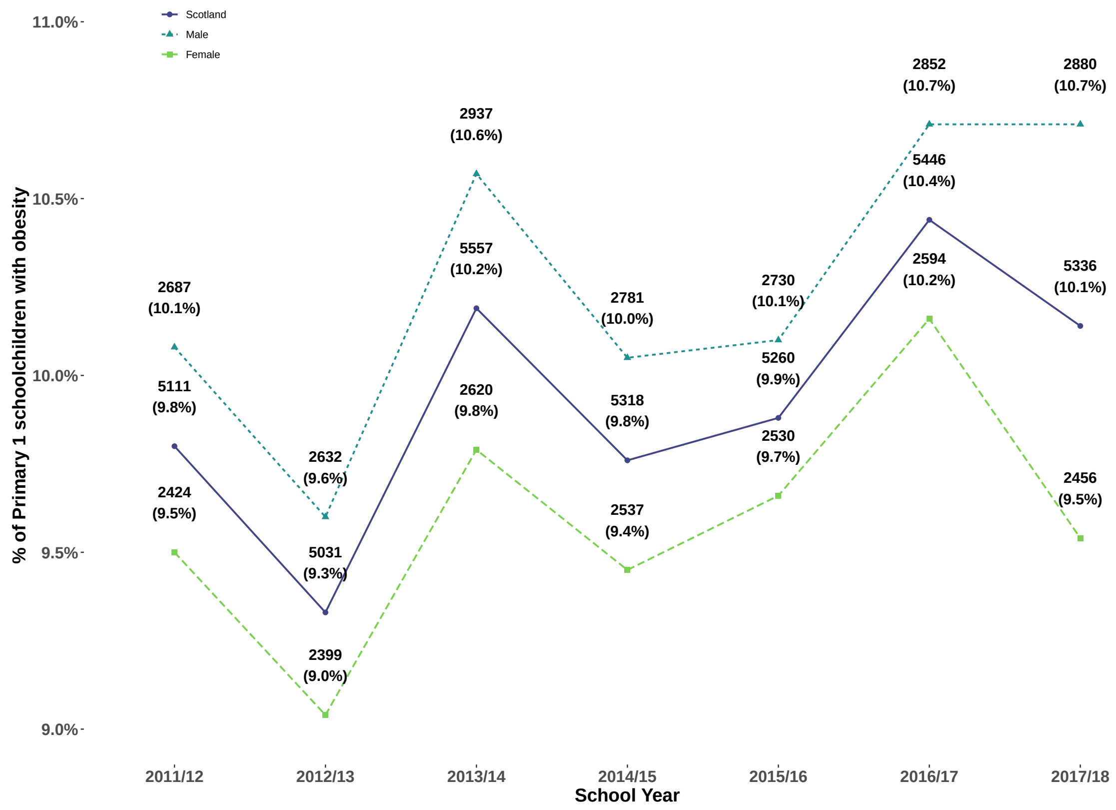

Figure 4.15: Prevalence of obesity in Primary 1 children in Scotland according to sex between 2011/12 to 2017/18 (Appendix S)

adjusted odds of overweight across the seven school years when compared to 2011/12 (Table 4.4) suggesting a stable prevalence through the study period. As deprivation increased so too did the odds of overweight, with those children from SIMD 1 having adjusted odds of overweight 1.40 (95% CI: 1.34 to 1.47; p<0.001) times that of children from SIMD 10 (Table 4.4). There were differences in adjusted odds of overweight in 4-year-old children compared to 5-year-olds (aOR: 1.14; 95% CI: 1.10 to 1.19; p<0.001) (Table 4.4). The adjusted odds of overweight was lower for children aged-6 than those aged-5 (aOR: 0.90; 95% CI: 0.87 to 0.93; p<0.001) (Table 4.4).

4.4.7 Trends and inequalities in obesity (2011-2018) (RQ2.1 & RQ2.2)

For obesity, in 2011/12 the prevalence was 9.8% (n=5,111/52,173) slightly rising to 10.1% (n=5,336/52,632) in 2017/18, although no trend was identified (slope for trend=0.001; 95% CI: 0.000 to 0.003; p=0.13). Females had consistently lower prevalence of obesity than males, but the differences were small. The gradients of slopes for prevalence in

Table 4.4: Adjusted odds ratios and 95% confidence intervals for overweight versus healthy weight based on multivariable multinomial regression model adjusted by area-based deprivation, sex, age, and school year

Factor	Healthy Weight		Over-weight		Total	OR[1]	95% CI[2]	p	aOR[3]	95% CI[2]	p
	n	%	n	%	n						
Sex											
Female	141977	77.5	22137	12.1	183089	-	Ref	-	-	Ref	-
Male	144534	76.0	23447	12.3	190100	1.04	[1.02,1.06]	<0.001	1.05	[1.02,1.07]	<0.001
Year											
2011	40112	76.9	6315	12.1	52173	-	Ref	-	-	Ref	-
2012	41838	77.6	6464	12.0	53944	0.98	[0.95,1.02]	0.32	0.98	[0.95,1.02]	0.35
2013	41641	76.3	6809	12.5	54556	1.04	[1.00,1.08]	0.044	1.04	[1.00,1.08]	0.032
2014	42042	77.1	6546	12.0	54498	0.99	[0.95,1.03]	0.56	0.99	[0.95,1.03]	0.57
2015	40870	76.8	6494	12.2	53222	1.01	[0.97,1.05]	0.63	1.01	[0.97,1.05]	0.66
2016	39751	76.2	6477	12.4	52164	1.04	[1.00,1.07]	0.07	1.03	[1.00,1.07]	0.09
2017	40257	76.5	6479	12.3	52632	1.02	[0.98,1.06]	0.25	1.02	[0.99,1.06]	0.20
SIMD[4]											
1 (MD[5])	33363	73.0	5980	13.1	45715	1.40	[1.34,1.47]	<0.001	1.40	[1.34,1.46]	<0.001
2	31075	73.8	5456	13.0	42110	1.37	[1.31,1.44]	<0.001	1.36	[1.30,1.43]	<0.001
3	28538	74.3	4908	12.8	38427	1.34	[1.28,1.41]	<0.001	1.34	[1.28,1.40]	<0.001
4	27708	75.3	4647	12.6	36817	1.31	[1.25,1.37]	<0.001	1.30	[1.24,1.37]	<0.001
5	27005	76.6	4332	12.3	35268	1.25	[1.20,1.32]	<0.001	1.25	[1.19,1.31]	<0.001
6	26548	77.0	4332	12.6	34494	1.28	[1.22,1.34]	<0.001	1.27	[1.21,1.33]	<0.001
7	27965	78.2	4363	12.2	35765	1.22	[1.16,1.28]	<0.001	1.22	[1.16,1.28]	<0.001
8	28489	79.3	4123	11,5	35911	1.13	[1.08,1.19]	<0.001	1.13	[1.08,1.19]	<0.001
9	29054	80.6	4020	11.2	36053	1.08	[1.03,1.14]	0.001	1.08	[1.03,1.13]	0.002
10 (LD[6])	26766	82.0	3423	10.5	32629	-	Ref	-	-	Ref	-
Age[7]											
4	16924	74.5	3118	13.7	22703	1.15	[1.11,1.20]	<0.001	1.14	[1.10,1.19]	<0.001
5	233600	76.8	37314	12.3	304152	-	Ref	-	-	Ref	-
6	35987	77.7	5152	11.1	46334	0.90	[0.87,0.92]	<0.001	0.90	[0.87,0.93]	<0.001

Multivariable Multinomial Regression Results

Type 3 Results:	**Factor**	**LR[8] χ^2**	**Df[9]**	**p**	**Res Dev[10]**	**R[2,11]**
	Sex	391.6	3	<0.001	547953.2	0.6%
	Year	86.3	18	<0.001		
	SIMD	2253.1	27	<0.001		
	Age	144.9	6	<0.001		

$n + n$ does not equal total as total includes those with underweight and obesity.

[1]OR - odds ratio; [2]CI - confidence interval; [3] aOR - adjusted odds ratio; [4]SIMD - Scottish Index of Multiple Deprivation;
[5] MD - Most Deprived 10%; [6] LD - Least Deprived 10%; [7] Age in years; [8] LR - Likelihood ratio;
[9] Res Dev - Residual Deviance; [10] df - degrees of freedom; [11] R^2 - McFadden's R^2

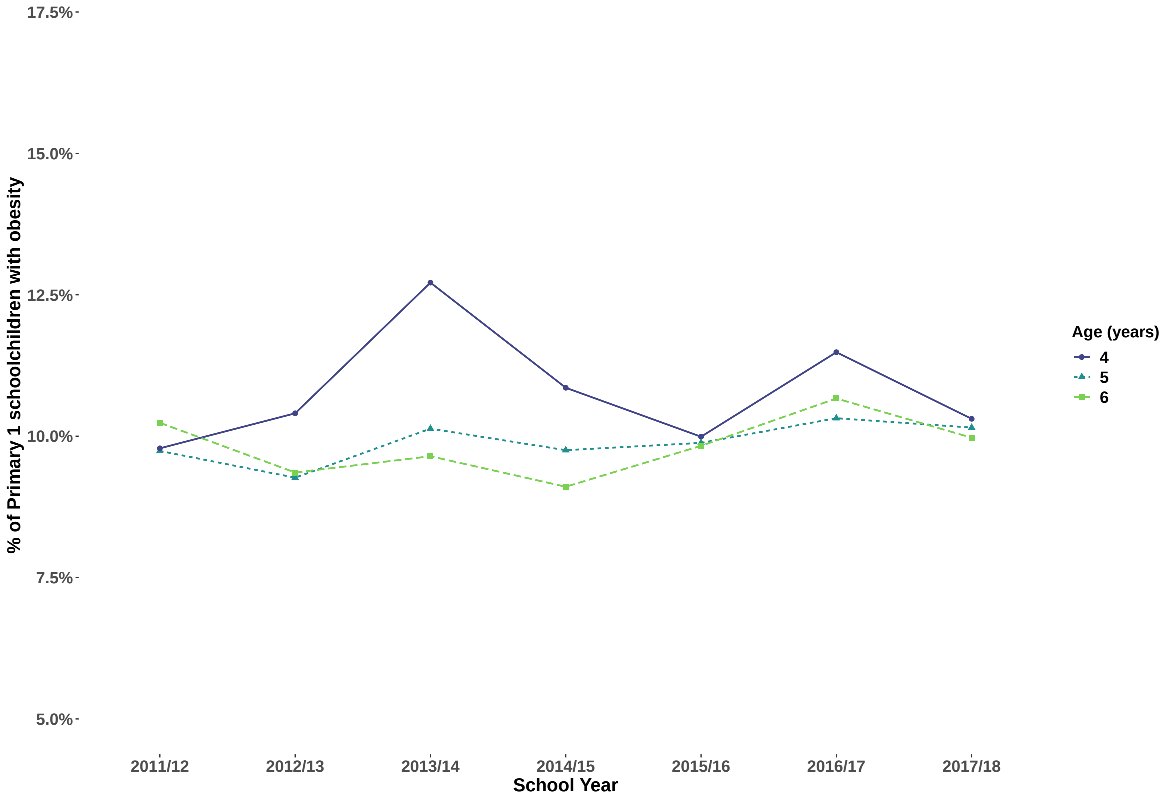

Figure 4.16: Prevalence of obesity in Primary 1 children in Scotland according to age between 2011/12 to 2017/18

obesity for males and females were not different (p for year/sex interaction=0.58).

Prevalence of obesity was similar for children aged 5- and- 6-years-old. The prevalence of obesity increased in children aged 4-years-old between 2011/12 (9.8%; n=264/2,698) and 2017/18 (10.3%; n=366/3,551) which was also the case for children aged 5-years (2011/12 - 9.7%; n=4,254/43,682; 2017/18 - 10.2%; n=4,267/42,032) (Figure 4.16). Prevalence of obesity slightly reduced in 6-year-old children from 10.2% (n=593/5,793) in 2011/12 to 10.0% (n=703/7,049) in 2017/18 (Figure 4.16). There was no difference in prevalence of obesity over time across the age groups (p for year/age interaction=0.93).

4.4.7.1 Socioeconomic inequalities in obesity (2011-2018) (RQ2.2)

A clear social gradient was observed for the prevalence of obesity in children (Figure 4.17). Children from the 10% most deprived areas (SIMD 1) experienced the highest prevalence of obesity consistently between 2011/12 and 2017/18, with the prevalence rising from 11.9% (n=755/6,355) to 13.5% (n=845/6,246). At the other end of the socioeconomic scale, those from the 10% least deprived areas (SIMD 10) consistently

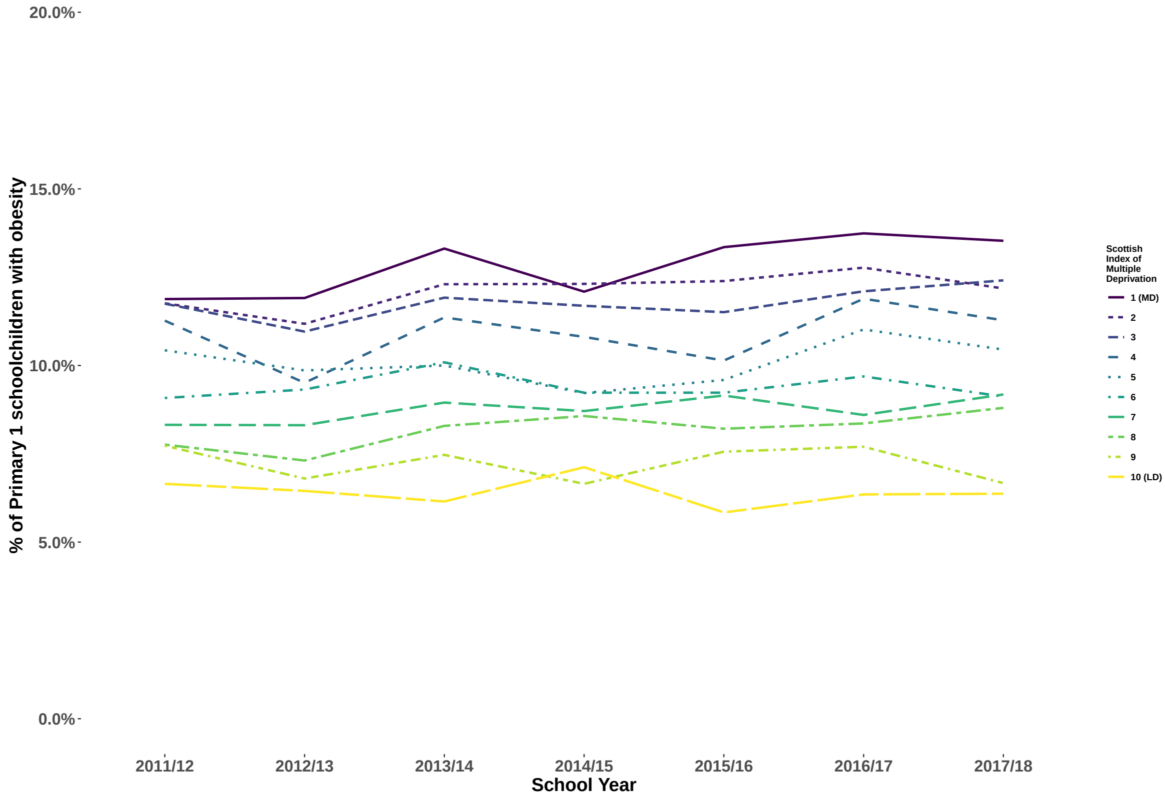

Figure 4.17: Prevalence of obesity by area-based deprivation and school year in Primary 1 children in Scotland (Appendix T). MD - Most Deprived 10%; LD - Least Deprived 10%

experienced the lowest prevalence of obesity over time (6.6% (n=295/4,439) in 2011/12; 6.4% (n=308/4,837) in 2017/18). The differences between SIMD tenths were similar over time (p for year/SIMD interaction=0.23).

Although the prevalence of obesity remained constant overall in Scotland, children from the 10% most deprived areas had an increased risk of obesity in 2017/2018 than in 2011/2012 (RR=1.14; 95% CI; 1.04 to 1.25; p=0.005) (Figure 4.18), while the risk remained unchanged in children from the 10% least deprived areas (RR=0.95; 95% CI: 0.82 to 1.11; p=0.55).

4.4.7.2 Slope and relative indices for obesity (2011-2018) (RQ2.2)

For obesity, the SII was estimated at 6.5 (95% CI: 5.6 to 7.5) in 2011/12, rising to 8.1 (95% CI: 7.2 to 9.0) in 2017/18, with evidence to suggest the absolute inequalities followed an upwards trend (slope=0.30; 95% CI: 0.05 to 0.55; p=0.028) over the study period (Figure 4.19). The RII, too, followed an upwards trend (slope=0.05; 95% CI:

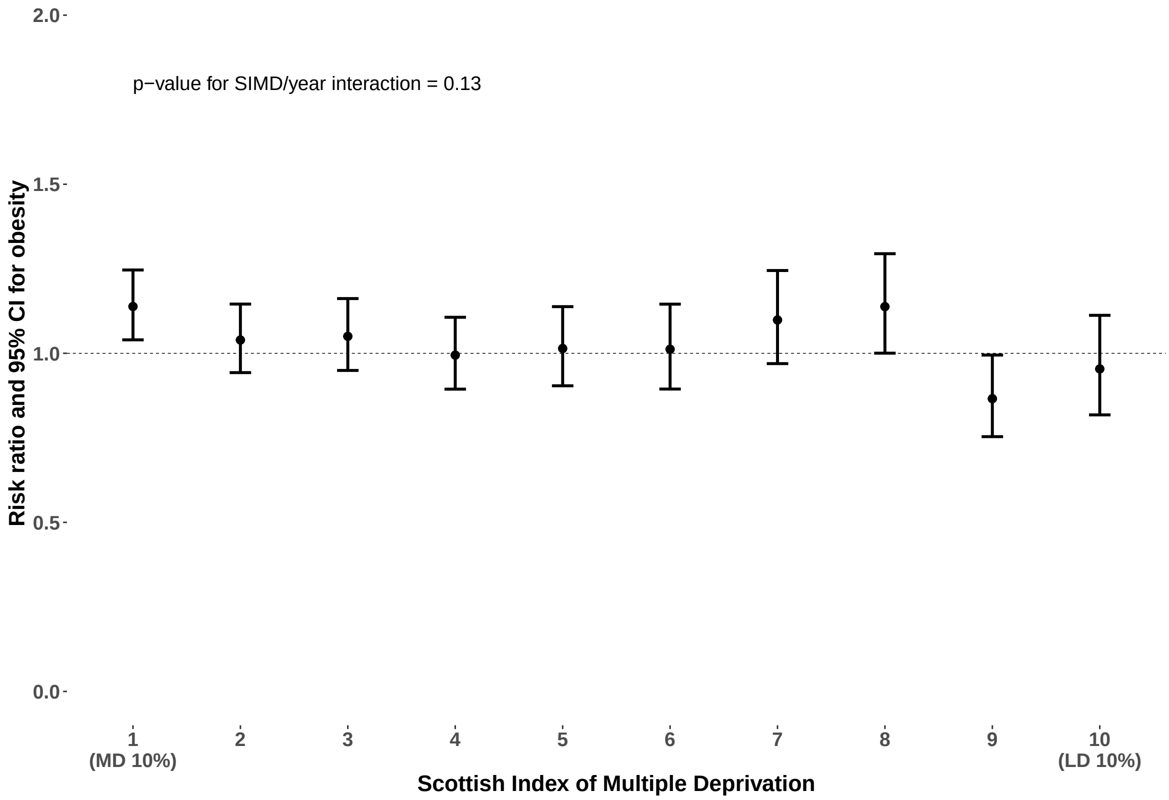

Figure 4.18: Risk ratios and 95% confidence intervals for the prevalence of obesity in 2017/18 versus 2011/12 for each tenth of the Scottish Index of Multiple Deprivation. LD 10% Least Deprived 10%; MD 10% Most Deprived 10%

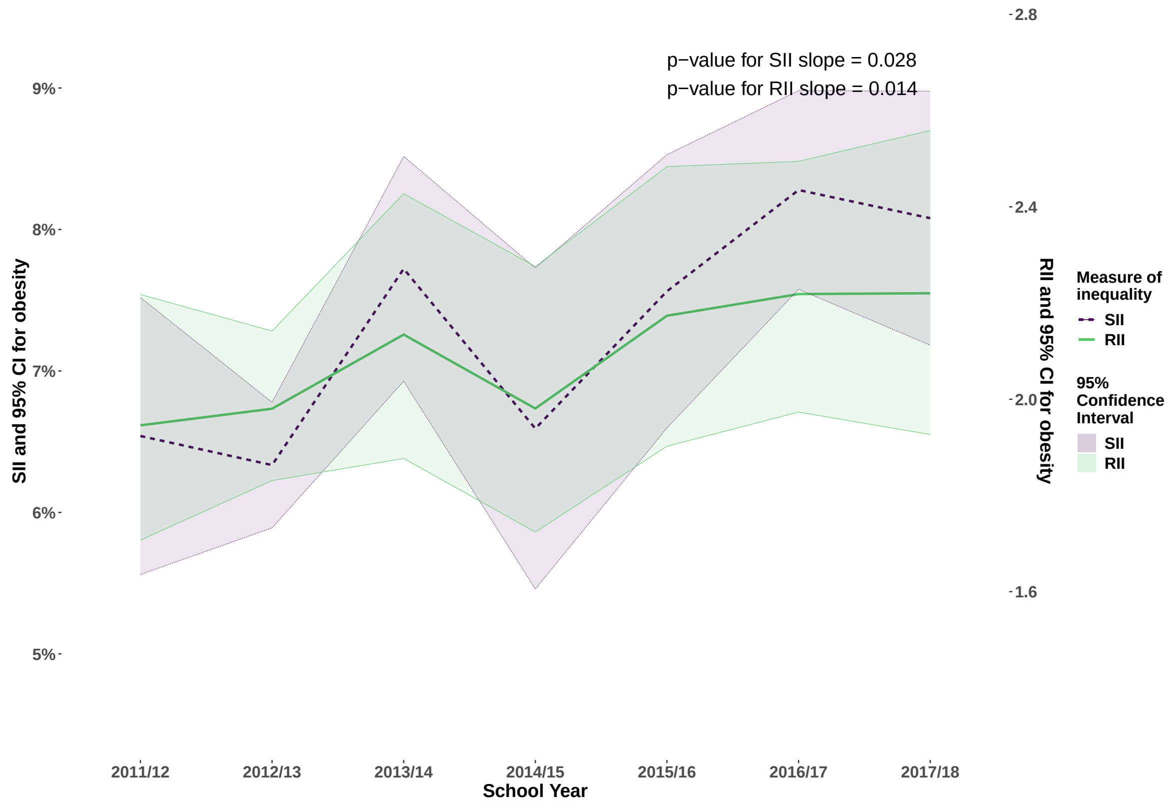

Figure 4.19: Slope and Relative Index of Inequality for obesity Primary 1 population in Scotland (Appendix U). SII - Slope Index of Inequality; RII - Relative Index of Inequality

0.01 to 0.08; p=0.014) between 2011/12 and 2017/18, rising from 1.95 (95% CI: 1.71 to 2.22) to 2.22 (95% CI: 1.93 to 2.56) (Figure 4.19).

4.4.8 Factors independently associated with childhood obesity (RQ2.3)

Sex, school year, area-based deprivation, and age were all found to be significant risk factors of obesity compared to health weight. From the likelihood ratio χ^2 scores it is evident that SIMD has the biggest effect on the model, followed by sex (Table 4.4).

Males had very slightly higher adjusted odds of having obesity than females with an adjusted odds ratio of 1.09 (95% CI: 1.07 to 1.12; p<0.001). There were some differences across school year, with children measured in 2012/13 having lower adjusted odds of obesity than 2011/12 (aOR: 0.94; 95% CI: 0.94 to 0.98; p=0.004), whilst children in 2013/14 (aOR: 1.04; 95% CI: 1.00 to 1.09; p<0.001), 2016/17 (aOR: 1.07; 95% CI: 1.03 to 1.11; p=0.001), and 2017/18 (aOR: 1.04; 95% CI: 1.00 to 1.09; p=0.042) had higher adjusted odds of obesity than children from 2011/12 suggesting a slight increase in obesity over the study period. There was a clear social gradient with children from more deprived areas having higher adjusted odds of obesity. Children from the 10% most deprived areas had adjusted odds of obesity 2.25 (95% CI: 2.13 to 2.37; $p<0.001$) times greater than children from the 10% least deprived areas. Children aged 6-years-old children had no difference in adjusted odds of obesity compared to 5-year-old children (aOR: 0.99; 95% CI: 0.96 to 1.03; $p=0.62$) (Table 4.5). This was different for 4-year-old children in that they had higher adjusted odds of obesity than 5-year-olds during the study period (aOR: 1.10; 95% CI: 1.05 to 1.15; $p<0.001$) (Table 4.5).

4.5 Chapter Summary

The aim of this chapter was to explore trends and inequalities in childhood BMI status of children in Primary 1 living in Scotland. We used routinely collected data from CHSP-S over seven years to construct several cohorts of children and examined trends in prevalence and inequalities over time.

This study has shown a very slight decrease in the prevalence of underweight amongst 5-year-old children in Scotland between 2011/12 and 2017/18. The prevalence difference in all groupings of BMI status between males and females has been consistent through the cohort years and there was no clear social gradient. When looking at the prevalence across the SIMD tenths, there is a lot of fluctuation. This is likely due to the small number of children with underweight in each SIMD tenth and year. There was little change in risk of underweight in 2011/12 versus 2017/18, with no trend evident in the SII and RII over the years.

Prevalence of overweight across the seven years has remained fairly consistent overall, however, this has masked an increase in the prevalence of females with overweight. Absolute and relative inequalities remained stable over the study period, however these still exist.

Males had consistently higher prevalence of obesity than females over the study period. There was a clear social gradient in the prevalence of obesity. Obesity prevalence in

Table 4.5: Adjusted odds ratios and 95% confidence intervals for obesity versus healthy weight based on multivariable multinomial regression model adjusted by area-based deprivation, sex, age, and school year

Factor	Healthy Weight		Obesity		Total	OR[1]	95% CI[2]	p	aOR[3]	95% CI[2]	p
	n	%	n	%	n						
Sex											
Female	141977	77.5	17560	9.6	183089	-	Ref	-	-	Ref	-
Male	144534	76.0	19499	10.3	190100	1.09	[1.07,1.11]	<0.001	1.09	[1.07,1.12]	<0.001
Year											
2011	40112	76.9	5111	9.8	52173	-	Ref	-	-	Ref	-
2012	41838	77.6	5031	9.3	53944	0.94	[0.91,0.98]	0.006	0.94	[0.90,0.98]	0.004
2013	41641	76.3	5557	10.2	54556	1.05	[1.01,1.09]	0.025	1.04	[1.00,1.09]	0.034
2014	42042	77.1	5318	9.8	54498	0.99	[0.95,1.03]	0.73	1.00	[0.96,1.04]	0.83
2015	40870	76.8	5260	9.9	53222	1.01	[0.97,1.05]	0.63	1.01	[0.97,1.05]	0.69
2016	39751	76.2	5446	10.4	52164	1.08	[1.03,1.12]	<0.001	1.07	[1.03,1.11]	0.001
2017	40257	76.5	5336	10.1	52632	1.04	[1.00,1.08]	0.06	1.04	[1.00,1.09]	0.042
SIMD[4]											
1 (MD[5])	33363	73.0	5865	12.8	45715	2.24	[2.13,2.37]	<0.001	2.24	[2.13,2.36]	<0.001
2	31075	73.8	5108	12.1	42110	2.10	[1.99,2.21]	<0.001	2.10	[1.99,2.21]	<0.001
3	28538	74.3	4519	11.8	38427	2.02	[1.91,2.13]	<0.001	2.02	[1.91,2.13]	<0.001
4	27708	75.3	4009	10.9	36817	1.85	[1.75,1.95]	<0.001	1.85	[1.75,1.95]	<0.001
5	27005	76.6	3552	10.1	35268	1.68	[1.59,1.78]	<0.001	1.68	[1.59,1.78]	<0.001
6	26548	77.0	3241	9.4	34494	1.56	[1.47,1.65]	<0.001	1.56	[1.47,1.65]	<0.001
7	27965	78.2	3126	8.7	35765	1.43	[1.35,1.51]	<0.001	1.43	[1.35,1.51]	<0.001
8	28489	79.3	2941	8.2	35911	1.32	[1.24,1.40]	<0.001	1.32	[1.24,1.40]	<0.001
9	29054	80.6	2602	7.2	36053	1.14	[1.08,1.21]	<0.001	1.14	[1.08,1.21]	<0.001
10 (LD[6])	26766	82.0	2096	6.4	32629	-	Ref	-	-	Ref	-
Age[7]											
4	16924	74.5	2440	10.7	22703	1.12	[1.07,1.17]	<0.001	1.10	[1.05,1.15]	<0.001
5	233594	76.8	30067	9.9	304152	-	Ref	-	-	Ref	-
6	35987	77.7	4552	9.8	46334	0.98	[0.95,1.02]	0.30	0.99	[0.96,1.03]	0.62

Multivariable Multinomial Regression Results

Type 3 Results:	**Factor**	**LR[8] χ^2**	**Df[9]**	**p**	**Res Dev[10]**	**$R^{2,11}$**
	Sex	391.6	3	<0.001	547953.2	0.6%
	Year	86.3	18	<0.001		
	SIMD	2253.1	27	<0.001		
	Age	144.9	6	<0.001		

$n + n$ does not equal total as total includes those with underweight and overweight.
[1]OR - odds ratio; [2]CI - confidence interval; [3] aOR - adjusted odds ratio; [4]SIMD - Scottish Index of Multiple Deprivation; [5] MD - Most Deprived 10%; [6] LD - Least Deprived 10%; [7] Age in years; [8] LR - Likelihood ratio; [9] Res Dev - Residual Deviance; [10] df - degrees of freedom; [11] R^2 - McFadden's R^2

children from the 10% most deprived areas increased over the study period whilst the prevalence in other SIMD tenths plateaued. This has led to an increase in both absolute and relative inequalities between 2011/12 and 2017/18.

Chapter 5

Results

Association Between Caries Experience and BMI Status in Primary 1 Schoolchildren in Scotland

5.1 Overview

This chapter explores the association between caries experience and BMI status in children from Primary 1 in Scotland from 2011 to 2018, describing the shape of the relationship over the seven cohort years and exploring the effect of area-based deprivation on the potential association between caries and BMI status.

5.2 Aims

The overall aim of this chapter is to explore the association between childhood caries experience and BMI status of schoolchildren in Primary 1 living in Scotland. To do this the following research questions will be answered:

RQ3.1. What is the relationship between childhood BMI status and caries experience in Primary 1 children in Scotland between 2011 and 2018?

RQ3.2. If there is a relationship between BMI status and caries experience, is it modified by area-based deprivation (SIMD)?

RQ3.3. Do BMI Standard Deviation Scores (SDS) differ between children with and without caries experience?

5.3 Methods

5.3.1 Cohort assembly for Chapter 5

Research question 3 asks "what is the relationship between BMI status and caries experience in Primary 1 children in Scotland between 2011 and 2018?" (Section 1.13). All children included in the RQ1 Cohort and RQ2 Cohort (Sections 3.3.1 and 4.3.1) were considered to be included to answer Research Question 3. However, only children who had both a valid NDIP Primary 1 Basic Inspection and CHSP-S review were included (Figure 5.1). A valid area-based deprivation (SIMD) measurement was also required.

This formed the cohort that will be defined as Research Question 3 (RQ3 Cohort) throughout this thesis.

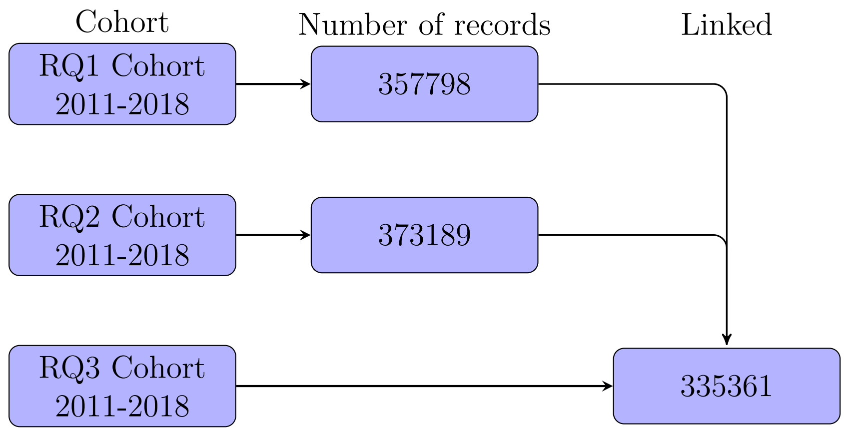

Figure 5.1: Flow chart of creation of Research Question 3 cohort. RQ - Research Question

5.3.2 Linkage of the RQ1 and RQ2 Cohorts

The RQ1 Cohort (NDIP caries experience) was linked to the RQ2 Cohort (CHSP-S BMI) using the child's unique ID which is appended to the datasets in the Safe Haven (Section 2.4.4). This created the RQ3 Cohort. The records had a 100% success for matching dates of birth between the two datasets (mainly due to the work completed for NDIP Primary 1 dates of birth in Section 2.11.9). There was a 99.8% success in matching sex across the two datasets, although, due to CHSP-S dataset having a pre-populated CHI number, the sex from this record was used. For the same reason, the measurement for area-based deprivation (SIMD) at time of inspection was also taken from this dataset, although, it is possible a child may have moved to an area from a different deprivation level between exams. This is true for 5.6% of records in the linked cohort.

The RQ3 Cohort has a total of 335,361 records. These are Primary 1 children with both a valid NDIP Primary 1 Basic inspection and CHSP-S review. There were 93.7% of children from RQ1 Cohort who successfully linked to the RQ2 Cohort and 89.9% RQ2 records successfully linking to RQ1 Cohort (Table 5.1). The number of CHSP-S data successfully linking is consistent at around 89% over the seven cohorts, whereas, there is a slight fluctuation in the percentage of successful links from the NDIP Primary 1 Cohort, from a low of 90.5% in 2016/17 to a high of 95.3% in 2012/13 and 2013/14.

Table 5.1: Total and percentage of children in Research Question 3 Cohort

School Year	Total number of children in RQ1[1] Cohort (a)	Total number of children in RQ2[1] Cohort (b)	Total number of children in RQ3[1] Cohort		
	n	n	n	% of a	% of b
2011/12	49288	52173	46417	94.2	89.0
2012/13	50619	53944	48222	95.3	89.4
2013/14	51824	54556	49369	95.3	90.5
2014/15	51932	54498	49349	95.0	90.6
2015/16	51216	53222	47840	93.4	89.9
2016/17	51214	52164	46334	90.5	88.8
2017/18	51705	52632	47830	92.5	90.9
Total	**357798**	**373189**	**335361**	**93.7**	**89.9**

[1]RQ - research question

Table 5.2 presents the characteristics of the cohorts by age, sex, and area-based deprivation (SIMD). There is a very slightly higher number of males (50.9%; n=170,745/335,361) than females (49.1%; n=164,616/335,361), which is consistent with births record by sex in Scotland (National Records Scotland, 2019a). A higher proportion of children live in the most deprived areas than any other SIMD group, with 23.1% (n=77,580/335,361) living in the most deprived areas, compared to 18.7% (n=62,697/335,361) in the least deprived. This trend is consistent with NRS population estimates for area-based deprivation by age for SIMD 2016 (National Records Scotland, 2019b). The majority of children are aged 5-years-old, with 87.0% (n=291,715/335,361) of the total cohort being this age. This is in line with logic as 5-year-old is the age that most children start school at Primary 1 level in Scotland.

5.3.3 Study design, data sources, and definitions

This chapter is a repeated cross-sectional analysis using large population-based datasets. The cohort used to answer this question is as described in Section 5.3.1. In this chapter caries experience is defined as in Section 2.15.1 where *obvious caries experience* will be referred to as *caries experience*. Different categories of BMI will be used as previously defined in Section 2.15.2).

Table 5.2: Characteristics of children by age, sex, and area-based deprivation in Research Question 3 Cohort

	2011/12		2012/13		2013/14		2014/15		2015/16		2016/17		2017/18		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
SIMD[1]																
1 (MD)[2]	10614	22.9	11225	23.3	11542	23.4	11155	22.6	11183	23.4	11112	24.0	10749	22.5	77580	23.1
2	9308	20.1	9766	20.3	9740	19.7	9974	20.2	9615	20.1	9401	20.3	9654	20.2	67458	20.1
3	8814	19.0	9152	19.0	9507	19.3	9072	18.4	8803	18.4	8400	18.1	8824	18.4	62572	18.7
4	9278	20.0	9506	19.7	9692	19.6	9446	19.1	9162	19.2	8748	18.9	9222	19.3	65054	19.4
5 (LD)[3]	8403	18.1	8573	17.8	8888	18.0	9702	19.7	9077	19.0	8673	18.7	9381	19.6	62697	18.7
Sex																
Male	23717	51.1	24557	50.9	25078	50.8	25033	50.7	24301	50.8	23607	50.9	24452	51.1	170745	50.9
Female	22700	48.9	23665	49.1	24291	49.2	24316	49.3	23539	49.2	22727	49.1	23378	48.9	164616	49.1
Age[4]																
4	2281	4.9	1859	3.9	2072	4.2	2364	4.8	2389	5.0	2285	4.9	2133	4.5	15383	4.6
5	40590	87.4	42078	87.3	42760	86.6	43144	87.4	41553	86.9	40122	86.6	41468	86.7	291715	87.0
6	3546	7.6	4285	8.9	4537	9.2	3841	7.8	3898	8.1	3927	8.5	4229	8.8	28263	8.4
Total	**46417**	**13.8**	**48222**	**14.4**	**49369**	**14.7**	**49349**	**14.7**	**47840**	**14.3**	**46334**	**13.8**	**47830**	**14.3**	**335361**	

[1]SIMD - Scottish Index of Multiple Deprivation; [2] MD - Most Deprived 20%; [3] LD - Least Deprived 20%;
[4] Age in years old

5.3.4 Statistical analysis

This chapter uses bar plots to visualise the prevalence of caries experience within each group of BMI status over time (2011-2018). A bar plot is also used to show the relationship between caries experience and BMI status with each SIMD fifth. Univariable and multivariable binary logistic regression is used to estimate odds ratios (ORs) and adjusted odds ratios (aORs), respectively, for the association between caries experience and BMI status adjusted for sex, age, school year, and SIMD fifths using the methods and diagnostic criteria discussed in Section 2.21. The modelling strategy is discussed in Section 2.24. SIMD fifths have been used to ensure each grouping has a sufficient number of individuals to provide enough power for the statistical tests given the groupings will be smaller than the previous two chapters. For this analysis there was a decision to be made on which outcome, caries or BMI status, should be treated as the dependent variable. To the authors best knowledge there is no test for categorical outcomes as to the direction of the association, however, a model with caries experience as the dependent variable was compared to one with BMI status. ORs and aORs were compared across the two models and no bias was identified. Caries experience was chosen as the dependent variable. Forest plots were used to visualise the aORs. BMI SDS was modelled against caries experience and SIMD using linear regression to evaluate the difference in BMI SDS in caries experience across SIMD fifths. The mean, standard deviation, median, minimum, maximum, quartile 1, and quartile 3 BMI SDS values were calculated and presented for each SIMD fifth split by caries experience.

5.4 Results

5.4.1 Association between caries experience and BMI status (RQ3.1)

Overall the prevalence of caries experience in the cohort was highest in Primary 1 children with obesity (34.9%; n=11,494/32,960), followed by those with underweight (32.6%; n=1,157/3,550) (Table 5.3). Prevalence was lowest in children with healthy weight (29.8%; n=76,806/257,848). Children with overweight had a 31.5% (n=12,932/41,003)

Table 5.3: Prevalence of caries experience by body mass index status

BMI[1] Status	Caries Experience		No Caries Experience		Total
	n	%	n	%	
Underweight	1157	32.6	2393	67.4	3550
Overweight	12932	31.5	28071	68.5	41003
Healthy Weight	76806	29.8	181042	70.2	257848
Obesity	11494	34.9	21466	65.1	32960
Total	102389	30.5	232972	69.5	335361

[1]BMI - body mass index

prevalence of caries experience between 2011/12 and 2017/18 (Table 5.3).

Within Scotland in 2011/12 the prevalence of caries experience was highest in the children with obesity (35.4%; n=1,606/4,533), followed by the prevalence in children with underweight (34.7%; n=208/600) (Figure 5.2). This displays a 'U-shaped' curve where the children at the extremes of BMI (i.e., underweight and obesity) have the highest prevalence of caries experience. In 2012/13, the shape changes to a 'J-shaped' curve, where the group with obesity (37.1%, n=1,645/4,429) has the highest prevalence of caries experience, now followed by the population with overweight (33.3%, n=1,921/5,771). This pattern continued until 2015/16, at the point the 'U-shaped' curve reappeared which continued in the remaining two school years (Figure 5.2). Despite this change in shape no statistical trend was identified (p for year/BMI status interaction = 0.71).

For each group of BMI status, caries experience has been reducing overall, which is expected since caries experience has reduced year on year within Scotland over the study duration (Section 3.4.3). There was insufficient evidence to suggest that caries experience prevalence in the population with obesity changed over the years (slope for trend=-0.004, 95% CI: -0.010 to 0.002, p=0.14). This was true also for the children with underweight (slope for trend=-0.005, 95% CI: -0.017 to 0.008, p=0.38), although these estimates should be taken with caution due to smaller numbers. There was evidence to suggest that the prevalence of caries experience in those with healthy weight group (slope for trend=-0.008, 95% CI: -0.011 to -0.004, p=0.002) followed a downwards trend, however the slope coefficient was very small suggesting a small change. The prevalence of overweight followed a cubic trend over time (cubic slope for trend = 0.001, 95% CI: 0.000 to 0.001, p=0.009). Evidence from this suggests that caries experience has reduced for children with healthy weight, changed over time in children with overweight, but remained constant in children with underweight and obesity.

It was found that children with obesity had adjusted odds of caries 1.13 (95% CI: 1.10 to 1.16) times that of children with healthy weight (Table 5.4). An association was also found in children with overweight (aOR: 1.04; 95% CI: 1.02 to 1.06) although there was not enough evidence to suggest that children with underweight had higher adjusted odds (aOR: 1.06; 95% CI: 0.99 to 1.14) (Table 5.4).

5.4.2 Is the association between caries experience and BMI status modified by area-based deprivation? (RQ3.2)

This was explored because after adjusting for SIMD there was a large change in the adjusted odds ratio each level of BMI status. To explore this further, and potentially provide some further explanation, a model with an interaction between BMI status and SIMD was compared to a model without the interaction. The model with the interaction was deemed a better model (Table 5.5).

The relationship between caries experience and BMI status changed depending on SIMD fifth (p for interaction <0.001). In those living in the most deprived 20% areas, caries experience was very high (46.0%; n=35,656/77,580) and did not vary by BMI status, whereas in the 20% least deprived areas overall caries experience was far lower (16.5%; n=10,342/62,697) and varied significantly with BMI status (Figure 5.3). Compared to healthy weight children living in the lowest SIMD with underweight, overweight, or obesity had similar rates of caries experience, where were very high (circa 46.0% overall). For all other SIMD fifths children with obesity had higher odds of caries experience than those with healthy weight (Figure 5.4).

5.4.3 Do BMI Standard Deviation Scores differ between children with and without caries experience? (RQ3.3)

The previous sections focused on BMI groups, using epidemiological cut-offs, and the prevalence of caries experience. To fully explore the relationship between caries and obesity, BMI was also examined as a continuous variable using Standard Deviation

Figure 5.2: Prevalence of caries experience by BMI status and school year in Primary 1 children in Scotland (Appendix W). BMI - body mass index

Table 5.4: Unadjusted and adjusted odds ratio and 95% confidence interval for caries experience according to body mass index status adjusted for area-based deprivation, sex, age, and school year

BMI Status	Caries Experience		No Caries Experience		Total	OR[1]	95% CI[2]	p	aOR[3]	95% CI[2]	p
	n	%	n	%	n						
Underweight	1157	32.6	2393	67.4	3350	1.14	[1.06,1.22]	<0.001	1.06	[0.99,1.14]	0.10
Healthy weight	76806	29.8	181042	70.2	257848	-	Ref	-	-	Ref	-
Overweight	12931	31.5	28072	68.5	41003	1.09	[1.06,1.11]	<0.001	1.04	[1.02,1.06]	0.001
Obesity	11494	34.9	21466	65.1	32960	1.26	[1.23,1.29]	<0.001	1.13	[1.10,1.16]	<0.001
Logistic Regression Results											
Type 3 Results:				**Dev[4]**	**Df[5]**	**Res[6] Dev**	**p**	**C-statistic**			
			BMI[7]	379.8	3	393381	<0.001	0.65			
			Sex	197.1	1		<0.001				
			Year	388.9	6		<0.001				
			SIMD[8]	17864.3	4		<0.001				
			Age	480.1	2		<0.001				

[1]OR - odds ratio; [2]CI - confidence interval; [3]aOR - adjusted odds ratio; [4]Dev - Deviance; [5]Df - degrees of freedom; [6]Res - Residual;
[7] BMI - Body mass index; [8] SIMD - Scottish Index of Multiple Deprivation

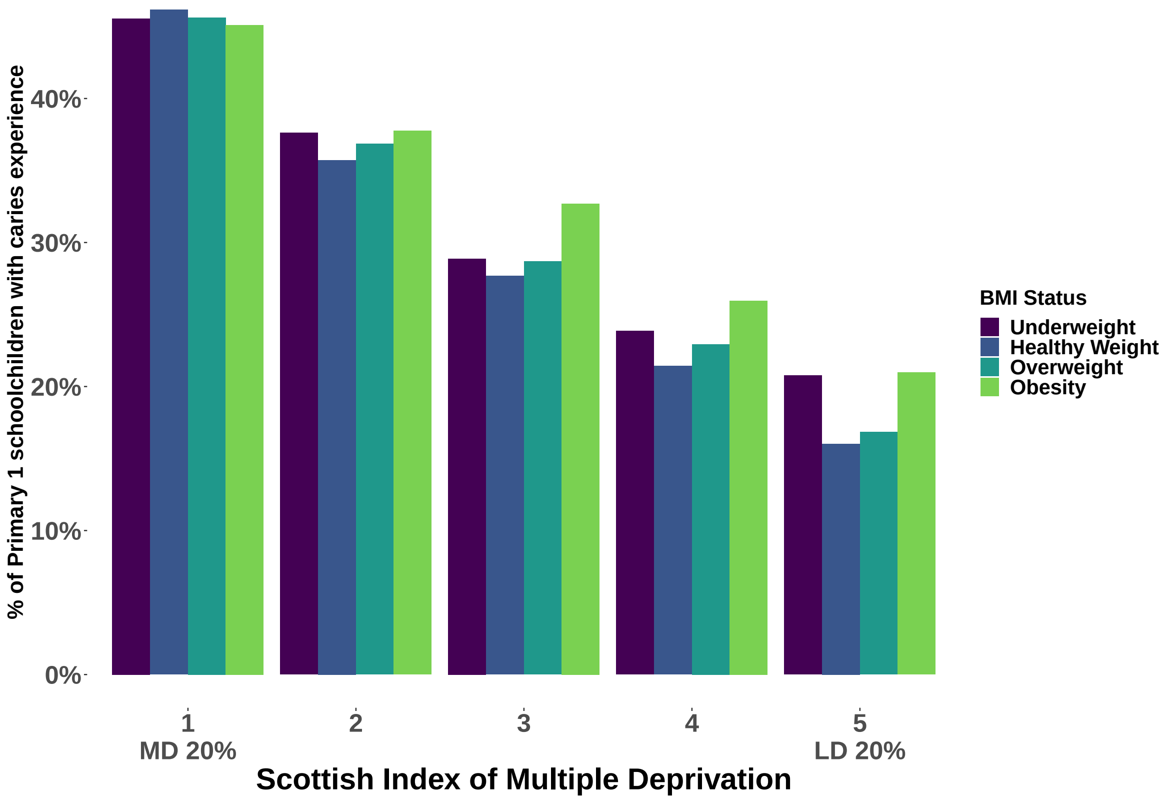

Figure 5.3: Prevalence of caries experience by area-based deprivation for each category of body mass index status. BMI - body mass index; MD - Most Deprived; LD - Least Deprived

Table 5.5: Analysis of variance comparing model with and without Body mass index and area-based deprivation interaction

Model	Res[1] Df[2]	Res[1] Dev[3]	Df[2]	Dev[3]	p	AIC[4]
1[5]	335344	393381				393415
2[6]	335332	392255	12	125.6	<0.001	393313

[1]Res - Residual; [2]Df - degrees of freedom; [3]Dev - Deviance; [4]AIC - Akaike Information Criterion

[5] Model 1: Caries experience dependent; body mass index status, Scottish Index of Multiple Deprivation, sex, age, and year independent variables;

[6] Model 2: Caries experience dependent; body mass index status and Scottish Index of Multiple Deprivation interaction, adjusted for sex, age, and year

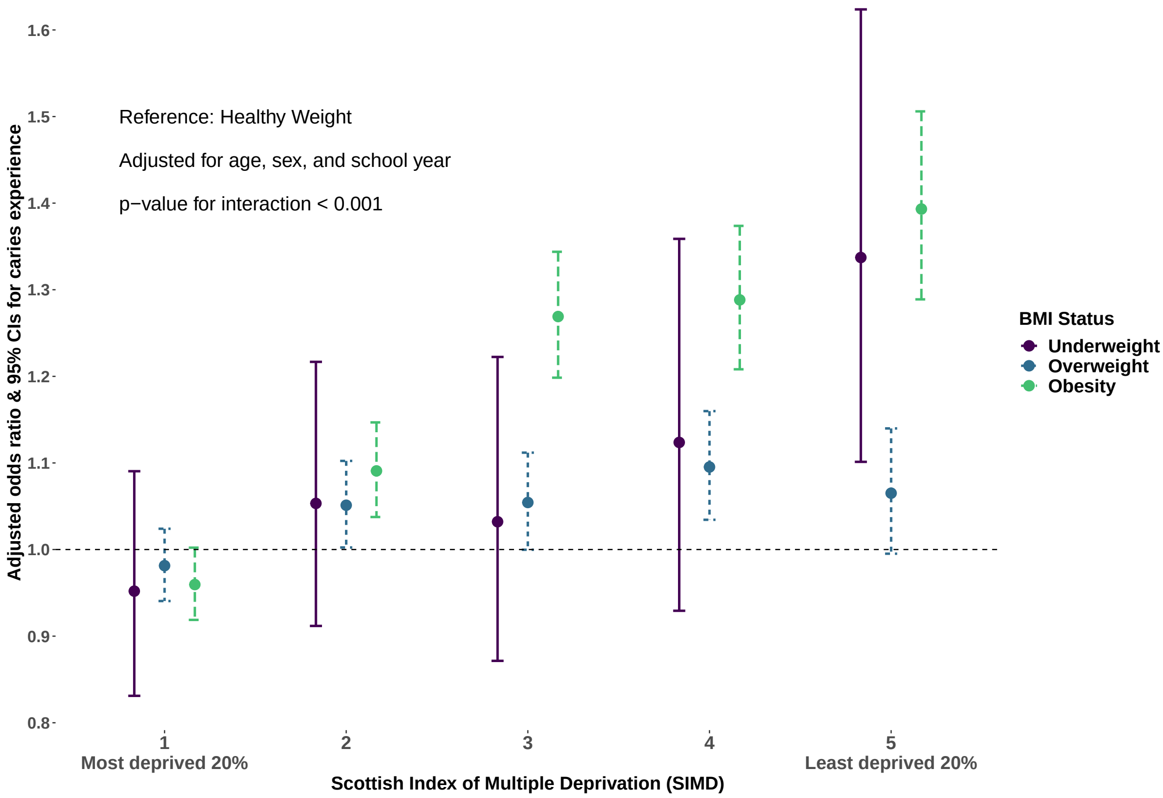

Figure 5.4: Adjusted odds ratio and 95% confidence intervals for caries experience according to BMI status partitioned by area-based deprivation and adjusted by year, age, and sex (Appendix W). 95% CI - 95% confidence interval; OR - odds ratio; aOR - adjusted odds ratio

Scores (SDS). Categorising BMI has limitations as grouping a continuous variable creates sharp cut-offs in which people on the border of each cut-off may be similar to each other. It also has the potential to mask inequalities at the extremes of BMI.

Based on a linear regression, BMI SDS was found to be associated with caries experience. This effect was modified by SIMD (p for interaction <0.001). There was a limited difference in BMI SDS between the children with and without caries experience in children from SIMD 1 areas (Table 5.6). There was a differential effect in SIMD 2 to 5 with children with caries having higher BMI SDS than children without caries (Table 5.6). The range of BMI SDS was higher in children with caries than children without caries.

Table 5.6: Descriptive statistics of body mass index Standard Deviation Scores by caries experience and area-based deprivation

	n	Mean	SD[1]	Median	Min	Q[2] 1	Q[2] 3	Max
Overall								
No Caries	232973	0.31	1.04	0.26	-5.93	-0.35	0.91	5.74
Caries	102388	0.37	1.10	0.31	-5.98	-0.33	1.00	5.99
SIMD[3] 1 (Most Deprived 20%)								
No Caries	41924	0.42	1.12	0.36	-5.72	-0.30	1.06	5.30
Caries	35656	0.41	1.13	0.34	-5.98	-0.32	1.04	5.99
SIMD[3] 2								
No Caries	43095	0.36	1.09	0.31	-5.92	-0.33	0.99	5.74
Caries	24363	0.39	1.11	0.34	-5.50	-0.31	1.03	5.52
SIMD[3] 3								
No Caries	44858	0.32	1.03	0.28	-5.93	-0.34	0.92	5.56
Caries	17714	0.38	1.09	0.32	-5.08	-0.32	1.00	5.57
SIMD[3] 4								
No Caries	50741	0.27	0.99	0.23	-5.88	-0.36	0.86	5.40
Caries	14313	0.33	1.05	0.29	-5.66	-0.34	0.94	5.52
SIMD[3] 5 (Least Deprived 20%)								
No Caries	52355	0.19	0.96	0.17	-5.59	-0.42	0.78	5.54
Caries	10342	0.25	1.03	0.20	-5.46	-0.41	0.85	5.80

[1] SD - Standard deviation; [2] Q - Quartile; [3] SIMD - Scottish Index of Multiple Deprivation

5.5 Chapter Summary

The aim of this chapter was to explore the association between caries experience and BMI status and SDS of children in Primary 1 living in Scotland between 2011 and 2018. Routinely collected data from NDIP and CHSP-S over seven years was used to construct seven cohorts of children.

This analysis has shown that the relationship between caries experience and BMI status has changed shape over time, however, no significant trend was identified. It was evident that the association between caries experience and BMI status differed for each SIMD fifth. Caries experience was very high in children from SIMD 1 and did not differentiate with BMI status, however, children from areas in SIMD 2 to 5 with obesity had higher odds of caries experience.

When considering BMI SDS rather than the groups based on epidemiological cut-offs, children with caries experience had higher BMI SDS than those without caries, but again this difference was only observed in SIMD 2 to 5.

This analysis confirms that childhood caries experience and BMI status were associated with each other in Primary 1 children in Scotland between 2011/12 and 2017/18, with children with obesity living in the 20% least deprived areas having higher odds of caries compared to children with healthy weight living in the same areas. This change in odds was not found in children living the 20% most deprived areas.

Chapter 6

Results

Trends and Associations in Co-existing Caries and Obesity

6.1 Overview

This chapter explores the trends in co-existing childhood caries experience and obesity in Primary 1 children in Scotland between 2011 and 2018. Factors associated with co-existing conditions will also be explored. Both conditions have been known to have an impact on a child's quality of life with both conditions marked as early risk factors for other NCDs which may develop later in life (Kassebaum et al., 2017; Weihrauch-Blüher et al., 2018). Caries and obesity are known to be public health problems within Scotland, with both conditions being unequally distributed across the socioeconomic scale (Information Services Division Scotland, 2018b; Macpherson et al., 2018). Identifying if there a group of children who experience both caries and obesity is important given the prevalence of both conditions and the problem they may pose to current and future public health services. The Childsmile programme may be able to target a specific group of children to improve the prevalence of both conditions.

6.2 Aims

The overall aim of this chapter is to explore the trends in co-existing childhood caries experience and BMI status of schoolchildren in Primary 1 living in Scotland between 2011 and 2018, as well as any factors associated with co-existing conditions. To do this the following research questions will be answered:

RQ4.1. What are the trends in prevalence and socioeconomic inequalities in those children who experience co-existing caries experience and obesity and have these changed over time between 2011 and 2018?

RQ4.2. What are the socioeconomic inequalities in the children with co-existing conditions?

RQ4.3. Which factors of year, sex and area-based deprivation SIMD are associated with a child having co-existing caries experience and obesity?

6.3 Methods

6.3.1 Cohort assembly for Chapter 6

Research question 4 asks "what are the trends in prevalence and socioeconomic inequalities in those children who have co-existing caries experience and obesity and have these changed over time between 2011 and 2018?", respectively (Section 1.13). The cohort used to answer this research question is the same as RQ3 Cohort (Section 5.3.1, Figure 6.1).

The official definition for this cohort is children who were in Primary 1 between 2011/12 and 2017/18 who had a valid NDIP Primary 1 Basic Inspection and CHSP-S review and valid area-based deprivation (SIMD) measurement. This cohort will be defined as Research Question 4 Cohort (RQ4 Cohort) throughout this chapter.

Table 6.1 presents the characteristics of the RQ4 Cohort by age, sex, and area-based deprivation (SIMD). There is a very slightly higher number of males (50.9%; n=170,745/

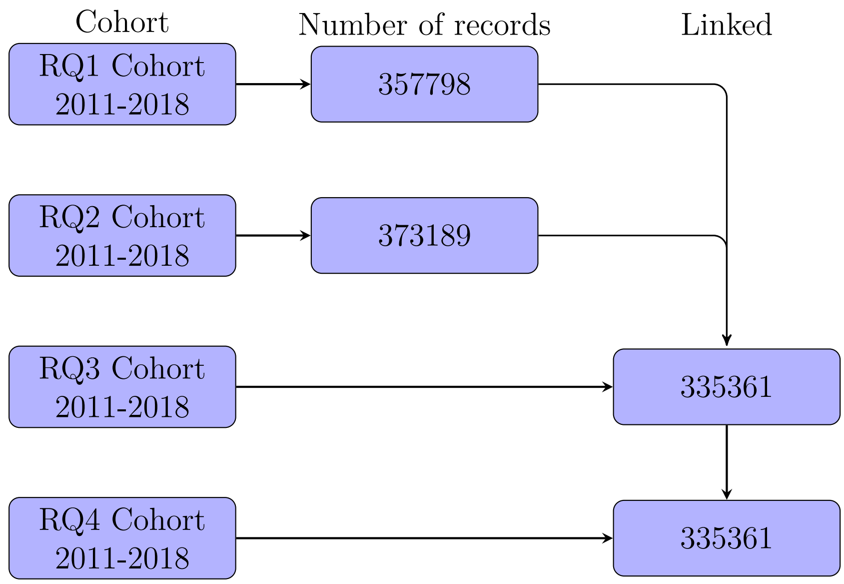

Figure 6.1: Flow chart of creation of Research Question 4 Cohort. RQ - Research Question

335,361) than females (49.1%; n=164,616/335,361), which is consistent with births record by sex in Scotland (National Records Scotland, 2019a). A higher proportion of children live in the most deprived areas than any other SIMD group, with 23.1% (n=77,580/335,361) living in the most deprived areas, compared to 18.7% (n=62,697/ 335,361) in the least deprived. This trend is consistent with NRS population estimates for area-based deprivation by age for SIMD 2016 (National Records Scotland, 2019b). The majority of children are aged 5-years-old, with 87.0% (n=291,715/335,361) of the total cohort being this age. This is in line with logic as 5-year-old is the age that most children start school at Primary 1 level in Scotland.

6.3.2 Study design, data sources, and definitions

This chapter focuses on co-existing caries experience and obesity. Definitions of caries experience (Section 2.15.1) and obesity (Section 2.15.2) are provided in previous sections. Children in the RQ4 Cohort have been categorised into one of four groups:

- *Co-existing conditions* - children who have caries experience and obesity
- *Caries only* - children who have caries experience but not obesity
- *Obesity only* - children who have obesity but no caries experience
- *Neither* - children who do not have caries experience or obesity

Table 6.1: Characteristics of children by age, sex, and area-based deprivation in Research Question 4 Cohort

	2011/12		2012/13		2013/14		2014/15		2015/16		2016/17		2017/18		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
SIMD[1]																
1	10614	22.9	11225	23.3	11542	23.4	11155	22.6	11183	23.4	11112	24.0	10749	22.5	77580	23.1
(MD)[2]																
2	9308	20.1	9766	20.3	9740	19.7	9974	20.2	9615	20.1	9401	20.3	9654	20.2	67458	20.1
3	8814	19.0	9152	19.0	9507	19.3	9072	18.4	8803	18.4	8400	18.1	8824	18.4	62572	18.7
4	9278	20.0	9506	19.7	9692	19.6	9446	19.1	9162	19.2	8748	18.9	9222	19.3	65054	19.4
5	8403	18.1	8573	17.8	8888	18.0	9702	19.7	9077	19.0	8673	18.7	9381	19.6	62697	18.7
(LD)[3]																
Sex																
Male	23717	51.1	24557	50.9	25078	50.8	25033	50.7	24301	50.8	23607	50.9	24452	51.1	170745	50.9
Female	22700	48.9	23665	49.1	24291	49.2	24316	49.3	23539	49.2	22727	49.1	23378	48.9	164616	49.1
Age[4]																
4	2281	4.9	1859	3.9	2072	4.2	2364	4.8	2389	5.0	2285	4.9	2133	4.5	15383	4.6
5	40590	87.4	42078	87.3	42760	86.6	43144	87.4	41553	86.9	40122	86.6	41468	86.7	291715	87.0
6	3546	7.6	4285	8.9	4537	9.2	3841	7.8	3898	8.1	3927	8.5	4229	8.8	28263	8.4
Total	**46417**	**13.8**	**48222**	**14.4**	**49369**	**14.7**	**49349**	**14.7**	**47840**	**14.3**	**46334**	**13.8**	**47830**	**14.3**	**335361**	

[1]SIMD - Scottish Index of Multiple Deprivation; [2] MD - Most Deprived 20%; [3] LD - Least Deprived 20%;
[4] Age in years old

As an association was found between caries and obesity in children in Primary 1 in Scotland in the previous chapter (Chapter 5), the focus of this chapter was on co-existing caries and obesity, and as such only this group is presented, compared to children with neither condition. All models included the *caries only* and *obesity only* groups and corresponding results can be found in Appendix Y.

6.3.3 Statistical analysis

This chapter uses line graphs to visualise the prevalence of co-existing conditions and neither condition over time (2011-2018) overall and for different factors which may be associated with co-existing conditions: sex; age; and area-based deprivation (SIMD). To test for difference in trend over time within each factor, binary logistic regression models were used with a year (treated numerically) and factor interaction, using the co-existing condition status as the outcome. A model was built for co-existing versus neither condition on its own.

Multivariable multinomial regression is used to estimate adjusted odds ratios (aORs) for the association between co-existing conditions and other factors (sex, age, school year, and SIMD) using the methods and diagnostic criteria discussed in Section 2.22. Forrest plots were used to visualise the aORs. The modelling strategy is discussed in Section 2.24. Slope Index of Inequality (SII) and Relative Index of Inequality (RII) are estimate to examine absolute and relative measures of inequalities in the children with co-existing conditions (Section 2.25).

6.4 Results

6.4.1 Prevalence of co-existing caries and obesity and neither condition (RQ4.1)

From Section 5.4.1 it was clear that those children living in SIMD 2 to 5 areas with obesity had a higher prevalence of caries experience. This chapter explores trends and inequalities in children with co-existing obesity and caries experience simultaneously compared to those with only one of the conditions and those with neither.

The prevalence of children with co-existing obesity and caries experience simultaneously in Scotland plateaued over the years (slope for trend=0.000; 95% CI: -0.001 to 0.001; p=0.91), with a 3.5% (n=1,606/46,417) prevalence in 2011/12 and 3.4% (n=1,649/47,830) prevalence in 2017/18 (Figure 6.2A). The prevalence of having co-existing conditions followed roughly the same trend for males and females (p for year/sex interaction=0.81). The prevalence of co-existing conditions in males was 3.7% in both 2011/12 (n=870/23,717) and 2017/18 (n=905/24,452), while prevalence in females was 3.2% in both 2011/12 (n=736/22,700) and 2017/18 (n=744/23,378) (Figure 6.2A). The prevalence of co-existing conditions did not vary much by age (Figure 6.3A) (p for year/age interaction = 0.35).

The prevalence in the group of children in Scotland with *neither* condition has seen a slight rise (slope for trend=0.006; 95% CI: 0.003 to 0.009; p=0.004) from 61.0% (n=28,327/46,417) in 2011/12 to 64.5% (n=30,861/47,830) in 2017/18 (Figure 6.2B), which is due to the prevalence of caries experience reducing. In 2011/12, 59.6% (n=14,134/23,717) of males had *neither* condition, rising to 63.4% (n=15,509/24,452) in 2017/18. The prevalence of *neither* condition in females rose from 62.5% n=14,193/ 22,700) in 2011/12 to 65.7% (n=15,352/23,378) in 2017/18 (Figure 6.2B), however there was no difference in the trends between males and females (p for year/sex interaction = 0.50). Children aged 4 consistently had the highest prevalence of neither condition compared to children aged 5-years and aged 6-years (Figure 6.3B). There was no evidence to suggest that the prevalence of neither conditions changed over time between age groups (p for year/age interaction=0.85).

6.4.2 Socioeconomic inequalities in children with co-existing obesity and caries over time (RQ4.2)

There was a clear social gradient observed in the prevalence of children with co-existing conditions (Figure 6.4). Absolute differences in prevalence of co-existing conditions remain consistent through the years (p for year/SIMD interaction=0.36), although there is a small decrease in the prevalence of co-existing conditions in children living in areas in SIMD 5. In 2011/12 the absolute inequalities in the prevalence

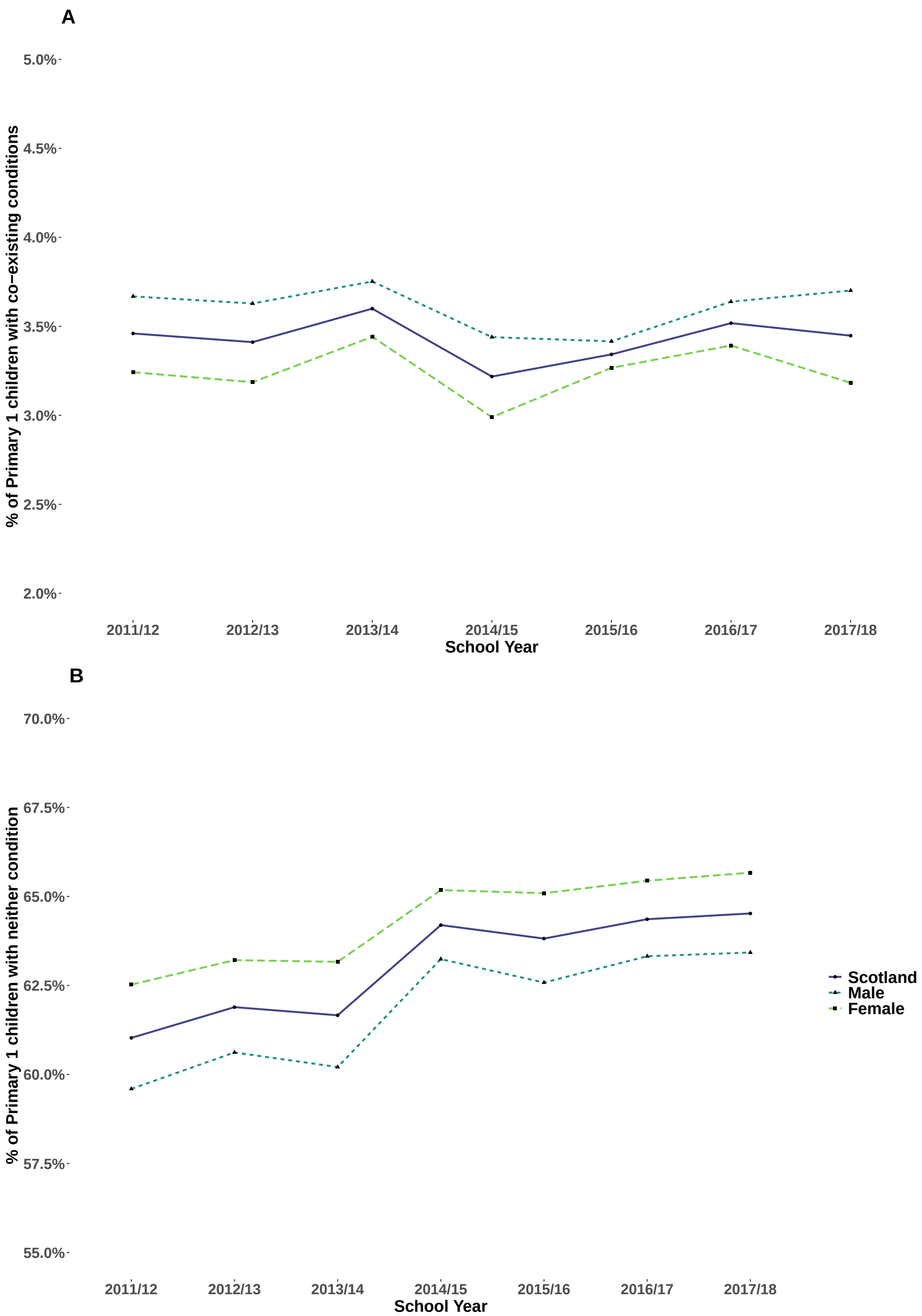

Figure 6.2: Prevalence of co-existing caries and obesity (A) and neither condition (B) in Primary 1 schoolchildren by sex and school year (Appendix Z)

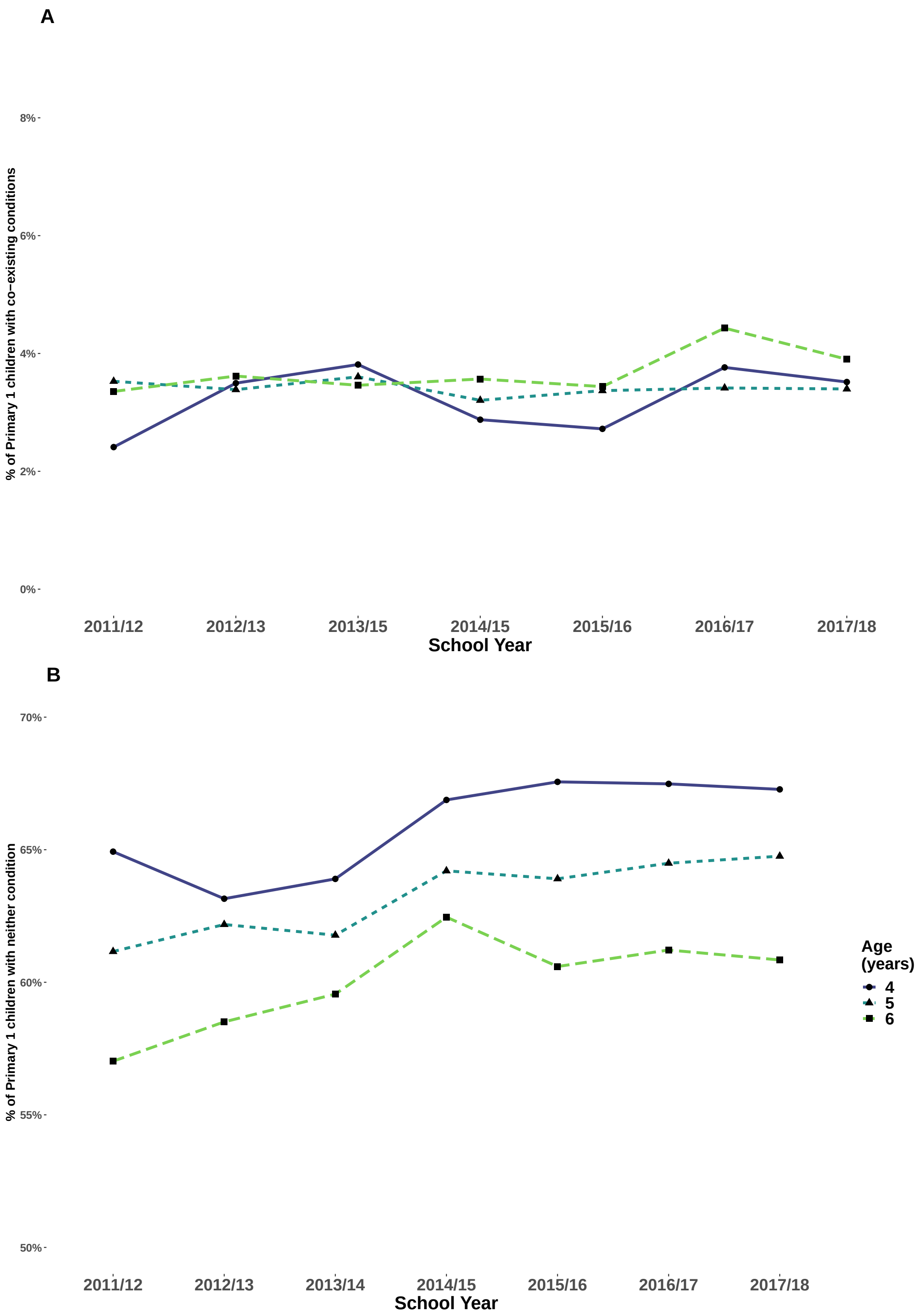

Figure 6.3: Prevalence of co-existing caries and obesity (A) and neither condition (B) in Primary 1 schoolchildren by age in years and school year

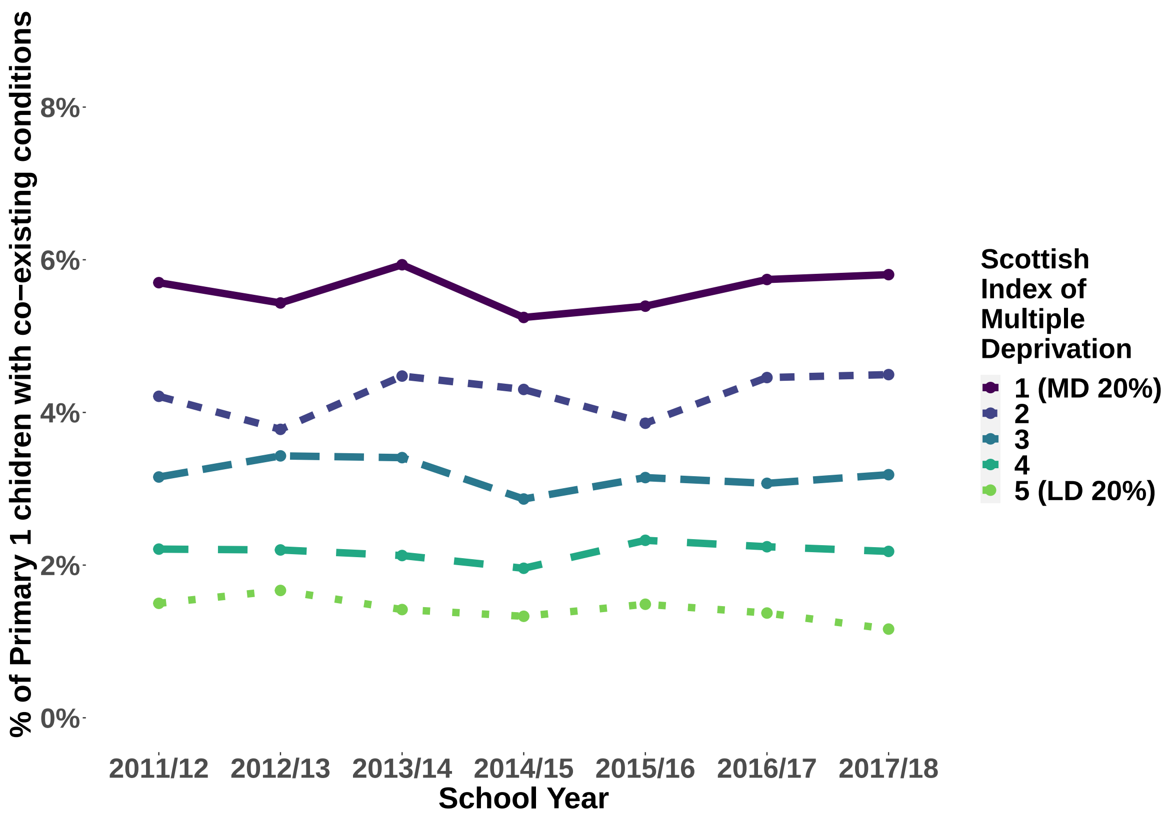

Figure 6.4: Prevalence of co-existing caries and obesity by area-based deprivation and school year in Primary 1 children in Scotland (Appendix AA). MD 20% - Most Deprived 20%; LD 20%- Least Deprived 20%

of co-existing conditions was 4.2% (n=479), with the prevalence in the 20% most deprived areas (SIMD 1) being recorded at 5.7% (n=605/10,614) in 2011/12 and 1.5% (n=126/8,403) in the least deprived fifth (SIMD 5) in the same year. In 2017/18, 5.8% (n=624/10,749) from the most deprived areas (SIMD 1) had co-existing conditions, while 1.2% (n=109/9,381) of those in the least deprived areas (SIMD 5) had co-existing conditions, a difference of 4.6% (n=515).

6.4.2.1 Slope and relative indices over time for children with co-existing conditions (RQ4.2)

The SII for the co-existing conditions remained large and consistent between 2011/12 and 2017/18 (Figure 6.5). The SII changes from 5.0% (95% CI 4.5% to 5.6%) in 2011/12 to 5.8% (95% CI 5.5% to 6.0%). The, already large, RII appears to have increased between 2011 and 2018, although no statistical trend was observed. The RII changes from 5.05 (95% CI 4.48 to 5.69) to 6.25 (95% CI 4.50 to 8.69) between 2011/12 and 2017/18 (Figure 6.5).

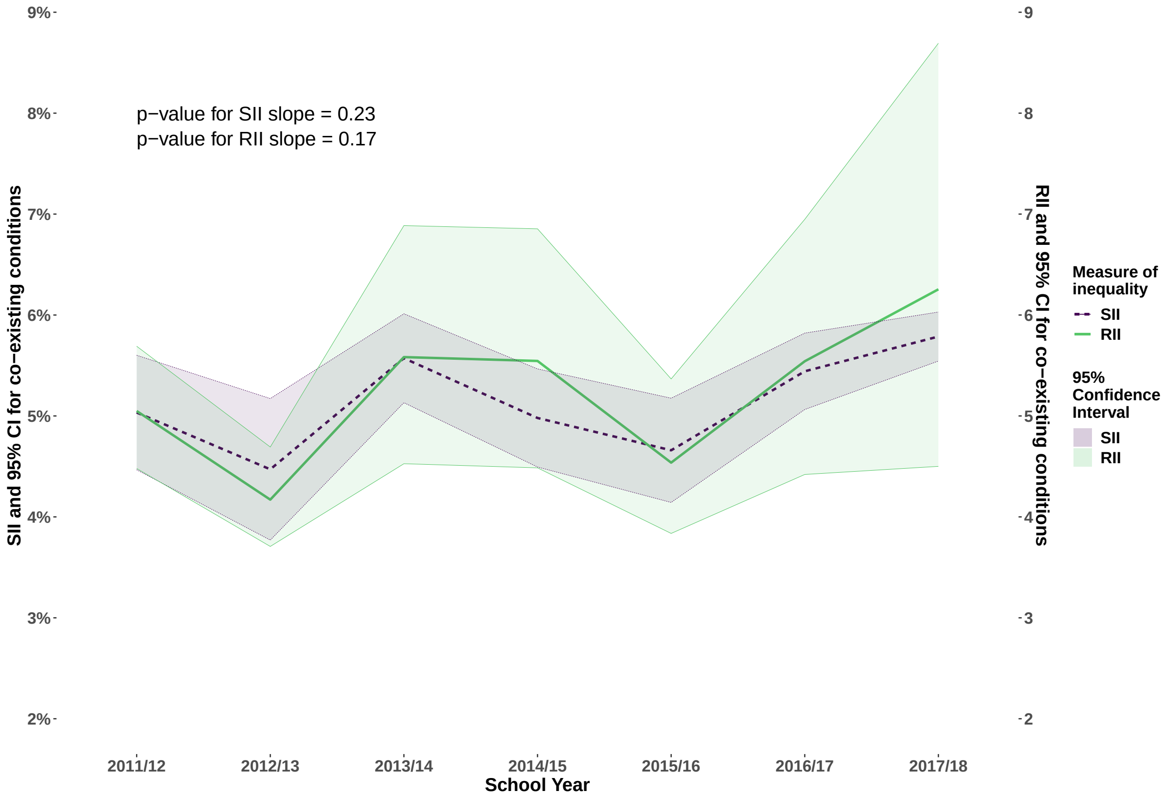

Figure 6.5: Slope Index of Inequality and Relative Index of Inequality for children with co-existing caries and obesity (Appendix AB). SII - Slope Index of Inequality; RII - Relative Index of Inequality

6.4.3 Factors independently associated with childhood co-existing conditions (RQ4.3)

This section assesses which of the factors: SIMD, age, sex, and year are independently associated with co-existing caries and obesity compared to children with neither condition.

As socioeconomic deprivation worsens, the adjusted odds of having co-existing conditions (vs neither) increase when compared to the least deprived (SIMD 5) (Figure 6.6). Those in the most deprived areas (SIMD 1) had adjusted odds of having co-existing conditions 6.63 (95% CI: 6.16 to 7.14; p<0.001) times higher than those in the least deprived areas (SIMD 5). Even those in the second least deprived areas (SIMD 4) have higher adjusted odds of having co-existing conditions than those from SIMD 5 areas (aOR: 1.67; 95% CI: 1.54 to 1.82; p<0.001). Males have slightly higher odds than females to have co-existing conditions, with an aOR of 1.16 (95% CI: 1.12 to 1.20; p<0.001). There was limited difference in the odds of having co-existing conditions,

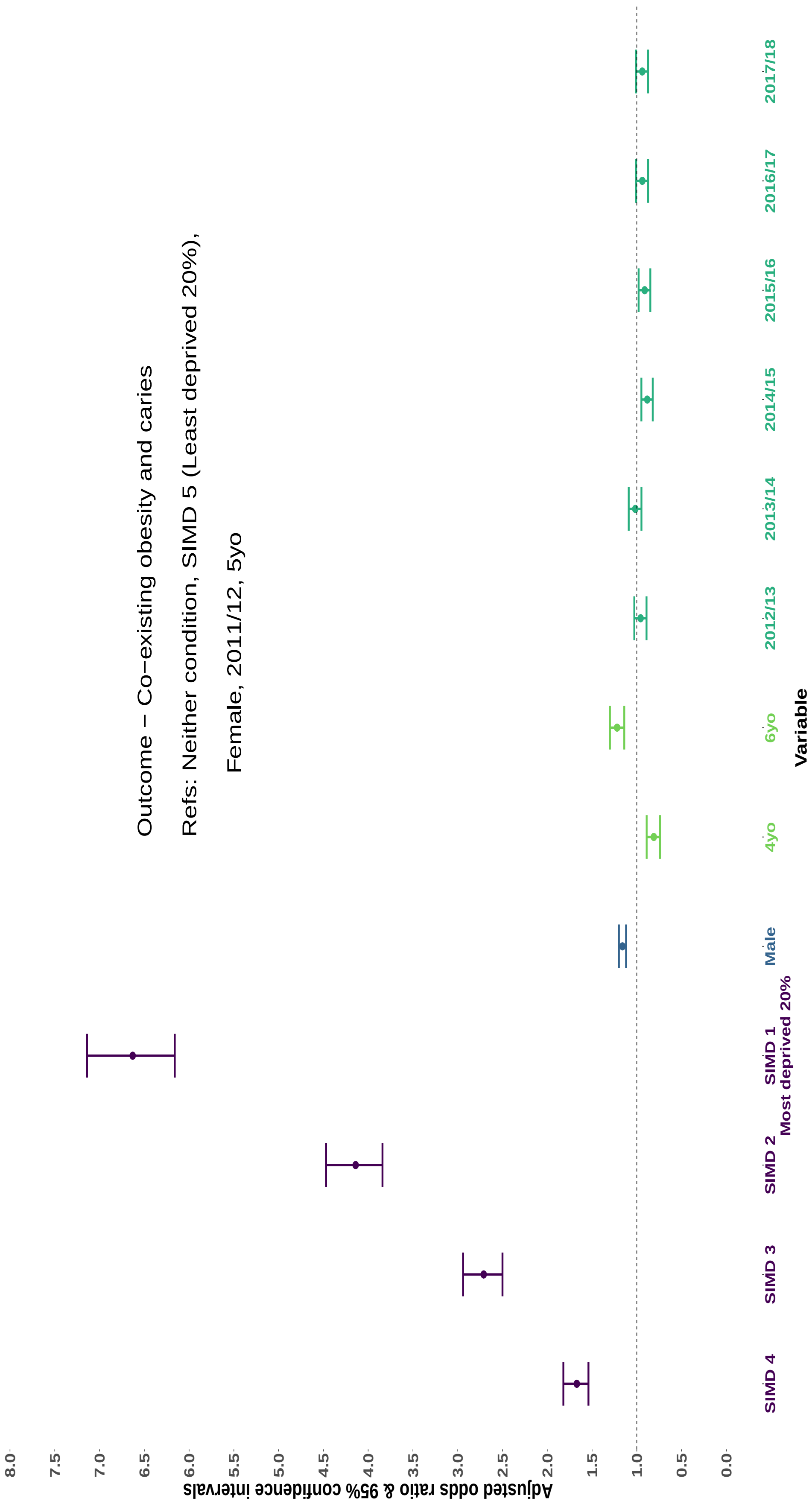

Figure 6.6: Adjusted odds ratios and 95% confidence intervals from a multinomial regression of co-existing caries and obesity against sex, age, school year and area-based deprivation (Appendix AC). SIMD - Scottish Index of Multiple Deprivation; yo - years old

compared to the neither group through the years, except a slight reduction in odds in 2014/15 and 2015/16. The odds of co-existing conditions in 4-year-old children is lower than children aged 5 (aOR: 0.81; 95% CI: 0.74 to 0.89; p<0.001), whereas children aged 6 had higher odds (aOR: 1.22; 95% CI: 1.14 to 1.30; p<0.001).

6.5 Chapter Summary

The aim of this chapter was to explore trends and inequalities in children who experience co-existing caries and obesity of children in Primary 1 living in Scotland. Routinely collected data was used from NDIP and CHSP-S over seven years to construct a cohort of children and examine the trends and prevalence over time (2011 to 2018).

The prevalence of children who experience co-existing caries and obesity in Primary 1 in Scotland is fairly stable over the seven cohort years, with wide inequalities. There is some evidence that inequalities are getting larger relative to the stable prevalence in the latter years.

The prevalence of caries only has reduced over the cohort years, following the trend of caries overall. Prevalence of obesity only has plateaued between 2011/12 and 2017/18. Inequalities too exist in children in the caries only and obesity only groupings, although these are not on the same magnitude as those with co-existing conditions.

Chapter 7

Results

Exploring the Role of Childsmile Interventions in Reaching and Mitigating the Risk of Children with Co-existing Conditions

7.1 Overview

This chapter details the results of the analysis of the cohort to evaluate the reach and impact of the Childsmile programme, the national child oral health improvement programme for Scotland, particularly to children with co-existing childhood caries and obesity in Primary 1 in Scotland. The Childsmile programme aims to improve oral, and general, health in children from birth to 5-years-old in Scotland, with the goal to reduce oral health inequalities. The programme theory for Childsmile, as articulated in the Logic Model (Section 1.9.6), states that the programme should aim to improve general health as well as oral health via the common risk factor approach particularly in relation to dietary sugar (Sheiham et al., 2000). As such the programme expects to see improvements in obesity as long term-outcomes in addition to its primary outcome of dental caries. This thesis has shown that children with co-existing conditions are a small but particularly vulnerable group, exactly the group that the Childsmile programme needs to reach in order to reduce socioeconomic inequalities. Therefore this chapter will examine whether children with co-existing conditions have been reached by the Childsmile programme. This will start with Primary 1 children and look retrospectively back to birth to compare the reach of various interventions in this group to that of their peers with neither condition. Additionally, this chapter will look prospectively from birth to assess if children having Childsmile dietary interventions delivered by the programme are less at risk of co-existing conditions than children not receiving any dietary interventions.

7.2 Aims

RQ5.1. Has the Childsmile programme reached children with co-existing conditions by 5 years of age between 2015 and 2018 in terms of Childsmile prevention interventions in

(i) primary dental care services (e.g., dietary advice, toothbrushing advice, fluoride varnish application)?

(ii) community settings (e.g., home support from Dental Health Support Worker)?

(iii) educational settings (e.g., supervised nursery toothbrushing)?

(iv) any setting?

RQ5.2. Has the dietary interventions of the Childsmile programme reached children with co-existing conditions by 5 year of age between 2015 and 2018 in

(i) primary dental care services (e.g., dietary advice, toothbrushing advice, fluoride varnish application)?

(ii) community settings (e.g., home support from Dental Health Support Worker)?

(iii) both primary dental care and community settings?

RQ6. Has the delivery of Childsmile dietary interventions by 5 years of age had an impact on the prevalence of co-existing dental caries experience and obesity between 2015 and 2018?

7.3 Methods

7.3.1 Cohort assembly for Chapter 7

Research question 5 investigates whether children with co-existing caries and obesity in Primary 1 have been reached by the Childsmile preventive dental, community services, and educational settings from birth to 5 years of age between 2015 and 2018. Research question 6 asks whether access to Childsmile dietary interventions prevented co-existing caries and obesity between 2015 and 2018. The analysis only includes children who were in Research Question 4 (RQ4) Cohort (Section 6.3.1) born on or after January 1st 2011, who were in Primary 1 between 2015/16 and 2017/18. Records in the cohort were linked to Childsmile intervention datasets, and data without matches were excluded. There was no inclusion bias found in the analysis when comparing prevalence of sex and area-based deprivation.

Only children from RQ4 Cohort were considered as these are children who have received a valid NDIP Primary 1 and CHSP-S inspection, providing a valid measure of caries experience and BMI as well as having a valid area-based deprivation (SIMD) measurement. The decision to exclude children born before January 1st 2011 was due to the national rollout of the Childsmile programme in 2011. Children born before this date may have missed some of the Childsmile programme interventions. By only including children born on or after the January 1st 2011 it provides every child included in this analysis an equal opportunity to have received all interventions. It was clear from the results in Sections 2.11.5 and 2.11.8 that the number of interventions delivered increased between 2010/11 and 2011/12 justifying the decision to exclude children based on date of birth.

The RQ5 Cohort includes children who were born after January 1st 2011, and in Primary 1 between 2015/16 and 2017/18, tracked from birth until the day before their 5th birthday using securely linked child-level data across seven databases: National Dental Inspection Programme (NDIP) Primary 1 (part of RQ4 cohort), Child Health Systems Programme - School (CHSP-S) (part of RQ4 cohort), Management Information & Dental Account System (MIDAS) (MIDAS Participation and Treatment), Health Informatics Centre (HIC) Dental Health Support Worker (DHSW) Practice

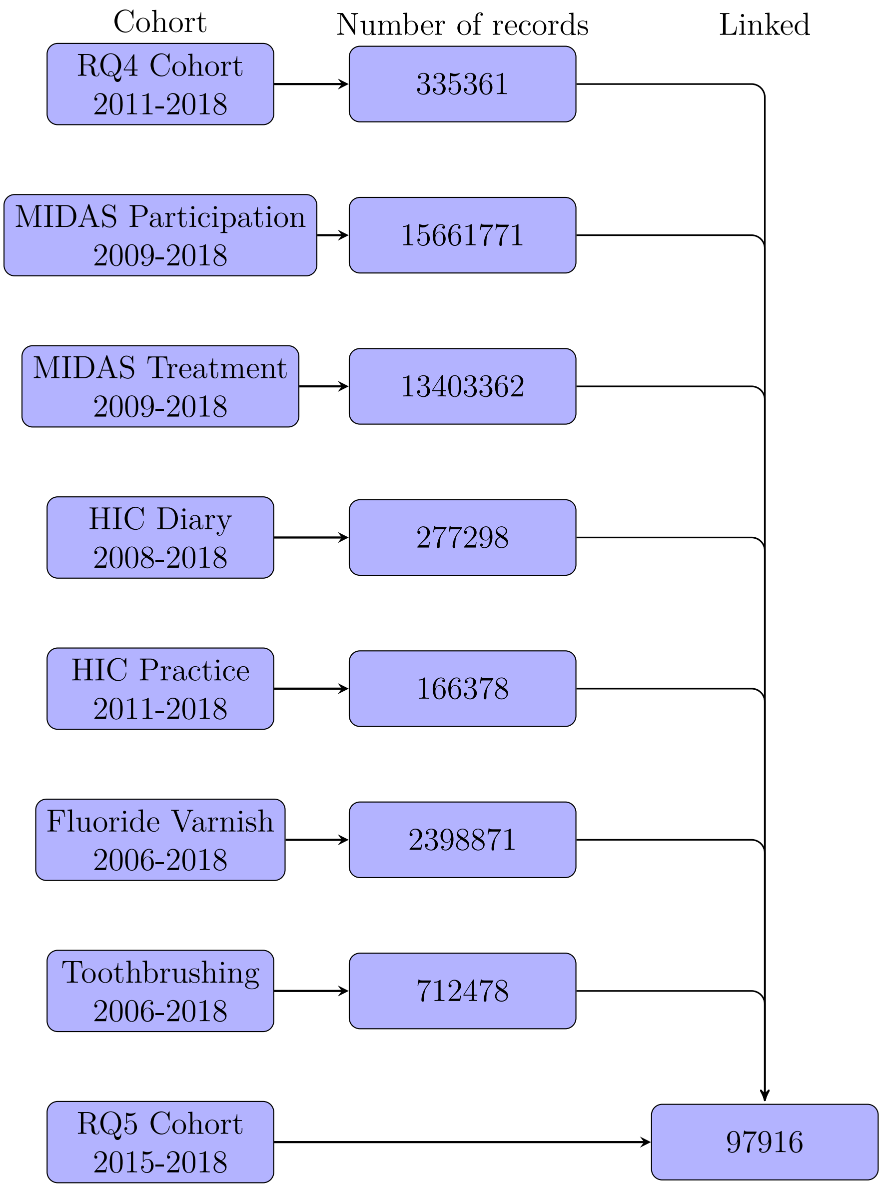

Figure 7.1: Flow chart of creation of Research Question 5 Cohort. RQ - Research Question; MIDAS - Management Information & Dental Account System; HIC - Health Informatics Centre

Diary Events (HIC Diary), HIC DHSW Practice Interventions (HIC Practice), HIC Fluoride Varnish Visit (Fluoride Varnish), Toothbrushing Consent (Toothbrushing) (Sections 2.8.2 to 2.9.6, Figure 7.1).

Table 7.1 presents the characteristics of the RQ5 Cohort by age, sex, and area-based deprivation (SIMD). There is a very slightly higher number of males (50.6%; n=54,9525/ 97,916) than females (49.4%; n=48,391/97,916), which is consistent with births record by sex in Scotland (National Records Scotland, 2019a), although there were more females included in the school year 2015/16 than males, although this will not have much impact given the much smaller sample size in 2015/16. A higher proportion of children live in the 20% most deprived areas than any other SIMD fifth, with 23.4%

(n=22,936/97,916) living in the most deprived areas, compared to 19.0% (n=18,639/97,916) in the least deprived 20%. This trend is consistent with NRS population estimates for area-based deprivation by age for SIMD 2016 (National Records Scotland, 2019b). The majority of children are aged 5-years-old, with 86.0% (n=84,238/97,916) of the total cohort being this age. This is in line with logic as 5-year-old is the age that most children start school at Primary 1 level in Scotland. There were no children aged 6-years-old in 2015/16 which is due to cut-off regarding date of birth being applied for this analysis.

7.3.2 Outcome measures

The outcome measures for these analysis are in two parts. The measures for Research Question 5.1 and 5.2 relate to the children with co-existing conditions' access to preventive dental services compared to children with neither condition:

- Dental practice service (RQ5.1(i)) - attendance at NHS primary dental care (General Dental Services (GDS)) at least once from birth to 5 years of age (ever/never) via the Management Information & Dental Account System (MIDAS). MIDAS is a NHS Scotland dental service administration database. GDS are high street dental practices providing routine dental services (Public Health Scotland, 2023a). Receipt of Childsmile oral health improvement programme interventions in a dental practice at least once from birth to 5 years of age (ever/never). Childsmile prevention in primary dental care (dietary advice, toothbrushing instruction, and fluoride varnish) using MIDAS (Public Health Scotland, 2023a).

- Community settings (RQ5.1(ii)) - receipt of Childsmile programme interventions in a community setting at least once from birth to 5 years of age (ever/never). Home or community oral health support by trained Dental Health Support Worker (DHSW) (Public Health Scotland, 2023b).

- Educational settings (RQ5.1(iii)) - receipt of Childsmile programme interventions in a nursery/school setting at least once from birth to 5 years of age (ever/never). Fluoride varnish application in nursery/school; nursery supervised toothbrushing. The Childsmile databases are developed by University of Dundee Health

Table 7.1: Characteristics of children by age, sex, and area-based deprivation in Research Question 5 Cohort

	2015/16		2016/17		2017/18		Total	
	n	%	n	%	n	%	n	%
SIMD[1]								
1 (MD)[2]	1243	27.6	10944	24.0	10749	22.5	22936	23.4
2	1037	23.0	9256	20.3	9654	20.2	19947	20.4
3	789	17.5	8276	18.2	8824	18.4	17889	18.3
4	728	16.2	8555	18.8	9222	19.3	18505	18.9
5 (LD)[3]	710	15.8	8548	18.8	9381	19.6	18639	19.0
Sex								
Male	1971	43.7	23102	50.7	24452	51.1	49525	50.6
Female	2536	56.3	22477	49.3	23378	48.9	48391	49.4
Age[4]								
4	1785	39.6	2285	5.0	2133	4.5	6203	6.3
5	2722	60.4	40048	87.9	41468	86.7	84238	86.0
6	0	0.0	3246	7.1	4229	8.8	7475	7.6
Total	**4507**	**4.6**	**45579**	**46.5**	**47830**	**48.8**	**97916**	

[1]SIMD - Scottish Index of Multiple Deprivation; [2] MD - Most Deprived 20%; [3] LD - Least Deprived 20%;
[4] Age in years old

Informatics Centre (HIC) and collated and stored by Public Health Scotland. They consist of data on the timing and nature of contacts with the Childsmile programme and prevention interventions (Public Health Scotland, 2023b).

- Receipt of the Childsmile programme dietary interventions at least once from birth to 5 years of age (ever/never) (RQ5.2). The dietary advice interventions in dental practice service (via GDS) (RQ5.2(i)) and community settings (via DHSW) (RQ5.2(ii)) were used to derive the following variables: dietary advice at primary dental care; dietary advice from DHSW, signposting to a food/diet related community/voluntary organisations from DHSW (Public Health Scotland, 2023a,b).

The outcome measure for Research Question 6 is the prevalence of co-existing caries and obesity versus the prevalence of neither condition. Children with either caries and obesity only were separated were excluded from this analysis.

7.3.3 Covariates and confounders

Sex (Male/Female), age of child (years), cohort year (2015/16, 2016/17, 2017/18), and area-based socioeconomic status (derived from the SIMD) were considered possible confounding variables as previous chapters have shown these to be associated with the prevalence of co-existing conditions (Chapter 6), as well as caries experience and BMI separately (Chapters 3 and 4).

Specifically for Research Question 6 additional variables were used as covariates in a categorical manner: regular attendance at the GDS; dietary advice at primary dental care (capped at 5 doses to account for the dentist not receiving payments for more than one dose per 12 calendar months (Scottish Dental, 2021)); dietary advice from DHSW; signposting to food/diet related community/voluntary organisations from DHSW.

7.3.4 Statistical analysis

Tables were created to look at the reach of each Childsmile component to children with co-existing conditions and neither condition (RQ5.1). Each intervention (ever/never) was modelled against the prevalence co-existing conditions versus neither condition and adjusted for age, sex, school year, and SIMD using modified Poisson regression to estimate adjusted risk ratios (aRRs) for the difference in probability of being reached by the each component of the Childsmile programme (Section 2.23). A model was created using any Childsmile intervention as the outcome, assessing the reach of the programme overall.

Tables were created to look at the reach of each dietary intervention to children with co-existing conditions and neither condition (RQ5.2). The intervention (ever/never) was modelled against the prevalence of co-existing conditions versus neither condition and adjusted for age, sex, school year, and SIMD using the same methods as described as above and presented in Section 2.23. A further model was created looking at the reach of dietary advice components overall against the same independent variables.

The impact of the Childsmile dietary interventions (RQ6) were considered using modified Poisson regression (Section 2.23), this time with the dependent variable of co-existing conditions, coded as 1, versus neither condition, coded as 0. The independent variables in this instance were the number of times each child has received a dietary intervention, treated as a categorical variable to allow for the comparison to a baselines. In the case of the dietary advice at the GDS, the number of times was partitioned by the child's regular attendance status (non-attender, non-regular attender, regular attender) to attempt to account for attendance and identify the impact of the intervention.

All models described above produced RRs and adjusted risk ratios (aRRs), along with 95% confidence interval (CI) using robust standard errors, which are described in more detail in Section 2.23.

7.4 Reach of Childsmile Interventions (RQ5.1)

Among children who had neither condition, 92.4% had attended the GDS at least once in the first five years compared to 87.9% of children with co-existing conditions (aRR: 0.96; 95% CI: 0.95 to 0.98) (Table 7.2). Of the children who had "ever" attended the GDS, 81.9% of children with co-existing condition had "ever" received prevention intervention in the form of dietary advice, toothbrushing instruction, and/or FVA

(Section 2.16.1.2) compared to 83.2% of children with neither condition (aRR: 0.98; 95% CI: 0.96 to 0.99) (Table 7.2).

Children with co-existing conditions in Primary 1 were more likely to be referred to a DHSW for additional home-based support but were less likely to receive that support once referred. Of children with neither condition, 21.4% were referred to a DHSW compared to 28.6% of children with co-existing conditions (Table 7.3). However, almost 20% of those with co-existing conditions who were referred never received any DHSW support (due to issues between the referral and contact phase, including could not contact family and declined service) compared to 14% of those with neither condition who were referred (Table 7.3).

After adjustment, children with co-existing conditions were no more or less likely to have participated in nursery supervised toothbrushing than those with neither condition (aRR: 0.99; 95% CI: 0.97 to 1.01). Although, 51.7% of children with co-existing conditions had at least one FVA at nursery or school compared to 41.3% of children with neither condition. This effect largely disappeared after adjustment for area-based deprivation (FVA in nursery/school is a targeted intervention to more deprived areas) (aRR: 1.03; 95% CI: 1.00 to 1.07) (Table 7.4).

A very high percentage (97.7%; n=95,629/97,916) of children in this cohort had received at least one Childsmile intervention over the first 5 years of life. This percentage did not change significantly between children with neither or co-existing conditions (aRR: 0.99; 95% CI: 0.98 to 1.00) (Table 7.5).

7.5 Reach of the Childsmile Programme Dietary Interventions (RQ5.1)

As obesity and caries are both considered NCDs and both share common risk factors, including sugar consumption, it was important to look at whether children with co-existing conditions were being targeted for dietary advice support at the GDS and in the home setting by DHSWs.

Table 7.2: Reach of preventive dental services according to co-existing conditions. Unadjusted and adjusted risk ratios and 95% confidence intervals

	Attendance at GDS[1]			Diet, toothbrushing advice, FVA[2] at GDS[1,3]		
	% (n/N)	RR[4] [95% CI[5]]	aRR[6] [95% CI[5]]	% (n/N)	RR[4] [95% CI[5]]	aRR[6] [95% CI[5]]
Condition Group						
Neither	92.4 (58452/63227)	Referent		83.2 (48654/58452)	Referent	
Co-existing	87.9 (2946/3351)	0.95 [0.94,0.96]	0.96 [0.95,0.98]	81.9 (2414/2946)	0.98 [0.97,1.00]	0.98 [0.96,0.99]
Caries	89.4 (22194/24820)	0.97 [0.96,0.97]	0.98 [0.97,0.98]	82.7 (18346/22194)	0.99 [0.99,1.00]	0.99 [0.98,0.99]
Obesity	90.8 (5916/6518)	0.98 [0.97,0.99]	0.99 [0.98,0.99]	83.9 (4961/5916)	1.01 [1.00,1.02]	1.00 [0.99,1.02]
Total	91.4 (89508/97916)			83.1 (74375/89508)		

[1] GDS: General Dental Services (Ever/Never); [2] FVA: Fluoride Varnish Application; [3] Must have ever attended GDS;
[4] RR: risk ratio; [5] 95% CI: 95% Confidence Intervals;
[6] aRR: adjusted risk ratio - adjusted for sex, SIMD fifth, age, and school year

Table 7.3: Reach of Childsmile DHSW interventions in home or community setting. Unadjusted and adjusted risk ratios and 95% confidence intervals

	Referred to DHSW[1]			Contact with DHSW[1,2]		
	% (n/N)	RR[3] [95% CI[4]]	aRR[5] [95% CI[4]]	% (n/N)	RR[3] [95% CI[4]]	aRR[5] [95% CI[4]]
Condition Group						
Neither	21.4 (13523/63188)	Referent		85.9 (11612/13523)	Referent	
Co-existing	28.5 (955/3349)	1.33 [1.26,1.41]	1.08 [1.03,1.15]	81.9 (782/955)	0.95 [0.94,0.96]	0.96 [0.95,0.98]
Caries	28.6 (7088/24792)	1.34 [1.30,1.37]	1.12 [1.09,1.15]	82.4 (5838/7088)	0.97 [0.96,0.97]	0.98 [0.97,0.98]
Obesity	23.3 (1515/6513)	1.09 [1.04,1.14]	1.00 [0.95,1.04]	85.1 (1289/1515)	0.98 [0.97,0.99]	0.99 [0.98,0.99]
Total	23.6 (23081/97842)			84.6 (19521/23081)		

[1] DHSW: Dental Health Support Worker; [2] Contact with DHSW: Successful contact given referred to DHSW;
[3] RR: Risk Ratio; [4] 95% CI: 95% Confidence Interval;
[5] aRR: Adjusted Risk Ratio adjusted for sex, Scottish Index of Multiple Deprivation fifth, age, and school year

Table 7.4: Reach of Childsmile interventions in nursery and school settings. Unadjusted and adjusted risk ratios and 95% confidence intervals

	NSTB[1]			FVA[2] Nursery/School		
	% (n/N)	RR[3] [95% CI[4]]	aRR[5] [95% CI[4]]	% (n/N)	RR[3] [95% CI[4]]	aRR[5] [95% CI[4]]
Condition Group						
Neither	79.6 (50105/62962)	Referent		41.3 (26059/63087)	Referent	
Co-existing	81.6 (2723/3337)	1.03 [1.01,1.04]	0.99 [0.97,1.01]	51.7 (1727/3342)	1.25 [1.21,1.29]	1.03 [1.00,1.07]
Caries	80.5 (19915/24732)	1.01 [1.00,1.02]	0.98 [0.98,0.99]	49.9 (12348/24765)	1.21 [1.19,1.23]	1.03 [1.01,1.04]
Obesity	82.2 (5327/6482)	1.03 [1.02,1.05]	1.02 [1.00,1.03]	47.2 (3065/6497)	1.14 [1.11,1.17]	1.05 [1.02,1.08]
Total	80.1 (78070/97513)			44.2 (43199/97691)		

[1] NSTB: Nursery Supervised Toothbrushing; [2] FVA: Fluoride Varnish Application; [3] RR: risk ratio;
[4] 95% CI: 95% Confidence Intervals;
[5] aRR: adjusted risk ratio - adjusted for sex, Scottish Index of Multiple Deprivation fifth, age, and school year

Table 7.5: Reach of Any Childsmile Intervention according to co-existing conditions. Unadjusted and adjusted risk ratios and 95% confidence intervals

	Any Component[1]		
	% (n/N)	RR[2] [95% CI[3]]	aRR[4] [95% CI[3]]
Condition Group			
Neither	97.8 (61866/63227)	Referent	
Co-existing	97.0 (3249/3351)	0.99 [0.98,1.00]	0.99 [0.98,1.00]
Caries	97.3 (24145/24820)	0.99 [0.99,1.00]	0.99 [0.99,1.00]
Obesity	97.7 (6369/6518)	1.00 [0.99,1.00]	1.00 [0.99,1.00]
Total	97.7 (95629/97916)		

[1] Any Childsmile Component: Any of Nursery Supervised Toothbrushing, Fluoride Varnish Application at Nursery/School, Attendance at General Dental Service, Contact with Dental Health Support Worker
[2] RR: Risk Ratio; [3] 95% CI: 95% Confidence Intervals
[4] aRR: Adjusted Risk Ratio adjusted for sex, Scottish Index of Multiple Deprivation fifth, age, and school year

Children with co-existing conditions in Primary 1 were very slightly less likely to receive dietary advice at the GDS, given that they had attended, with an adjusted risk ratio of 0.97 (95% CI 0.95 to 0.99) compared to children with neither condition (78.0% vs 79.1%) (Table 7.6). Although the same children were very slightly more likely to receive dietary advice from a DHSW (aRR: 1.02; 95% CI: 1.00 to 1.05) given that they had been contacted by a DHSW (90.4% vs 88.3%) (Table 7.6). Despite this, children with co-existing conditions were less likely to be signposted to nutritional services by a DHSW (aRR: 0.71; 95% CI: 0.52 to 0.98) compared to children with neither condition (4.7% vs 5.9%) (Table 7.6).

There was no evidence to suggest that children with co-existing conditions were more or less likely to receive any of the dietary components of Childsmile (aRR: 0.99; 95% CI: 0.97 to 1.00) than children with neither condition (Table 7.7).

7.6 Impact of the Childsmile Dietary Interventions on Co-existing Conditions (RQ5.2)

Table 7.8 presents the results of a modified Poisson regression analysis of co-existing conditions according to a) attendance dietary interventions delivered in a dental practice and b) delivered by a DHSW in the family home. The variables were derived using information from the delivery of the intervention, where dental professionals or DHSW record if the intervention was delivered.

There appeared to be a difference in risk of co-existing conditions between children who did not attend the GDS regularly and those that did (Table 7.8). Focusing on the number of dietary advice, it does appear that children who received more dietary advice had a reduced risk of co-existing conditions. These risk estimates remained after adjusting for socioeconomic status.

The DHSW intervention showed a slightly different picture with those children receiving at least two dietary interventions from a DHSW having a greater risk of co-existing conditions than those receiving fewer dietary interventions (7.1% vs 12.1%) (Table 7.8). However, as this intervention is targeted to children from the most socioeconomically

Table 7.6: Reach of Dietary Components of Childsmile according to co-existing conditions group. Unadjusted and adjusted risk ratios and 95% confidence intervals

	Dietary Advice at GDS[1] Having Attended at Least Once			Dietary Advice from DHSW[1] Having Received a DHSW Intervention			Signposting to Food/Diet Organisations from DHSW[1] Having Received a DHSW Intervention		
	% (n/N)	RR[2] [95% CI[3]]	aRR[4] [95% CI[3]]	% (n/N)	RR[2] [95% CI[3]]	aRR[4] [95% CI[3]]	% (n/N)	RR[2] [95% CI[3]]	aRR[4] [95% CI[3]]
Condition Group									
Neither	79.1 (46222/58452)	Referent		88.3 (10258/11612)	Referent		5.9 (686/11612)	Referent	
Co-existing	78.0 (2299/2946)	0.99 [0.97,1.01]	0.97 [0.95,0.99]	90.4 (707/782)	1.02 [1.00,1.05]	1.02 [1.00,1.05]	4.7 (37/782)	0.80 [0.58,1.11]	0.71 [0.52,0.98]
Caries	78.3 (17381/22194)	0.99 [0.98,1.00]	0.97 [0.97,0.98]	88.5 (5168/5838)	1.00 [0.99,1.01]	1.00 [0.99,1.01]	5.7 (335/5838)	0.97 [0.86,1.10]	0.88 [0.77,0.99]
Obesity	79.9 (4727/5916)	1.01 [1.00,1.02]	1.00 [0.99,1.02]	88.8 (1145/1289)	1.01 [0.99,1.03]	1.00 [0.98,1.02]	5.4 (70/1289)	0.92 [0.72,1.17]	0.85 [0.67,1.07]

[1] GDS: General Dental Services; DHSW: Dental Health Support Worker

[2] RR: Risk Ratio; [3] 95% CI: 95% Confidence Intervals;

[4] aRR: Adjusted Risk Ration adjusted for sex, Scottish Index of Multiple Deprivation fifth, age, and school year

Table 7.7: Reach of Any Dietary Component of Childsmile according to co-existing conditions group. Unadjusted and adjusted risk ratios and 95% confidence intervals

	Any Childsmile Diet[1]		
	% (n/N)	RR[2] [95% CI[3]]	aRR[4] [95% CI[3]]
Condition Group			
Neither	81.6 (48203/59068)	Referent	
Co-existing	82.3 (2479/3011)	1.01 [0.99,1.03]	0.99 [0.97,1.00]
Caries	81.9 (18507/22610)	1.00 [1.00,1.01]	0.98 [0.98,0.99]
Obesity	82.2 (4943/6014)	1.01 [0.99,1.02]	1.00 [0.98,1.01]

[1] Any Childsmile Diet Component: Any of Dietary Advice at General Dental Services, Dietary Advice from Dental Health Support Worker, Signposting to Food/Diet Organisations from Dental Health Support Worker
[2] RR: Risk Ratio; [3] 95% CI: 95% Confidence Intervals
[4] aRR: Adjusted Risk Ratio adjusted for sex, Scottish Index of Multiple Deprivation fifth, age, and school year

Table 7.8: Impact of diet focused Childsmile interventions according to co-existing conditions. Unadjusted and adjusted risk ratios and 95% confidence intervals

		Neither % (n/N)	Co-existing % (n/N)	RR[1] [95% CI[2]]	aRR[3] [95% CI[2]]
Attendance	**No. of Times Received Dietary Advice at General Dental Service[4]**				
NAt[4]	0	92.2 (4775/5180)	7.8 (405/5180)	1.22 [1.08,1.38]	1.05 [0.93,1.19]
Non Reg[5]	0	93.6 (7871/8409)	6.4 (538/8409)	Referent	
Non Reg[5]	1	92.5 (9330/10084)	7.5 (754/10084)	1.17 [1.05,1.30]	1.06 [0.95,1.17]
Non Reg[5]	2	93.3 (6426/6890)	6.7 (464/6890)	1.05 [0.93,1.19]	0.96 [0.85,1.08]
Non Reg[5]	3	95.1 (3264/3433)	4.9 (169/3433)	0.77 [0.65,0.91]	0.70 [0.60,0.83]
Reg[6]	0	97.6 (4359/4468)	2.4 (109/4468)	0.38 [0.31,0.47]	0.49 [0.40,0.59]
Reg[6]	1	96.7 (4636/4793)	3.3 (157/4793)	0.51 [0.43,0.61]	0.58 [0.49,0.69]
Reg[6]	2	96.3 (5981/6210)	3.7 (229/6210)	0.58 [0.50,0.67]	0.65 [0.56,0.76]
Reg[6]	3	96.3 (7554/7845)	3.7 (291/7845)	0.58 [0.50,0.67]	0.62 [0.54,0.71]
Reg[6]	4	97.3 (6431/6607)	2.7 (176/6607)	0.42 [0.35,0.49]	0.43 [0.36,0.50]
Reg[6]	5	97.8 (2600/2659)	2.2 (59/2659)	0.35 [0.27,0.45]	0.34 [0.26,0.44]
No. of Times Received Dietary Advice from DHSW[7,8]					
NR[9]		95.4 (49665/52059)	4.6 (2394/52059)	0.65 [0.57,0.74]	0.86 [0.74,0.99]
0		92.9 (3265/3513)	7.1 (248/3513)	Referent	
1		93.9 (9733/10368)	6.1 (635/10368)	0.87 [0.75,1.00]	0.82 [0.70,0.95]
2+		87.9 (525/597)	12.1 (72/597)	1.71 [1.33,2.19]	1.23 [0.86,1.75]
No. of Times Signposted to Food/Diet Organisation from DHSW[7,8]					
NR[9]		95.4 (49665/52059)	4.6 (2394/52059)	0.69 [0.64,0.74]	0.86 [0.80,0.93]
0		93.3 (12837/13755)	6.7 (918/13755)	Referent	
1+		94.9 (686/723)	5.1 (37/723)	0.77 [0.56,1.06]	0.71 [0.51,0.97]

[1] RR: Risk Ratio; [2] 95% CI: 95% Confidence Intervals;
[3] aRR: Adjusted Risk Ratio adjusted for sex, Scottish Index of Multiple Deprivation fifth, age, and school year;
[4] NAt: No Attend; [5] Non Reg: Non regular attendance (attended in 1 to 3 of first 5 years of life);
[6] Reg: Regular attendance (attended in 4 or 5 of first five years of life);
[7] DHSW: Dental Health Support Worker;
[8] additionally adjusted for the total number of interventions from a DHSW;
[9] NR: Not Referred

deprived families/communities, this increased risk attenuated after adjustment for socioeconomic status. Children who received one dietary intervention from the DHSW had reduced risk of co-existing conditions with further reduction after adjusting. There was evidence that signposting to food/diet related community/voluntary organisations was associated with a decreased risk of co-existing conditions compared to children who were referred to a DHSW but received no signposting.

7.7 Chapter Summary

The Childsmile programme was successful in "ever" reaching children who developed co-existing caries and obesity at a similar rate as those without the condition, although this was not consistent across all Childsmile interventions. Children with co-existing conditions were less likely than their counterparts without either condition to have ever attended the GDS, and if attended less likely to have received dietary advice, toothbrushing instructions, and/or fluoride varnish application interventions. They were also less likely to have a successful contact with a trained DHSW. However, they were more likely to have been referred to a DHSW and to have received fluoride varnish application in nursery or school. The reach of nursery supervised toothbrushing was found to be similar between children with co-existing conditions and children with neither condition.

In terms of dietary interventions, the Childsmile programme was able to have reached children with co-existing caries and obesity at a similar level to those without either condition. However, children with co-existing conditions were less likely to have received dietary advice in the GDS or to have been signposted to food/diet related community/voluntary organisations by a DHSW than children with neither condition. On the other hand, children with co-existing conditions were more likely to have received dietary advice from a DHSW.

Children with co-existing caries and obesity received fewer doses of dietary advice in the GDS and were signposted to food/diet related community/voluntary organisations fewer times than children without either condition. However, children with co-existing conditions had received more doses of dietary advice from a DHSW on average.

A higher number of doses of dietary advice in the GDS was found to reduce the risk of co-existing conditions compared to children who attended the GDS but did not receive any dietary advice, regardless if the child was a non-regular or regular attender. If a child received more doses of dietary advice from a DHSW, they were at a higher risk of co-existing conditions, however, this effect may be due to the targeted nature of the DHSW intervention to more disadvantaged families. Finally, children who received more signposting to food/diet related community/voluntary organisations had a reduced risk of co-existing conditions compared to children who were referred to a DHSW but did not receive signposting.

Chapter 8

Discussion

8.1 Importance of Thesis and Key Findings

Obesity and dental caries are among the first observable non-communicable diseases in the early years and markers of further health issues into adulthood. By identifying a group of individuals (in childhood) at greater risk of both obesity and caries could potentially allow better targeting of interventions designed to tackle the common underlying risk factors (such as high sugar consumption and other social determinants). This ultimately could lead, with the right interventions, to better prevention, improved health, and a potential reduction in inequalities in these health outcomes, which would also have considerable cost savings to the NHS and wider societal benefits.

Childsmile, the national child oral health improvement programme in Scotland is already embedded within the infrastructure of the NHS and reaches all children from birth to 17 years. It already delivers interventions in multiple settings through a cross-sectoral group of health workers, and adopts a proportional universalism approach (Section 1.8.1). It also had the potential to reach and impact the population at risk of other conditions, such as obesity. The wider health improvement potential of Childsmile remains largely untapped particularly given the wide population reach and highly skilled workforce. In the current times, when budgets are stretched, cross-sectoral collaboration is essential. Utilising existing infrastructure, resources, and expertise within a fully established programme to test new interventions provides opportunities for wider general health improvements in the populations and provides the public with value for money and an anticipated higher return on investment.

This research has several important findings:

i) The prevalence of childhood caries in Primary 1 (approx 5-years-old) children reduced in Scotland between 2011 and 2018, however large absolute inequalities persisted across socioeconomic groups and relative inequalities rose.

ii) The prevalence of childhood obesity in Primary 1 (approx 5-years-old) children in Scotland plateaued between 2011 and 2018 which masked increasing trends in children from the most deprived areas. Therefore, during this period absolute and relative inequalities increased across socioeconomic groups.

iii) There was an association between childhood caries experience and BMI, although this was complicated as it changed over time, however children with obesity had consistently higher prevalence of caries experience in all years. The association was altered by area-based deprivation, with children living in 20% most deprived areas with obesity having no increased odds of caries experience compared to those with healthy weight. However, children with obesity living in 20% least deprived areas did have increased odds of having caries experience compared to children living in the same areas with healthy weight.

iv) There were 3.4% of children in Primary 1 (approx 5-years-old) in Scotland between 2011 and 2018 who experienced co-existing caries and obesity. The prevalence remained stable over the period 2011 to 2018, however, large inequalities existed at this early age.

v) The group with co-existing caries and obesity were less likely to attend the GDS even once in their first five years of life. Of those who did attend, children with co-existing conditions were less likely to receive prevention. Children with co-existing conditions were more likely to be referred to a DHSW but less likely to progress to a home visit where support could be provided.

vi) The reach of interventions involving dietary advice or signposting to community organisations delivering food/diet related community/voluntary organisations were, overall, similar in Primary 1 (approx 5-years-old) children in Scotland with co-existing caries and obesity and neither condition. However, the reach of dietary advice varied between GDS and DHSW in the groups. Children receiving more doses of dietary advice from the GDS reduced the risk of co-existing conditions.

A sequential review of key findings from each chapter will be presented individually, followed by a comprehensive analysis relating the thesis findings to literature in context.

8.2 Explanations and Interpretations of Caries Experience in Primary 1 Children in Scotland

The aim of this chapter was to explore trends and inequalities in caries experience of children in Primary 1 living in Scotland. These analyses used routinely collected data from NDIP over seven years to construct a cohort of children and examined trends in prevalence and inequalities over time.

This thesis found a reduction in caries prevalence overall within Scotland between 2011/12 and 2017/18. Prevalence of caries experience has followed a similar trend for males and females, although males have had a consistently higher prevalence over the cohort years albeit by a small amount. Caries prevalence reduced over time in children from all SIMD tenths. These results are consistent with the published NDIP reports (Macpherson et al., 2018), which include detailed epidemiology on dental caries prevalence in Primary 1 children since 2003. This provides confidence in the population-wide basic dental inspection data used in this thesis.

The relationship between caries experience and area-based deprivation has been widely reported (Locker, 2000; Peres et al., 2019; Watt et al., 1999). Harris et al. (2004) concluded that family income, low parental education, and parental occupation, which are all, to some degree, included as indicators for SIMD, albeit at the area level and not individual level, are risk factors in caries in deciduous teeth at 6-years-old. This thesis has found that caries experience was linked to area-based deprivation in Scotland, a finding which can be backed up by several previous studies conducted in Scotland. Monitoring programmes such as the NDIP programme have consistently published results which linked caries experience and area-based deprivation (Macpherson et al., 2018). An older repeated cross-sectional study in Scotland which used Carstairs scores from the 2001 census reported the same finding (Blair et al., 2013). This thesis adds to the existing literature in Scotland by analysing the association between caries and area-based deprivation in greater detail by focusing on SIMD tenths, instead of SIMD fifths (Macpherson et al., 2018) and Carstairs sevenths (Blair et al., 2013). Using SIMD tenths allows the identification of children from the very most deprived and very least deprived areas. Using SIMD tenths over SIMD fifths does come with its own warnings as it is possible that the use of SIMD tenths could stretch inequalities and potentially be misleading in direct comparison to other results. However, it also enables a finer analysis of children from the most disadvantages communities. No other study to the researcher's knowledge had reported on the SII and RII of caries experience data for these cohort years in Scotland. This thesis found that absolute inequalities (SII) slightly increased over time, although relative inequalities (RII) remained consistent. Two studies have published SII and RII on caries severity (dmft) using Scottish data (Blair et al., 2013; Macpherson et al., 2018) thus the results from these studies cannot be directly compared to the results presented in this thesis. Macpherson et al. (2018) found that the SII for caries severity (dmft) was 1.93 in 2017/18, which has reduced almost year on year (slight increase between 2015/16, SII 1.84, and 2017/18) since 2009/10 which recorded a SII of 2.42. RII has increased overall from 1.58 in 2009/10 to 1.71 in 2017/18, suggesting a rise in relative inequalities for the severity of caries (Macpherson et al., 2018). Since the time period for this thesis it has been found that the SII was 1.76 in 2019/20 and RII was 1.70 (Macpherson et al., 2020). Due to the challenges of the COVID-19 pandemic, no further SII and RII results have been reported. Although these results are not directly comparable with the results of this thesis, they do tell a similar story of the inequalities in dental caries in Scotland i.e., that there exists large inequalities among caries experience in Primary 1 children in Scotland.

Reducing health inequalities is an extremely difficult challenge for policy makers. Mackenbach (2011) argues that a programme alone cannot reduce relative health inequalities and wider socioeconomic policy or reform is required to tackle the underlying inequalities and level the relative health inequality gradient. Moreover, Mackenbach states that these inequalities can only be reduced further if governments have a democratic mandate which make necessary policy changes possible and that success of a programme could actually be determined by its ability to not increase inequalities, however programmes which can deliver improvement across all socioeconomic deprivation groups would be classed as successful. During the designing of the Childsmile programme, increasing inequalities was identified as a potential risk (Shaw et al., 2009). Whilst Childsmile has played an important role in reducing the prevalence of caries experience, this research shows that despite this, absolute inequalities have remained stable between 2011/12 and 2017/18, while relative inequalities have only slightly increased over the same period. To achieve an equal reduction in absolute and relative inequalities, interventions much reach equal proportions from both ends of the socioeconomic scale, whilst having the same impact on both sides. Both these conditions are extremely hard to accomplish. To reduce relative inequalities, interventions must have greater reach and/or effectiveness in those from the lower end of the socioeconomic scale (Mackenbach, 2015), an idea coined as proportionate universalism by Marmot et al. (2010). These arguments relate to non-changing relative inequalities, however, this thesis has noted increasing relative inequalities. Evidence has previously shown rising inequalities with reducing prevalence is not uncommon. Between the 1970s and 1990s, a decline in childhood mortality was accompanied by stable or increasing relative inequalities (Cleland et al., 1992; Minujin et al., 2003). Mackenbach (2015) argues that there is a strong case for aiming to reduce absolute inequalities, as with quick reducing prevalence, relative inequalities become extremely difficult to reduce, however, this argument takes place in the context of mortality, which is likely tougher to tackle, and does not discuss increasing relative inequalities. In the years of austerity since 2010, when there were dramatic changes to economic and fiscal policy in the UK (Marmot et al., 2020), Childsmile has not only been battling against inequalities in caries, but also growing wider socioeconomic inequalities (Marmot et al., 2020). Large scale policy changes would be required in many areas before national programmes, such as Childsmile, could have an impact on reducing inequalities (Mackenbach, 2011). In the past, caries prevention has mainly focused on oral health education, however, it has been reported that this approach is more likely to increase inequalities as they are more likely to be taken up by children and families from lesser deprived areas (S. Macintyre, 2007). Interventions which address wider environmental and social determinant issues are required, as well as a specific focus on those that need it most (Beeston et al., 2014). Aims to reduce caries experience must be multi-faceted and support wider community issues rather than just individual behaviour (Macpherson et al., 2019a).

National surveillance of caries experience in England is conducted by the National Dental Epidemiology Programme (Office for Health Improvement & Disparities, 2023). The 2019 report (for the school year 2018/19) found that caries prevalence was 23.4%. This was a decrease from the 2012 report (for the school year 2011/12) which reported a prevalence of 27.9% (Public Health England, 2020). These results are lower than the prevalence found in Scotland by this thesis (32.9% in 2011/12 and 29.5% in 2017/18). The National Dental Epidemiology Programme in England relies on an explicit opt-in consent which is likely to lead to less children from more deprived areas being included in the sample (Hunt et al., 2013), which could be a potential explanation for the higher prevalence of caries in Scotland, however this is only likely to explain so much. Absolute inequalities were found to be lower in England 2019 (SII 26.8%) (Public Health England, 2020), whilst this thesis found a SII of 36.9% in 2017/18 (the end point of this thesis). Health inequalities are commonly reported to be higher in Scotland than in England, with healthy life expectancy being reported to be the lower in Scotland than the rest of the UK and also in areas with similar socioeconomic status (National Records Scotland, 2022; Office for National Statistics, 2022), particularly so in Glasgow where it worse than in areas, such as Liverpool, Manchester, and Belfast, with similar socioeconomic deprivation (D. Walsh et al., 2016). It is possible caries is following the same trend.

The COVID-19 pandemic will likely impact the caries experience of young children in Scotland. In the last NDIP report before the pandemic published in 2020, 73.5% of Primary 1 children were caries free, continuing the improvement in the prevalence of caries reported by previous NDIP reports and this thesis (Macpherson et al., 2020). The prevalence of caries decreased over all SIMD fifths, however absolute inequalities remained unchanged as the prevalence decreased at a similar rate at both ends of the socioeconomic scale. Only one NDIP report has been published which has included data on Primary 1 (approx 5-years-old) children in Scotland post COVID-19 when access to schools to for NDIP was not permitted. The detailed inspection was postponed for this report and only the basic inspection of Primary 1 was conducted (Conway et al., 2022). The inspection managed to capture 76% (usually around 88%) of all Primary 1 children despite challenges that remained due to the pandemic. From this inspection it was found that 73.1% of children in Primary 1 had no obvious caries experience (Conway et al., 2022). This follows the increasing trend in the prevalence of children with no caries experience, continuing on from the 70.5% in 2017/18 in

Scotland (Section 3.4.2). Absolute differences in inequality have remained large with the prevalence of no caries experience being 58.4% in SIMD 1 (20% most deprived areas) versus 85.8% in SIMD 5 (20% least deprived areas), giving a difference of 27.4%. This thesis found that the estimates for this in 2017/18 were 54.9% in SIMD 1 and 84.8% in SIMD 5, a difference of 29.9% (results permuted from Section 3.4.5). As no detailed inspection was conducted in this year, SII and RII for caries severity were not calculated. The COVID-19 pandemic seems to have stalled the decreasing prevalence of caries in Primary 1 children Scotland, a trend which started in 2003/04 (Macpherson et al., 2018).

8.3 Explanations and Interpretations of body mass index Status in Primary 1 Children in Scotland

The prevalence of underweight, healthy weight, overweight, and obesity in the present thesis were similar to the published national surveillance reports, so too were the absolute differences in prevalence between the most and least deprived (Information Services Division Scotland, 2018a), however, deprivation was measured in SIMD tenths in this thesis but SIMD fifths in the national reports. The published reports fall short of examining inequalities statistically, which is where the present thesis adds to the evidence base compared with previous reports.

8.3.1 Explanations and interpretations relating to underweight

This thesis has shown a very slight decrease in the prevalence of underweight amongst 5-year-old children in Scotland between 2011/12 and 2017/18. The prevalence difference between males and females has been consistent through the cohort years and there was no clear social gradient. When looking at the prevalence across the SIMD tenths, there is a lot of fluctuation. This is likely due to the small number of children with underweight in each tenth and year. There was little change in risk of underweight in 2011/12 versus 2017/18, with no trend evident in the SII and RII over the years. BMI being linked with socioeconomic measures has been long reported (Chi et al., 2017) and this thesis adds to the evidence.

There are no other data to the researcher's knowledge on the prevalence and inequalities of underweight children during the years of austerity. Despite increasing concern over the public health impact of the increasing levels of child poverty (Scottish Government, 2020a), food insecurity and the use of food banks in the UK since the introduction of austerity policy (Marmot et al., 2020), there is very little evidence on the prevalence, trends, and inequalities in childhood underweight. The prevalence of underweight across the seven cohort years of Primary 1 children in Scotland was consistently low relative to the UK 1990 references, with no evidence of an increase or decrease and no clear social gradient observed over the period. These results for underweight are best taken with caution due to the small sample size of children with underweight in this cohort of children. Any misclassification of children with BMI SDS close to the cut-off for underweight could drastically change the results presented in this thesis.

Awareness of the burden of underweight, which was considered a historical child health issue in the UK, has only recently increased, and there has been a perception that early childhood underweight is a public health problem for low- and- middle-income countries rather than high-income countries (Branca et al., 2020). As a result, there are relatively few similar studies from high-income countries which can be compared against the findings of the present thesis. The dearth of evidence also means that the associated social inequalities are poorly understood. Further research will be required to understand why social inequalities in early childhood underweight appear to have decreased in Scotland from the late 1990s (Armstrong et al., 2003) to 2011/12 (present thesis), and then remained relatively stable from 2011/12 to 2017/18. In a previous Scottish cross-sectional study of social inequalities in underweight in early childhood which used routinely collected data from 1998/99, there was a marked social patterning of underweight in those years (Armstrong et al., 2003). The one-off study by Armstrong et al. (2003) accessed health data for approximately 80% of the preschool population in Scotland in 1998/99, using Carstairs Deprivation Category (Carstairs et al., 1990) as an area-based socioeconomic measure. Measures of underweight were taken at 39 to 42 months (between 3- and- 3.5-years old). In the cohort, 3.3% of children were recorded as having underweight, a considerably higher prevalence than in this present thesis, however, the children were younger than the children included in this thesis. The study also found a social gradient in the prevalence of underweight. The monitoring programme for BMI, the CHSP-S programme, has previously reported very little inequalities in children with underweight between children from the most and least deprived areas. In 2011/12 the absolute differences in prevalence was 0.1% (1.3% in SIMD 1 versus 1.2% in SIMD 5). The difference was then the same in 2017/18, however, with children from SIMD 5 having the higher prevalence (1.0% in SIMD 1 versus 1.1% in SIMD 5). Differences this small have been observed in the most recent monitoring publication (Public Health Scotland, 2022b). The author is not aware of any other Scottish trend analysis of data in social patterning in childhood underweight.

White et al. (2016) in an earlier analysis of routine data from children aged 5- and-11-years-old in England showed a stable prevalence and stable inequalities in the population with underweight, similar to the present thesis. The data from England was collected on an opt-in consent basis, which usually skews data towards children from the least deprived areas being more likely to participate (Hunt et al., 2013). A slightly higher, and increasing, RII between 2007/08 and 2011/12 was found in the English data than this present thesis, however the RII estimate includes both 5- and-11-years-old children so it is not possible to directly compare these estimates. Much of the analysis by White et al. (2016) combined both age groups for the prevalence and inequalities in underweight.

8.3.2 Explanations and interpretations relating to obesity

This thesis has found that while the overall prevalence of obesity plateaued between 2011 and 2018, both absolute and relative inequalities have increased (Section 4.4.7.2) indicating a masking of increased prevalence in children from the most deprived areas. Further research will be required to understand why social inequalities in early childhood obesity increased in Scotland (and England (White et al., 2016)) over the decade of austerity in the UK as suggested by the present thesis. BMI being linked with socioeconomic factors or area-based deprivation has been long reported (Chi et al., 2017) and this thesis adds to the evidence. Although it is difficult to attribute causality, this report strongly suggests that a decade of austerity has adversely impacted on the social determinants of health in the short, medium, and long term, with the impact of child poverty most likely showing their effects on long term health outcomes (Marmot et al., 2020). Within the last decade in Scotland there have been changes to mortality rates that have never been witnessed before. Since 2012, improvements to mortality rates have either slowed or stopped, with death rates in the 20% most deprived areas increasing, with evidence linking these negative outcomes to austerity in the UK (D. Walsh et al., 2023). A slowing of previous increases in childhood obesity prevalence in the past decade has been observed in other high-income countries, probably due to increased awareness of the problem and/or public policy efforts (Hardy et al., 2017; Reilly et al., 2011). However, this thesis shows that childhood obesity over the past decade in Scotland has not only increased in prevalence in children from the most deprived areas but marked widening of inequalities have emerged over the socioeconomic status distribution. Reducing health inequalities is a high priority of public health policy in the UK. In future years these inequalities will contribute to further inequalities in non-communicable diseases given the well-established comorbidities of childhood obesity, such as diabetes and heart disease (Hardy et al., 2017; Reilly et al., 2011). The period of austerity in the UK led to sweeping cuts to social security which in turn led to increases in poverty, particularly children living in poverty. This was in addition to cuts in NHS funding and local budget cuts in Scotland, which the evidence presented by D. Walsh et al. (2023) support thesis hypotheses that these widening inequalities could be driven by austerity. In England, Sure Start children's centres were local authority run essential community-based centres across the country targeting young children (under 5-years-old) and their families in order improve health and reduce the risk of obesity (Mason et al., 2021). Initial evaluation of this programme reported mixed results (Melhuish et al., 2008), however children in areas with a centre were less likely to have overweight than children in areas without centres (Sammons et al., 2015). Since the introduction of austerity, spending on the programme has reduced by 53% , which Mason et al. (2021) estimate there was an additional 4,575 (95% CI: 1,751 to 7,399) children with obesity and 9,174 (95% CI: 2,689 to 15,660) children with overweight or obesity with the current funding, compared to the expected numbers if the pre-austerity levels of funding had been preserved.

Due to austerity cuts, and other social issues such as ones caused by the COVID-19 pandemic, there has been a marked increase in food insecurity and the use of food banks in the UK (Scottish Government, 2022c; The Trussell Trust, 2023a), with the rise in use of food banks being directly linked to cuts from local authorities and central welfare spending (Loopstra et al., 2015). Food insecurity is the worry of running out of food, however, the definition may also include the nutritional quality of the food.

An estimated 9% of households in Scotland experienced food insecurity (worried about running out of food) in 2021, with 34% of single parents having this worry (Scottish Government, 2022c). Food insecurity has led to the Trussell Trust network providing 259,744 emergency food parcels across the UK in 2022/23, a 30% increase from 2021/22 (The Trussell Trust, 2023a). Children from food insecure homes have an increased risk of developing obesity later in life (Speirs et al., 2016). The more healthier foods can be more expensive in supermarkets leading to less purchases of nutrient foods and more purchases of higher sugary foods, with sugary foods providing more calories per unit cost (Drewnowski, 2010; Drewnowski et al., 2005). To follow the NHS EatWell Guide, families in the 10% lowest income households would be required to spend around 75% of their income on food, compared to just under 20% in middle income households and 5% for the 10% highest earning households (Food Foundation, 2019). Food parcels from food banks are unlikely to contain any fresh fruit or vegetable but are likely to contained processed foods and food with high sugar content (e.g., biscuits, fruit juices, and tinned fruit) (The Trussell Trust, 2023b). A survey of nurseries in England found that managers in nurseries from the third most deprived areas in England were more likely to perceive food insecurity and obesity as issues within their establishment than managers in nurseries from the third least deprived areas (Benjamin-Neelon et al., 2017). Given food insecurity and obesity are both associated with socioeconomic deprivation, a combination of these two problems in likely to compound effects, particularly now after the COVID-19 pandemic (Tester et al., 2020).

There are multiple reasons that obesity can occur in childhood, with a bio-socioecological framework able to explain the development of obesity in the modern age (Jebeile et al., 2022). Drivers of this include biological tendency, socioeconomic factors, and environmental factors. One of these socioeconomic factors includes the socioeconomic status of the family, but also area affects (Jebeile et al., 2022). This thesis adds to this evidence showing area-based socioeconomic deprivation is associated with obesity. The study by Armstrong et al. (2003) previously mentioned found a lower prevalence of obesity (8.5%) although this study was conducted in 2003 and on the Scottish National Preschool Child Health Surveillance System data from children, aged 3- to-3.5-years-old, roughly a year younger than the children in the present thesis. Similar prevalence of socioeconomic inequalities were observed despite the use of Carstairs index sevenths of deprivation in the 2003 study and SIMD tenths in this thesis. The main drivers of obesity can be categorised into six categories, which appear in order of scale: Public policy, Society; Community and built environment; Child care and school; Family and peers; Individual (Jebeile et al., 2022). Mackenbach (2011) argues that the public policy risks must first be reduced before the individual risks can be reduced. Wider public policy would include policies and investment in availability (cost and availability) of food, transport, media influence and marketing, and wider agriculture. General society and local communities can help individuals through policy, for example, safe spaces to exercise, reducing number of fast food restaurants, and making food available, and good access to primary health care (Jebeile et al., 2022). Furthermore, socioeconomic policy includes the Soft Drink Industry Levy ('sugar tax') or fatty food tax as well as policies around commercial determinants such a food pricing, regulation, and labelling. Once these wider socioecological issues have been resolved, or at least improved, can the individual make necessary changes to their behaviour to reduce risk of obesity and increase general health. The Childsmile programme fits to all these categories through mandated dental inspections in schools through public policy, aiming to change wider societal behavioural towards diet and oral health, providing community support through DHSWs, providing nursery supervised toothbrushing and free toothbrushes and toothpastes in nursery and school, and providing support to the family and individually from in the GDS and from DHSWs.

The COVID-19 pandemic was likely to have an effect on the prevalence of obesity in Scotland. Since the pandemic there have been two national publications which report on BMI status in Primary 1 children in Scotland, however one inspection was conducted immediately before the pandemic in 2019/20. The 2019/20 report was cut short due the start of the pandemic with a population coverage of only 41% (Public Health Scotland, 2020), compared to 88% in 2017/18 (Information Services Division Scotland, 2018a) and 76% in 2018/19 (Information Services Division Scotland, 2019a), however the report authors note that the 41% was a representative sample of Scotland. The prevalence of obesity in 2019/20 was found to be 10.4% (Public Health Scotland, 2020), which was similar to the prevalence found in this thesis between 2011/12 (9.8%) and 2017/18 (10.3%), continuing the stable trend in prevalence. The 2020/21 report, the first after the pandemic which captured 37% of the population in Primary 1, presented a considerable rise in prevalence of obesity increasing to 15.5% (Public Health Scotland, 2021b) although the prevalence in 2021/22 reduced to 11.7% (Public Health Scotland, 2022b). The 2021/22 report was able to capture 92% of the population in Primary 1. The increase in prevalence was seen across all SIMD fifths, however, absolute inequalities increased in 2020/21, with a 12.9% difference between children living in the 20% most deprived (21.3%) and 20% least deprived areas (8.4%). Absolute inequalities were 8.2% in 2021/22 (15.5% in SIMD 1 and 7.3% in SIMD 5). It should be noted that the results in the 2020/21 report should be interpreted with caution given the smaller coverage and the fact that there was a higher percentage of children aged 6-years-old included in the sample (9.1% in 2020/21 versus 1.4% in 2018/19). This difference should be minimal due to using age-standardised methods to measure BMI, however, the increased age gives a greater chance for obesity to develop. The difference in age was likely due to more reports being conducted later in the school year due some 'catch up' of measurements caused by the pandemic (Public Health Scotland, 2021a). The 2020/21 inspection also included more children than usual from NHS Greater Glasgow & Clyde where prevalence of obesity has been known to be greater given the higher levels of socioeconomic deprivation in this Health Board. These differences in the sample may partly explain the sudden and large increase in the prevalence of obesity between 2011/12 to 2019/20 and 2020/21. The 2021/22 report returned to a more 'normal' method of coverage. Future publications will be required to understand the full impact of COVID-19 in childhood obesity.

PHS has developed a "systems-based approach to diet and healthy weight" (Public Health Scotland, 2022a). This has taken on a whole system approach, adhering to the Scottish Government's aim to halve childhood obesity and reduce inequalities by 2030. The Scottish Government, Food Standards Scotland, Obesity Action Scotland, and PHS aim to work collaboratively to pilot the whole systems approach and have agreed to identify local problems to address in four whole systems approach areas. All areas involved adopted a whole systems approach with three main components which were to develop health priorities, the creation of PHS, and the development of the whole systems approach to wider public health (Public Health Scotland, 2022a). Instead of thinking of health problems on an individual level, the whole system approach shifts focus to understanding the complexity of health conditions through wider systems, organisations, and environments. Public Health Scotland (2022) note a whole systems approach involves developing methods and practices to better understand of public health challenges and identify actions for a range of stakeholders to collaborate.

There were a range of recommendations published which included communication of preliminary findings, development of a bespoke model for Scotland, incorporating the model into guidance, avoid the reliance on people who participate in events, setting up working groups, identify the responsibilities of national, regional, and local levels in implementing the model, identify appropriate geographic levels, identify a future normal way of working, and understanding that it takes time to see outcomes (Public Health Scotland, 2022c). The report authors note progress has been made applying a whole systems approach, however, many of the desired outcomes are yet to be met.

8.4 Explanations and Interpretations of the Association Between Caries Experience and body mass index Status in Primary 1 Children in Scotland

8.4.1 Explanations relating to shape of relationship

The association between caries and BMI status was shown to have change shape over the research period (2011 to 2018). Initially, there was a U-shaped relationship, followed by a J-shaped before the U-shaped curve re-appeared and established itself. This backs up the double-burden of underweight and obesity presented in Chapter 4. Public Health England, in 2019, published a report on the association between caries experience and BMI status in 5-year-old children in the school year 2016/17 using data from the National Dental Epidemiology Programme and National Child Measurement Programme (Public Health England, 2019). This report found a similar shape and trend of relationship to this thesis, where children with obesity had the highest prevalence of caries experience, followed by underweight. The prevalence of caries in these two groups were 27.5% and 26.8%, respectively, although, both the data and obesity source programmes in England at the time used an opt-in consent system which generally include less children from more socioeconomically deprived backgrounds (Conway et al., 2008; Lorant et al., 2007; Roberts et al., 2020).

8.4.2 Explanations relating to the association

This thesis has shown a significant association between caries experience and obesity over the thesis time period (2011 to 2018). This finding has been previously identified in published studies. A systematic review by Manohar et al. (2020) found a significant association between caries and obesity in early childhood in cohort studies but not case-control studies. Only one study, out of nine included in the meta-analysis, was conducted in the United Kingdom (Kay et al., 2010). The cohort study, published in 2010, used data from ALSPAC (Golding et al., 2001) and measured caries and obesity of 985 children at 61-months-old (circa 5-years-old). The study found no evidence of an association between caries experience and BMI, however BMI was measured on a continuous scale, with reasons such as lower prevalence of caries than the wider population and a potential source of bias relating to a skewed social class representation in the sample as an explanation for this finding. This adds to evidence from Hooley et al. (2012), Hayden et al. (2013), and Alshihri et al. (2019) which all show that different measures of BMI may lead to differing results in the association between caries and obesity. The systematic review by Manohar et al. (2020) reports significant associations between caries and obesity were found in studies published in Sweden (children aged 6-years-old) (Alm et al., 2011), India (3- to- 6-years-old) (Bhoomika et al., 2013), Canada (2- to- 6-years-old) (Davidson et al., 2016), United States of America (birth to 5-years-old) (Marshall et al., 2007), and Brazil (birth to 6-years-old) (Ribeiro et al., 2017), however, these included a mix of continuous and categorical BMI. One further study published in Iran (2- to- 4-years-old) found no association using a continuous measure for BMI (Porhashemi et al., 2016). A further cross-sectional study from the USA utilised data for 2,775 children aged 2- to- 5-years-old from the National Health and Nutrition Examination Survey between 2011 to 2018 (Piovesan et al., 2022). The relationship between caries experience, defined as dft, and obesity was explored using different international standards to define obesity: World Health Organization; Centre for Disease Control and Prevention; International Obesity Task Force. After adjusting for sex, age, race/ethnicity, family socioeconomic status, child intake of added sugar, and total energy intake, there was no significant association between caries experience and obesity in any of the obesity cut-offs used. Piovesan et al. (2022) note that children in this sample were more likely to be White, older, have healthy weight, and have more educated parents than the excluded children, which means the sample is unlikely to be representative of the wider population in the USA. The authors of the study further mention that data was not available on missing teeth which may mean the prevalence of caries experience is underestimated, furthermore, the dietary assessment was self-reported which may not be accurate.

Paisi et al. (2019) published a systematic review of body mass index and dental caries in young people aged 1- to- 18-years-old. This review included studies with significant heterogeneity in the results and so no meta-analysis could be conducted. No significant associations were found between caries and BMI, however, two of the less flawed studies included in the review found a positive relationship between caries and BMI, both of which were conducted in India.

A cross-sectional study conducted in England, published in 2020, found no linear association between caries and obesity when adjusting for confounders: area-based deprivation, dental attendance, lone parenthood, white ethnicity, and living in areas of fluoridated water (Ravaghi et al., 2020). Caries was defined by the dmft index and treated numerically which is a key difference between this study and the thesis which only has caries prevalence rather than severity. A further cross-sectional study published in 2018 used data of 347 children aged 4- to- 6-years-old in Plymouth, England (Paisi et al., 2018), and found no significant association between caries and BMI (OR=1.14; 95% CI: 0.96 to 1.34; p=0.13), however, it highlighted the effect area-based deprivation has on both caries and BMI. It is worth noting that the odds ratio reported by Paisi et al. (2018) is similar to the odds ratio identified in this thesis after adjusting for area-based deprivation but before exploring interactions (aOR=1.13; 95% CI: 1.10 to 1.16; p<0.001) so it is possible with a higher powered study that an association would have been identified.

A systematic review and meta-analysis by Hayden et al. (2013) found a small overall association between obesity and caries in the permanent dentition, in which the prevalence of caries was higher in children with obesity than children with healthy weight. No such association was reported in the primary dentition. It as not possible to analyse permanent dentition in this thesis due to the age of the children (approx 5-years-old) in the data used. The review by Hayden et al. (2013) included 14 studies, none of which were conducted in the UK. The studies included had a wide age range, from 12-months-old to 18-years-old. Due to the progressive nature of obesity and caries, the authors of the review suggested that the association may increase with age. This thesis found a significant association at 5-years-old, and an increase with age (4- and-6-years-old; Chapters 3 and 4), albeit a narrow/young age gap, which may mean that the association may increase with age.

There are very few studies which investigate the common risk factors of obesity and caries. Most studies focus on these separately. Studies by Harris et al. (2004) and Reilly et al. (2005) have focused on the risk factors of caries in children under 6-years-old and obesity in children aged 7-years, respectively. Many more risk factors were identified for caries than the eight identified for obesity in children. Out of these multiple risk factors, only sleep duration and duration watching television were reported as risk factors in both studies/conditions.

This thesis is not the first time that caries and obesity has been linked using Scottish data, however it is the first since 2006 and at a national level. A small cross-sectional study of 165 children aged 3- to- 11-years-old (mean age 5.7-years-old) attending Glasgow Dental Hospital for a tooth extraction was conducted by Cameron et al. (2006). All children in this study had caries with a dmft between 1 and 20 and were grouped by dmft index into two groups: 1-7 and 8-20, with BMI measurements standardised using Cole's UK 1990 reference curves (Section 1.4.1, Cole et al., 1995). The study found that children who had more severe caries (dmft 8 to 20) had a lower BMI SDS than children with less severe caries (dmft 1 to 7). This sample is not representative of the Scottish population given that every child included had caries and 71% of the sample were from the two most deprived sevenths (measured using Carstairs index). The thesis found a positive association between caries and BMI SDS, a result that is more common in Europe and USA than in other parts of the world. Studies from Asia and South America were more likely to find an inverse association and studies conducted in USA, South America and Europe were likely to find no association (Hooley et al., 2012). Hooley et al. (2012) suggests that higher standards of living and access to dental care can play a major role in the different results from different parts of the world. Studies from developing countries, as well as countries with severe dental caries, were more likely to find an inverse relationship, where either higher caries were associated with lower BMI or vice versa. Furthermore, more similar to the results of this thesis, one cross-sectional study on children age 8- to- 12-years-old in India found a U-shaped association, with both high and low BMI found to be associated with caries

(Sharma et al., 2009). One reason why systematic reviews struggle to reach definitive conclusions about the relationship between the two conditions is that while some studies considered socioeconomic status as a factor, the specific systematic review conducted by Hooley et al. (2012) did not include any studies which explored the possibility of socioeconomic status influencing the association between caries and obesity. However, this thesis discovered a noteworthy impact of area-based socioeconomic deprivation on this association, whereby children in Scotland with obesity experience different odds of caries depending on their area-based deprivation (Section 5.4.2).

Hooley et al. (2012) suggested a non-linear relationship between caries and BMI, which is another possible reason for inconsistent results for the association. The systematic review has shown that children with underweight are at a higher risk of caries, a result replicated in this thesis, but with differences in odds of caries across SIMD fifths. Children with underweight experience the same reduced salivary flow found in those with obesity which could promote the development of caries (Psoter et al., 2005). Underweight in the past has been under represented in studies and although this present thesis is population-based, there has been a reducing prevalence of underweight in Scotland between 2011 and 2018 (Chapter 4). This in turn has lead to large uncertainty in the underweight results from which it is hard to draw meaningful conclusions in this group. Due to this under representation, other studies have combined underweight within the healthy weight category (Hooley et al., 2012), leading to inaccurate results due to the potential masking of nature of the relationship. Alshihri et al. (2019), more recently, provided opinions of the inconsistent findings in the association between caries and obesity. Reasons provided are limited study design and/or statistical analyses, small sample size, anthropometric measures (BMI measured continuously or categorised), caries diagnoses (dmft or dmfs), and age and gender of sample.

A more recent population-based retrospective study in New Zealand measured caries status as well as BMI in 27,333 children aged 5-years-old between January 2014 and December 2015 (Aung et al., 2021). It was found that the prevalence of caries was higher in children with overweight or obesity. This analysis was repeated but grouped by ethnicity, which found that the association was only observed in children previously from Europe who had moved to New Zealand. This reaffirms the findings of Hooley et al. (2012) that positive associations are more common in studies conducted in Europe and makes sense in context of this thesis that there was a positive association found in children in Scotland where 92% of the population in Scotland report their ethnicity as White Scottish or British (Scottish Government, 2021).

8.4.3 Explanations relating to the modifying effect of area-based deprivation

The modifying effect of area-based deprivation on the association between caries and BMI was evident in the results published in this thesis, where children from SIMD 2 to 5 areas with obesity had higher odds of caries but children from SIMD 1 areas had no increased odds. To the author's best knowledge, there are no studies which have tested for an interaction involving socioeconomic status for young children, however the suggestion of a modifying effect has been supported by various systematic reviews (Hayden et al., 2013; Paisi et al., 2019) and cross-sectional studies (Paisi et al., 2018; Piovesan et al., 2022). There has been some suggestions as to reasons for the effect of socioeconomic status on the association between caries and obesity. Hayden et al. (2013) has suggested the consumption of refined foods may explain some of the effect, and Paisi et al. (2018) suggested dietary habits as a possible reason. Paisi et al. (2018) also considered the association between sugary food and obesity, although no association was found. Suggested reasons for this was either the reliance on self-reported dietary information or the recording of consumption frequency rather than actual quantities consumed. Other reasons for the lack of evidence between sugar in the interrelationship may be due to limitations of studies, or potentially to more sinister suppressing of evidence as proposed by Kearns et al. (2019). However, despite this, sugar sweetened beverages (SSBs) have been linked to obesity (Malik et al., 2013). A systematic review on the relationship between SSBss and body weight in children and adults by Malik et al. (2013) found that in randomised control trials in children identified a reduction in BMI gain when consumption of SSBs were reduced. To the author's best knowledge, the most recent study to measure sugar intake across socioeconomic status groups in Scotland was the Survey of Diet Among Children 2010 (Masson et al., 2012). This survey found that in children aged 3- to- 16-years-old that children from the most and least socioeconomically deprived areas consumed the same amount of sugars in terms of percentage of total intake, however, children from the most deprived areas consumed more sugar in grams, mainly in the form of non-milk extrinsic sugars and sucrose. The dietary sugar came from different sources too, with children from the most deprived areas consuming more sugars through SSBs than those from the least deprived areas, whereas children from the least deprived areas consumed more sugars from biscuits, cakes, pastries, and whole fruit. This thesis did not have the data available to test for the dietary effect on the association between caries and BMI status, however, given the pivotal role of sugars in caries and obesity (Chi et al., 2017; Harris et al., 2004) and consumption linked to socioeconomic status (Masson et al., 2012) it is likely that diet would explain some of the modifying effect that area-based deprivation had on the association between caries experience and obesity found in this thesis.

Another possible explanation for the association between caries and BMI status being modified by area-based deprivation could be toothbrushing with fluoride toothpaste. A previous PhD thesis from Scotland has shown that children from most deprived areas were more likely to consent to the supervised toothbrushing as part of the Childsmile programme (Kidd, 2019). This finding does not take into account toothbrushing at home, which could help explain the higher prevalence of caries in children from more deprived areas. Prevalence of twice-a-day toothbrushing in Scotland, in 2014, was reported to be higher in children from the least deprived areas compared to the most deprived areas (Levin et al., 2014). It is likely that a combination of diet and toothbrushing would explain the effect that area-based deprivation has on the association between caries and obesity, however, this does not explain the effect of area-based deprivation on the association between caries and obesity found in this thesis which showed children with obesity living in SIMD 2 to 5 areas having higher odds of caries than children with healthy weight but no extra odds for children with obesity living in SIMD 1 areas (Section 5.4.2). Further research into dietary and toothbrushing and toothpaste behaviours would be required to explain the association.

It has been reported that both caries and obesity in children share common risk factors. Uerlich et al. (2021) reported that four risk factors had a direct influence on both caries and BMI in childhood (mean age 5.7-years-old). The cohort study was on 171 children from the Born in Bradford cohort (Born in Bradford, 2017) in 2014/15. These were: alcohol consumption of mother after birth, frequency of child consuming SSBs, emotional and behavioural difficulties, and being male. This is in addition to the already established common risk factors diet and social determinants (Sheiham et al., 2000; Watt, 2012). Uerlich et al. (2021) noted large missing data in their study and as such data imputation was used, although the data for obesity and caries was complete. There was a reverse sex split to the present thesis i.e., more females than males in the sample compared to more males than females in this thesis.

8.5 Explanations and Interpretations of Co-existing Conditions in Primary 1 Children in Scotland

The prevalence of co-existing caries and obesity remained stable throughout the cohort years (2011 to 2018). To the researcher's best knowledge no other study has focused on co-existing caries and obesity continually over this time period in Scotland or the rest of the UK. Previous publications from Public Health England have reported on the association between caries and obesity in 2016/17 (Public Health England, 2019), for which the prevalence of co-existing conditions could be calculated. Prevalence of co-existing conditions was 2.4% (n=1,600/67,003). This was lower than the 3.4% found in this thesis. The data used in England were obtained via opt-in consent which generally include less children from more socioeconomically deprived areas (Conway et al., 2008; Lorant et al., 2007; Roberts et al., 2020), which limits direct comparisons. A recent thesis by Uerlich (2020), using data from the Born in Bradford study (Born in Bradford, 2017), showed a prevalence of 3.5% (n=6/171) in 2014/15, which is more consistent with the results of this thesis although this was only a one year estimate. The thesis by Uerlich (2020) had a very small sample size (n=171) and only from one specific area in England.

Very few studies have been published recently around the world which estimated the prevalence of co-existing caries and obesity or at least could be calculated from the data available. National survey data from the United States of America has been previously used to estimate the prevalence of co-existing conditions, however, the last study was published in 2008 and used data from 1999 to 2002. Prevalence of co-existing conditions in 2- to- 5-year-old children was circa 3.9% (∼56/1,449) (Kopycka-Kedzierawski et al., 2008). These data only included dental caries in primary dentition. Although with such a large time difference between the cohorts (9 years difference between end point of study and start point of the research) and geographical differences (USA in the study versus Scotland in this thesis) it is difficult to compare these results. Other countries have more recently published the prevalence of co-existing conditions. A prevalence of 3.8% (14/373) was reported in a small cross-sectional study in Greenland among children born in 2005 to 2007 with a median age of 6.6-years-old, the time when outcomes were measured (Madsen et al., 2017). Prevalence of dental caries was higher (57.1%) and obesity lower (5.1%) in this cohort despite a similar prevalence of co-existing conditions to the present thesis. A cross-sectional study from Greece reported a 0.5% prevalence of caries and obesity in children with a mean age of 4.2-years in from 2180 children aged 2.5- to 5.9-years-old in 2013, although there was a much lower prevalence of obesity (3.2%) and caries (10.0%) at this time than observed in Scotland (Pikramenou et al., 2016).

This thesis has found significant and consistent socioeconomic inequalities in the prevalence of co-existing childhood caries and obesity during the research time period, which remained consistently large over time (2011-2018). These children with co-existing conditions have compounded needs and potential preventive interventions utilising the common risk factor approach could be developed (Sheiham et al., 2000; Watt, 2012). However, this group has not previously been identified as an important target/priority group for the Childsmile programme in Scotland and there is a need to identify the risk factors of this group. To the author's best knowledge there are no studies to estimate the inequalities in children with co-existing caries and obesity.

8.6 Explanations and Interpretations of the Reach and Impact of the Childsmile Programme

The primary goal of the Childsmile programme is to reduce inequalities in oral health. Its objective is to enhance the overall well-being of children from birth to 5-years-old in Scotland by addressing oral health concerns. According to the programme's theory, outlined in the Logic Model (Section 1.9.6), Childsmile should strive to enhance both oral and general health by utilising the common risk factor approach, particularly in relation to dietary sugar (Sheiham et al., 2000). Consequently, the programme anticipates long-term benefits such as reduced obesity rates, in addition to its primary focus on preventing dental caries. This analysis started with Primary 1 children and looked retrospectively back to birth to compare the reach of various interventions in this group to that of their peers with neither condition. Additionally, this chapter looked prospectively from birth to assess if children having Childsmile dietary interventions delivered by the programme were less at risk of co-existing conditions than children not receiving any dietary interventions.

8.6.1 Reach of general dental services among children with co-existing conditions

All children in Scotland should be able to register and attend a “high-street” general dental practitioner in the General Dental Services (GDS) within their first year of life (Childsmile, 2020). Attendance at the GDS could be for any reason and with or without preventive care or intervention. Since 2010, Scotland has a lifetime registration policy in the GDS which means patients only require to attend the GDS once to maintain lifetime registration, although practitioners can deregister patients. Registration with the GDS is not necessarily a good marker of dental attendance, therefore the participation measure (attending a least once within a five year period) was introduced (Information Services Division Scotland, 2018c). Roughly 90% of children aged 3- to- 5-years were registered with the GDS between 2013 and 2019, however this was estimated at 73.1% in September 2022, which is the lowest recorded rate for this group (Public Health Scotland, 2023a). Registration nears 100% in children aged 6- to- 12-years-old which correspond with children receiving a NDIP inspection at Primary 1 (roughly 5-years-old) and then receiving the results of these with the hope that families contact the GDS to arrange an appointment where necessary or continue usual care in the GDS. The NDIP programme was paused for 2020/21 and limited in 2021/22 which may explain the reduced registration rate (Public Health Scotland, 2023a). Whilst registration with the GDS was high, between 2012 and 2020, national reports showed that participation of children aged 3-to- 5-years-old with the GDS, given that they were registered, was roughly 90.0%, however, this has reduced to around 51.5% by early 2022 but recovered to 70.6% in September 2022 (Public Health Scotland, 2023a). This thesis found that overall child attendance, at least once in the child’s first 5 years of life, in the GDS was 91.4% between 2015/16 and 2017/18, however children with co-existing caries and obesity were less likely to attend at least once within their first

5 years of life, even when adjusted for SIMD, which is known to affect attendance with the GDS, with those from the most deprived areas having the lowest level of attendance (Information Services Division Scotland, 2018c). Whilst families are recommended to attend the GDS twice per year, it is important to understand if families are taking their children in the first place to then begin dialogue with the dentist or dental nurses around their child's oral health. Previous work has suggested that Childsmile DHSWs have been successful in getting targeted children from more socioeconomically deprived areas into dental practices at a younger age (Hodgins et al., 2018), however, area-based deprivation was unable to explain all differences. Previous reports have highlighted the increase in initial registration with the GDS (Information Services Division Scotland, 2018c), although an ongoing challenge may be maintaining this dental service contact as the child gets older.

8.6.2 Reach of Childsmile prevention interventions in the GDS among children with co-existing conditions

The Childsmile prevention interventions in the GDS are a universal component of the Childsmile Programme, meaning that all children should attend the GDS and should receive the preventive interventions regardless of socioeconomic status. This thesis found that children with co-existing conditions were less likely to have ever received Childsmile prevention intervention in the GDS than children with neither condition, given that they had attended the GDS at least once, even after adjusting for other confounders. Childsmile monitoring reports have shown that participation with Childsmile prevention interventions at GDS has increased over the years for each intervention (dietary advice, toothbrushing instruction, and fluoride varnish application) (Central Evaluation & Research Team, 2018), although no aggregated total attendance was estimated. These reports, as well as the present thesis, have shown a relatively high proportion of children who do attend the GDS receive a Childsmile prevention intervention although there remains room for improvement. A previous study from Scotland using administrative data from 2014/15 reported a lower prevalence of children in Primary 1 receiving a Childsmile prevention intervention (71.0%) compared to this thesis (83.1%) (Kidd et al., 2020), however the analysis by Kidd et al. (2020) only used one cohort year which was outside this thesis time period which could explain some of the differences in participation. A further study using administrative data in Scotland from 2016/17 to 2018/19 found 83.6% of children in Primary 1 received Childsmile prevention interventions at least once in their first 5 years of life (Sherriff et al., 2022), which is very similar to the prevalence from this thesis.

8.6.3 Reach of Dental Health Support Workers among children with co-existing conditions

The DHSW component of the Childsmile programme is intended to be targeted to children who need it most. Theoretically, 20% of children would be targeted, with these children being from the 20% most deprived areas. In the present cohort, 23.5% of children have been targeted for a DHSW visit. These findings are similar to previous reports using national administrative data in Scotland (Kidd et al., 2020; Sherriff et al., 2022). It is difficult to compare this percentage to the Childsmile monitoring report as the sample size is not given, although just over 27,000 children were targeted for a DHSW visit over the study period (Central Evaluation & Research Team, 2018) compared to the roughly 23,000 in the present thesis. Children with co-existing conditions were more likely to have been targeted for a DHSW visit before and after adjusting for year, age, sex, and area-based deprivation. The magnitude of the effect reduced after adjusting, likely due to SIMD and as a result of targeting, although SIMD does not fully explain the relationship.

Whilst the DHSW role aims to serve 20% of the population within each NHS Health Board, the distribution of deprivation is not equal across Scotland. If operated as planned, the DHSW should be able to target all children from the 20% most deprived areas. However, there are higher concentrations of socioeconomic deprivation in NHS Greater Glasgow and Clyde in which 37% of the population live within the 20% most deprived areas compared to only 4% in NHS Grampian (Scottish Government, 2016a). The children most in need for interventions from a DHSW are those from the 20% most deprived areas in Scotland so using “within NHS Health Board SIMD” (rather than national-level SIMD) may not necessarily be the best approach for targeting. Health Visitors are able to refer any family to a DHSW based on the family’s circumstances, regardless of area-based deprivation. There was some evidence, albeit anecdotal, to suggest that in some areas all children in the community were being referred to a DHSW by the Health Visitor (Hodgins, 2017). This could potentially lead to resources being misplaced with families who do not require the support receiving the support instead of being signposted directly to the GDS by the Health Visitor. If the Health Visitor is able to better refer families to the GDS, then the limited resources of the DHSW can be used effectively to maximise impact and to ensure the families who require the intervention most receive it. However, both caries and obesity are progressive conditions which may have not yet manifested by the time of the DHSW intervention. It is likely that children classified as having co-existing conditions at Primary 1 did not have caries and/or obesity at the time of intervention and thus were not identified to require extra support from the DHSW, or even to be referred to a DHSW in the first instance.

A key component of the DHSW is being able to contact the family to perform a successful intervention, defined as when the DHSW is able to meet with the family at their home. Overall, 84.6% of all children who are referred to a DHSW are then successfully contacted. Despite being more likely to be referred, children with co-existing conditions were less likely to have had a successful contact than children with neither condition. The exact reason why these children do not have a successful contact in unclear, however reasons may include, but are not limited to, the family could not be contacted, family refusal, or DHSW not attempting to engage the family due to time constraints. These findings suggest work must be done to ensure children who require help are then seen by a DHSW. In these cases, time must be taken to inform and convince the family of the importance and potential of the DHSW intervention. Work by Hodgins et al. (2018) has shown that DHSW are able to link children into the GDS at a younger age than children who were not contacted. The work suggested that DHSW were able to improve the family's attitude towards oral health as the families must be motivated to attend the GDS moving forward. This motivation could lead to better oral health behaviours at home. A previous thesis has reported that DHSWs only have the resources to support families who were identified at being low- to- medium-risk of caries instead of those at highest risk of caries (Young, 2017). Therefore it is possible that the DHSW are unable to provide the necessary level of intervention to children with co-existing conditions. It is not known if the children with co-existing conditions identified in this thesis have a higher risk of caries than the rest of the cohort or the children with caries but not obesity, however, given that the prevalence of co-existing conditions have remained stable over the thesis time period, whilst caries prevalence overall has reduced, it shows that the caries is harder to prevent in this group.

8.6.4 Reach of nursery supervised toothbrushing programme among children with co-existing conditions

The intention of the nursery supervised toothbrushing component of Childsmile is to be delivered universally with the aim that 100% of nurseries participating across Scotland and that 100% of children have the opportunity to brush each day they attend a participating establishment. While the reach of the intervention overall falls a little short of its own target, over 95% of nurseries have been taking part in the programme since 2014/15. Overall 80.1% of the current cohort participated in the nursery supervised toothbrushing programme. This is lower than the participation prevalence found by Kidd (2019), however, differences in the way the toothbrushing consent is now recorded and derived can explain the differences. The prevalence in the thesis is similar to the population-based linkage analysis using Scottish data by Sherriff et al. (2022) in the analysis of reach of the Childsmile programme to children with additional support years between 2016/17 and 2018/19. There were no differences in the reach of the nursery supervised toothbrushing programme across the groups when adjusting for area-based deprivation, sex, year, and age, with children with co-existing conditions participating at a similar rate to children with neither condition. The nursery supervised toothbrushing programme will not have an affect on obesity so would not be a main focus for interventions to reduce the prevalence of co-existing caries and obesity.

8.6.5 Reach of fluoride varnish application in nursery and school among children with co-existing conditions

The application of fluoride varnish in nursery and school is targeted to nurseries and schools based on the proportion of children attending the establishment who live in more deprived areas. This thesis found that 44.2% of children in Primary 1 between

2015/16 and 2017/18 received at least one fluoride varnish application in nursery or school which is a similar result to Childsmile monitoring reports (Central Evaluation & Research Team, 2018) and previous studies using national administrative data in Scotland (Kidd, 2019; Sherriff et al., 2022). Children with co-existing conditions were more likely to receive a fluoride varnish application than children with neither condition before adjusting for confounders. After adjusting the association remains but to a lower magnitude. This is likely due to the SIMD effect as children from SIMD 1 were more likely to have co-existing conditions and were expected to be targeted more by the fluoride varnish application component. Despite this reduction in effect size, it appears that SIMD is not able to fully explain the association and that children with co-existing conditions were more likely to receive at least one fluoride varnish application in nursery or school than children with neither condition. This component is targeted to nurseries and schools and includes all children registered at the nursery or school with valid parent/carer consent. The intervention is unable to target children at an individual level thus children who should be targeted may miss out and children who would not be targeted (i.e., children from less socioeconomically deprived areas) may receive the fluoride varnish application. Previous research was conducted to identify the best way to target children, either: using national caries data to rank the schools in proportion of children with caries experience within each school and regional NHS Health Board; using local area-based deprivation measure of child's home postcode and ranks schools within regional NHS Health Board by proportion of children with home postcodes in the most deprived local quintile (local SIMD 1); using national caries data to rank the schools by the proportion of children with caries experience regardless of NHS Health Board; using area-based deprivation of child's home postcode to rank the schools by proportion of children with home postcodes in the 20% most deprived areas (SIMD 1) (Brewster et al., 2013). This cross-sectional study reported that in Scotland only circa 50% of those targeted by an intervention are deemed to be at higher risk and thus require the intervention. Creating a targeting approach which reached the majority of children who require the intervention is extremely difficult. Brewster et al. (2013) suggested that for the Childsmile programme the most appropriate method of targeting was based on area-based deprivation in comparison to using caries prevalence. Recent evidence has questioned the preventive effect of fluoride varnish on caries experience delivered via public health programmes (Sousa et al., 2019; Tickle et al., 2017), as well as the effectiveness and cost-effectiveness of the nursery fluoride varnish component as part of Childsmile (Anopa et al., 2022; McMahon et al., 2020). It should be noted that the fluoride varnish application will have no effect on the prevalence of obesity.

8.6.6 Reach of Childsmile overall among children with co-existing conditions

This thesis has found Childsmile programme overall was able to reach 97.7% of children at least once with at least one component during the child's first five years of life (Section 7.4). This was driven largely by the high attendance rates in the GDS for prevention interventions. The programme was slightly less likely to have reached children with co-existing conditions compared to children with neither condition. The difference could have been larger if not for the fluoride varnish at nursery or school component on the Childsmile programme, which was the only component included in this overall analysis which children with co-existing conditions were more likely to have received than children with neither condition, but is also an intervention which will have no impact on the prevalence of obesity. This analysis did not include children who were targeted by a DHSW but not seen as these children would have not actually received any intervention. The Childsmile prevention intervention received by children in dental practices was only applicable to those who had already attended a dental practice and thus did not contribute to expanding the overall reach of Childsmile.

8.6.7 Reach of dietary components of Childsmile among children with co-existing conditions

Dietary interventions are included in dental practices (brief dietary advice) and from DHSWs (brief dietary advice and signposting). Of children who attended the dental practice, 78.9% then received dietary advice in the practice, with a median of two interventions (mean 1.82) in the child's first five years of life. Children were able to receive any amount of dietary advice interventions at the dental practices although practices were only paid for one dietary advice intervention a year so the maximum was capped at five interventions. This thesis has shown that despite high attendance in the GDS, not all children received the advice. This would fall to the dental team to provide the dietary advice, however monitoring reports have shown that only 88.4% of dental practices were providing Childsmile interventions in 2017/18 and 86.0% in 2016/17 (no data for NHS Western Isles were available) (Central Evaluation & Research Team, 2017, 2018). This could help explain the fact that 21.1% of children who attended the GDS did not receive dietary advice. Although, there will also be children who attend the GDS for intervention/treatment where the delivery of dietary advice may not be appropriate at that time. It is not possible to tell the content and intensity of the advice given, or even in fact if delivered at all, however the data are checked for fraudulent claims to ensure accuracy. Childsmile monitoring reports publish information on the prevalence of dietary advice however these results are not directly comparable since the monitoring reports the age group into 0- to- 2-year-olds and 3- to- 5-year-olds and report on financial years (Central Evaluation & Research Team, 2018). Evidence to support the effectiveness of chair-side dietary advice is weak, there is some evidence from a systematic review that this type of intervention is effective at changing dietary behaviour, although there remains little evidence to suggest that this is beneficial to caries prevention outcomes (Harris et al., 2012). There is evidence from a systematic review to suggest that chair-side dietary advice does better when aimed at changing fruit and vegetable diet than interventions aimed at reducing sugar consumption, although this was across all ages and not focused on children (Harris et al., 2012). There is also the added dimension of delivering advice to parents/carers in order to change the behaviour of a child which is challenging.

Children received a median of one dietary advice intervention (mean 0.96) from a DHSW within the child's first five years of life. This coincides with the fact that most children who are seen by a DHSW are generally only seen once (Kidd, 2019). Of all children seen by a DHSW, 88.5% received dietary advice. In theory, all children who see a DHSW should receive dietary advice (Young, 2017), although it appears this is not the case in practice. DHSW appointments usually last around 20 minutes (Young, 2017), so it is possible that on some of the more challenging situations time runs out. That said, a DHSW may use their professional opinion to focus on other more pressing issues or believe the family does not need the dietary support. Children with co-existing conditions were more likely to have received dietary advice than children with neither conditions. It appears children who eventually do develop co-existing conditions have received dietary advice, which leads to questions around the interventions effectiveness.

The dietary advice given to families is very general and only motivated families may engage, whilst some families feel they are being lectured to (Young, 2017). It is also likely to only be delivered on one occasion which questions the effectiveness.

The signposting of families to relevant community/voluntary organisations is not a routine intervention by a DHSW and will only be delivered if the DHSW deems the family to require further support. This would explain the low percentage of families who are signposted to food/diet related organisations. In the RQ5 Cohort, 5.8% of children were signposted overall, although the median number of times children were signposted was 0 (mean 0.06). Signposting is generally carried out following environmental or verbal cues detected by DHSW and is mentioned during normal conversation (Young, 2017). Previous qualitative evidence has suggested that the low prevalence of signposting could be partly explained by the DHSW's lack of knowledge on signposting and also lack of recording of signposting as it may be done quite informally where the DHSW has not realised they have signposted (Young, 2017). Furthermore, community/voluntary organisations must be available in the local community to be signposted to. Regardless of reason, if families are not signposted to relevant organisations then they may not get the help that they require or DHSWs could be over-stretching themselves by providing help outwith their remit. The signposting/community linking component of the Childsmile programme is a key part of wider social prescribing which is where health practitioners refer patients with complex needs to receive support from wider community organisations (Kimberlee, 2015; South et al., 2008). Social prescribing can directly improve health outcomes, but also increase social contacts and networks within communities. Children with co-existing conditions were much less likely to have received signposting to a food/diet related community organisation from a DHSW and were also less likely to receive as many 'doses' of the signposting intervention. This result appears to show that children who ultimately do require help the most are not receiving available support. Care must be taken to ensure families are aware of the support available in the local community to try improve the prevalence of co-existing caries and obesity, however, given the progressive nature of both caries and obesity, it is possible that the need for support is not observed early in the life when the DHSW intervention takes place (roughly 4- to- 6-months old).

8.6.8 Impact of Childsmile dietary components among children with co-existing conditions

It was possible to estimate a risk for co-existing conditions compared to neither condition across different dietary interventions in the Childsmile programme. This analysis is unable to prove if the interventions prevented co-existing caries and obesity, only if the interventions were associated with the outcome due to not knowing when caries and obesity developed, only that it was present in Primary 1 (approx 5-years-old). The analysis is also unable to determine the directionality of the condition and the intervention i.e., did the co-existing conditions appear before or after the intervention. The more dietary advice interventions in the GDS, regardless of how regular they attended, a child receives the less likely they were to have co-existing conditions. This finding may not be as a result of the intervention but that parents/carers who take their children to the GDS on more occasions may be more motivated in other aspects of health, including in diet.

When it comes to dietary advice from the DHSW, children who were not targeted had the lowest risk of co-existing conditions, while children who had at least two dietary advice interventions had the highest risk. This is likely a result of the targeted design of the DHSW intervention as children who require the least help would not be targeted and children who require the most help would receive more interventions (Macpherson et al., 2015). It is unknown if the co-existing conditions, more so obesity given that teeth are unlikely to have erupted, were already present at the time of intervention or if the intervention happened prior to the outcome when the intervention happens at 4- to- 6-months-old. Either way, it appears that a higher number of dietary advice interventions from a DHSW do not seem to reduce the risk of co-existing conditions, suggesting that this intervention may not be effective. While it is not possible to confirm if intervention came before or after the caries and obesity, the aim of the DHSW is to reach the children before teeth develop. These children were deemed to require further support from the DHSW as very few children receive multiple interventions (Kidd, 2019), which adds to evidence that DHSWs do not have the resources to support families at greatest need. Evidence shows that downstream interventions may not work (Harris et al., 2012) and it will require more effort to reduce sugar and improve diets at an individual level, alongside the existing midstream interventions from DHSWs such as the signposting to community services.

Of the small number of children signposted to food/diet related community/voluntary organisations, children who were signposted at least once were associated with a lower risk of co-existing conditions. This seems logical as if the family were signposted, they are more likely to receive the help that they require. Motivation must also play a part, as the family, even if signposted, must still be motivated to engage with the services but it is also critical that the organisations signposted to were accessible. Children who were targeted but not signposted had the highest risk of co-existing conditions, meaning these children who were most at risk did not engage with the services that may have helped or the services may not have reached the families. There is evidence to suggest that signposting has helped since the risk of co-existing conditions was slightly lower in children who received at least one intervention of signposting compared to children that were not even targeted to a DHSW in the first instance. A systematic review on interventions to link families with preschool children to community support by Burns et al. (2021) found that more active support to facilitate the linking of families from healthcare services to community-based organisations proved more effective than the signposting, which tends to be quite passive with DHSWs i.e., where information of the organisation is simply provided rather than facilitating/supporting attendance e.g., with arranging an appointment and/or transport. Burns et al. (2021) reports that referral or facilitation have better outcomes than signposting.

8.7 Possible Future Interventions

8.7.1 Upstream interventions

While evidence is still emerging, it does not appear that the UK Soft Drinks Industry Levy (sugar tax) has had the immediate impact on prevalence and risk of obesity as desired (Rogers et al., 2023b). However, the levy has successfully reduced the amount of sugar purchased from SSBs across the UK (Pell et al., 2021). The reduction in risk reported so far appears to only be in older children (girls aged 10- to- 11-years-old) than the age group used in the thesis. Previous evidence has shown that consumption of SSBs at 5-years-old is linked with obesity at 7- to- 8-years-old in Scotland (A. Macintyre et al., 2018), however an earlier study in England, with a smaller sample size (n=521) found consumption of SSBs at 5-years-old was not linked to increased adiposity at 9-years-old (Johnson et al., 2007). Added sugars in drinks only account for 30% of all added sugars in the diet of children aged 1- to- 3-years old (Griffith et al., 2020) so it is possible that the sugar tax will not be able to have a full effect on caries and obesity by 5-years-old. Further taxation on sugar, not only in liquids, may be required. Furthermore, with evidence linking consuming ultra-processed foods (food dense with calories and usually high in fat and sugar content) with obesity (Carter et al., 2016; Pan American Health Organization, 2015b; Schulte et al., 2015) and caries (Cascaes et al., 2023), it may be required to extend the sugar tax to include a tax on fat. A previous tax on saturated fats in Denmark was introduced in 2011, but removed in 2012. A 2.14€/kg tax was imposed on foods which contained for than 2.3g of saturated fat per 100g of food (Smed, 2012). No data was reported on young children, however, there was a 4.4% reduction in consumption of saturated fat in adolescents aged 15- to- 19-years-old (Smed et al., 2016). In this same age group over the same period (2009 to 2012), vegetable intake increased by 14.3% in females and 1.9% in males but fruit intake reduced by 3.7% in both sexes. The repealing of the tax appeared not to be a public health issue rather than economic issue (Vallgårda et al., 2015). The tax was criticised for increasing prices for the consumer and the increased administrative burden on companies. It was also reported that it was affecting cross-border trade with Danes going across the border to neighbouring countries to buy the foods that had been taxed in Denmark. Vallgårda et al. (2015) noted that in the repeal bill there was no mention of health, nutrition, or obesity. If a tax on fat was to be introduced in the UK, these economic issues must be strongly considered. Furthermore, Griffith et al. (2011) argue that policy must be clear about what it aims to tackle, for example all saturated fats or only saturated fats in certain food products (e.g., chocolate and sweets but not milk). It must also consider what are the alternatives. For example, if butter was taxed a person may move to margarine, which tends to be higher in salts and thus creating another problem. If alternative foods are not at a reasonable price then a fat tax may add a financial strain on those at the lower end of the socioeconomic scale. Further research will be required to identify the effectiveness of the sugar tax but also identify if a tax on fat would be a credible option.

8.7.2 Midstream interventions

Linking families to food/diet related community/voluntary organisations needs to be better optimised in the Childsmile programme. Signposting is more passive than facilitated linking to organisations (Burns et al., 2021) and also only works if the organisations are able to engage with families. The organisations who families are linked to require the training, skills, and resources to support families adopt behavioural change related to diet for improved child oral and general health, which is not always necessarily the case. The Scottish Government from July 2019 to March 2022 provided grants of various sizes to 22 community organisations which aimed to improve oral health in Scotland as part of the Challenge Fund (Scottish Government, 2019). Following these initial grants, the Scottish Government is currently piloting a programme in which it funds two charities in Lothian, Scotland, allowing the charities to deliver community support (Scottish Government, 2022a). This is part of the aim for a sustained legacy from the Challenge Fund. The funding for these pilots started in April 2022 and runs until March 2025. One of the programmes, *Eat Well for Oral Health*, is a community-based food skills and nutrition project part funded by the Scottish Government and delivered via the Edinburgh Community Food Initiative (Eat Well for Oral Health, 2023). The programme is aimed at anyone affected by socioeconomic (or racial) inequalities across Edinburgh and Lothian. The aim of this programme is to enhance the oral health of children, families, and specific communities by promoting the exchange of knowledge on diet and nutrition, and by improving cooking abilities and boosting confidence through a community-centered approach. Participants on the six week course also receive further signposting, with support for oral health, guidance on accessing dental practice, and free nutrition and oral health resources (Eat Well for Oral Health, 2023). The other programme in Lothian, *LINKnet Mentoring*, aims to reduce oral health inequalities amongst ethnic minorities. The programme brings together communities to deliver important oral health messages, as well as general health-improvement messages. The programme supports individuals as well as families and is open to anyone looking for support (Scottish Government, 2022a) There will be an ongoing challenge to spread this learning and resources across Scotland.

The ToyBox-Scotland intervention was trialled in Scotland to understand its feasibility (Malden et al., 2019). The intervention is based on the original ToyBox intervention which was a preschool obesity prevention interventions with the aim to use innovative and evidence-based theory to prevent obesity in children aged 4- to- 6-years-old (Manios, 2012). The original intervention was developed by 15 partners across the European Union although Malden et al. (2019) adapted the programme to be suitable in Scottish preschools. The intervention which had a main focus on intervention in educational settings in the form of 2.5 hours training for practitioners and delivering the preschools with class room materials, for example, hands puppets and activity guides. The guidelines had a focus on increasing physical activity and reducing sedentary behaviour (Malden et al., 2019) but also eating and snacking and water consumption. BMI of the child was measured at the start of the intervention in early 2018 with follow-up measurement taken 15 to 17 weeks later, with BMI then standardised using WHO growth curves. The intervention was delivered over 18 weeks and split into two mains part with the first 12 weeks focused on introducing the topics and the last 6 weeks on repetition of key messages. Forty-two children were randomised into either the intervention group (n=26, 22 analysed) or the control group (treatment as usual, n=16, 14 analysed). Results found that BMI z-score increased for both groups between baseline and follow-up, although slightly more for the control group. However, daily time spent physically active reduced in the intervention group and daily sedentary time increased, including a reduction in daily step count, which were replicate of the control group but larger reductions were identified in the intervention group, although these levels still remained higher than the control group (Malden et al., 2019). The authors state that there was good engagement in the intervention within preschools, however, not at home, and more work would be required to encourage this participation at home. Malden et al. (2019) note that this intervention would require greater adaptation to be considered for a wider roll-out in Scotland. The Childsmile programme in its current form does not make use of any of the interventions from the ToyBox study, however, based on the results and conclusions from the authors of the trial it is unlikely any ideas could be used in their current form.

The use of text messages to communicate informative and/or motivational material has been used successfully in previous interventions for obesity (Gillespie et al., 2020; Smith et al., 2013; Taveras et al., 2012). This could be a useful, easy, and low-cost tool for DHSWs to utilise to deliver material at set intervals to many families simultaneously. This would mean information delivered by text would not be particularly tailored but could trigger positive behaviour that may have been lost after the DHSW visit. A previous systematic review found that text messages were most commonly used for goal setting, promoting self-monitoring of behaviour, identifying and solving barriers to overcome a problem, and techniques to change behaviour (Free et al., 2013). Out of the 27 studies which focused on changing health behaviour, 24 had BMI as the primary outcome. Only 2 these studies included in the review recorded a positive improvement on waist circumference (Beasley et al., 2006; Burke et al., 2011), however, importantly no study had a negative effect on the relevant outcome of interest. All these studies which had BMI as a primary outcome were conducted in adults (Free et al., 2013). Head et al. (2013) conducted a meta-analysis on 19 studies of which only one study focused on children, although the mean age was 8.7-years-old. The meta-analysis by Head et al. (2013) found a significant positive effect on health behaviour and health-related outcomes in interventions which utilised text messaging. Three studies focused on weight loss, which when pooled, showed a statistically significant reduction in weight. The meta-analysis also noted that there were no significant differences between interventions which used a mix of theory and text messaging and interventions which only used text messaging. The two systematic reviews noted, Free et al. (2013) and Head et al. (2013), show contrasting results despite being published in the same year. A key difference in search strategy was Free et al. (2013) excluded interventions which used mixed mobile technologies, whereas these were include by Head et al. (2013). Overall, text messaging is a low cost and easy implemented tool that could be used to promote good health behaviour and serve as a reminder of material discussed during the DHSW visit. A further qualitative study on 50 children aged 11- to- 13-years-old focused on the acceptability of text messages to promote behaviour change to improve oral health of young children living in deprived areas as part of the Brushing RemInder 4 Good oral HealTh (BRIGHT) Trial (Elyousfi et al., 2022). Text messages were delivered to the children twice daily for a fortnight to remind them to brush their teeth. The text messages were deemed to be acceptable, however the authors have noted that some children described the texts as ‘annoying’ and in fact blocked the number to stop receiving the messages. The authors are unable to tell how many of the texts that were sent were actually delivered and read (Elyousfi et al., 2022). Care must be taken to decide on the appropriate frequency of texts to ensure maximum impact with little frustration from the family and to ensure that the intervention does not increase inequalities adopted by more affluent families. Those who receive the text messages must be included in the design of the messages to ensure appropriateness (Elyousfi et al., 2022). Care must be taken to ensure the families who require the support the most do have the capabilities to receive these messages by first having a phone able to receive messages and potentially one connected to the internet depending on how to messages were delivered (Honeyman et al., 2020).

There is a debate around whether or not area-based deprivation can show the true state of inequalities or whether the focus must be on individuals' socioeconomic circumstances (e.g., income, wealth, education, occupation, status/prestige) (S. Macintyre, 1993). Focusing on area-based inequalities does have some advantages, it allows differences to be identified in groups which have different communities, access to health and general services and the physical and social environment (S. Macintyre, 1993). However area-based measures fail to capture individuals resources, finances, and skills. S. Macintyre (2007) argues that instead of asking individuals to change behaviours, which most policy is based on, more deprived areas could be made to look and feel like less deprived areas by improving services and green spaces, access to services, and the cost and availability of healthy food products. There must also be an attempt to reduce 'obesogenic environments' so the surrounding environment does not influence the risk of obesity or other health conditions (Jones et al., 2007). The inequalities observed could be part of a wider picture observed across England in recent years, with a report from the Health Foundation reporting on falling life expectancy in people from the most disadvantaged (and marginalised) groups.

8.7.3 Downstream interventions

The current roles of Childsmile Dental Health Support Workers primarily provide interventions focused on caries prevention. The role of the DHSW is to link families to a dental practice, promote oral health behaviour change, and signpost families to community organisations. DHSWs will make contact with the targeted family when the child is roughly 3-months-old and deliver a fully tailored intervention (Childsmile, 2016). Home visits usually last up to one hour and further visits are provided where the DHSW feel the family require extra support. The majority of interventions developed, particularly for obesity, consist of multiple follow up interventions, with progress tracked over a longer period of time. While the current Childsmile model allows the

DHSWs to visit the family more than once, current level of resources do not support this, with most families only seen once, likely due to resources being stretched and the potential that families who do not need the support are receiving a visit from a DHSW (Hodgins, 2017). The Childsmile DHSWs are in a unique position as they are part of a national programme funded by the Scottish Government and, theoretically, they are available to all families from more socioeconomically deprived areas who are identified by health visitors as requiring extra support. The Childsmile programme recently received additional funding and recruited 41.5 (whole time equivalent) more DHSWs across Scotland (personal communication King, P, Childsmile Programme Manager). With the additional funding and new resources, there could be potential opportunities to adapt and improve the DHSW interventions delivered, broadening the scope to fully address diet related interventions to help reduce prevalence of obesity and as such co-existing caries and obesity.

To the author's best knowledge, there are very few interventions which take place as a single/one-off follow up as per the DHSW intervention. However, most of the DHSW follow up is via linking to either dental practices or community organisation. Usually direct follow up from the DHSW will only occur if they feel the family require further help, which only happens for a small number of families (Kidd, 2019). Most interventions developed include many months of follow up with more frequent interventions which is not feasible in the Childsmile model. A previous intervention, Healthy Habits, Happy Homes (4H) (Taveras et al., 2012), which ran in Boston, USA, was adapted for the Scottish population. Healthy Habits, Happy Homes Scotland (4Hs), developed by Gillespie et al. (2020), aimed to prevent obesity in young children. Twenty-six families were recruited from 126 invites, with 61.5% of families living in the most deprived areas in Scotland. The feasibility study found that the original 4H study could be translated to Scotland, particularly using Motivational Interviewing (MI). MI is a style of communication which focuses on the "language" of change, designed to strengthen personal motivation to a particular goal by exploring the person's personal reasons for change (Miller et al., 2012). A practitioner delivering interventions through MI will focus on four processes: engaging, focusing, evoking, and planning, to lead the patients to autonomously identify and choose the best way to adopt change (Miller et al., 2012). Gillespie et al. (2020) reported that the MI approach was positively received in the Canada roll out of the 4H programme (O'Kane et al., 2019). The 4H intervention is a home-based intervention which takes into account social context of the participants and psychosocial constructs which affect behaviour (Taveras et al., 2012). Health educators deliver specifically tailored counselling based on a baseline assessment of the home, social support, barriers, and catalysts of behaviour change. The intervention had three major components: 1) motivational coaching during home visits and by phone, 2) educational materials and behaviour change activities posted, 3) weekly text messages on behaviour change strategies and the acquisition of household routines. The total intervention period was 6-months. The mailed materials and tools to catalyse behaviour change were emailed monthly. Home visits, of which there were 4, lasted 60 minutes each. Four 20 minute long telephone calls were conducted, as well as 2 texts a week for 16 weeks and 1 text a week for a further 8 weeks. The intervention was well received by the families taking part, with 89% of families reporting they were at least satisfied with the intervention and 98% of families willing to recommend the programme to a friend. The 4H intervention is clearly a lot larger than the current DHSW intervention as part of Childsmile. With the current structure of Childsmile, an intervention as intense as the 4H intervention is unlikely to be feasible but that is not to say certain aspects could not be utilised. The translation of motivational material away from not only obesity would require initial research and work but then could be used for many years, while some information on nutrition and diet could be retained to try reduce the risk of co-existing caries and obesity. In addition, a small number of families could receive more intense support using this method.

Borrello et al. (2015) noted a previous lack of evidence on the effect of MI on obesity in adolescents and even less on children with obesity. The literature review aimed to identify studies with an application of MI for the treatment of obesity in children from 2- to- 11-years-old in which the primary target of the MI was the child (Borrello et al., 2015). Three out of 6 studies found that the use of MI had greater effect on changing BMI than the usual care. A previous review of reviews highlighted the benefit of MI for encouraging families to adopt healthier behaviours, particularly for BMI (Dooley et al., 2017). This review of reviews aimed to find out what non-oral-health professionals in practice and public settings were doing to address childhood obesity and reduced consumption of sugar-sweetened beverages in children under 12-years-old. Dooley et al. (2017) found seven reviews which indicated a positive effect of MI. Some of the larger studies included in the review indicated improved in the short-term weight trajectory along with improvements in caloric intake. Additionally, a systematic review of 29 family-based interventions by Ling et al. (2016) reported interventions on obesity worked better in young children than in older children, highlighting the importance of adopting good behaviour from an early age. Interventions where parents were actively involved proved effective, albeit it was found that school-based interventions, such as increasing physical activity and promoting improve diet, were also effective due to cost-effectiveness, sustainability, natural environments for healthy eating choices, and can be integrated into usual practice.

The parental involvement bodes well for the current DHSW delivered interventions as they are able to access to family from a very young age to try ensure the best start to life. It has been noted in the past that whilst there is a clear theory for the delivery of the DHSW component of Childsmile, there is apparent ambiguity on how the interventions are delivered in different NHS Health Boards and by different DHSWs (Young, 2017). This could be largely due to the tailored approach that DHSW must take to ensure maximum effectiveness of the intervention but also from the organisational structural role of the DHSW in each NHS Health Board where some have multiple different roles while others can focus on supporting families (Young, 2017). In addition to parental/carer involvement other family members could be considered. Evidence shows that grandparents play a role in supporting their families general health (Chambers et al., 2022). Chambers et al. (2022) also suggest that family-based interventions may be limited if they do not involve the grandparents where appropriate to do so.

Currently, DHSWs attend 6 days of training which is delivered by NHS Education for Scotland (NES, 2023), although currently mainly delivered online over 6 modules. DHSWs in the past have noted a variation in their readiness for the role following the national and local training courses (Young, 2017). There has been disagreement between some DHSWs whether or not the training provided is enough and that they have learned more from 'learning on the job'. The learning on the job is key for continuous development, although, it is not particularly suitable for families receiving intervention from DHSWs in the early stages of their career. Care must be taken to improve the courses so DHSWs can be ready from the start. An improvement on the training could also consider providing DHSWs with skills to provide appropriate interventions for children with medium- to- high-risk of caries, and hopefully obesity, although these children would have to be first identified as high-risk. Based on the findings of this thesis area-based deprivation is a key factor of children with both caries and obesity on their own and co-existing. Other factors which may be an early identifier of co-existing caries and obesity include: shorter duration of breastfeeding; increase formula use; increased acculturation; developmental conditions (Chi et al., 2017). DHSWs are currently trained on MI, using a mix of theory and role-play/practice with other DHSWs. At present, only one day of training on MI is provided to DHSWs. This training is not in the core training and is included in additional follow up training. This training was first introduced in 2016 and as such the children included in the cohorts in the thesis may not have received the motivational style interviewing, however, behavioural change techniques would have been adopted by the DHSWs. Gillespie et al. (2020) has suggested at least 3 days of behaviour change, including MI, training is required, including a mix of both theory and practical elements, followed by peer support and supervision. If MI was to be considered for greater implementation in the DHSW intervention then training would also need to be adapted to include more material relating to MI.

While DHSWs have proven successful at linking families from more socioeconomically deprived areas into dental practices at a younger age (Hodgins et al., 2018), it still remains that a portion of the children have never attended a GDS within their first five years of life. CHATTERBOX was previously developed to help DHSWs engage families in a discussion about difficulties they encountered when trying to access the GDS, using a series of cards which were pictorial representations of the parents' daily life (Chambers et al., 2010). In conversion with the DHSW, parents use the cards by placing the cards in order of the daily activities. Parents are encouraged to add notes to the cards to further discuss the activities (Nanjappa et al., 2014). This activity aims to provide parents the opportunity to discuss concerns about taking the child to the dentist and promotes a discussion. The timeline of cards is photographed and recorded so they can be discussed at any future visits. Nanjappa et al. (2014) noted a potential limitation of this intervention was it was not always possible to have multiple visits to the family, with one visit not being enough for parents/carers to open up. The authors go on to recommend the use of CHATTERBOX in other community settings. This idea of identifying barriers has been replicated in The Netherlands (de Jong-Lenters et al., 2019). The 'Uitblinkers' (translates to 'Brilliant Stars') intervention aims to promote the practice of twice daily toothbrushing in children. The intervention is conducted in dental practices with targeted parents/carers of children aged 2- to-10-years-old to identify barriers parents/carers face in getting their children to brush their teeth and providing strategies from learning theory (de Jong-Lenters et al., 2019). A non-randomised cluster-controlled trial is being conducted in 40 dental practices to assess the effectiveness of the intervention over a 24-month period in 3- to-4-year-old children (at start of intervention). At the time of publication of this thesis, the results have not been published. If this role is effective a version of this and CHATTERBOX may be useful to the DHSW intervention.

As previously discussed, there is little evidence as to whether chair-side interventions work at changing behaviours and more so reducing sugar consumption (Section 8.6.7). The UK Government, in 2014 although last updated in 2021, published an evidence-based tool-kit for the prevention of oral diseases to support dental teams (UK Government, 2021). This guidance, titled 'Delivering Better Oral Health', aims to provide a nationwide consistent approach to prevention of oral disease. Dental professionals are in a position to provide support to encourage behavioural change, however, this can only be done if the child/family is attending a dental practice and if the patient or family feels motivated and capable to adopt a behavioural change. Dental professionals are encouraged to help build a patients motivation to change when they are ready to do so, which involves building a rapport and trust with the patient (UK Government, 2021). This can only be done if the patient attends the dentist regularly so a relationship can be forged, which may not be the case for children in Scotland. A previous repeated cross-sectional study using population-based administrative data in Scotland found that only 40.5% of children in Primary 1 in Scotland regularly attended (attending at least four out of first five years of life) the GDS (Sherriff et al., 2022). Without this continued regular contact with a child/family, a dental professional is unable to help with the behaviour change cycle, and they will be unable to identify which stage of the behavioural change cycle the child/family is at. The dental teams may be providing information around the issues that the patient already knows, but that time could be better spent preparing the patient with the necessary skills and knowledge to make the change or time spent setting and planning goals. The guidance by UK Government, 2021 includes information on support behavioural change for reducing sugar as part of a healthier diet. While this guidance does exists, it is unknown whether it is being delivered as envisaged or if it is having an impact. Moreover, the current primary care dental contract (currently being redesigned) does not pay the dental team to adequately deliver the full range of prevention. Although, the Childsmile programme had successfully introduced prevention payments for toothbrushing instruction and dietary advice.

Guidelines show that the two most important practices for good dietary behaviours include eating the right amount of food relative to the person's activity and eating a range of types of food (UK Government, 2021). However, without support this advice will likely have no impact. A multi-center randomised controlled trial conducted in the UK found a 30 minute structured conversation with children aged 5- to- 7-years-old and their families, who were in for caries treatment, reduced the risk of new caries after intervention compared to those in the control group (Pine et al., 2020). The trial recruited 224 children from across the UK who were attending as assessment and/or extraction clinic, with 88 children analysed as part of the intervention and 103 as part of the control. The intervention, denoted as a "talking" intervention, is a 30-minute therapeutic conversation between a dental nurse and a children and their parent/carers. The conversation is structured into six segments: building rapport; ask about pros and cons; feedback; readiness to change; action plan; dental appointment and thanks (Pine et al., 2020). The intervention is delivered using Motivational Interviewing (MI) techniques and aims to build parent/carer's self-reliance for twice-daily toothbrushing using fluoride toothpaste, controlling free sugar intake particularly at bedtime, and attending a dentist regularly for preventive care rather than just when symptoms arise. The dental nurses were provided with one day of training on motivational interviewing with particular skills in changing talk, developing a plan for change, and confirming commitments to a change in behaviour. The nurses then conducted further practice within clinics. The nurses role was to help explore opportunities with parents/carers to explore the potential to change behaviour and not only stating what they should do. The goal was for the parents/carers to adopt one or two behavioural goals. The control group received educational information relating to tooth eruption between 6- and- 14-years-old, with no discussion on caries prevention, although families were encouraged to attend the dental practice as usual. Mean age of the child were 6.3-years-old in the intervention group and 6.4-years-old in the control group and mean dmft was high in both groups at baseline (6.8-years in intervention group, 6.5-years in control group). The child was then inspected two year after intervention for evidence of new caries. The odds ratio of new caries experience two years after intervention in the intervention group was 0.49 (95% CI: 0.26 to 0.90) times that of the control group, with corresponded with a 29% reduction in risk (Pine et al., 2020). This randomised trial has shown that MI has the capability to help reduce caries experience in children who already had caries experience. This adds to the evidence of MI techniques for reducing obesity prevalence. MI techniques have not been analysed on both caries and obesity simultaneously but this approach could be adopted by DHSWs to support behavioural change of families with children with co-existing caries and obesity. The 30 minute time length of intervention would fit well within the DHSWs time constraints with each family. Downstream interventions can work to improve health, however, they can only go so far. Wider societal reforms and required to allow people to adopt the changes that downstream interventions generally promote.

8.7.4 Section summary

Building on this initial review of potential future interventions/developments for the Childsmile programme, the Childsmile programme could review the full range of options and assess the feasibility of adopting and adapting/improving diet related interventions across the multiple components/settings of the programme. These include the dietary advice delivered by Dental Health Support Workers and in the GDS, as well as the linking to food/diet related community/voluntary organisations at the wider community level. Furthermore, dietary related intervention in educational settings could be explored, with new policies introduced.

8.8 Strengths

8.8.1 Population coverage

A main strength of this thesis is the high coverage of the population of children in Primary 1 in Scottish schools allowing this thesis to be the first time research on caries and obesity, individually and together, has been conducted on a sample this large in a contemporary population sample. The high coverage was made possible due to the

NDIP and CHSP-S programmes running at school level. During a period of austerity policies, having such a high coverage, the selection bias has been limited, particularly given that the measurements of caries experience and BMI status are collected with opt-out consent. The high coverage means it can be confidently stated that the results from this thesis are representative of the Scottish population, including in terms of age, sex, and socioeconomic status, as well as geographic areas of Scotland. The large sample size also provides sufficient power for statistical tests on the population, as well as on sub-groups including those split by area-based deprivation, BMI status, and co-existing status.

8.8.2 Routine administrative data and data linkage

A strength of routine administrative data is the reduced time and monetary cost in collecting the data as it was already collected for other uses. That is not to minimise the extensive work conducted by colleagues of the author, prior to the author beginning the research, in gaining approval from ethical boards and the Public Benefit and Privacy Panel for use of the data as well as costs for initial data collection and ongoing use of the NHS NSS National Safe Haven. The ethical approval received to use the data did not involve contacting patients which saved time and the intrusion of the participant's daily life, and any delays on waiting for responses. The quality of the data was discussed in Chapter 2, however, this was a clear strength of the thesis. The data obtained were an accurate representation of published national reports, such as the National Dental Inspection Programme (Macpherson et al., 2018) and Child Health Surveillance Programme School (Information Services Division Scotland, 2018a) reports. In addition to this, the measurements of caries experience and BMI status were conducted by trained, and in the case of caries experience, calibrated clinicians to ensure accurate measurements and there was no reliance of self-reported data. The supervised toothbrushing, nursery and school fluoride varnish application, and the DHSW intervention data were sourced from the Health Informatics Centre (HIC).

Data from the DHSW interventions undergo regular quality control reports so that any quality issues (e.g., invalid postcodes or date of births that do not match the CHI number) can be resolved as close to point of data input as possible. This minimises the risk of the DHSW forgetting information from the intervention, maximising the accuracy on the data. This is particularly important for the DHSW intervention as the DHSWs may cover many topics during the visit. These data are subject to regular quality control checks and reports are provided to regional Childsmile teams who are able to correct mistakes or clarify any quality issues such as invalid postcodes or date of births. The Management Information & Dental Account System (MIDAS) data are primarily used for the remuneration of dentists for the treatment provided in the GDS. Therefore, due to the in-built financial incentives associated with collecting the data, the records are recorded accurately, with 100% match of date of births across records. There are also regular checks for fraudulent claims which provides confidence in the accuracy of the data.

The MIDAS and HIC datasets are not pre-populated with the Community Health Index (CHI) of the child. This means CHI-seeding must be used, where the key identifiers of the child are linked to the CHI database to identify matches and thus allowing the data to be linked to other data, health related and non-health related, e.g., educational datasets (Clark, 2015). Previous research has shown that 96% to 99% of individuals in Scotland have a CHI (Pavis et al., 2015). The high availability of this number allows near maximum data collection of children in Scotland. An assessment of the quality of data linkage was conducted which found PHS Trusted Third Parties has 99.7% precision in record matching, with National Records Scotland (NRS) having 99.6% precision (Clark et al., 2022). This assessment suggests high quality of data linkage in Scotland which allows confidence in having the correct child allocated to the correct record.

8.8.3 Data management

All data were stored and managed in accordance with strict information governance and ethical approvals. This involved the adherence to strict protocols regarding data disclosure. All data reported in this thesis was subject to approval by electronic Data Research and Innovation Service (eDRIS) to ensure no identifying information was reported. Furthermore, all data was managed in accordance to robust standard operating procedures developed by the author and colleagues. This ensure that the data were responsibly managed and yielded accurate output. All code was shared with colleagues to ensure accuracy in the code.

8.8.4 Data analysis

Another strength is the in-depth analysis with prior hypotheses and research questions. These approaches of robust data linkage and analysis of national/population high quality datasets are major strengths of this thesis. Comprehensive statistical techniques were used to test the hypotheses and answer the research questions.

8.9 Limitations

There are some limitations of reporting data for secondary analysis purposes, but these were relatively minimal.

8.9.1 Limitations of measurement of caries experience

A limitations of the caries experience data stem from not having information on the severity of caries experience. That said, it would be costly and exhaustive to capture that level of data on all children as per the detailed NDIP programme given the detail and time that each inspection requires. Another limitation is the NDIP inspection is only available to children in local authority. Roughly 4% of children attend an independent school annually (Scottish Council of Independent Schools, 2020). The 4% is likely to be made up largely of children from the higher end of the socioeconomic scale meaning that they are disproportionately missing from the data. On the contrary, children from the most deprived areas are more likely to be absent from school and therefore miss out on a dental inspection or weight and height measurement (Scottish Government, 2017). It is likely that this thesis is missing children from both ends of the socioeconomic scale. As aforementioned, 4% of children attend independent schools, meaning that roughly 96% of children would be eligible for an NDIP inspection. The *RQ1 Cohort* (Section 3.3.1) in this thesis includes 87.7% of children from the estimated population of children in mainstream schools which is a very high population coverage, however this leaves roughly 8.4% of children unaccounted for. A previous repeated cross-sectional study reported that children who experience social issues (such as interrupted learning, looked after, family issues, risk of exclusion), who are more likely to be from deprived areas, were less likely to receive a NDIP Primary 1 basic inspection than children with no additional support needs (Sherriff et al., 2022). By comparing population estimates, including a sex and SIMD partition (National Records Scotland, 2019b), with the cohorts presented in this thesis, there is a similar breakdown of number of males and females and also a similar distribution of children in each SIMD decile. Ultimately, the author has confidence that this cohort is representative of the overall population despite missing some children. The linkage process was robust and did not exclude many records from the expected total in the published reports. Due to the study having a high linkage rate, it is a representative cohort of the population.

8.9.2 Limitations of measurement of BMI status

A limitation in this thesis from the BMI measurement. Obesity is an excess of body fatness rather than an excess of body weight (Javed et al., 2015). Since body fatness is difficult to measure directly in large population-based surveys, a high BMI-for-age is used widely as a proxy for high body fatness (Reilly et al., 2010b). Using BMI-for-age as a proxy underestimates 'true' obesity substantially compared with excessive fatness, however it remains a useful tool for BMI surveillance (Diouf et al., 2018). It is therefore likely that the true obesity prevalence in Scotland is greater than the estimates presented which were based on BMI-for-age and that we have provided conservative estimates for obesity prevalence among 5-year-old children in Scotland. More accurate measures of body fatness, e.g., DEXA scan or hydrostatic weighing (Section 1.4.1) would be extremely difficult and costly to conduct at a national scale. Despite this, it has been shown previously that BMI is a robust measure of an individual's body fat in children over 2-years-old (Bellizzi et al., 1999)

8.9.3 Limitations of reducing population coverage

The proportion of children included in the analysis compared to the NRS population estimates (National Records Scotland, 2019a) reduced in each year, although this change was proportionate across socioeconomic groups. PHS suggest the reasons for this decline in coverage include shortage of staff to conduct inspections and technical issues with recording inspection findings in the system (Information Services Division

Scotland, 2019a).

8.9.4 Limitations of socioeconomic deprivation

Individual-level socioeconomic measures were not available as part of the routine administrative data and therefore area-based deprivation level was used. Area-based deprivation, measured by SIMD in this thesis, risks including children with individual socioeconomic different from the deprived areas. There are limitations of using area-based deprivation as a proxy measure, particularly when making inferences about a whole group rather than individuals i.e., ecological fallacy. This also does not allow for heterogeneity in individual-level risk factors and disease levels within areas of residence (Clelland et al., 2019). Despite this, the interventions analysed in this thesis, particularly in the case of attendance or prevention intervention at GDS, rely on access to health services which is a key component of area-based deprivation so it is useful to look at this. Area-based socioeconomic measures do have some strengths in capturing area-related effects such as access to services.

8.9.5 Limitations of data linkage

Whilst data linkage is undoubtedly a key strength of this thesis, it comes with its limitations. Linkage errors are likely to increase in studies which use longitudinal data such as the present thesis (Grzeskowiak et al., 2013). Issues are likely to appear due to families moving home or name changes. As more children are added to the data, the total number of errors are likely to increase too although the percentage of these errors should remain constant. However, the author is confident that the cohorts used in this thesis are an accurate reflection of the population of Primary children in Scotland during the study period (2011-2018).

8.9.6 Limitations of data available

A limitation of using routine administrative dataset is the inability to choose the questions asked to individuals and variables included in the data. There are many variables, particularly information relating to the dietary intervention, which would have been a useful addition to this thesis such as diet behaviour or sugar consumption. However, dietary information on data this large would likely come with it's own limitations. From the information available in the data, mainly the Childsmile interventions lack information on the content and intensity of the dietary advice and only if the child received the intervention. There is also no information on who delivered the dietary advice in the GDS or if there was any follow-up on the advice. Data on the information would be useful to look into if the intensity, quality, and length of interventions would play a part on the outcome. This limitation leads into the toothbrushing data. In this data it was not known if the child did participate in nursery supervised toothbrushing, only that the child's family provided positive consent to participate and attend a nursery signed up to daily supervised toothbrushing.

The Childsmile logic model (Section 1.9.6) sets out desired outcomes from the programme. This includes many behavioural outcomes, including reducing dental anxiety, reducing consumption and frequency of consumption of sugar, good oral health practice, increased knowledge and skills in improving children's oral health. Unfortunately, not all the outcomes are possible to accurately obtain information on at a national level. Information related to these outcomes, and other in the logic model, could have been included in models to understand the pathway between Childsmile and the children with co-existing caries and obesity.

8.9.7 Limitations of timing of interventions

The analysis in the thesis did not consider the specific timing of contacts or treatments in relation to age or calendar time. It is also unable to identify if the co-existing caries and obesity were present before, during, or after the intervention was delivered so it is difficult to know if the interventions had an impact. Furthermore, it did not take into account when a contact or treatment occurred. For instance, it did not address whether a child with three dietary advice interventions had both interventions within the first three years of their life, or if they were spread out over a period of five years. Furthermore, it did not explore the possibility of these contacts being concentrated in the two years preceding the child's fifth birthday. The examination did not evaluate the spacing between dental practice contacts. However, it is likely that the contacts with the DHSWs were concentrated in the early years, while the toothbrushing intervention was regular and consistent (limited to school days and excluding weekends or holidays). On the other hand, the fluoride varnish component was probably spaced out according to the protocol for nursery and school visits, which suggests that the two annual visits should be delivered in different academic terms. It is reasonable to suspect that the combinations of these contact components and their relationship with the timing of each delivery could impact co-existing caries and obesity. However, measuring the timing of contacts in relation to the endpoint was not within the scope of the thesis. Nevertheless, the dose response of the dietary advice intervention in the GDS suggests that the contacts were more likely to be spread out over time rather than clustered together.

8.10 Recommendations

The following sections highlight some key recommendations based on the findings of this thesis in relation to the Childsmile programme. The recommendations range from policy to practice and are based on components which focus on dietary interventions.

8.10.1 Childsmile Dental Health Support Worker component

The findings from this thesis suggest that more work could be done to ensure children who have co-existing caries and obesity are being targeted by DHSWs. This is based on the fact that children who are at risk of co-existing caries and obesity are only slightly more likely to have been referred to a DHSW after accounting for area-based deprivation. However, even in those referred they are less likely to then be seen by a DHSW. This could happen for many reasons, including being missed on the referral list, unable to contact the family, or the family refusing contact. Care and time must be taken to ensure these families receive the DHSW intervention (including dietary advice and community linking where appropriate) when referred and take time explaining the importance and the benefit of the intervention. Given that co-existing caries and obesity is unlikely to develop before the DHSW intervention, these children must be identified as high risk by understanding the risk factors of this group. This thesis has identified that area-based deprivation will increase the risk of co-existing conditions, however, future research could be conducted to identify other key characteristics of this group which could be risk factors. There it would be difficulty doing this on a population-basis given the limited number of information on families that is collected at the national level so a smaller scale, but more detailed, study would likely be required. This would come with its own challenges given the smaller prevalence of co-existing caries and obesity in Scotland and given the fact that this group is less likely to be reached by a DHSW or in fact primary dental care.

DHSWs on average have one visit to each family. It is likely that this is not enough to effect behavioural change. The DHSWs require more resources to allow further visits to families who require the support most. Interventions could also involve other carer providers of the child, for example, in cases where grandparents often look after the child. This would aid a whole family approach to the child's health. The intensity of the intervention must also be considered as the intensity and quality of the intervention must be greater for to have a impact of behaviours of the family. The intensity of the intervention could also be recorded to enhance the evaluation.

At present it has been suggested that Dental Health Support Workers are only equipped with the resources to help families with children at a low- to- medium-risk of caries. It is possible that health visitors are not referring the most vulnerable families to DHSWs. While oral health is important it is of lower priority to other more pressing needs and challenges. This referral process and intervention must be substantially developed and improved to support behavioural change in dietary behaviours to help support those at a medium- to- high-risk of caries and obesity. Motivational Interviewing (MI) is currently adopted by DHSWs, however, the amount used could be increased by the DHSW as this has been shown in other interventions to positively improve health outcomes, mainly obesity, which shares the common risk factor of diet with caries (UK Government, 2021). MI would require some extra resources and training but given the recent influx of increased staff levels now could be the perfect time to adopt such a change. Text messages could potentially be used as a low cost way to send reminders. However, given the issues with digital health at potentially increasing inequalities these should be used sparingly and only as simple reminders of motivational messages.

While it does appear that signposting families to food/diet related community/voluntary organisation does reduce the risk of co-existing conditions, a more active linking/ facilitation could be adopted in this process. Evidence shows that active linking/facilitation works better than passive signposting at getting families to engage with the organisations in the wider community (Burns et al., 2021). DHSWs could improve their active recording of signposting by converting to the facilitation, which could help to ensure the true number of referrals are being recorded and analysed given that previous research has suggested that DHSWs do not always realised they have signposted a family to a service. The signposting is a two-pronged problem as the organisations must be prepared and supported with the skills and resources to support families. These organisations require funding from the Scottish Government to help train staff or volunteers to deliver support, be it through nutritional courses and cooking classes or wider social determinants work e.g., income maximisation, welfare benefit support, etc. If funding is not available, there needs to be ways developed to deliver support with less funds, a problem which charities could not solve alone. Direct financial transfers incentives are a possibility if funds are available. Thus far, in the UK financial incentives have been limited to initiatives related to smoking cessation in pregnant women (Tappin et al., 2015) but could be adapted to other behaviours relating to caries and obesity. These financial incentives could include food vouchers for the purchase of healthier food items such as fruit and vegetables.

8.10.2 Childsmile dietary advice in general dental services component

The Childsmile prevention intervention, mainly the delivery of dietary advice at the General Dental Services (GDS), appears to have an impact on the risk of co-existing conditions if the child has attended the GDS and received the advice, even after adjusting for area-based deprivation and the number of times attended the GDS. This suggests that regular attendance in the GDS is key to reducing the risk as more attendance provides more opportunities for the intervention could be delivered. This regular attendance would also be crucial to the dentist or dental nurse being able to build a relationship with families to support any changes in behaviour, be it oral health or dietary advice. This could be enhanced with MI approach (UK Government, 2021).

This would allow a better understanding of the family's situation and willingness to change. Currently DHSWs only first refer the family to the GDS or at least support registration, however, this does not mean the family will then continually attend unless oral health becomes an issue, which appears to be the case with children with co-existing conditions less likely to receive Childsmile prevention intervention in the GDS even when attending in the first place. The first visit must be a pleasurable experience for the child and family so the family feels encouraged to attend more and can see the benefit on these appointments. With this, however, it must be known if children are regularly attending the GDS, so a recommendation for PHS would be the introduction of a more regular attendance measure, for example, annual attendance, instead of the current bi-annual attendance which could potentially miss the attendance of children attending before 2-years-old.

8.10.2.1 Interventions in educational settings

Interventions could make more use of educational settings for the delivery of dietary interventions to children and their parents/carers. The Childsmile nursery supervised toothbrushing programme has proved successful in reaching children in schools across Scotland, even those with co-existing caries and obesity. Educational settings are where practitioners will have the access to almost every child in Scotland and should be given due consideration. Interventions in educational settings may include nursery and school food policy or the further promotion of good oral health and nutrition practices.

8.10.3 Wider societal recommendations

Research regarding the Soft Drinks Industry Levy remains limited with studies reporting the effectiveness of the 'sugar tax' only now emerging. Further policies and regulation must be considered surrounding sugar and further diet beyond SSBs. Political lobbying must continue to force the sugar industry to make necessary changes to formulation to improve oral health and obesity. This may include reducing the price of healthy food or developing policy on ultra-processed foods. Availability of these foods must be limited in schools with schools providing healthy, but substantial, alternatives and children must be taught about healthy eating.

Existing literature points to the fact that individual behavioural change will mean very little if there is no wider change in society, through reducing wider socioeconomic inequalities. Childsmile is currently battling inequalities in caries experience as well as wider societal issues, such as budget cuts from austerity, which is a challenge the programme is not equipped or designed for. Wider socioeconomic inequalities must be addressed to reduce the inequalities and improve the access to services and healthy food in the more deprived areas. A reverse of austerity would be required to see a stop in the rising socioeconomic inequalities experience in mortality and life expectancy that is currently being observed, as well as the evidence that 5-year-old children in the UK are getting shorter (NcD.RisC, 2023). The current cost of living crisis will only increase the current inequalities and more support is required from the Scottish and UK Governments to address the issues and support the families who require help the most. Whilst other major issues exist, such as making decisions whether to heat the home or feed the family, families will not be able to focus on improving their health, regardless of the reach and impact of the Childsmile programme.

8.10.4 Future research recommendations

8.10.4.1 Further research relating to co-existing caries and obesity

An updated analysis would assess how the effect of the COVID-19 pandemic on the prevalence and inequalities of co-existing caries and obesity. With national reports following the pandemic showing the prevalence of obesity is increasing, it is possible the prevalence of co-existing conditions has followed this trend, but further data linkage analysis would be required to confirm this.

The thesis identifies the group of children with co-existing caries and obesity in Scotland but little remains known regarding this group. Area-based deprivation has been identified as a key factor in a child having co-existing conditions, however, SIMD is distributed across the country so it is unknown if specific areas (e.g., health boards or council areas) in Scotland have a higher prevalence than others. Further research could be conducted to identify which areas these children live to identify further aspects related to the risk of co-existing conditions. Information relating to this may help health visitors better refer these children most at risk to DHSWs. This will allow DHSWs to provide the necessary interventions to the most vulnerable families.

The thesis has recognised children with co-existing conditions are being reached less by the dietary interventions of Childsmile, however, it remains to be identified if the interventions have mitigated inequalities in this group. Further analysis could be conducted to investigate this.

8.10.4.2 Further research relating to Childsmile interventions

Evidence suggests that current dietary interventions do not work. Further research should be conducted on the development of brief sugar interventions and what can be done to maximise the impact of this intervention. A wider systematic review could be conducted to identify which components have worked best at successfully changing behaviour relating to diet.

8.10.4.3 Further research relating to policy

Future research on the Soft Drinks Industry Levy in the UK is poised to explore several key areas. One important aspect will be evaluating the long-term effectiveness of the levy in reducing sugar consumption and improving public health outcomes. Researchers must assess whether the levy's financial incentives have led to a significant decrease in the production and consumption of SSBs, and whether this has translated into measurable improvements in prevalence of caries and obesity. It should also be considered the resulting development of product reformulation and healthier alternatives to identify if children have moved onto potentially more harmful alternatives. Furthermore, future research must explore the potential for the Soft Drinks Industry Levy to serve as a model for similar policy interventions, considering its effectiveness, feasibility, and transferability to different contexts (e.g., ultra-processed foods or high fat content food). The choice to buy healthier food items must be made easier for families. Spending up to 75% of income on food to meet healthy eating guidelines is not feasible (Food Foundation, 2019). Governments have previously used Value-Added Tax (VAT) to promote consumer spending. This could be extended to healthier foods by reducing the VAT on these items to increase purchases in these food items, whilst making it more affordable for families, particularly those from lower income households.

8.11 Conclusions

This is the first evaluation of the Childsmile programme's ability to reach and impact children with co-existing caries and obesity. The evaluation involved analysing data on caries and obesity outcomes by linking individual child health records from several routine administrative datasets. This section will present the conclusions drawn from the findings of the research in relation to addressing the aims of the thesis, which were to:

(a) to measure the prevalence and socioeconomic inequalities in childhood dental caries experience and obesity in Primary 1 (circa 5-years-old) school children in Scotland, separately and together between 2011 and 2018.

(b) to examine the interrelationship between childhood dental caries experience and obesity.

(c) to measure the prevalence and socioeconomic inequalities in co-existing childhood dental caries experience and obesity between 2011 and 2018.

(d) to explore the reach and impact of the national child oral health improvement programme for Scotland, Childsmile, in preventing childhood dental caries experience and obesity between 2015 and 2018.

Inequalities have been identified in young children with caries experience, obesity, and co-existing caries and obesity in Scotland, compounded by reduced and variable access to preventive dental services in children with co-existing conditions. Further efforts are needed to develop and improve preventive care pathways for children with co-existing caries and obesity and integrate oral health to wider healthcare systems for these children to mitigate against health inequalities.

There is an infrastructure set up in Scotland via the Childsmile programme to target interventions to the most in need at an intensity percentage to need. The programme reached most of these children at least once in 5 years, so the opportunity exists to deliver targeted interventions, however, the delivery of Childsmile prevention interventions in the GDS or engagement with a DHSW by family are lower in this group. This suggests more work is required to enhance/optimise prevention pathways. It is also not clear if the content and quality of the dietary interventions and if they in fact "worked" or if they were just a proxy for more motivated/engaged individuals/families.

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A Literature Search Strategy

1 child/ or child, preschool/ or infant/

2 (child* or infant* or paediatri* or pediatri* or infant* or youth or student*).tw.

3 Schools/

4 (school* adj2 (primary or elementary or junior or infant or kindergarten)).tw.

5 (“school age child*” or “school-age child*”).tw.

6 (home or domicil* or domestic or homecare* or (visiting adj3 service*) or (community adj2 (nursing or care)) or household).tw.

7 (health adj3 (nurse* or worker* or care*)).tw.

8 (nurse* or care* or support or worker).tw.

9 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8

10 exp Dietary Sugars/

11 (sweet* or sugar* or sucrose or “discretionary calorie” or “energy dense” or “junk food” or “soft drink” or cake* or pastry or pastries or biscuit* or pudding* or jam? or marmalade* or confectioner* or chocolate* or ((energy or sport*) adj1 drink*) or yog?urt or cereal* or juice* or snack* or candy or candies or dessert* or fizzy or soda or pop or beverage* or drink* or diet* or food*).tw.

12 Sweetening Agents/

13 (sugar adj3 intake).tw.

14 10 or 11 or 12 or 13

15 (prevent* or program* or strategy or strategies* or intervention* or policy or policies or initiative* or guideline*).tw.

16 Motivation/

17 Health Behavior/

18 Patient Compliance/

19 Health Promotion/

20 Patient Education as Topic/

21 Health Education/

22 (((behavio?r or behavio?rs) adj3 (change or changed or changing or modifying or modified or modification)) or lifestyle).tw.

23 (instruct* or advice or advise* or educat* or teach* or train*).tw.

24 (attitude adj3 (change or changed or changing or modifying or modified or

modification)).tw.

25 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24

26 14 and 25

27 Dental Caries/

28 exp Oral Health/

29 exp Oral Hygiene/

30 exp Tooth Demineralization/

31 exp Tooth Remineralization/

32 Dental Plaque/

33 (caries or carious or DMF* or decay* or plaque or periodont* or deminerali* or cavit* or lesion* or reminerali*).tw.

34 ((mouth or oral or dental or teeth or tooth) adj6 care).tw.

35 ((control or remov*) adj3 plaque).tw.

36 (toothbrush* or tooth-brush* or toothpaste* or tooth-paste* or dentifric*).tw.

37 ((mouth or oral or dental or teeth or tooth) adj6 health).tw.

38 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37

39 exp Obesity/

40 Body Weight/

41 exp "Body Weights and Measures"/

42 Body Mass Index/

43 (obes* or overweight or "over weight" or (body adj2 weight) or ((body or mass or abdominal or intra-abdominal or ectopic or subcutaneous) adj2 fat) or ((change* or gain* or loss) adj2 weight) or adipos* or waist-circumference* or "body-mass index" or BMI or waist-to-hip or waist-hip).tw.

44 39 or 40 or 41 or 42 or 43

45 38 and 44

46 38 or 44

47 9 and 26 and 45

48 9 and 26 and 46

49 9 and 26 and 38

50 9 and 26 and 44

51 47 or 49

52 ("clinical trial" or randomi?ed or placebo or randomly or trial*).tw.

53 Clinical Trial/

54 Comparative Study/

55 52 or 53 or 54

56 51 and 55

B Public Benefit and Privacy Panel for Health and Social Care Approval Letter

Public Benefit and Privacy Panel for Health and Social Care
nss.PBPP@nhs.net
www.informationgovernance.scot.nhs.uk

NHS SCOTLAND

Mr Ahmed Mahmoud,
University of Glasgow Dental School,
378 Sauchiehall Street,
Glasgow,
G2 3JZ

Date: 16th November 2018
Your Ref:
Our Ref: 1516-0368 Mahmoud

Dear Mr Mahmoud,

Re Application: Application 1516-0368 Mahmoud - Evaluation of Childsmile Outcomes
Version: 4

Further to your approval issued by the Public Benefit and Privacy Panel for Health and Social Care on 2nd November 2015, I am writing to confirm that we accept the amendment(s) to the proposal notified on 15/11/2018.

The accepted amendments are:

1. Add a new PhD student to the application for access to the data.

2. Add additional variables in order to achieve our aims and objectives from the linkage project:

- episode start date,
- episode end date,
- placement type,
- episode end date,
- foster placement type,
- legal reason for each episode,
- placement type for each episode and care plan for each episode.

Please note that any conditions attached to your original approval remain in place and you should continue to comply with those conditions outlined in the approval letter. In addition, please provide the amended Information Sharing Agreement with Scottish Government/ Education Analytical Services Division.

This approval is given to process data as specified in the approved application form, and is limited to this.

Requests for access to NHS Scotland data as part of this approved application should be supported by evidencing a copy of your approval letter and application form to the relevant local board contacts/data providers.

I would take this opportunity to remind you of the declaration you have made in your application form committing you to undertakings in respect of information governance, confidentiality and data protection.

Yours sincerely,

Phil Dalgleish
Panel Manager
NHS Scotland Public Benefit and Privacy Panel for Health and Social Care
Email: **nss.PBPP@nhs.net**

C National Safe Haven Statistical Disclosure V1

National Safe Haven: Requesting Outputs

The request form and checklist will help you develop your requests for outputs and prepare for disclosure control. Following this advice will help you anticipate some of the queries that might come back to you, meaning that your outputs could be released faster.

Processing Time: All outputs are checked by two members of eDRIS staff before being released. Please allow us sufficient time to review and assess your output. We aim to turnaround a request within 3 working days. However, this could vary dependent on the quantity, staff availability and complexity of tables, charts or other files in your request.

Consider the following prior to requesting a file to be released from the National Safe Haven (see also the more detailed checklists on p. 3-4):

- Make sure your titles and descriptions are clear and self-explanatory
- Make sure your outputs do not contain embedded data which could be made available after release
- Check for small, potentially disclosive numbers
- Differencing from previously released outputs: Have you produced similar analysis before that combined with this output could be used to identify someone?
- Do you need it released? Do you want a draft output to be released so that you can discuss with your project team? You could consider reviewing it within the National Safe Haven alongside any members of your project team that are named in your governance documentation and have completed relevant Information Governance training.

On completion save in the Results folder and email your eDRIS researcher coordinator to request release of your files. Your output files that have been cleared for disclosure by your eDRIS research coordinator will be sent to you via email.

Acknowledgements in publications:

The eDRIS team ask that you acknowledge the use of our service and the National Safe Haven in any publications/presentations where appropriate. An example of this is shown below:

"The authors would like to acknowledge the support of the eDRIS Team (Public Health Scotland) for their involvement in obtaining approvals, provisioning and linking data and the use of the secure analytical platform within the National Safe Haven."

National Safe Haven Output Request Form

Study Number: ______________________________

Name: _____________________________________

Date of request: _____________

Date of sign out (eDRIS office use only) _______________

I have read the 'A guide for users requesting outputs from the National Safe Haven'	☐
I have completed the Disclosure Control Checklist	☐
I confirm that the requested outputs fall within the scope of the project's aims and objectives	☐

Brief description of study cohort including dates and geographical coverage of data.

E.g. Cohort consists of people admitted to hospital between 1981 and 1990 with disease x for the whole of Scotland with follow up until December 2018.

Please complete the table below for each file to be released. (insert additional rows if required)

File name	File Type e.g. Word, excel, PDF, R code etc.	Description of file contents	Is this an update to a previously released file? If so, please provide details of changes	Reason for release (eg internal/draft/publication)
Tables for XYZ	Word	Table 3 - Estimated incidence rate of disease x v2: Estimated incidence rate of disease x with 95% CI stratified by year of diagnosis and age at diagnosis	Yes – re-run as error spotted in original code. Changed figures highlighted in yellow. Previous file called Table 3 - Estimated incidence rate of disease x	internal

Disclosure Control Checklist for National Safe Haven Outputs Requests

Complete the following checks:
(Please answer all questions)

Frequency tables/charts

	Yes	No
Are there any cells in the table with a value >0 and ≤5?	☐	☐
If there is any sensitive information or low-level geography, are there any cells in the table with a value >0 and ≤10?	☐	☐
Are there any columns or rows dominated by zeros or 100% of observations?	☐	☐
Are there any cells with suppressed values/hidden columns or rows?	☐	☐
Has the table used a different population base from previous similar tables?	☐	☐
Has the table used a different variable breakdown from a previous similar table?	☐	☐
Has the table used a different definition or source for a variable previously tabulated?	☐	☐
Are there any minima/maxima present?	☐	☐

Models

	Yes	No
Does the model have fewer than 10 residual degrees of freedom?	☐	☐
Does the model description quote or plot any individual values, such as minimum or maximum values or outliers?	☐	☐
Does the model description include a residual plot or residual values?	☐	☐
Has the model used a different population base from a previously described model?	☐	☐
Is the regression undertaken on a single unit?	☐	☐
Does the regression solely consist of categorical variables?	☐	☐

Coding files (syntax)

	Yes	No
Is the code clearly annotated with comments to assist the reviewer?	☐	☐
Are there any references or figures in the comments or code that could lead to potential identification of individuals?	☐	☐
Are there any pseudo anonymised ID numbers included in the code or the comments?	☐	☐
Has the volume of code needed been minimised?	☐	☐
Are there any counts from the data present in the comments or code?	☐	☐

- **Any white** boxes ticked, your output will fail SDC. If you think your output should still pass, please discuss this with your research coordinator.

- **Any light grey** boxes ticked, your output may fail SDC. If your output fails, your research coordinator can also provide advice about how to re-design your outputs so they will pass.

- **All dark grey** boxes ticked, your output is likely to pass SDC, but it still needs to be checked.

The research coordinator will compare your outputs to all outputs previously released from the same dataset to make sure it is not possible to identify any individuals or small cells by comparing outputs.

Because of this, it is a good idea to think carefully about the population base and variable breakdowns you will need to use later on, before you release your first outputs.

Example scenarios:

Changing variable breakdowns

- You release a table showing a variable against age and sex, in wide age bands (i.e. 16-39, 40-64, 65+). Later you decide to release some tables with different age bands (16-39, 40-59, 60+), to coincide with routine screening for a particular disease starting at age 60. The new tables can be compared against the old tables to produce a table of information about people in your sample aged 60-64. Your new tables will only pass SDC if they would pass for the 60-64 age group in their own right.

Excluding data points

- You release some tables of results based on your whole sample of linked records. You later discover that a particular medical condition interacts with the effect you are investigating, so you decide to exclude all individuals with this medical condition from your analysis. Your new tables could now be compared against the original tables you released, to reveal information about the people you excluded from your analysis. Your new tables will now only pass SDC if the equivalent table for the excluded group also passes in its own right. If the group you want to exclude is small, this will limit your chances of any tables passing SDC.

Adding data points

- You release some data on all individuals registered as blind or partially sighted, and later decide to widen the scope to all individuals with any visual impairment in order to have a larger sample size for your model. Your new outputs could be used to produce results about all people with visual impairments who are not registered as blind or partially sighted. These outputs will also need to pass an SDC check.

Changing definitions

- You release some results on all individuals in your sample who said they were retired at a certain date. You later change your definitions to include only people who both said they were retired, and were over the state pension age at that date. Any new outputs will reveal some information about people who retired under the state pension age, and this will also need to pass an SDC check.

- You release some data on all individuals in your sample who said they were retired at a certain date. You later change your definitions to use HMRC records showing whether or not an individual received a state pension. This would not necessarily create a problem for SDC, as it is possible to be either retired with no state pension or receiving a state pension while not retired.

D Medical Research Council, GDPR and Confidentiality Quiz Certificate Ryan Stewart (September 2018)

MRC Medical Research Council

Regulatory Support Centre

This is to certify that:

Ryan Stewart

Passed

Research, GDPR and confidentiality Quiz

Date / Time	Student Score	Passing Score	Result
September 25, 2018 6:11 pm	77.77	70	Pass

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E Medical Research Council, GDPR and Confidentiality Quiz Certificate Ryan Stewart (November 2020)

This is to certify that:

Ryan Stewart

Passed

Research, GDPR and confidentiality Quiz

Date / Time	Student Score	Passing Score	Result
November 2, 2020 5:33 pm	100	70	Pass

(Click here to print this page)

F Medical Research Council, GDPR and Confidentiality Quiz Certificate Ryan Stewart (June 2023)

MRC Medical Research Council

Regulatory Support Centre

This is to certify that:

Ryan Stewart

Passed

Research, GDPR and confidentiality Quiz

Date / Time	Student Score	Passing Score	Result
June 1, 2023 12:33 pm	100	70	Pass

(Click here to print this page)

G Child Health Surveillance Programme 6 to 8 weeks Review Form

MEDICAL-IN-CONFIDENCE **HEALTH VISITOR COPY**

6 to 8 Week Assessment (Gestational Age) *IF THE CHILD IS MORE THAN 12 WEEKS OLD PLEASE USE AN 'UNSCHEDULED' FORM*

SCHEDULED DATE OF ASSESSMENT: ACTUAL DATE OF ASSESSMENT:

CHI NO HB
GENDER
HEALTH VISITOR
TREATMENT CENTRE
GP PRACTICE

PLEASE PRINT CLEARLY IN BALL POINT PEN EDD

Please check the information above and if appropriate, enter amendments below. Please also advise the GP of any changes.
Change of name to: Change of GP to:
Change of TC to: CHSP PS SIRS Change of Caseload HV to:
Change of address to: Postcode:

Carer present with child at review (Y) Primary carer Additional carer Other Current LAC Status

Blood Spot Results *
PKU
CHT
CF
MCD
HBO
HCU
MSU
GA1
IVA

Ethnicity: * Is English 1st language at home? (Y/N) * Bilingual/multilingual (Y/N) *

Vitamin K given I/M (Y/N) * Oral (Y/N) *

Primary carer current smoker (Y/N) Child exposed to 2nd hand smoke (Y/N)

FEEDING:-
Ever breast fed (Y/N) * Always exclusively breast fed (Y/N) *
Current feeding (B, F, M, O, U) (previous 24 hours) Child's age when breast feeding stopped: Weeks * Days *

Sleeping: (Y/N) Prone Supine Side Newborn Hearing Screening Results R * L *

Concerns raised by carer, enter (R)
Feeding/Diet Growth/Weight Sleep Development Physical Health Other

Development outcome of assessment: **N** - No Concerns **C** - Concern newly suspected **P** - Concern/Disorder previously identified **X** - Assessment incomplete
Gross Motor Hearing Speech, Language & Communication Vision Personal/Social
Tools: - indicate all used during the review to support developmental assessment (see over for codes)

Growth: Length (cms) Weight (kg) OFC (cms) Date measured

For each of the items below, enter **N** - normal, **A** - abnormal, **D** - doubtful or uncertain, **I** - not done/incomplete.

Heart Hips R L Testes R L Genitalia Femoral Pulses R L Eyes: (red reflex) R L

Future action: enter code if applicable **P** - Provide **S** - Signposted to **D** - Discuss with **R** - Request assistance from **W** - Refused
GP Parenting Support Audiology Speech & Language Community Paediatrics CAMHS Childsmile
Smoking Cessation Child Healthy Weight Early Education Financial Advice Services Social Work Physio/OT Other Services

Summary: list any **issues** likely to be relevant to the child's ongoing health, development or well-being. **ENTER ISSUE STATUS**
PLEASE PRINT CLEARLY Issue Status Read Code
(1)
(2)
(3)
(4)

Recall to HV in wks Appt - enter S, M, L Reason for recall
Recall to GP in wks Appt - enter S, M, L Reason for recall

Health Plan Indicator (HPI) * **Updated HPI** Support Needs Status *

Summary comment

Practitioners involved in review (enter Y for all that apply) HV Staff Nurse Nursery Nurse/FSW GP Other

Place of review (enter Y for all that apply) Home Clinic GP Practice Other

Signature Print Name ID No
Signature Print Name

ver 1.12 131217 (ver 1.11 030417)

CHILD HEALTH PROGRAMME – PRE-SCHOOL

Items marked with an * will be pre-printed with data, if already recorded on the system

Current LAC Status

0	Not currently looked after by local authority
1	Looked after at home
2	Looked after with friends/relatives (placed with friends or relatives who are not approved foster carers)
3	Looked after with foster carers (placed with approved foster carers provided by or purchased by the local authority)
4	Looked after with prospective adopters
5	Looked after in other community placement (eg supported accommodation, hospital)
6	Looked after in residential care (any form of residential care eg local authority or voluntary children's home or crisis care refuge)

Ethnicity Code List

This code list was developed for the 2011 census and is the agreed national NHS Scotland standard list.
Code 99 indicates that the individual was not asked, if they decline to answer code 98 should be used

Group A - White

1A	Scottish
1B	Other British
1C	Irish
1K	Gypsy / Traveller
1L	Polish
1Z	Other white ethnic group

Group B – Mixed or Multiple Ethnic Groups

2A	Any mixed or multiple ethnic groups

Group C – Asian, Asian Scottish or Asian British

3F	Pakistani, Pakistani Scottish or Pakistani British
3G	Indian, Indian Scottish or Indian British
3H	Bangladeshi, Bangladeshi Scottish or Bangladeshi British
3J	Chinese, Chinese Scottish or Chinese British
3Z	Other Asian, Asian Scottish, Asian British

Group D - African

4D	African, African Scottish or African British
4Y	Other African

Group E – Caribbean or Black

5C	Caribbean, Caribbean Scottish or Caribbean British
5D	Black, Black Scottish or Black British
5Y	Other Caribbean or Black

Group F - Other Ethnic Group

6A	Arab, Arab Scottish or Arab British
6Z	Other ethnic group

Group G – Refused / Not Provided By Patient

98	Refused / Not provided by patient

Group H – Not Known

99	Not known

Current Feeding

B	Breast milk only
F	Formula milk only
M	Mixed breast and formula milk
O	Other
U	Unknown

Tools used to support developmental assessment

01	PEDS	**07**	SSLM
02	PEDS:DM	**08**	M-CHAT
03	ASQ 3	**10**	Other validated questionnaire
05	SDQ	**11**	None
06	ASQ:SE		

Blood Spot Results

BLANK	No result
NORM	Not suspected
REF	Suspected (Referred to Specialist)
VER	Awaiting verification
UNKN	Unknown / Unavailable
RFSD	Refused / Declined
LATE	Late tested (CF only)
NONE	Test not done

Newborn Hearing Screening Results

P	Pass
R	Refer
W	Withdrawn
I	Not done / Incomplete

Issue Status Code

When an issue is entered for the first time, the issue status code must be entered.
Subsequent pre-printed issues must have status updated in the issue status column

0	Referred /Assistance requested
1	Issue ongoing
(#) 2	No longer has issue
(#) 3	Amend issue (must add new issue)
4	No information available
(#) 5	Issue/Code incorrectly recorded
6	Discharged due to DNA

NB SYMBOL (#) INDICATES USE OF THIS CODE WILL CLOSE A PROBLEM

Health Plan Indicator (HPI)

C	Core Programme
A	Additional Programme
U	Unknown

Support Needs Status

0	Not active on SNS
1	Active – not yet notified to Doctor
2	Active – not yet assessed
3	Active – being assessed
4	Previously on SNS
8	No Planned Assessment

6 – 8 WEEK ASSESSMENT 070316

H Description of the NDIP Primary 1 Dataset

The NDIP Primary 1 dataset provides the results from the NDIP Primary 1 basic inspection held in all Local Authority primary schools in Scotland and some private. Included indices are from children who were in the *RQ1 cohort* (Section 3.3.1). Excluded indices were of children who were removed through the data cleaning process (Section 2.14.1). The included indices may be double counted in table where records were later identified as repeat exam or duplicated observation ((Table 2).

The **'Match Weight'** which indicates the linkage match weight for the index was complete for 100% of the included and excluded indexes. This was true too for the **'Date of Birth'** variable. The **'Sex'** variable, which gives the sex of the child, had a 100% completion rate and a similar breakdown of males and females included and excluded (Table 2).

'School Postcode' provided the postcode of the school that the inspection took place. This was complete for 99.9% of included indexes. If the exam was a success, **'No Exam'** would be marked as 'Not Applicable'. The rest of this variable indicates the reason that the inspection was unsuccessful. There is a difference in breakdown between the included and excluded records but this would be expected as a criteria for being included was that the inspection was valid. Calibration inspections were conducted to ensure consistency across the DHSW. If the inspection was for calibration purposes, **'Repeat Exam'** was marked as 'True'. This variable was complete for 100% of records in both the included and excluded indexes (Table 2).

The next set of variables provided indicate the dental health of the child. **'A1 - Abscess or Infection'** for complete for 100% of records overall, which was also the case for **'A2 - Gross Caries'**. **'A3 - Obviously Carious Permanent Tooth'** was complete for 99.6% of the included indexes. The indexes where this was missing was narrow down to one NHS Health Board which if the child did not have a permanent tooth the record was left blank. 'Missing' records in this instance could be counted as 'No'. **'B1 - Obviously Carious Primary Tooth'**, **'B2 - Possibly Carious Permanent Tooth'**, **'B3 - Missing Primary Molar'**, and **'B4 - Evidence of Restorations'** all were complete for 100% of records in the included and excluded indexes. **'B5 - Poor Oral Health'** was missing for 41.5% of the included records. This was due to some NHS Health Boards not recording this variable, however, since this study classes **'B5 - Poor Oral Health'** as no obvious caries experience the missing records did not impact results. **'C - No Obvious Caries Experience'** was complete for 97.3% of the included indexes. Some NHS Health Boards left this variable blank in certain situations, mainly when the child already had received a '1' in another level. It would be expected that if the child did not have an exam that some of the above variables would be missing, although the software used automatically filled in invalid records as '0' for all of the dental health variables. The **'Overall Category'** was an automatically derived variable by the system to indicate which letter should be sent home to parents (Section 2.8.2.1) (Table 2).

'NDIP Year' indicated the school year which the inspection took place. This was complete for 100% of records in the included and excluded indexes (Table 2).

The NHS Health Board of the exam was record in **'Health Board of NDIP Examination'**, which was complete for 99.8% of included indexes. This was missing more 10.1% of the excluded indexes. If the missing records are removed, the break down of each health board is fairly similar for the included and excluded records. The area-based deprivation measurement of the child's home postcode at the time of inspection was provided for SIMD 2012 and SIMD 2016 in quintile and deciles. For **'SIMD 2012 Scottish Quintile'**, 99.9% of the included indexes had a valid SIMD 2012 record, which was the case for **'SIMD 2012 Scottish Decile'**. Focusing on **'SIMD 2012 Scottish Quintile'**, a higher proportion more children from SIMD 1 are excluded compared to included, and a slight lower proportion of SIMD 5. This could be explained by children from SIMD 1 are more likely to be absent from school (Scottish Government, 2017) and thus not receive a valid NDIP examination. This was similar too for **'SIMD 2016 Scottish Quintile'** and **'SIMD 2016 Scottish Decile'**. Within the included indexes, **'SIMD 2016 Scottish Quintile'** and **'SIMD 2016 Scottish Decile'** was complete for >99.9% of records, with 9.9% of records missing a measurement in the excluded indexes (Table 2).

Table 2: Frequency of categories within each variable of the National Dental Inspection Programme Primary 1 data set, after data linkage, by records included in and excluded from the final research question 1 cohort

Variable	Completeness			
	Included		Excluded	
	n	%	n	%
Match Weight				
Complete	366268	100.0	34942	100.0
Missing	0	0.0	0	0.0
Date of Birth				
Complete	366268	100.0	34941	100.0
Missing	0	0.0	1	0.0
Sex				
Male	187399	51.2	18259	52.3
Female	178869	48.8	16683	47.7
Missing	0	0.0	0	0.0
School Postcode				
Complete	365736	99.9	34727	99.4
Missing	532	0.1	215	0.6
Date of Inspection				
Complete	366268	100.0	34939	100.0
Missing	0	0.0	3	0.0
No Exam				
Not Applicable	362648	99.0	4273	12.2
Absent	368	0.1	21651	62.0
Child Refusal	26	0.0	2220	6.3
No Detailed Explanation	0	0.0	4	0.0
Not Attending	2486	0.7	3015	8.6
Parental Refusal	18	0.0	2983	8.5
Remove From List	717	0.2	816	2.3
Missing	5	0.0	0	0.0
Repeat Exam				
False	362571	99.0	34894	99.9
True	3697	1.0	48	0.1
A1 - Abscess or Infection				
0	360654	98.5	34860	99.8

1	5,614	1.5	82	0.2
Missing	0	0.0	0	0.0
A2 - Gross Caries				
0	338618	92.5	34514	98.8
1	27,650	7.5	428	1.2
Missing	0	0.0	0	0.0
A3 - Obviously Carious Permanent Tooth				
0	364586	99.5	34769	99.5
1	306	0.1	3	0.0
Missing	1376	0.4	170	0.5
B1 - Obviously Carious Primary Tooth				
0	284758	77.7	33789	96.7
1	81510	22.3	1153	3.3
Missing	0	0.0	0	0.0
B2 - Possibly Carious Permanent Tooth				
0	365177	99.7	34923	99.9
1	1091	0.3	19	0.1
Missing	0	0.0	0	0.0
B3 - Missing Primary Molar				
0	345494	94.3	34685	99.3
1	20774	5.7	257	0.7
Missing	0	0.0	0	0.0
B4 - Evidence of Restorations				
0	332953	90.9	34449	98.6
1	33315	9.1	493	1.4
Missing	0	0.0	0	0.0
B5 - Poor Oral Health				
0	209055	57.1	20206	57.8
1	5232	1.4	123	0.4
Missing	151981	41.5	14613	41.8
C - No Obvious Caries Experience				
0	113427	30.9	31560	90.3
1	243131	66.4	2475	7.1
Missing	9710	2.7	907	2.6

Overall Category				
A	29596	8.1	456	1.3
B	84246	23.0	1118	3.2
C	248530	67.9	2481	7.1
X	3656	1.0	30854	88.3
Missing	240	0	33	0.0
NDIP Year				
2011/12	50859	13.9	4877	14.0
2012/13	51555	14.1	5407	15.5
2013/14	53625	14.6	4676	13.4
2014/15	52549	14.3	4861	13.9
2015/16	52638	14.4	4684	13.4
2016/17	52096	14.2	5429	15.5
2017/18	52946	14.5	5008	14.3
Health Board of NDIP Examination				
AA NHS Ayrshire & Arran	24811	6.8	1854	5.3
B NHS Borders	7557	2.1	548	1.6
DG NHS Dumfries & Galloway	9572	2.6	966	2.8
F NHS Fife	26248	7.2	2708	7.7
FV NHS Forth Valley	21228	5.8	1896	5.4
G NHS Grampian	39439	10.8	3763	10.8
GGC NHS Greater Glasgow & Clyde	77346	21.1	6206	17.8
H NHS Highland	20298	5.5	1910	5.5
La NHS Lanarkshire	48049	13.1	3670	10.5
Lo NHS Lothian	58489	16.0	5027	14.4
O NHS Orkney	1491	0.4	49	0.1
S NHS Shetland	1634	0.4	103	0.3
T NHS Tayside	27473	7.5	2596	7.4
WI NHS Western Isles	1765	0.5	123	0.4
Missing	868	0.2	3523	10.1
Scottish Index of Multiple Deprivation 2012 Scottish Quintile				
1	86969	23.7	9122	26.1
2	73421	20.0	6881	19.7
3	69964	19.1	5957	17.0

4	70793	19.3	5263	15.1
5	64607	17.6	4205	12.0
Missing	514	0.1	3514	10.1
Scottish Index of Multiple Deprivation 2012 Scottish Decile				
1	45637	12.5	4956	14.2
2	41332	11.3	4166	11.9
3	37216	10.2	3634	10.4
4	36205	9.9	3247	9.3
5	35453	9.7	3039	8.7
6	34511	9.4	2918	8.4
7	36176	9.9	2743	7.9
8	34617	9.5	2520	7.2
9	33973	9.3	2295	6.6
10	30634	8.4	1910	5.5
Missing	514	0.0	3514	10.1
Scottish Index of Multiple Deprivation 2016 Scottish Decile				
1	44376	12.1	4879	14.0
2	41442	11.3	4203	12.0
3	38169	10.4	3713	10.6
4	35900	9.8	3299	9.4
5	33989	9.3	2869	8.2
6	33065	9.0	2824	8.1
7	33874	9.2	2598	7.4
8	35298	9.6	2538	7.3
9	36456	10.0	2446	7.0
10	33609	9.2	2112	6.0
Missing	90	0.0	3461	9.9
Scottish Index of Multiple Deprivation 2016 Scottish Quintile				
1	85818	23.4	9082	26.0
2	74069	10.2	7012	20.1
3	67054	18.3	5693	16.3
4	69172	18.9	5136	14.7
5	70065	19.1	4558	13.0
Missing	90	0.0	3461	9.9

I Description of the CHSP-S Dataset

The CHSP-S dataset provides the results from the CHSP-S inspection held in all Local Authority primary schools in Scotland. Included indexes are from children who were in the *RQ2 cohort* (Section 4.3.1). Excluded indexes were from children who were not included in the cohort (Table 3).

'Date of Birth' variable provides the date pf birth of the child as is complete for 100% of all indexes. The date the exam took place was recorded under **'Date of Exam'** and was complete for all indexes. **'Sex'** indicates the sex of the child and has a 100% completion rate for both the included and excluded indexes. There was a similar breakdown of males and females between the included and excluded indexes (Table 3).

Anthropometric measures were recorded in the variables **'Height'** and **'Weight'**, which were used to calculate the **'BMI'** of the child. The BMI was then converted in to BMI SDS scores and recorded under **'BMI Standard Deviation Score'**. These were then converted into centiles which was provided in **'BMI Centile'**. All these variables had a 100% completion rate for the both the included and excluded indexes (Table 3).

Each primary school is given a unique code which is provided in the **'Code of School'** variable, with a 100% completion rate. The NHS Health Board of the school, **'Health Board of School'** was complete for 100% of records of the included indexes. Of the excluded indexes, 58.4% had a missing **'Health Board of School'** record. When excluding the missing records, the breakdown of health boards varies between the included and excluded variables, however, due to the small number of indexes excludes, slight changes in the number from each health board can affect the percentage. The area-based deprivation measurement of the child's home postcode was provided for SIMD 2012 and SIMD 2016 in quintile and deciles. For **'SIMD 2012 Scottish Quintile'**, 99.8% of the included indexes had a valid SIMD 2012 record, which was the case for **'SIMD 2012 Scottish Decile'**. Focusing on **'SIMD 2012 Scottish Quintile'**, a similar proportion of children from all SIMD fifths are excluded compared to included. This was similar too for **'SIMD 2016 Scottish Quintile'** and **'SIMD 2016 Scottish Decile'**. Within the included indexes, **'SIMD 2016 Scottish Quintile'** and **'SIMD 2016 Scottish Decile'** was complete for 100.0% of records, with 58.4% of records missing a measurement in the excluded indexes (Table 3).

Table 3: Frequency of categories within each variable of the Child Health Systems Programme - School data set, after data linkage, by records included in and excluded from the final research question 2 cohort

Variable	Completeness			
	Included		Excluded	
	n	%	n	%
Date of Birth				
Complete	373189	100.0	878	100.0
Missing	0	0.0	0	0.0
Date of Exam				
Complete	373189	100.0	878	100.0
Missing	0	0.0	0	0.0
Sex				
Male	190100	50.9	445	50.7
Female	183089	49.1	433	49.3
Missing	0	0.0	0	0.0
Height				
Complete	373189	100.0	878	100.0
Missing	0	0.0	0	0.0
Weight				
Complete	373189	100.0	878	100.0
Missing	0	0.0	0	0.0
Body Mass Index				
Complete	373189	100.0	878	100.0
Missing	0	0.0	0	0.0
Code of School				
Complete	373189	100.0	878	100.0
Missing	0	0.0	0	0.0
Body Mass Index Standard Deviation Score				
Complete	373189	100.0	878	100.0
Missing	0	0.0	0	0.0
Body Mass Index Centile				

Complete	373189	100.0	878	100.0
Missing	0	0.0	0	0.0
Health Board of School				
NHS Ayrshire & Arran	26076	7.0	14	1.6
NHS Borders	7754	2.1	3	0.3
NHS Dumfries & Galloway	9601	2.6	8	0.9
NHS Fife	27292	7.3	32	3.6
NHS Forth Valley	22442	6.0	27	3.1
NHS Grampian	39243	10.5	65	7.4
NHS Greater Glasgow & Clyde	77676	20.8	52	5.9
NHS Highland	21158	5.7	29	3.3
NHS Lanarkshire	48606	13.0	60	6.8
NHS Lothian	59543	16.0	57	6.5
NHS Orkney	1376	0.4	0	0.0
NHS Shetland	1800	0.5	9	1.0
NHS Tayside	28870	7.7	4	0.5
NHS Western Isles	1752	0.5	5	0.6
Missing	0	0.0	513	58.4
Scottish Index of Multiple Deprivation 2012 Scottish Quintile				
1	88516	23.7	80	9.1
2	74735	20.0	67	7.6
3	71419	19.1	80	9.1
4	72568	19.4	67	7.6
5	6332	17.5	58	6.6
Missing	619	0.2	526	59.9
Scottish Index of Multiple Deprivation 2012 Scottish Decile				
1	46566	12.5	41	4.7
2	41950	11.2	39	4.4
3	37882	10.2	33	3.8
4	36853	9.9	34	3.9
5	36082	9.7	43	4.9
6	35337	9.5	37	4.2
7	37179	10.0	38	4.3
8	35389	9.5	29	3.3

9	34435	9.2	27	3.1
10	30897	8.3	31	3.5
Missing	619	0.2	526	59.9
Scottish Index of Multiple Deprivation 2016 Scottish Decile				
1	45053	12.1	45	5.1
2	42380	11.4	41	4.7
3	38830	10.4	32	3.5
4	36582	9.8	34	3.9
5	34914	9.4	37	4.2
6	33837	9.1	48	5.5
7	34445	9.2	33	3.8
8	36231	9.7	28	3.2
9	36994	9.9	25	2.9
10	33923	9.1	43	4.9
Missing	0	0.0	513	58.4
Scottish Index of Multiple Deprivation 2016 Scottish Quintile				
1	87433	23.4	86	9.8
2	75412	20.2	65	7.4
3	68751	18.4	85	9.7
4	70676	18.9	61	7.0
5	70917	19.0	68	7.7
Missing	0	0.0	513	58.4

J Description of the Management Information & Dental Account System Participation Dataset

The MIDAS Participation dataset indicates each time an individual has interacted with a GDS. Within this dataset there is no information on the reason for interaction, only that the interaction happened and on which given date. Included indexes are from children who were in the *RQ5 cohort* (Section 7.3.1). Excluded indexes were from children who were not included in the cohort.

The **'Date of Birth'** and **'Sex'** variables have 100% completion rate for both the included and excluded indexes. The sex breakdown was similar between the included and excluded indexes (Table 4).

The **'Start Date of Treatment'** variable had a 100% completion rate overall and indicates on what date the interaction took place. The unique number which the dentist submits claim under is given in the variable **'List Number'**, **'Location Number'**, which gives the unique code for each dental practice, and **'Dentist Postcode'**, which provides the postcode of the practice, all had a 100% completion rate for the included and excluded records (Table 4).

Table 4: Frequency of categories within each variable of the Management Information & Dental Account System Participation data set, after data linkage, by records included in and excluded from the final research question 5 cohort

Variable	Completeness			
	Included		Excluded	
	n	%	n	%
Date of Birth				
Complete	628345	100.0	127414	100.0
Missing	0	0.0	0	0.0
Sex				
Male	317267	50.5	65834	51.7
Female	311078	49.5	61580	48.3
Missing	0	0.0	0	0.0
Start Date of Treatment				
Complete	628345	100.0	127414	100.0
Missing	0	0.0	0	0.0
List Number				
Complete	628345	100.0	127414	100.0
Missing	0	0.0	0	0.0
Location Number				
Complete	628345	100.0	127414	100.0
Missing	0	0.0	0	0.0
Dentist Postcode				
Complete	628345	100.0	127414	100.0
Missing	0	0.0	0	0.0

K Description of the Management Information & Dental Account System Treatment Dataset

The MIDAS Treatment dataset details interactions with a GDS which resulted in a fee claimable treatment. Included indexes are from children who were in the *RQ5 cohort* (Section 7.3.1). Excluded indexes were from children who were not included in the cohort.

Variables which indicate the **'Date of Birth'** and **'Sex'** of the child have 100% completion rate for both the included and excluded indexes. The sex breakdown was similar for the included and excluded indexes (Table 5).

The **'Start Date of Treatment'** variable, which indicates the date the treatment began had 100% completion rate overall. The **'Stop Date of Treatment'** variable indicates the date that the treatment ends. This variable had 99.4% completion rate overall, although if treatment ends on the same day as it began, this variable does not need to be completed. It can be assumed that a missing **'Stop Date of Treatment'** means it is the same day as **'Start Date of Treatment'** (Table 5).

The **'Fee Code'** is a 6-digit code and has a 100% completion rate, for the included and excluded indexes, as this indicates which treatment was provided. The first four digits correspond to the treatment code as in the Statement of Dental Remuneration (SDR) (Scottish Dental, 2021). The last two digits indicate the number of each treatment received e.g. a fee code ending in '02' indicates two of the treatments were provided. **'App 4 Treatment Item'** has a 96.8% completion rate for the included indexes and 96.3% the excluded indexes. Missing records on this variable are likely due to the **'Fee Code'** variable not having a corresponding name in the SDR, however the description of the treatment is provided in **'App 4 Treatment Description'** which has a 100% completion rate. The **'Number of Courses Claimed'** has 100% completion rate. This variable indicates the last two digits of the **'Fee Code'** (Table 5).

Variables corresponding to the dentist and location: **'List Number'**, **'Location Number'**, and **'Dentist Postcode'** all have 100% completion rate for both the included and excluded indexes (Table 5).

Table 5: Frequency of categories within each variable of the Management Information & Dental Account System Treatment data set, after data linkage, by records included in and excluded from the final research question 5 cohort

Variable	Completeness			
	Included		Excluded	
	n	%	n	%
Date of Birth				
Complete	888549	100.0	182097	100.0
Missing	0	0.0	0	0.0
Sex				
Male	447377	50.3	93280	51.2
Female	441172	49.7	88817	48.8
Missing	0	0.0	0.0	0.0
Start Date of Treatment				
Complete	888549	100.0	182097	100.0
Missing	0	0.0	0	0.0
Stop Date of Treatment				
Complete	883188	99.4	180768	99.3
Missing	5,361	0.6	1,329	0.7
Fee Code				
Complete	888549	100.0	182097	100.0
Missing	0	0.0	0	0.0
List Number				
Complete	888549	100.0	182097	100.0
Missing	0	0.0	0	0.0
Location Number				
Complete	888549	100.0	182097	100.0
Missing	0	0.0	0	0.0
Dentist Postcode				
Complete	888549	100.0	182097	100.0
Missing	0	0.0	0	0.0
App 4 Treatment Item				
Complete	860204	96.8	175279	96.3

Missing	28345	3.2	6818	3.7
App 4 Treatment Description				
Complete	888549	100.0	182097	100.0
Missing	0	0.0	0	0.0
Number of Courses Claimed				
Complete	888549	100.0	182097	100.0
Missing	0	0.0	0	0.0

L Description of Health Informatics Centre Dental Health Support Worker Diary Event Dataset

The HIC DHSW Diary Event dataset records all children referred to a DHSW. This dataset does not include any information on the interventions itself, only initial contacts with the family. Included indexes are from children who were in the *RQ5 cohort* (Section 7.3.1). Excluded indexes were from children who were not included in the cohort.

The **'Date of Birth'** variable had a 100% completion rate for the included and excluded indexes, while the **'Sex'** variable had 96.6% completion rate overall. There was a similar breakdown in the sex between the included and excluded indexes. The **'Health Board'** variable provided the NHS Health Board which the child lived and had a 100% completion rate. The anonymised name of the Childsmile staff member who entered the record was provided in **'Anonymised Childsmile Staff Name'** variable with 100% completion. Each unique staff member name was ran through the linkage agent to provide unique numbers, which are fully anonymised. Also provided was the postcode of the Childsmile staff member from the variable **'Postcode of Childsmile Staff'** which is was complete for 73.5% of the included indexes and 75.8% of excluded (Table 6).

The **'Referral By/At'** variable, which has a 96.6% completion rate for the included and excluded indexes, provides information on who referred the child to a DHSW, and **'Date of Referral'** indicates the date on which the referral happened. This has a 97.5% completion rate overall (Table 6).

The **'Statement Read'** variable indicates if the family were read the Childsmile statement on referral. This has a completion rate of 92.7% for the included indexes and 94.1% of the excluded. **'Contact Type'** provides the type of contact made by the DHSW and has a 100% completion rate. The start date of the contact is provided through the **'Start Date of Contact'** variable and has a 100% completion rate, and the **'End Date of Contact'** indicates the end date of the contact. This has a completion rate of 82.2% for the included indexes and 83.1% for the excluded. If this variable is missing, it can be assumed the end date of the contact was the same as the start date (Table 6).

Table 6: Frequency of categories within each variable of the Health Informatics Centre Diary Event data set, after data linkage, by records included in and excluded from the final research question 5 cohort

Variable	Completeness			
	Included		Excluded	
	n	%	n	%
Date of Birth				
Complete	51886	100.0	15683	100.0
Missing	0	0.0	0	0.0
Sex				
Male	26879	51.8	8407	53.6
Female	24790	47.8	7211	46.0
Missing	217	0.4	65	0.4
Health Board				
Ayrshire & Arran	5115	9.9	999	6.4
Borders	2759	5.3	654	4.2
Dumfries & Galloway	2832	5.5	841	5.4
Fife	2689	5.2	1407	9.0
Forth Valley	1663	3.2	473	3.0
Grampian	1393	2.7	395	2.5
Greater Glasgow	15351	29.6	5009	31.9
Highland	5038	9.7	1475	9.4
Lanarkshire	8872	17.1	2592	16.5
Lothian	4839	9.3	1454	9.3
Orkney	6	0.0	1	0.0
Shetland	30	0.1	2	0.0
Tayside	1296	2.5	381	2.4
Western Isles	3	0.0	0	0.0
Missing	0	0.0	0	0.0
Anonymised Childsmile Staff Name				
Complete	51886	100.0	15683	100.0
Missing	0	0.0	0	0.0

Postcode of Childsmile Staff				
Complete	38142	73.5	11887	75.8
Missing	13744	26.5	3796	24.2
Referral By / At				
Clinic	1670	3.2	424	2.7
Dentist	2225	4.3	638	4.1
Health Visitor	39980	77.1	11997	76.5
NHS	418	0.8	130	0.8
Other	7031	13.6	2350	15.0
Self	346	0.7	78	1.5
Missing	216	0.4	66	0.4
Date of Referral				
Complete	50580	97.5	15289	97.5
Missing	1306	2.5	394	2.5
Statement Read				
No	23289	47.8	7501	47.8
Yes	24826	44.9	7251	46.2
Missing	3771	7.3	931	5.9
Contact Type				
Appointment	322	0.6	135	0.9
Letter	5255	10.1	1649	10.5
Other Pro	1287	2.5	545	3.5
Phone Inter	6970	13.4	1853	11.8
Phone Other	10111	19.5	3011	19.2
Text	811	1.6	332	2.1
Visit Cold	1860	3.6	616	3.9
Visit Pre	25270	48.7	7452	48.1
Missing	0	0.0	0	0.0
Start Date of Contact				
Complete	51886	100.0	15683	100.0
Missing	0	0.0	0	0.0
End Date of Contact				
Complete	42631	82.2	13036	83.1
Missing	9255	17.8	2647	16.9

M Description of Health Informatics Centre Dental Health Support Worker Practice Dataset

The HIC DHSW Practice dataset includes records interventions by a DHSW. This data includes successful and unsuccessful interventions. Included indexes are from children who were in the *RQ5 cohort* (Section 7.3.1). Excluded indexes were from children who were not included in the cohort.

'Date of Birth' is complete in 100% of record for both the included and excluded indexes. **'Sex'** is 99.8% complete overall and has a similar breakdown of males and females for the included and excluded indexes. The NHS Health Board of the child, provided through **'Health Board'** is 100% complete, with similar distributions in the included and excluded indexes (Table 7).

The **'Anonymised Childsmile Staff Name'** has 100% completion rate, however, the **'Postcode of Childsmile Staff'** only has 69.5% completion rate for the included indexes and 71.7% of the excluded (Table 7).

'Referral By/At' indicates where the referral to a DHSW took place and is completed for 99.5% of records overall. The **'Date of Referral'** variable is complete for 98.0% of records (Table 7).

'Statement Read', which was complete for 89.9% of records of the included indexes, indicates if the family were read the Childsmile statement. **'Date of Intervention'** indicates the date that the intervention took place. This has a 100% completion rate overall. **'Type of Intervention'**, which has a 96.9% completion rate for included indexes and 97.2% for excluded index, notes in which manner the intervention was delivered. **'Result of Intervention'** indicates the result of the intervention and is complete for 96.9% of the included indexes. A variable was available for the reason which the intervention was declined. This was provided in the variable **'Reason for Declined Visit'** and had a completion rate of 7.1% of the included indexes. This variable was only completed if **'Result of Intervention'** was marked as 'Declined' (Table 7).

The dataset provides information on the delivery of the interventions. **'Dietary Advice Given'** indicates if the child received dietary advice from the DHSW and has a completion rate of >99.9%. **'Toothbrushing Advice Given'** noted if the DHSW provided advice on toothbrushing. This was complete for >99.9% of records. **'Dental Pack Delivered'** is used to know if the DHSW provided the dental pack to the family and is complete for >99.9% records. In the all interventions, if the intervention was unsuccessful, as defined in **'Result of Intervention'**, the record for the interventions was automatically marked as '0' (Table 7).

After the first intervention from a DHSW, they decide on future interventions for the child. **'Continued Home Support'** indicates if the child requires further support from a DHSW. **'Appointment with Dental Services'** indicates if the DHSW has made an appointment with dental services for the child. Both the variables have >99.9% completeness. **'Dental Practice Code'** denotes if the dental service code of the family and has a 36.6% completion rate for the included indexes (Table 7).

'Re-contact Family' indicated if the family for to be recontacted and was complete for >99.9% of records. The DHSW may chose to refer the family back to the health visitor or public health nurse and this was noted in the variable **'Referred to Health Visitor'**, which has a >99.9% completion rate. **'Re-schedule Appointment'** indicates if the appointment is to be rescheduled and is complete for >99.9% of records. **'Refused Childsmile'** notes if the family have refused Childsmile and is complete for 99.9% of records. **'No Further Action'** indicates if the child is registered with a dental practice and is complete for 99.9% of records. If the family could not be contacted it was recorded in **'Family Could Not Be Contacted'**. This was complete for >99.9% of records (Table 7).

The DHSW may also signpost the family to other services. The variable **'Signposted to Another Service'**, which was complete for 73.6% of included indexes and 74.4% of the excluded indexes, indicates if this was the case. **'List of Services Signposted To'** provides a list of the services the family were signposted to. This was complete for 5.1% of included indexes, however it was only completed when **'Signposted to Another Service'** was equal to 'yes' (Table 7).

Table 7: Frequency of categories within each variable of the Health Informatics Centre Practice data set, after data linkage, by records included in and excluded from the final research question 5 cohort

Variable	Completeness			
	Included		Excluded	
	n	%	n	%
Date of Birth				
Complete	34600	100.0	10175	100.0
Missing	0	0.0	0	0.0
Sex				
Male	17662	51.0	5354	52.6
Female	16863	48.7	4797	47.1
Missing	75	0.2	24	0.2
Health Board				
Ayrshire & Arran	3503	10.1	622	6.1
Borders	1052	3.0	245	2.4
Dumfries & Galloway	921	2.7	262	2.6
Fife	1460	4.2	668	6.6
Forth Valley	585	1.7	160	1.6
Grampian	682	2.0	196	1.9
Greater Glasgow	13490	39.0	4360	42.9
Highland	2730	7.9	724	7.1
Lanarkshire	7896	22.8	2262	22.2
Lothian	1743	5.0	519	5.1
Orkney	4	0.0	1	0.0
Shetland	28	0.1	2	0.0
Tayside	503	1.5	154	1.5
Western Isles	3	0.0	0	0.0
Missing	0	0.0	0	0.0
Anonymised Childsmile Staff Name				
Complete	34600	100.0	10175	100.0
Missing	0	0.0	0	0.0
Postcode of Childsmile Staff				

Complete	24040	69.5	7292	71.7
Missing	10560	30.5	2883	28.3
Referral By / At				
Clinic	1207	3.5	316	3.1
Dentist	708	2.1	204	2.0
Health Visitor	28787	83.2	8253	81.1
NHS	129	0.4	51	0.5
Other	3480	10.1	1268	12.5
Self	131	0.4	29	0.3
Missing	158	0.5	54	0.5
Date of Referral				
Complete	33893	98.0	9974	98.0
Missing	707	2.0	201	2.0
Statement Read				
No	12612	36.5	3846	37.8
Yes	18481	53.4	5428	53.3
Missing	3507	10.1	901	8.9
Date of Intervention				
Complete	34600	100.0	10175	100.0
Missing	0	0.0	0	0.0
Type of Intervention				
Appointment	307	0.9	136	1.3
Clinic	2480	7.2	770	7.6
Home visit	23148	66.9	7019	69.0
Other	886	2.6	207	2.0
Telephone	6704	19.4	1762	17.3
Missing	1075	3.1	281	2.8
Result of Intervention				
Declined	2469	7.1	741	7.3
No entry	6288	18.2	1935	19.0
Success	24768	71.6	7218	70.9
Missing	1075	3.1	281	2.8
Reason for Declined Visit				
Declined	643	1.9	189	1.9

Inconvenient	768	2.2	254	2.5
Member ill	209	0.6	73	0.7
Other	851	2.5	225	2.2
Missing	32129	92.9	9434	92.7
Dietary Advice Given				
No	13708	39.6	4034	39.6
Yes	20890	60.4	6139	60.3
Missing	2	0.0	2	0.0
Toothbrushing Advice Given				
No	15672	45.3	4721	46.4
Yes	18926	54.7	5452	53.6
Missing	2	0.0	2	0.0
Dental Pack Delivered				
No	18834	54.4	5652	55.5
Yes	15764	45.6	4521	44.4
Missing	2	0.0	2	0.0
Continued Home Support				
No	33439	96.6	9805	96.4
Yes	1159	3.4	368	3.6
Missing	2	0.0	2	0.0
Appointment with Dental Services				
No	20385	58.9	5955	58.5
Yes	14213	41.1	4218	41.5
Missing	2	0.0	2	0.0
Dental Practice Code				
Complete	12667	36.6	3762	37.0
Missing	21933	63.4	6413	63.0
Re-contact Family				
No	29423	85.0	8622	84.7
Yes	5175	15.0	1551	15.2
Missing	2	0.0	2	0.0
Referred to Health Visitor				
No	31873	92.1	9232	90.7
Yes	2725	7.9	941	9.3

Missing	2	0.0	2	0.0
Re-schedule Appointment				
No	33490	96.8	9795	96.3
Yes	1108	3.2	378	3.7
Missing	2	0.0	2	0.0
Refused Childsmile				
No	34398	99.4	10118	99.4
Yes	200	0.6	55	0.5
Missing	2	0.0	2	0.0
No Further Action				
No	23944	69.2	7211	70.9
Yes	10654	30.8	2962	29.1
Missing	2	0.0	2	0.0
Family Could Not Be Contacted				
No	33523	96.9	9892	97.2
Yes	1075	3.1	281	2.8
Missing	2	0.0	2	0.1
Signposted to Another Service				
No	23689	68.5	7011	68.9
Yes	1780	5.1	561	5.5
Missing	9131	26.4	2603	25.6
List of Services Signposted To				
Complete	1780	5.1	561	5.5
Missing	32820	94.9	9614	94.5

N Description of Fluoride Varnish Visit Dataset

The Fluoride Varnish Visit data are related to the application of Fluoride Varnish to children as part of the Childsmile Nursery and School Programme. Included indexes are from children who were in the *RQ5 cohort* (Section 7.3.1). Excluded indexes were from children who were not included in the cohort.

The **'Date of Birth'** variable was complete for >99.9% of records overall. **'Sex'** was complete for 100% of records and there was a similar breakdown of males and females between the included and excluded indexes (Table 8).

The **'Opt-out'** variable indicated if the parent had opted the child out of the Fluoride Varnish Programme. After discussions with HIC it was deemed that 'Missing' records were for children who had not been opted out and so could be counted as 'No'. This meant there was a 100% completion rate for the variable overall. There was a variable to record the date that the child was opted out called **'Date of Opt-out'** although this was not complete for any records (Table 8).

'Date of Consent' provided information on the date the consent was given and was completion for 100% of all indexes. There were multiple versions of the consent form and so the version was recorded under the **'Consent Version'** variable, which was complete for >99.9% of indexes (Table 8).

The date of the visit for the Fluoride Varnish application was recorded under **'Date of Visit'** and was complete for 88.1% of included indexes. **'Varnish Applied'** indicated if the varnish was applied. This had a 88.1% completion rate for the included indexes (Table 8).

'Varnish Applied by Postcode' indicated the postcode of the staff member who applied the Fluoride Varnish and was completed for 58.8% of included indexes. **'Batch of Varnish'** recorded the batch number of the Fluoride Varnish and **'Expiry Date of Batch'** noted the expiry date of the batch, which had a 77.8% completion rate for both variable in the included indexes. In these variables, those marked as 'Missing' included those who did not receive a Fluoride Varnish Application (Table 8).

There were variables to indicate issues for applying the fluoride varnish in each quadrant of the child's mouth. **'Applied to Quadrant 5'** indicated issues in quadrant 5 of the child's mouth and **'Applied to Quadrant 6'** indicated issues with quadrant 6 of the child's mouth, **'Applied to Quadrant 7'** indicated issues with quadrant 7, and **'Applied to Quadrant 8'** for quadrant 8 of the mouth. These quadrants were complete for 88.1% of the included indexes and 85.4% of the excluded indexes (Table 8).

'Referral for Possible Caries' indicated a referral to a dentist for possible caries. This was complete for 88.1% of included indexes. **'Referral for Possible Abscess'** noted a referral for an abscess and **'Referral for Other Reason'** noted a referral for another reason, with both complete for 88.1% of included indexes (Table 8).

'Reason Varnish Not Applied' noted the reason the varnish was not applied. The default was 'Missing' which includes children who received a Fluoride Varnish Application. This meant that the variable was only complete for 10.4% of included records and 14.8% of excluded records (Table 8).

Table 8: Frequency of categories within each variable of the Fluoride Varnish Visit data set, after data linkage, by records included in and excluded from the final research question 5 cohort

Variable	Completeness			
	Included		Excluded	
	n	%	n	%
Date of Birth				
Complete	383540	100.0	85422	100.0
Missing	5	0.0	0	0.0
Sex				
Male	190852	49.8	42998	50.3
Female	186714	48.7	40807	47.8
Missing	5979	1.6	1617	1.9
Opt-out				
No	223508	87.5	74932	87.7
Yes	1076	0.3	359	0.4
Missing	46961	12.2	10131	11.9

Date of Opt-out				
Complete	0	0.0	0	0.0
Missing	383545	100.0	85422	100.0
Date of Consent				
Complete	383545	100.0	85422	100.0
Missing	0	0.0	0	0.0
Consent Version				
No	498	0.5	156	0.7
Complete	383544	100.0	85422	100.0
Missing	1	0.0	0	0.0
Date of Visit				
Complete	337928	88.1	72932	85.4
Missing	45617	11.9	12490	14.6
Varnish Applied				
No	40012	10.4	12671	14.8
Yes	297916	77.7	60261	70.5
Missing	45617	11.9	12490	14.6
Varnish Applied by Postcode				
Complete	225572	58.8	45309	53.0
Missing	157973	41.2	40113	47.0
Batch of Varnish				
Complete	298500	77.8	60455	70.8
Missing	85045	22.2	24967	29.2
Expiry Date of Batch				
Complete	298488	77.8	60452	70.8
Missing	85057	22.2	24970	29.2
Applied to Quadrant 5				
No	323727	84.4	69424	81.3
Yes	14201	3.7	3508	4.1
Missing	45617	11.9	12490	14.6
Applied to Quadrant 6				
No	323834	84.4	69513	81.4
Yes	14094	3.7	3419	4.0

Missing	45617	11.9	12490	14.6
Applied to Quadrant 7				
No	320664	83.6	68610	80.3
Yes	17264	4.5	4322	5.1
Missing	45617	11.9	12490	14.6
Applied to Quadrant 8				
No	320867	83.7	68714	80.4
Yes	17061	4.5	4218	4.9
Missing	45617	11.9	12490	14.6
Referral for Possible Caries				
No	307663	80.2	65825	77.1
Yes	30265	7.9	7107	8.3
Missing	45617	11.9	12490	14.6
Referral for Possible Abscess				
No	337409	88.0	72799	85.2
Yes	519	0.1	133	0.2
Missing	45617	11.9	12490	14.6
Referral for Other Reason				
No	335673	87.5	72300	84.6
Yes	2255	0.6	632	0.7
Missing	45617	11.9	12490	14.6
Reason Varnish Not Applied				
Absent	24015	6.3	7123	8.3
Left	2580	0.7	984	1.2
Other	2723	0.7	707	0.8
Sore mouth	423	0.1	100	0.1
Unwell	118	0.0	32	0.0
Unwilling	10126	2.6	3722	4.4
Missing	343560	89.6	72754	85.2

O Description of Toothbrushing Consent Dataset

Toothbrushing Consent were dataset relating to the child's consent to take part in supervised toothbrushing element of Childsmile. It was possible for children to have more than one consent e.g. a consent in more than one nursery. Included indexes are from children who were in the *RQ5 cohort* (Section 7.3.1). Excluded indexes were from children who were not included in the cohort.

The **'Date of Birth'** variable had a >99.9% completion rate for both the included and excluded indexes, while the **'Sex'** variable had a 98.9% completion rate for the included indexes. There was a similar sex breakdown in the included and excluded datasets (Table 9).

The date that the consent was recorded under **'Date Consent Received'** and was complete for 100% of all records. There were many versions of the consent form. The version used is noted in the variable **'Consent Version'** and had a 100.0% completion rate. **'Toothbrushing Consent Result'** recorded the result of the consent and was complete for 98.8% of both included and excluded records, with the vast majority obtaining consent (Table 9).

If the child required help to find a dentist, it was recorded in **'Help to Find Dentist'**, only a small amount of children needed help, but this variable was complete for 100% of records in the included and excluded indexes. **'Contact for Update'** recorded if there was a contact to update future consent. This was missing for 99.4% of records for the included indexes. **'Parental Responsibility'** confirmed if the responsible parent of the child had signed the form, which was complete for 99.6% of records. **'Health Information'** noted if there health information available on the child. This was complete for 0.6% of included records. After discussions with HIC it was deemed that 'No', 'Investigation', and 'Missing' all meant 'No' (Table 9).

'Opt-out' variable reports if consent was removed for a child to participate in the toothbrushing programme. This was complete for 81.9% of the included records, although after discussions with HIC, it was clear that 'Missing' in fact was 'No'. There was a variable to record the date that the child was opted out called **'Date of Opt-out'** although this was not complete for any records (Table 9).

Table 9: Frequency of categories within each variable of the Toothbrushing Consent data set, after data linkage, by records included in and excluded from the final research question 5 cohort

Variable	Completeness			
	Included		Excluded	
	n	%	n	%
Date of Birth				
Complete	100559	100.0	22566	100.0
Missing	16	0.0	3	0.0
Sex				
Male	50781	50.5	11613	51.5
Female	48706	48.4	10655	47.2
Missing	1088	1.1	301	1.3
Date Consent Received				
Complete	100575	100.0	22569	100.0
Missing	0	0.0	0	0.0
Consent Version				
Complete	100575	100.0	22569	100.0
Missing	0	0.0	0	0.0
Toothbrushing Consent Result				
No	498	0.5	156	0.7
Yes	99874	99.3	22361	99.1
Missing	203	0.2	52	0.2
Help to Find Dentist				
Investigation	3531	3.5	926	4.1
No	89392	88.9	19474	86.3
Yes	7632	7.6	2164	9.6
Missing	20	0.0	5	0.0
Contact for Update				
Investigation	13	0.0	3	0.0
No	54	0.1	6	0.0
Yes	525	0.5	115	0.5
Missing	99983	99.4	22445	99.5

Parental Responsibility				
Investigation	122	0.1	34	0.2
No	282	0.3	116	0.5
Yes	100152	99.6	22414	99.3
Missing	19	0.0	5	0.0
Health Information				
Investigation	10	0.0	3	0.0
No	30	0.0	3	0.0
Yes	552	0.5	118	0.5
Missing	99983	99.4	22445	99.5
Opt-out				
No	82076	81.6	18589	82.4
Yes	317	0.3	109	0.5
Missing	18182	18.1	3871	17.2
Date of Opt-out				
Complete	0	0.0	0	0.0
Missing	100575	100.0	22569	100.0

P Prevalence of caries experience by sex & Scotland overall and school year

	2011/12		2012/13		2013/14		2014/15		2015/16		2016/17		2017/18	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Scotland														
Caries	16232	32.9	16476	32.5	16705	32.2	15435	29.7	15347	30.0	14902	29.1	15244	29.5
No caries	33056	67.1	34143	67.5	35119	67.8	36497	70.3	35869	70.0	36312	70.9	36461	70.5
Male														
Caries	8653	34.3	8756	33.9	8828	33.5	8094	30.7	8126	31.2	7866	30.0	8059	30.4
No caries	16569	65.7	17107	66.1	17500	66.5	18291	69.3	17940	68.8	18352	70.0	18,453	69.6
Female														
Caries	7579	31.5	7720	31.2	7877	30.9	7341	28.7	7221	28.7	7036	28.1	7185	28.5
No caries	16487	68.5	17036	68.8	17619	69.1	18206	71.3	17929	71.3	17960	71.9	18008	71.5

Q Prevalence of caries experience by area-based deprivation and school year

School	2011/12		2012/13		2013/14		2014/15		2015/16		2016/17		2017/18	
Year	n	%	n	%	n	%	n	%	n	%	n	%	n	%
SIMD 1	**(MD)**													
Caries	3171	53.2	3166	50.8	3309	51.4	2968	47.8	2926	47.2	2979	46.8	3012	47.5
No caries	2788	46.8	3066	49.2	3129	48.6	3247	52.2	3273	52.8	3381	53.2	3332	52.5
SIMD 2														
Caries	2498	45.7	2519	44.3	2554	43.6	2396	41.7	2431	41.2	2395	41.2	2504	42.6
No caries	2,967	54.3	3171	55.7	3299	56.4	3349	58.3	3466	58.8	3421	58.8	3373	57.4
SIMD 3														
Caries	2031	40.8	2022	38.9	2105	40.1	2019	37.4	2002	37.5	2002	37.6	1965	36.5
No caries	2942	59.2	3171	61.1	3145	59.9	3,382	62.6	3333	62.5	3318	62.4	3422	63.5
SIMD 4														
Caries	1748	35.7	1841	36.4	1877	36.6	1639	32.4	1643	32.9	1639	32.0	1681	32.9
No caries	3147	64.3	3214	63.6	3246	63.4	3421	67.6	3349	67.1	3486	68.0	3434	67.1
SIMD 5														
Caries	1502	32.0	1575	32.6	1645	31.7	1465	29.8	1415	29.6	1294	28.1	1391	29.6
No caries	3195	68.0	3252	67.4	3550	68.3	3,447	70.2	3366	70.4	3303	71.9	3315	70.4
SIMD 6														
Caries	1339	28.6	1366	28.7	1310	27.2	1244	26.6	1201	26.2	1113	24.2	1200	25.3
No caries	3350	71.4	3390	71.3	3509	72.8	3439	73.4	3385	73.8	3483	75.8	3543	74.7
SIMD 7														
Caries	1202	24.4	1323	25.9	1192	23.2	1040	21.9	1090	23.0	1054	22.2	1058	22.2
No caries	3731	75.6	3776	74.1	3939	76.8	3712	78.1	3639	77.0	3687	77.8	3701	77.8
SIMD 8														
Caries	1177	24.2	1052	21.6	1073	21.9	1069	21.0	997	20.4	933	19.1	936	19.0
No caries	3677	75.8	3817	78.4	3818	78.1	4011	79.0	3895	79.6	3955	80.9	3991	81.0
SIMD 9														
Caries	905	19.6	922	19.6	939	19.3	926	17.7	911	17.8	844	16.6	859	16.9
No caries	3711	80.4	3794	80.4	3928	80.7	4304	82.3	4212	82.2	4239	83.4	4221	83.1
SIMD 10	**(LD)**													
Caries	659	15.7	690	16.5	701	16.5	669	13.8	731	15.6	649	13.8	638	13.4
No caries	3548	84.3	3492	83.5	3556	83.5	4185	86.2	3951	84.4	4039	86.2	4129	86.6

SIMD - Scottish Index of Multiple Deprivation; MD - Most deprived 10%; LD - Least deprived 10%; Caries - Caries experience; No caries - No caries experience

R Slope and Relative Index of Inequality for 5-year-old schoolchildren in Scotland with caries experience

School Year	SII	95% CI	RII	95% CI
2011/12	38.1	(34.8, 41.5)	3.48	(3.15, 3.85)
2012/13	36.3	(33.9, 38.7)	3.28	(3.05, 3.52)
2013/14	36.8	(33.5, 40.0)	3.44	(3.26, 3.63)
2014/15	35.8	(33.4, 38.1)	3.61	(3.26, 4.00)
2015/16	34.2	(31.4, 37.0)	3.40	(3.23, 3.58)
2016/17	35.8	(33.0, 38.6)	3.80	(3.50, 4.12)
2017/18	36.9	(34.5, 39.3)	3.85	(3.47, 4.26)

SII - Slope Index of Inequality; RII - Relative Index of Inequality; CI - Confidence Interval

S Prevalence of BMI by sex & Scotland overall and school year

	2011/12		2012/13		2013/14		2014/15		2015/16		2016/17		2017/18	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Scotland														
Underweight	635	1.2	611	1.1	549	1.0	592	1.1	598	1.1	490	0.9	560	1.1
Healthy Weight	40112	76.9	41838	77.6	41641	76.3	42042	77.1	40870	76.8	39751	76.2	40257	76.5
Overweight	6315	12.1	6464	12.0	6809	12.5	6546	12.0	6494	12.2	6477	12.4	6479	12.3
Obesity	5111	9.8	5031	9.3	5557	10.2	5318	9.8	5260	9.9	5446	10.4	5336	10.1
Male														
Underweight	407	1.5	388	1.4	358	1.3	388	1.4	378	1.4	326	1.2	375	1.4
Healthy Weight	20267	76.0	21003	76.6	21021	75.6	21169	76.5	20625	76.3	20139	75.6	20,310	75.5
Overweight	3305	12.4	3386	12.4	3481	12.5	3327	12.0	3302	12.2	3314	12.4	3332	12.4
Obesity	2687	10.1	2632	9.6	2937	10.6	2781	10.1	2730	10.1	2852	10.7	2880	10.7
Female														
Underweight	228	0.9	223	0.8	191	0.7	204	0.8	220	0.8	164	0.6	185	0.7
Healthy Weight	19845	77.8	20835	78.5	20620	77.1	20873	77.8	20245	77.3	19612	76.8	19947	77.5
Overweight	3010	11.8	3078	11.6	3328	12.4	3219	12.0	3192	12.2	3163	12.4	3147	12.2
Obesity	2424	9.5	2399	9.0	2620	9.8	2537	9.5	2530	9.7	2594	10.2	2456	9.5

T Prevalence of BMI by area-based deprivation and school year

School Year	2011/12		2012/13		2013/14		2014/15		2015/16		2016/17		2017/18	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
SIMD 1 (MD)														
UW	75	1.2	70	1.0	66	1.0	79	1.2	76	1.2	71	1.1	70	1.1
HW	4685	73.7	5005	74.3	4970	72.9	4763	73.3	4659	72.0	4778	72.5	4503	72.1
OW	840	13.2	857	12.7	878	12.9	871	13.4	872	13.5	834	12.7	828	13.3
OB	755	11.9	802	11.9	908	13.3	786	12.1	864	13.4	905	13.7	845	13.5
SIMD 2														
UW	85	1.5	71	1.2	62	1.0	72	1.2	68	1.1	56	0.9	57	1.0
HW	4305	74.3	4530	74.7	4521	73.3	4496	74.1	4504	73.9	4397	72.6	4322	73.6
OW	721	12.4	785	12.9	827	13.4	752	12.4	767	12.6	829	13.7	775	13.2
OB	681	11.8	678	11.2	759	12.3	747	12.3	755	12.4	773	12.8	715	12.2
SIMD 3														
UW	77	1.5	84	1.5	52	0.9	55	1.0	72	1.3	57	1.1	65	1.2
HW	3887	74.2	4159	74.8	4055	73.8	4265	75.0	4129	74.3	3978	73.8	4065	73.9
OW	662	12.6	705	12.7	735	13.4	702	12.3	717	12.9	702	13.0	685	12.5
OB	616	11.8	609	11.0	655	11.9	665	11.7	640	11.5	652	12.1	682	12.4
SIMD 4														
UW	80	1.5	66	1.2	55	1.0	61	1.1	67	1.3	64	1.2	60	1.2
HW	3877	74.3	4098	76.5	4018	75.2	4020	75.7	3927	75.8	3880	74.4	3888	74.8
OW	674	12.9	681	12.7	662	12.4	654	12.3	661	12.8	652	12.5	663	12.8
OB	588	11.3	509	9.5	607	11.4	574	10.8	525	10.1	620	11.9	586	11.3
SIMD 5														
UW	53	1.1	59	1.2	60	1.1	63	1.2	49	1.0	45	0.9	50	1.0
HW	3757	76.1	3955	77.5	4156	76.6	3955	77.3	3910	77.5	3654	75.9	3618	75.0
OW	613	12.4	583	11.4	669	12.3	628	12.3	602	11.9	587	12.2	650	13.5
OB	515	10.4	503	9.9	543	10.0	472	9.2	484	9.6	531	11.0	504	10.5
SIMD 6														
UW	65	1.3	48	0.9	63	1.2	50	1.0	54	1.1	40	0.8	53	1.1
HW	3848	77.0	3997	78.4	3823	75.6	3788	76.9	3732	77.6	3647	77.0	3713	76.3
OW	633	12.7	576	11.3	661	13.1	634	12.9	579	12.0	591	12.5	658	13.5
OB	454	9.1	475	9.3	510	10.1	455	9.2	444	9.2	459	9.7	444	9.1
SIMD 7														
UW	46	0.9	50	0.9	37	0.7	49	1.0	46	0.9	39	0.8	44	0.9
HW	4118	78.6	4282	79.1	4260	78.1	3906	77.9	3865	77.6	3714	77.9	3820	78.1
OW	638	12.2	633	11.7	669	12.3	625	12.5	615	12.3	604	12.7	579	11.8
OB	436	8.3	450	8.3	488	8.9	437	8.7	456	9.2	410	8.6	449	9.2
SIMD 8														
UW	48	1.0	54	1.1	49	1.0	58	1.1	53	1.0	43	0.9	53	1.0
HW	4065	80.5	4107	80.3	4028	78.4	4211	78.8	4078	79.5	3954	78.7	4046	79.2
OW	545	10.8	581	11.4	638	12.4	615	11.5	577	11.2	605	12.0	562	11.0
OB	392	7.8	374	7.3	426	8.3	458	8.6	421	8.2	420	8.4	450	8.8
SIMD 9														
UW	55	1.1	52	1.0	47	0.9	51	0.9	58	1.1	46	0.9	68	1.3
HW	3922	80.0	4052	80.8	4123	80.2	4466	82.0	4184	80.1	4033	80.1	4274	80.7
OW	544	11.1	568	11.3	585	11.4	568	10.4	587	11.2	570	11.3	598	11.3
OB	379	7.7	341	6.8	384	7.5	362	6.6	395	7.6	388	7.7	353	6.7
SIMD 10 (LD)														
UW	51	1.1	57	1.3	58	1.3	54	1.1	55	1.2	29	0.6	40	0.8
HW	3648	82.2	3653	81.3	3687	81.8	4172	82.0	3882	82.1	3716	81.9	4008	82.9
OW	445	10.0	495	11.0	485	10.8	497	9.8	517	10.9	503	11.1	481	9.9
OB	295	6.6	290	6.5	277	6.1	362	7.1	276	5.8	288	6.3	308	6.4

SIMD - Scottish Index of Multiple Deprivation; MD - Most deprived 10%; LD - Least deprived 10%; UW - Underweight; HW - Healthy Weight; OW - Overweight; OB - Obesity

U Slope and Relative Index of Inequality for 5-year-old schoolchildren in Scotland with underweight, overweight and obesity

	Underweight				Overweight				Obesity			
School Year	**SII**	**95% CI**	**RII**	**95% CI**	**SII**	**95% CI**	**RII**	**95% CI**	**SII**	**95% CI**	**RII**	**95% CI**
2011/12	0.4	(0.1, 0.8)	1.42	(1.06, 1.90)	3.1	(2.0, 4.1)	1.28	(1.17, 1.41)	6.5	(5.6, 7.5)	1.95	(1.71, 2.22)
2012/13	0.1	(-0.2, 0.5)	1.13	(0.83, 1.53)	2.2	(1.8, 2.7)	1.21	(1.16, 1.25)	6.3	(5.9, 6.8)	1.98	(1.83, 2.14)
2013/14	-0.1	(-0.4, 0.2)	0.92	(0.68, 1.24)	2.3	(1.2, 3.4)	1.20	(1.09, 1.32)	7.7	(6.9, 8.5)	2.13	(1.88, 2.43)
2014/15	0.2	(0.0, 0.4)	1.21	(1.05, 1.39)	3.2	(1.9, 4.4)	1.29	(1.15, 1.45)	6.6	(5.5, 7.7)	1.98	(1.72, 2.28)
2015/16	0.1	(0.0, 0.3)	1.14	(0.98, 1.33)	2.6	(2.1, 3.1)	1.24	(1.18, 1.29)	7.6	(6.6, 8.5)	2.17	(1.90, 2.48)
2016/17	0.4	(0.2, 0.6)	1.52	(1.19, 1.94)	2.2	(1.1, 3.3)	1.19	(1.09, 1.30)	8.3	(7.6, 9.0)	2.22	(1.97, 2.49)
2017/18	0.1	(-0.2, 0.4)	1.11	(0.81, 1.52)	3.4	(2.1, 4.7)	1.30	(1.17, 1.46)	8.1	(7.2, 9.0)	2.22	(1.93, 2.56)

SII - Slope Index of Inequality; RII - Relative Index of Inequality; CI - Confidence Interval

V Unadjusted and adjusted odds ratios and 95% confidence intervals for a logistic regression of caries experience by BMI status and sex interaction, adjusted for area-based deprivation and school year

BMI Status	Caries experience		No caries experience		Total	OR	95% CI	p	AOR	Adjusted 95% CI	p
	n	%	n	%	n						
Male											
Underweight	751	32.5	1559	67.5	2310	1.08	(0.99, 1.18)	0.09	1.03	(0.94, 1.13)	0.53
Healthy Weight	40154	30.9	89961	69.1	130115	-	Reference	-	-	Reference	-
Overweight	6978	33.1	14095	66.9	21073	1.11	(1.08, 1.14)	<0.001	1.06	(1.03, 1.10)	<0.001
Obesity	6157	35.7	11090	64.3	17247	1.24	(1.20, 1.29)	<0.001	1.12	(1.08, 1.16)	<0.001
Female											
Underweight	406	32.7	834	67.3	1240	1.21	(1.07, 1.36)	0.002	1.15	(1.01, 1.30)	0.029
Healthy Weight	36652	28.7	91081	71.3	127733	-	Reference	-	-	Reference	-
Overweight	5954	29.9	13976	70.1	19930	1.06	(1.02, 1.09)	0.001	1.01	(0.98, 1.05)	0.52
Obesity	5337	34.0	10376	66.0	15713	1.28	(1.23, 1.32)	<0.001	1.14	(1.10, 1.18)	<0.001

OR - odds ratio; aOR - adjusted odds ratio; CI - confidence interval

W Unadjusted and adjusted odds ratios and 95% confidence intervals for a logistic regression of caries experience by BMI status and area-based deprivation interaction, adjusted for sex and school year

BMI Status	Caries experience		No caries experience		Total	OR	95% CI	p	AOR	Adjusted 95% CI	p
	n	%	n	%	n						
SIMD 1 (MD)											
Underweight	390	45.6	466	54.4	856	0.98	(0.85, 1.12)	0.72	0.96	(0.84, 1.10)	0.53
Healthy Weight	26296	46.2	30659	53.8	56955	-	Reference	-	-	Reference	-
Overweight	4620	45.6	5506	54.4	10126	0.98	(0.94, 1.02)	0.31	0.98	(0.94, 1.02)	0.33
Obesity	4350	45.1	5293	54.9	9643	0.96	(0.92, 1.00)	0.054	0.96	(0.92, 1.00)	0.07
SIMD 2											
Underweight	302	37.6	501	62.4	803	1.08	(0.94, 1.25)	0.27	1.06	(0.92, 1.22)	0.44
Healthy Weight	18041	35.7	32464	64.3	50505	-	Reference	-	-	Reference	-
Overweight	3170	36.9	5431	63.1	8601	1.05	(1.00, 1.10)	0.043	1.05	(1.00, 1.10)	0.047
Obesity	2850	37.8	4699	62.2	7549	1.09	(1.04, 1.15)	0.001	1.09	(1.04, 1.15)	0.001
SIMD 3											
Underweight	192	28.9	473	71.1	665	1.06	(0.90, 1.26)	0.5	1.04	(0.88, 1.23)	0.66
Healthy Weight	13300	27.7	34742	72.3	48042	-	Reference	-	-	Reference	-
Overweight	2230	28.7	5545	71.3	7775	1.05	(1.00, 1.11)	0.07	1.05	(1.00, 1.11)	0.07
Obesity	1992	32.7	4098	67.3	6090	1.27	(1.20, 1.34)	<0.001	1.27	(1.20, 1.34)	<0.001
SIMD 4											
Underweight	142	23.9	453	76.1	595	1.15	(0.95, 1.39)	0.15	1.13	(0.94, 1.37)	0.20
Healthy Weight	10990	21.4	40318	78.6	51308	-	Reference	-	-	Reference	-
Overweight	1767	22.9	5935	77.1	7702	1.09	(1.03, 1.16)	0.002	1.09	(1.03, 1.16)	0.003
Obesity	1415	26.0	4034	74.0	5449	1.29	(1.21, 1.37)	<0.001	1.29	(1.21, 1.37)	<0.001
SIMD 5 (LD)											
Underweight	131	20.8	500	79.2	631	1.37	(1.13, 1.67)	0.001	1.34	(1.11, 1.63)	0.003
Healthy Weight	8179	16.0	42859	84.0	41038	-	Reference	-	-	Reference	-
Overweight	1145	16.8	5654	83.2	6799	1.06	(0.99, 1.14)	0.09	1.06	(0.99, 1.13)	0.09
Obesity	887	21.0	3342	79.0	4229	1.39	(1.29, 1.50)	<0.001	1.39	(1.28, 1.50)	<0.001

SIMD - Scottish Index of Multiple Deprivation; MD - Most Deprived 20%; LD - Least Deprived 20%;
OR - odds ratio; aOR - adjusted odds ratio; CI - confidence interval

X Unadjusted and adjusted odds ratios and 95% confidence intervals for a logistic regression of caries experience by BMI SDS and area-based deprivation interaction, adjusted for sex and school year

BMI Status	Caries experience		No caries experience		Total	OR	95% CI	p	AOR	Adjusted 95% CI	p
	n	%	n	%	n						
SIMD 1 (MD)	35656	46.0	41924	54.0	77580	0.99	(0.98, 1.00)	0.08	0.99	(0.98, 1.00)	0.12
SIMD 2	24363	36.1	43095	63.9	67458	1.02	(1.01, 1.04)	0.003	1.02	(1.01, 1.04)	0.002
SIMD 3	17714	28.3	44858	71.7	62572	1.06	(1.04, 1.08)	<0.001	1.06	(1.04, 1.08)	<0.001
SIMD 4	14314	22.0	50740	78.0	65054	1.06	(1.04, 1.08)	<0.001	1.06	(1.04, 1.08)	<0.001
SIMD 5 (LD)	10342	16.5	52355	83.5	62697	1.06	(1.03, 1.08)	<0.001	1.06	(1.03, 1.08)	<0.001

SIMD - Scottish Index of Multiple Deprivation; MD - Most Deprived 20%; LD - Least Deprived 20%; OR - odds ratio; aOR - adjusted odds ratio; CI - confidence interval

Y Trends and Associations in *Caries Only* and *Obesity Only*

The following appendix relates to Chapter 6 and includes the analysis for the *Caries only* and *Obesity only* groups.

Y.1 Prevalence of *Caries only* and *Obesity only*

From Section 5.4.1 it was clear that those children with obesity had a higher prevalence of caries experience. This chapter explores trends and inequalities in children with co-existing obesity and caries experience simultaneously compared to those with only one of the conditions and those with neither.

In the group in Scotland with *Caries only*, there is a reduction in the prevalence with both sexes following the same trend (p for year/sex interaction=0.36). The *Caries only* prevalence in Scotland reduced (slope for trend=-0.007; 95% CI: -0.010 to -0.004; p=0.001) from 29.2% (n=13,557/46,417) in 2011/12 to 25.5% (n=12,180/47,830) in 2017/18 (Figure 1A), a difference similar to the cross-sectional estimates of caries experience (Section 3.4.3). The prevalence in males reduced by 4.4% (n=838) between 2011/12 (30.4%; n=7,204/23,717) and 2017/18 (26.0%; n=6,366/24,452). In females the equivalent reduction was 3.1% between 2011/12 (28.0%; n=6,353/22,700) and 2017/18 (24.9%; n=5,814/23,378) (Figure 1A), however the was no difference in the slopes between the sexes (p for year/sex interaction = 0.36). Children aged 4 consistently had the lowest prevalence of *Caries only* compared to children aged 5-years and aged 6-years (Figure 2A). There was no evidence to suggest that the prevalence of *Caries only* changed over time between age groups (p for year/age interaction=0.78).

The prevalence of *Obesity only* has levelled over the period of the study (slope for trend=0.001; 95% CI: 0.000 to 0.002; p=0.09) and there was insufficient evidence to suggest any differences in the slope over the years between males and females (p for year/sex interaction=0.50). The prevalence of *Obesity only* overall was 6.3% (n=2927/46417) in 2011/12 and 6.6% (n=3,140/47,830) in 2017/18 (Figure 1B). Males consistently had higher prevalence than females, with a prevalence of *Obesity only* of

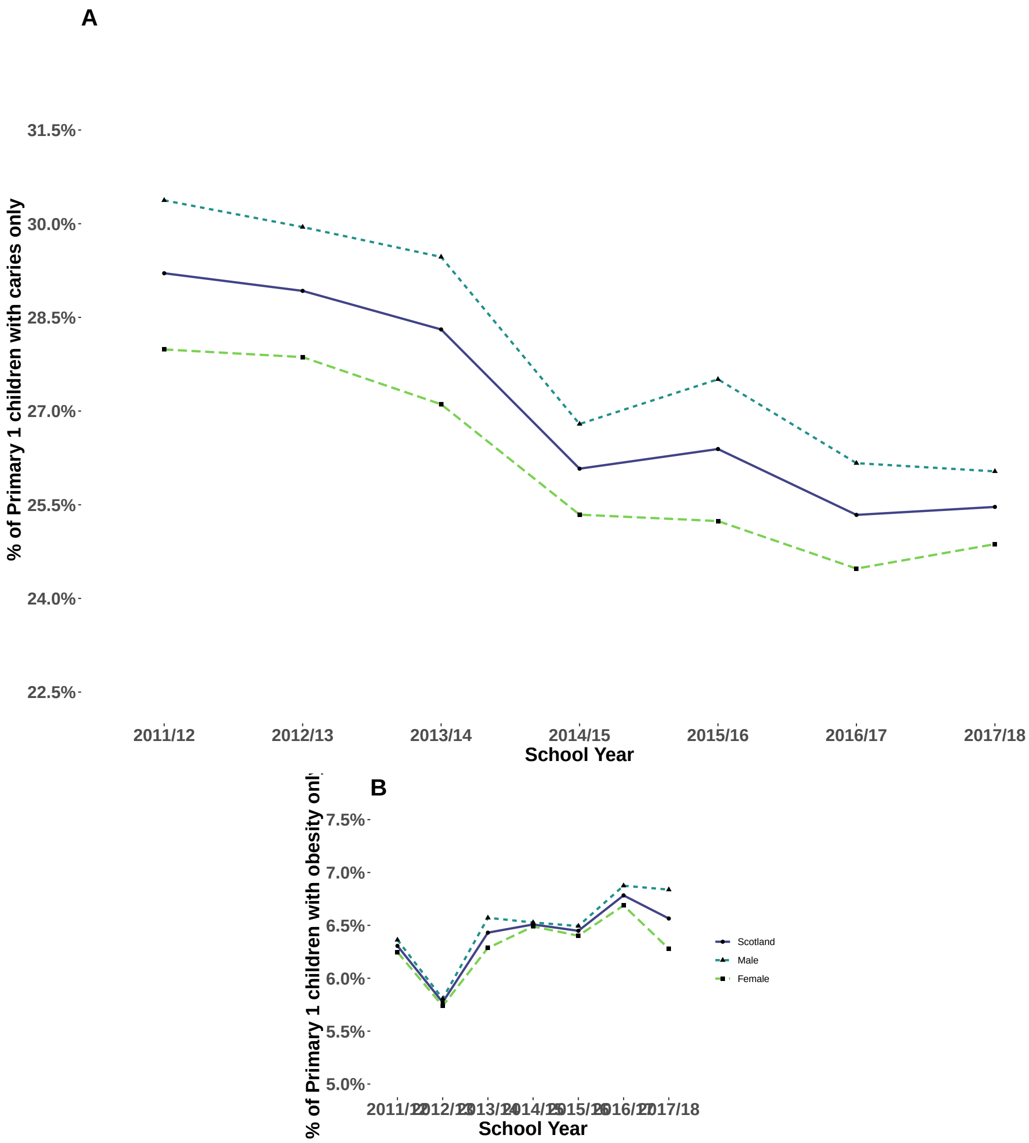

Figure 1: Prevalence of *Caries only* (A) and *Obesity only* (B) by sex and school year (Appendix Z)

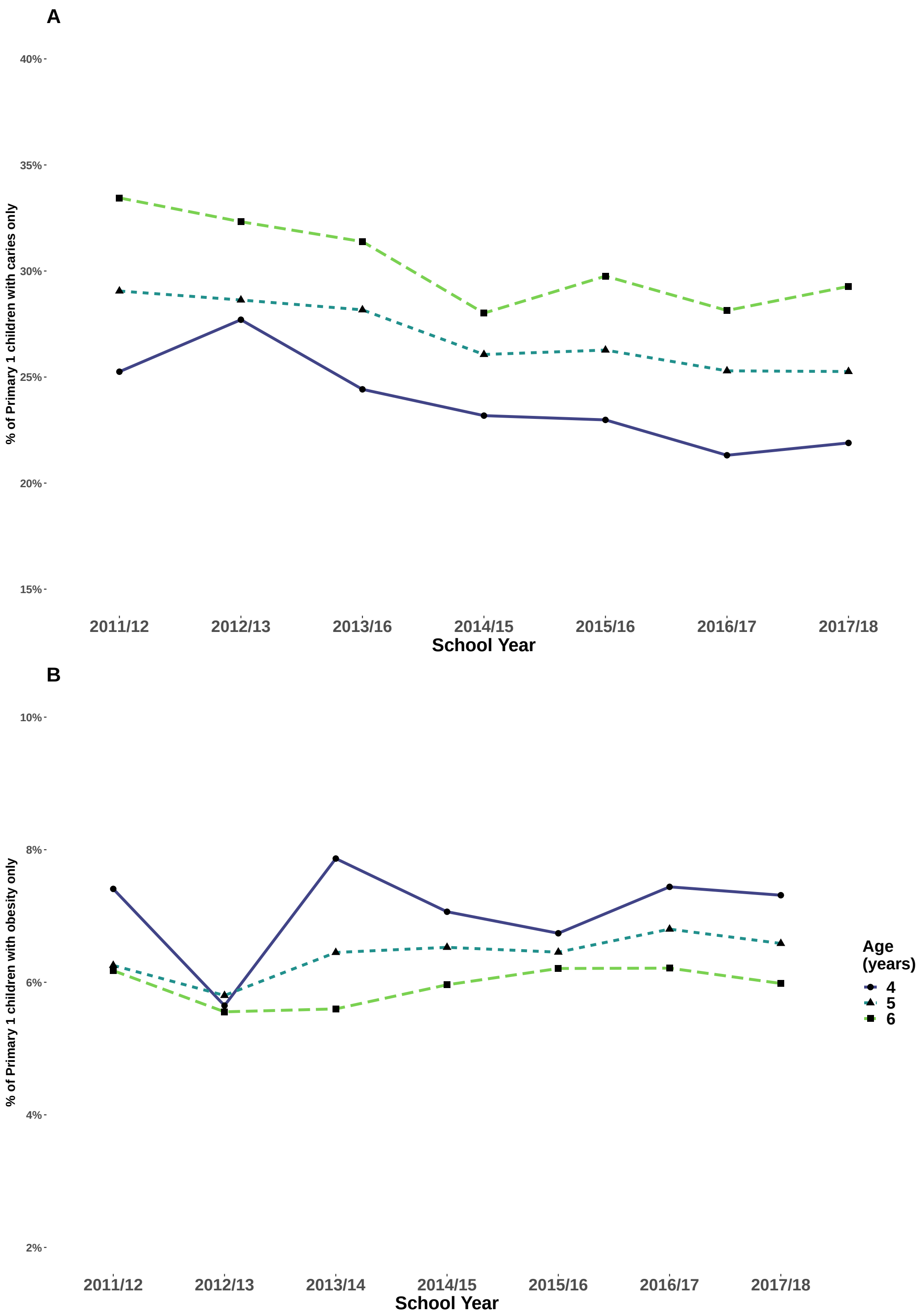

Figure 2: Prevalence of *Caries only* (A) and *Obesity only* (B) by age and school year

6.4% (n=1,509/23,717) in 2011/12 and 6.8% (n=1,672/24,452) in 2017/18, while in females the prevalence was 6.2% (n=1,418/22,700) in 2011/12 and 6.3% (n=23,378) in 2017/18 (Figure 1B). Children aged 6 consistently had the lowest prevalence of *Obesity only* compared to children aged 4-years and aged 5-years (Figure 2B). There was no evidence to suggest that the prevalence of *Obesity only* changed over time between age groups (p for year/age interaction=0.82).

Y.2 Trends and inequalities in children with caries experience only

Prevalence of *Caries only* had seen an overall decline across all levels of deprivation. There is a clear social gradient which does not change over the years (p for year/SIMD interaction=0.34) (Figure 3). Children from the 20% most deprived areas (SIMD 1) had a 43.5% (n=4,618/10,614) prevalence of *Caries only* in 2011/12 and then 38.7% (n=4,161/10,749) in 2017/18. In the least deprived areas (SIMD 5) 16.3% (n=1,370/8,403) of children had caries experience only in 2011/12, reducing to 14.0% (n=1,313/9,381) in 2017/18. There was an absolute difference of 27.2% (n=3,248) in caries experience only prevalence between children from the most and least deprived areas in 2011/12, and a difference of 24.7% (n=2,848) being recorded in 2017/18.

Y.2.1 Slope and relative indices over time for children with caries experience only

The SII follows a downwards trend over the study period, whereas there is not enough evidence to suggest that the RII follows a trend (Figure 4). The SII ranges from 32.8% (95% CI 29.6% to 36.0%) in 2011/12 to 30.4% (95% CI 27.1% to 33.7%) in 2017/18. The RII changes from 3.32 (95% CI 3.12 to 3.54) in 2011/12 to 3.60 (95% CI 3.43 to 3.78) in 2017/18 (Figure 4).

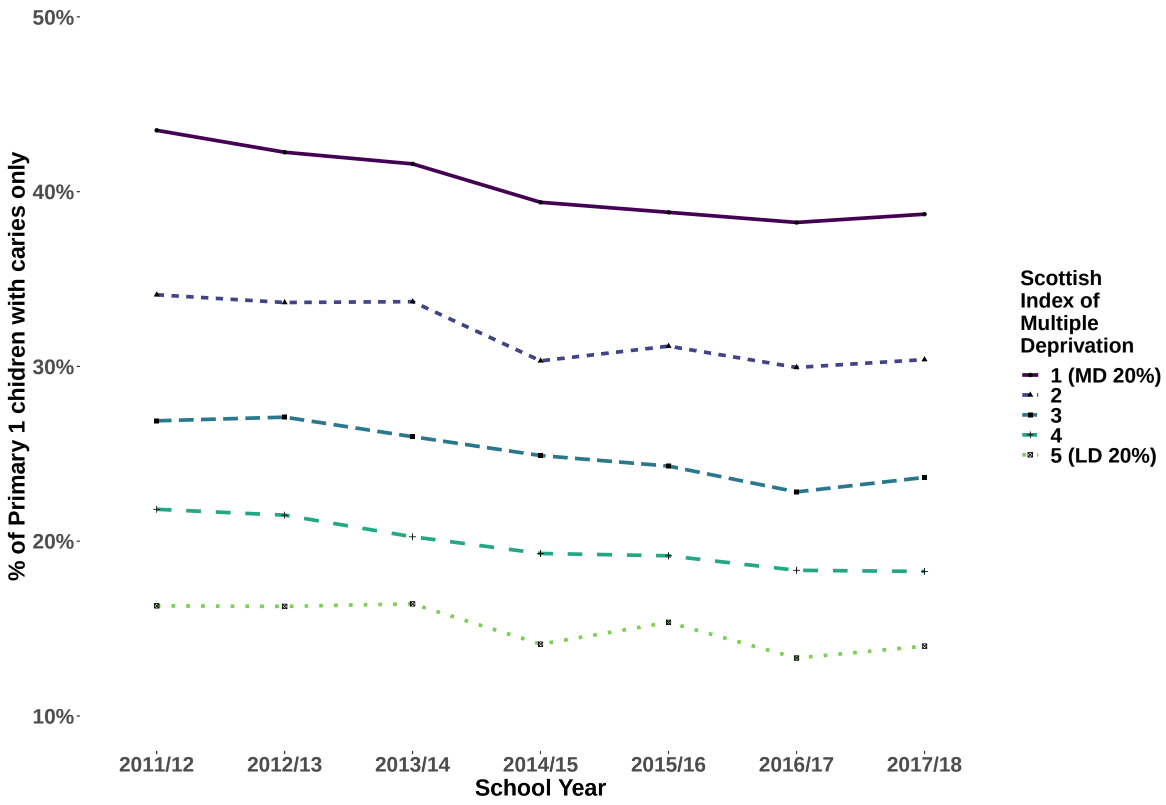

Figure 3: Prevalence of *Caries only* by area-based deprivation and school year in primary 1 children in Scotland (Appendix AA). MD 20% - Most Deprived 20%; LD 20%- Least Deprived 20%

Y.2.2 Factors independently associated with childhood caries only (RQ4.3)

Similar to the children with co-existing conditions (Section 6.4.3), as deprivation increases, so too does the odds of having *Caries only* when compared to the group with neither condition (Figure 5). The children from the most deprived areas (SIMD 1) had adjusted odds of having *Caries only* 4.49 (95% CI: 4.37 to 4.61; p<0.001) times that of those in the least deprived areas (SIMD 5). Males have higher odds of *Caries only* than female, with an estimated adjusted odds ratio of 1.12 (95% CI: 1.10 to 1.13; p<0.001). Over time (years), the adjusted odds of having caries experience only reduces, in line with caries experience prevalence reducing. This gave an adjusted odds ratio of 0.82 (95% CI: 0.80 to 0.85; p<0.001) of caries experience in 2017/18 compared to 2011/12. The odds of *Caries only* in 4-year-old children is lower than children aged 5 (aOR=0.78; 95% CI: 0.75 to 0.81; p<0.001), whereas children aged 6 had higher odds (aOR=1.26; 95% CI: 1.23 to 1.30; p<0.001).

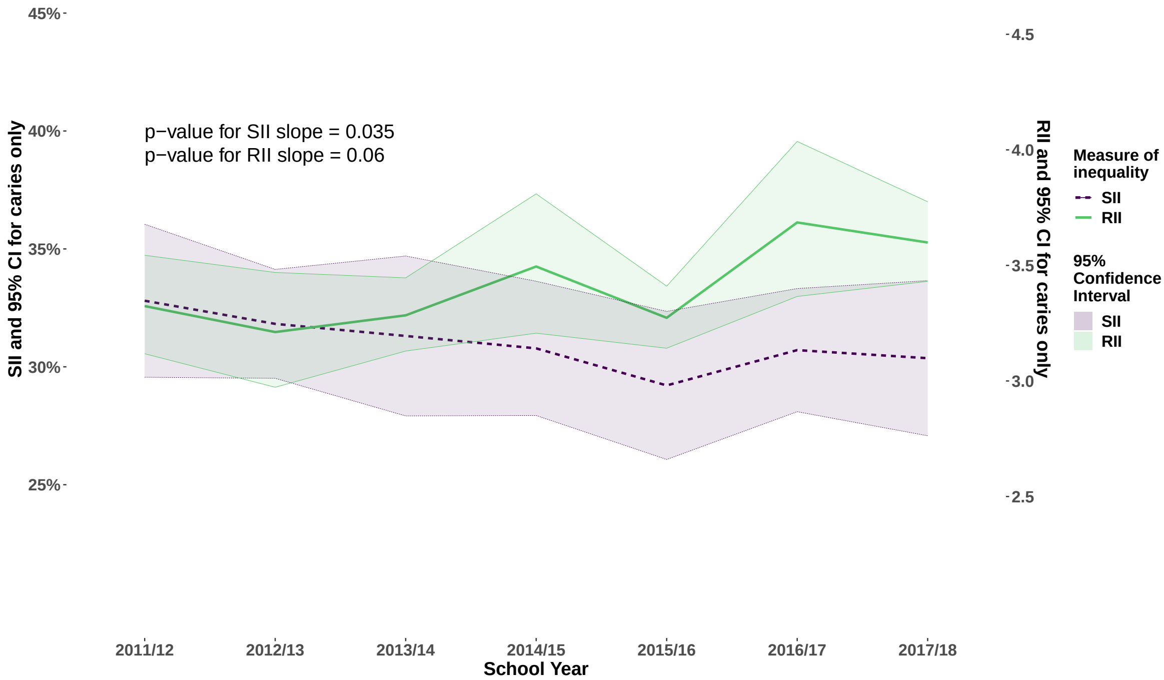

Figure 4: Slope Index of Inequality and Relative Index of Inequality for children with caries experience only (Appendix AB). SII - Slope Index of Inequality; RII - Relative Index of Inequality

Y.3 Trends and inequalities in children with Obesity only

There was no clear social gradient in the inequalities present in the *Obesity only* group, although children living in SIMD 5 areas had a consistently lower prevalence than children from other SIMD fifths (Figure 6). There was insufficient evidence to suggest that the prevalence of *Obesity only* between deprivation levels changed over the years (p for year/SIMD interaction=0.15). In 2011/12 and 2017/18, it was children from SIMD 2 (the second most deprived quintile) that had the highest prevalence of *Obesity only* (Figure 6). The prevalence of *Obesity only* remained lowest in the least deprived areas (SIMD 5), with a prevalence of 5.6% (n=473/8,403) in 2011/12 and 5.2% (n=491/9,381) in 2017/18. Prevalence of *Obesity only* in the most deprived areas (SIMD 1) went from 6.2% (n=654/10,614) in 2011/12 to 7.1% (n=759/10,749) in 2017/18.

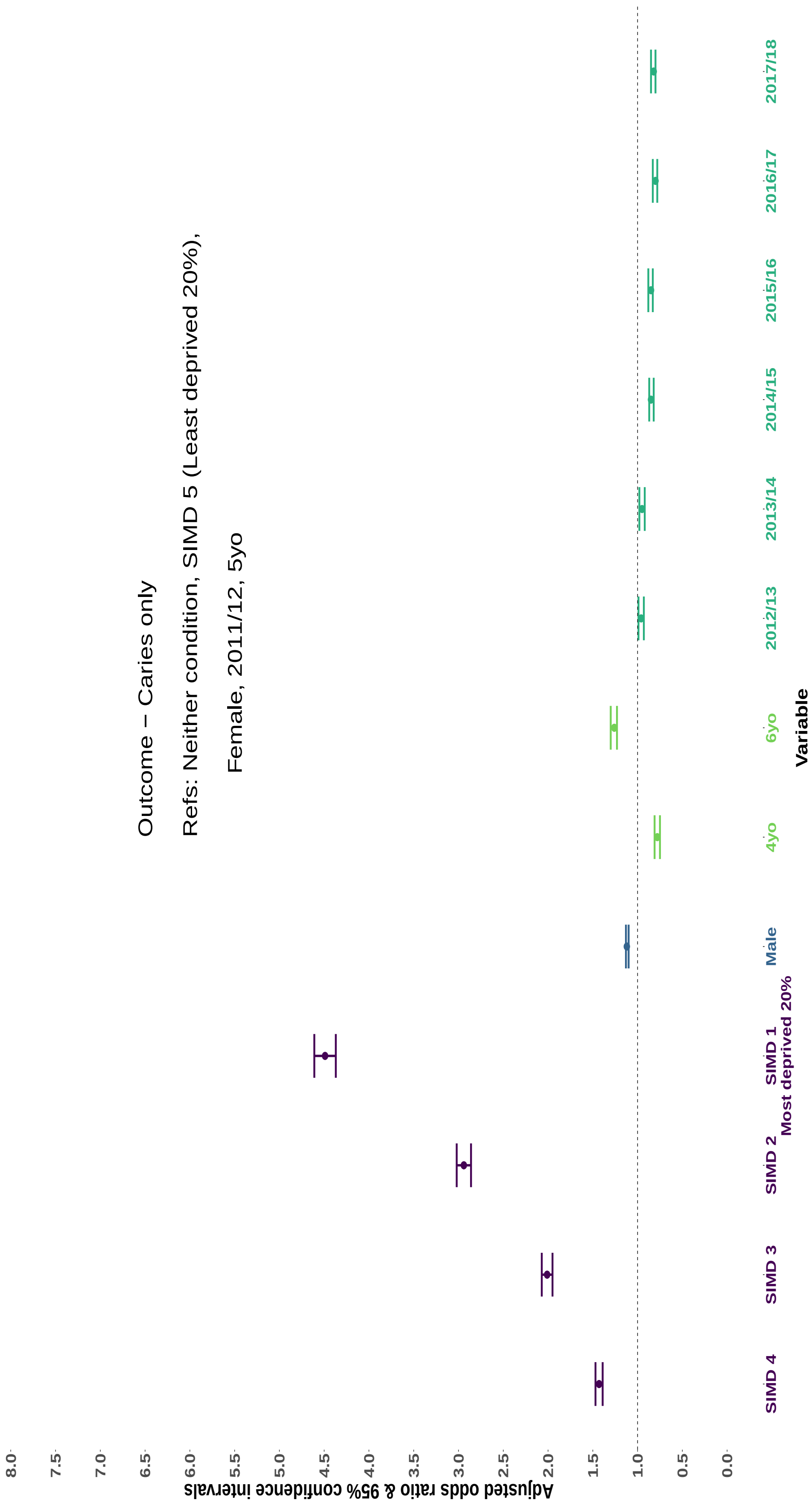

Figure 5: Adjusted odds ratios and 95% confidence intervals from a multinomial regression of *Caries only* against sex, school year and area-based deprivation (Appendix AC). SIMD - Scottish Index of Multiple Deprivation; yo - years old

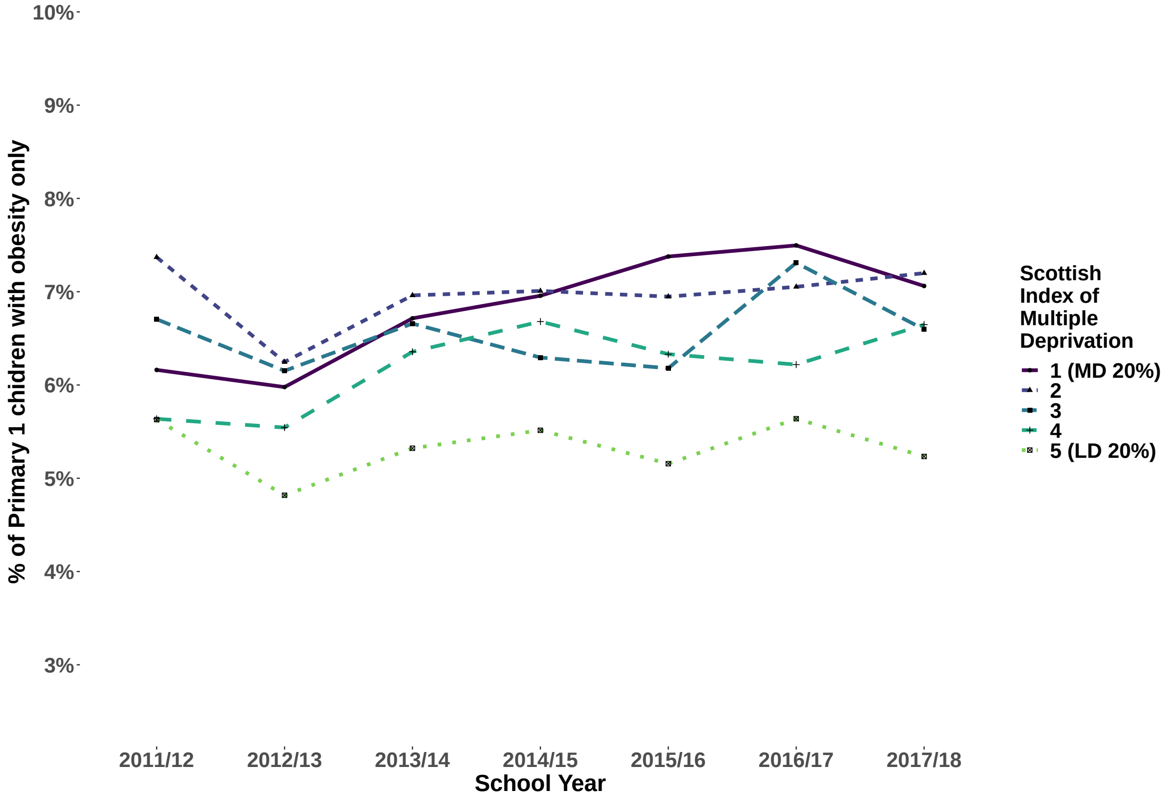

Figure 6: Prevalence of *Obesity only* by area-based deprivation and school year in primary 1 children in Scotland (Appendix AA). MD 20% - Most Deprived 20%; LD 20%- Least Deprived 20%

Y.3.1 Slope and relative indices over time for children with *Obesity only*

There is evidence to suggest that absolute inequalities have increased in the *Obesity only* group, whereas relative inequalities have remained constant over the study period. The inequalities remain smaller than the co-existing conditions and *Caries only* groups (Sections 6.4.2.1 & Y.2.1). The SII was 1.4% (95% CI -0.2% to 3.1%) in 2011/12. There was sharp rise in inequalities observed in 2015/16, although the SII estimate reduced afterwards to 2.2% (95% CI 0.9% to 3.5%) in 2017/18 (Figure 7). Although there was no systematic trend observed in the RII, it is worth noting that there not enough evidence to suggest any relative inequalities in 2011/12 (RII=1.24; 95% CI: 0.96 to 1.61), however, by 2012/13 and into 2017/18 there was evidence to suggest relative inequalities between children from the most and least deprived area, with the RII estimated at 1.38 (95% CI: 1.11 to 1.72) in 2017/18 (Figure 7).

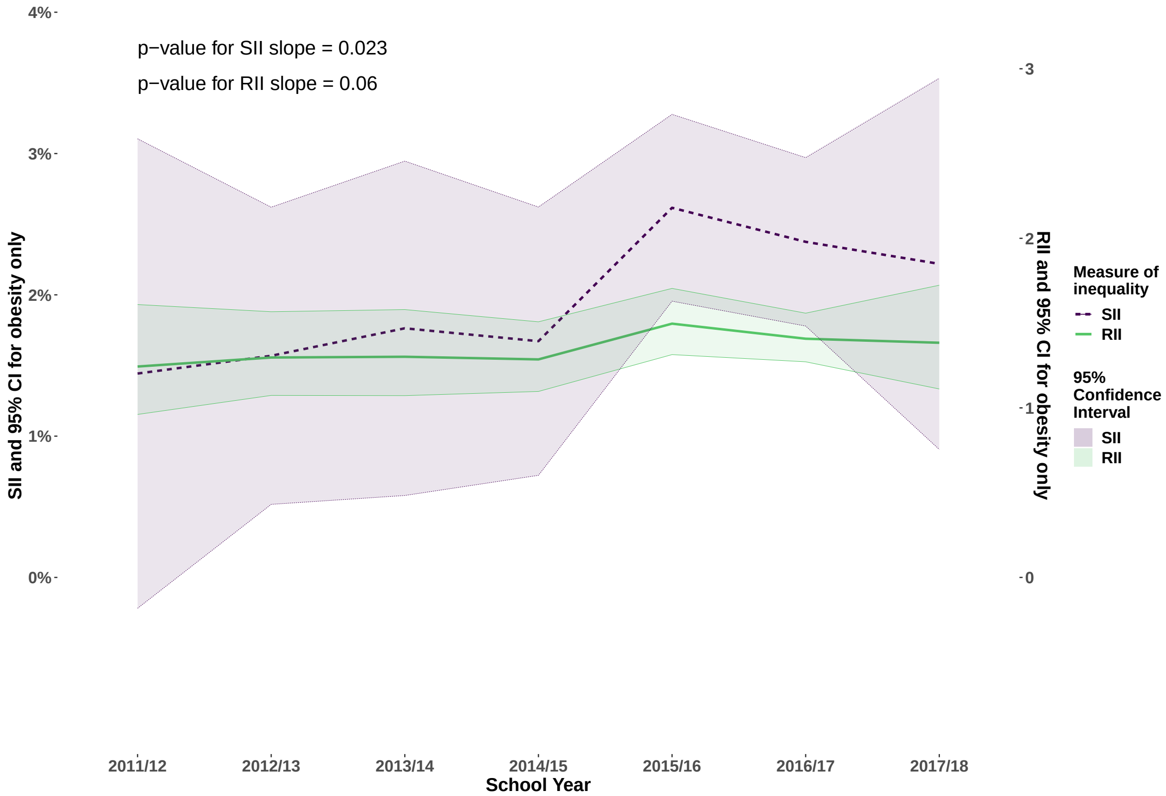

Figure 7: Slope Index of Inequality and Relative Index of Inequality for children with *Obesity only* (Appendix AB). SII - Slope Index of Inequality; RII - Relative Index of Inequality

Y.3.2 Factors independently associated with childhood obesity only (RQ4.3)

The adjusted odds ratio for the *Obesity only* group, albeit lower than those presented in Sections 6.4.3 and Y.2.2, still show the odds of having *Obesity only* rises as deprivation increases (Figure 8). Those children from the most deprived areas (SIMD 1) have adjusted odds of *Obesity only* 2.12 (95% CI: 2.03 to 2.22; p<0.001) times that of those from the least deprived areas (SIMD 5). Males have slightly higher adjusted odds of being in this group than females, with an odds ratio of 1.08 (95% CI: 1.05 to 1.11; p<0.001). There is suggestion of a slight drop in adjusted odds of being in the *Obesity only* group compared to the neither group in 2012/13 (aOR=0.90; 95% CI: 0.85 to 0.95; p<0.001), although the rest of years showed no difference compared to 2011/12, again suggesting this to be a consistent group with growing inequalities (Figure 8). The odds of *Obesity only* in 4-year-old children was no different to children aged 5 (aOR=1.01; 95% CI: 0.95 to 1.08; p=0.69), so too for children aged 6 (aOR=1.00; 95% CI: 0.95 to 1.06; p=0.85).

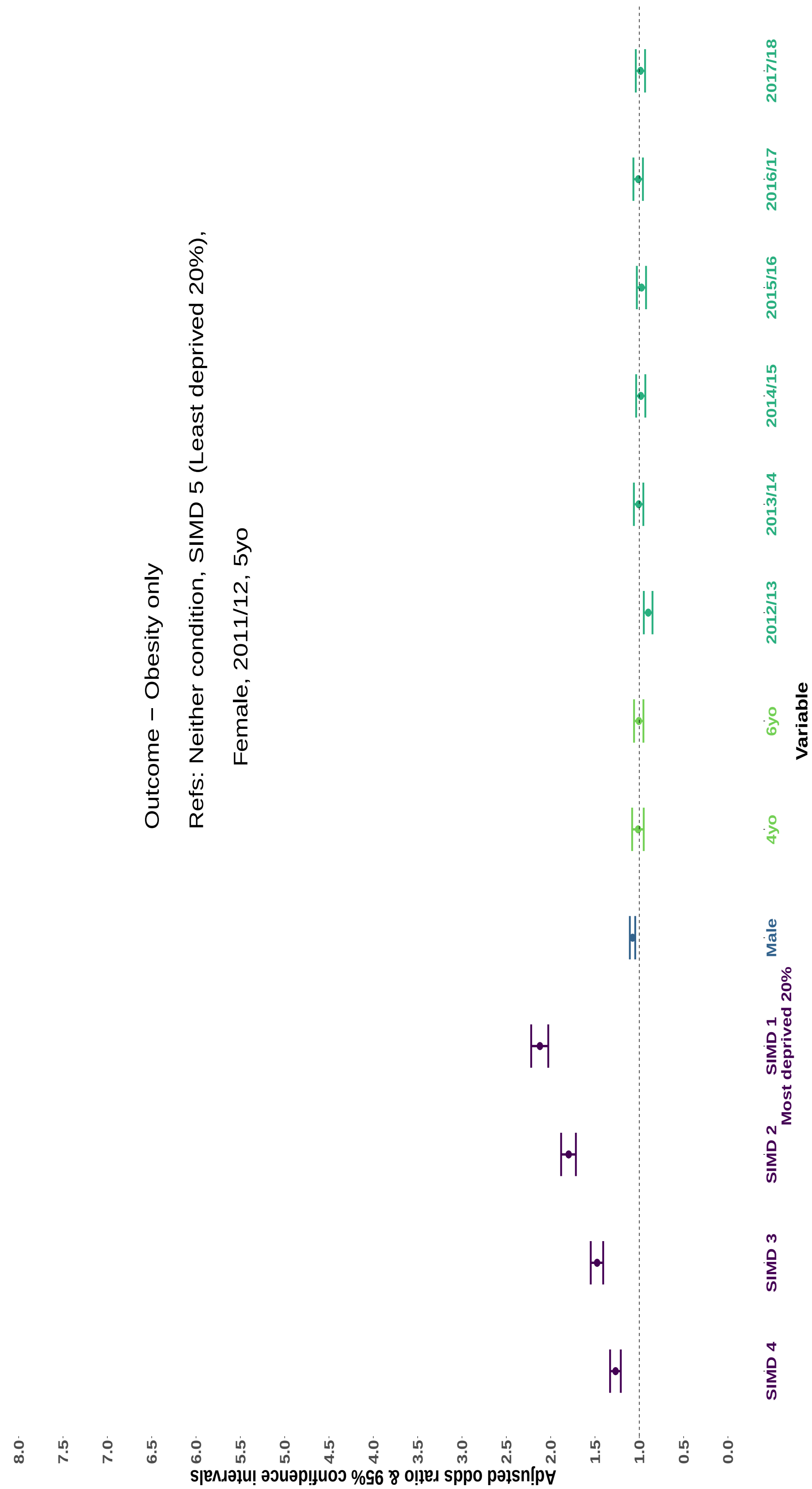

Figure 8: Adjusted odds ratios and 95% confidence intervals from a multinomial regression of *Obesity only* against sex, school year and area-based deprivation (Appendix AC). SIMD - Scottish Index of Multiple Deprivation; yo - years old

Z Prevalence of coexisting obesity and caries, caries only, obesity only and neither condition by sex and school year

	Total	Coexisting		Caries only		Obesity only		None	
		n	%	n	%	n	%	n	%
Scotland									
2011/12	46417	1606	3.5	13557	29.2	2927	6.3	28,327	61.0
2012/13	48222	1645	3.4	13948	28.9	2784	5.8	29845	61.9
2013/14	49369	1777	3.6	13975	28.3	3175	6.4	30442	61.7
2014/15	49349	1588	3.2	12869	26.1	3212	6.5	31680	64.2
2015/16	47840	1599	3.3	12626	26.4	3085	6.4	30530	63.8
2016/17	46334	1630	3.5	11740	25.3	3143	6.8	29821	64.4
2017/18	47830	1649	3.4	12180	25.5	3140	6.6	30861	64.5
Male									
2011/12	23717	870	3.7	7204	30.4	1509	6.4	14134	59.6
2012/13	24557	891	3.6	7354	29.9	1426	5.8	14,886	60.6
2013/14	25078	941	3.8	7390	29.5	1648	6.6	15099	60.2
2014/15	25033	861	3.4	6707	26.8	1634	6.5	15831	63.2
2015/16	24301	830	3.4	6685	27.5	1578	6.5	15208	62.6
2016/17	23607	859	3.6	6177	26.2	1623	6.9	14948	63.3
2017/18	24452	905	3.7	6366	26.0	1672	6.8	15509	63.4
Female									
2011/12	22700	736	3.2	6353	28.0	1418	6.2	14193	62.5
2012/13	23665	754	3.2	6594	27.9	1358	5.7	14959	63.2
2013/14	24291	836	3.4	6585	27.1	1527	6.3	15343	63.2
2014/15	24316	727	3.0	6162	25.3	1578	6.5	15849	65.2
2015/16	23539	769	3.3	5941	25.2	1507	6.4	15322	65.1
2016/17	22727	771	3.4	5563	24.5	1520	6.7	14873	65.4
2017/18	23378	744	3.2	5814	24.9	1468	6.3	15352	65.7

AA Prevalence of coexisting conditions, caries only, obesity only and neither condition by area based deprivation and school year

	Total	Coexisting		Caries only		Obesity only		None	
		n	%	n	%	n	%	n	%
SIMD 1 (MD)									
2011/12	10614	605	5.7	4618	43.5	654	6.2	4737	44.6
2012/13	11225	610	5.4	4743	42.3	671	6.0	5201	46.3
2013/14	11542	685	5.9	4800	41.6	775	6.7	5282	45.8
2014/15	11155	585	5.2	4394	39.4	776	7.0	5400	48.4
2015/16	11183	603	5.4	4341	38.8	825	7.4	5414	48.4
2016/17	11112	638	5.7	4249	38.2	833	7.5	5392	48.5
2017/18	10749	624	5.8	4161	38.7	759	7.1	5205	48.4
SIMD 2									
2011/12	9308	392	4.2	3174	34.1	686	7.4	5056	54.3
2012/13	9766	369	3.8	3287	33.7	610	6.2	5500	56.3
2013/14	9740	436	4.5	3283	33.7	678	7.0	5343	54.9
2014/15	9974	429	4.3	3024	30.3	699	7.0	5822	58.4
2015/16	9615	371	3.9	2996	31.2	668	6.9	5580	58.0
2016/17	9401	419	4.5	2815	29.9	663	7.1	5504	58.5
2017/18	9654	434	4.5	2934	30.4	695	7.2	5591	57.9
SIMD 3									
2011/12	8814	278	3.2	2370	26.9	591	6.7	5575	63.3
2012/13	9152	314	3.4	2480	27.1	563	6.2	5795	63.3
2013/14	9507	324	3.4	2470	26.0	633	6.7	6080	64.0
2014/15	9072	260	2.9	2259	24.9	571	6.3	5982	65.9
2015/16	8803	277	3.1	2139	24.3	544	6.2	5843	66.4
2016/17	8400	258	3.1	1917	22.8	614	7.3	5611	66.8
2017/18	8824	281	3.2	2087	23.7	582	6.6	5874	66.6
SIMD 4									
2011/12	9278	205	2.2	2025	21.8	523	5.6	6525	70.3
2012/13	9506	209	2.2	2043	21.5	527	5.5	6727	70.8
2013/14	9692	206	2.1	1963	20.3	616	6.4	6907	71.3
2014/15	9446	185	2.0	1823	19.3	631	6.7	6807	72.1
2015/16	9162	213	2.3	1756	19.2	580	6.3	6613	72.2
2016/17	8748	196	2.2	1604	18.3	544	6.2	6404	73.2
2017/18	9,222	201	2.2	1685	18.3	613	6.6	6723	72.9
SIMD 5 (MD)									
2011/12	8403	126	1.5	1370	16.3	473	5.6	6434	76.6
2012/13	8573	143	1.7	1395	16.3	413	4.8	6622	77.2
2013/14	8888	126	1.4	1459	16.4	473	5.3	6830	76.8
2014/15	9,702	129	1.3	1369	14.1	535	5.5	7669	79.0
2015/16	9077	135	1.5	1394	15.4	468	5.2	7080	78.0
2016/17	8673	119	1.4	1155	13.3	489	5.6	6910	79.7
2017/18	9381	109	1.2	1313	14.0	491	5.2	7468	79.6

SIMD - Scottish Index of Multiple Deprivation; LD - Least Deprived 20%; MD - Most Deprived 20%

AB Slope and Relative Index of Inequalities for coexisting conditions, caries only, obesity only and neither condition by school year

	Coexisting				Caries only				Obesity only			
School Year	**SII**	**95% CI**	**RII**	**95% CI**	**SII**	**95% CI**	**RII**	**95% CI**	**SII**	**95% CI**	**RII**	**95% CI**
2011/12	5.0	(4.5, 5.6)	5.05	(4.48, 5.69)	32.8	(29.6, 36.0)	3.32	(3.12, 3.54)	1.4	(-0.2, 3.1)	1.24	(0.96, 1.61)
2012/13	4.5	(3.8, 5.2)	4.17	(3.71, 4.69)	31.8	(29.5, 34.1)	3.21	(2.97, 3.47)	1.6	(0.5, 2.6)	1.30	(1.07, 1.57)
2013/14	5.6	(5.1, 6.0)	5.58	(4.53, 6.89)	31.3	(27.9, 34.7)	3.28	(3.13, 3.45)	1.8	(0.6, 2.9)	1.30	(1.07, 1.58)
2014/15	5.0	(4.5, 5.5)	5.54	(4.49, 6.85)	30.8	(27.9, 33.6)	3.50	(3.21, 3.81)	1.7	(0.7, 2.6)	1.29	(1.10, 1.51)
2015/16	4.7	(4.1, 5.2)	4.54	(3.84, 5.37)	29.2	(26.1, 32.3)	3.27	(3.14, 3.41)	2.6	(2.0, 3.3)	1.50	(1.31, 1.70)
2016/17	5.4	(5.1, 5.8)	5.54	(4.42, 6.95)	30.7	(28.1, 33.3)	3.69	(3.37, 4.04)	2.4	(1.8, 3.0)	1.41	(1.27, 1.56)
2017/18	5.8	(5.5, 6.0)	6.25	(4.50, 8.69)	30.4	(27.1, 33.7)	3.60	(3.43, 3.78)	2.2	(0.9, 3.5)	1.38	(1.11, 1.72)

SII - Slope Index of Inequality; RII - Relative Index of Inequality; CI - confidence interval

AC Odds ratio and adjusted odds ratio with 95% confidence intervals for multinomial regression of status by sex, school year and area-based deprivation

Variable	Status		None		OR	95% CI	p	AOR	Adjusted 95% CI	p
	n	%	n	%						
Coexisting										
2011/12	1606	3.5	28327	61.0	-	Reference	-	-	Reference	-
2012/13	1645	3.4	29845	61.9	0.97	(0.91,1.04)	0.44	0.96	(0.90,1.03)	0.28
2013/14	1777	3.6	30442	61.7	1.03	(0.96,1.10)	0.42	1.02	(0.95,1.10)	0.56
2014/15	1588	3.2	31680	64.2	0.88	(0.82,0.95)	0.001	0.88	(0.82,0.95)	0.001
2015/16	1599	3.3	30530	63.8	0.92	(0.86,0.99)	0.029	0.91	(0.85,0.98)	0.013
2016/17	1630	3.5	29821	64.4	0.96	(0.90,1.03)	0.31	0.94	(0.88,1.01)	0.09
2017/18	1649	3.4	30861	64.5	0.94	(0.88,1.01)	0.10	0.94	(0.88,1.01)	0.10
Male	6157	3.6	105615	61.2	1.16	(1.11,1.20)	<0.001	1.17	(1.12,1.21)	<0.001
Female	5337	3.2	105891	64.3	-	Reference	-	-	Reference	-
SIMD 1 (MD)	4350	5.6	36631	47.2	6.57	(6.11,7.08)	<0.001	6.57	(6.10,7.07)	<0.001
SIMD 2	2850	4.2	38396	56.9	4.11	(3.80,4.43)	<0.001	4.10	(3.80,4.43)	<0.001
SIMD 3	1992	3.2	40760	65.1	2.71	(2.50,2.93)	<0.001	2.70	(2.49,2.92)	<0.001
SIMD 4	1415	2.2	46706	71.8	1.68	(1.54,1.83)	<0.001	1.67	(1.54,1.82)	<0.001
SIMD 5 (LD)	887	1.4	49013	78.2	-	Reference	-	-	Reference	-
Caries only										
2011/12	13557	29.2	28327	61.0	-	Reference	-	-	Reference	-
2012/13	13948	28.9	29845	61.9	0.98	(0.95,1.00)	0.10	0.97	(0.94,1.00)	0.03
2013/14	13975	28.3	30442	61.7	0.96	(0.93,0.99)	0.004	0.95	(0.93,0.98)	0.001
2014/15	12869	26.1	31680	64.2	0.85	(0.82,0.87)	<0.001	0.85	(0.82,0.87)	<0.001
2015/16	12626	26.4	30530	63.8	0.86	(0.84,0.89)	<0.001	0.86	(0.83,0.88)	<0.001
2016/17	11740	25.3	29821	64.4	0.82	(0.80,0.85)	<0.001	0.81	(0.78,0.83)	<0.001
2017/18	12180	25.5	30861	64.5	0.82	(0.80,0.85)	<0.001	0.82	(0.80,0.85)	<0.001
Male	47883	28.0	105615	61.2	1.12	(1.10,1.13)	<0.001	1.13	(1.11,1.14)	<0.001
Female	43012	26.1	105891	64.3	-	Reference	-	-	Reference	-
SIMD 1 (MD)	31306	40.4	36631	47.2	4.43	(4.31,4.55)	<0.001	4.43	(4.32,4.55)	<0.001
SIMD 2	21513	31.9	38396	56.9	2.90	(2.82,2.98)	<0.001	2.90	(2.83,2.99)	<0.001
SIMD 3	15722	25.1	40760	65.1	2.00	(1.94,2.06)	<0.001	1.99	(1.94,2.05)	<0.001
SIMD 4	12899	19.8	46706	71.8	1.43	(1.39,1.47)	<0.001	1.43	(1.39,1.47)	<0.001
SIMD 5 (LD)	9455	15.1	49013	78.2	-	Reference	-	-	Reference	-
Obesity only										
2011/12	2927	6.3	28327	61.0	-	Reference	-	-	Reference	-
2012/13	2784	5.8	29845	61.9	0.90	(0.85,0.95)	<0.001	0.90	(0.85,0.95)	<0.001
2013/14	3175	6.4	30442	61.7	1.01	(0.96,1.06)	0.77	1.01	(0.95,1.06)	0.81
2014/15	3212	6.5	31680	64.2	0.98	(0.93,1.03)	0.46	0.98	(0.93,1.04)	0.51
2015/16	3085	6.4	30530	63.8	0.98	(0.93,1.03)	0.39	0.97	(0.92,1.03)	0.34
2016/17	3143	6.8	29821	64.4	1.02	(0.97,1.07)	0.48	1.01	(0.96,1.07)	0.68
2017/18	3140	6.6	30861	64.5	0.98	(0.93,1.04)	0.54	0.99	(0.93,1.04)	0.60
Male	11090	6.5	105615	61.2	1.07	(1.04,1.10)	<0.001	1.08	(1.05,1.11)	<0.001
Female	10376	6.3	105891	64.3	-	Reference	-	-	Reference	-
SIMD 1 (MD)	5293	6.8	36631	47.2	2.12	(2.03,2.22)	<0.001	2.12	(2.03,2.22)	<0.001
SIMD 2	4699	7.0	38396	56.9	1.80	(1.72,1.88)	<0.001	1.80	(1.72,1.88)	<0.001
SIMD 3	4098	6.5	40760	65.1	1.48	(1.41,1.55)	<0.001	1.48	(1.41,1.55)	<0.001
SIMD 4	4034	6.2	46706	71.8	1.27	(1.21,1.33)	<0.001	1.27	(1.21,1.33)	<0.001
SIMD 5 (LD)	3342	5.3	49013	78.2	-	Reference	-	-	Reference	-

OR - Odds Ratio; CI - Confidence Interval; AOR - Adjusted Odds Ratio; SIMD - Scottish Index of Multiple Deprivation; MD - Most Deprived 20%; LD - Least Deprived 20%