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An evaluation of nutrition welfare policies for low-income children in the United Kingdom.

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Abstract

Introduction

A child’s socioeconomic status is one factor determining their dietary quality. Food-assistance policies in the UK include Healthy Start and Universal Infant Free School Meals (UIFSM). Around 17% of the population are eligible for these policies, yet uptake can be as low as 55%. However, they are under-evaluated and consequently, not well-understood. This thesis aims to evaluate these nutrition welfare policies on measures of dietary intake in British children.

Methods

In this thesis, I quantitively analyse nationally representative datasets to evaluate a range of food assistance policies, including Healthy Start and UIFSM. Multivariable regression methods were used to test how programme participation impacted the dietary intake in UK children. Indicators used to describe the impact of the policies on dietary intake included household purchases, nutrient and food content and degree of industrial food processing in the diet.

Results

Overall, I demonstrated mixed impacts of the food-assistance policies on the dietary intake of children. For instance, I did not find evidence that Healthy Start participation was associated with increased fruit and vegetable expenditure. Yet, I found that UIFSM was associated with lower national intakes of ultra-processed foods associated with packed lunches, contributing to lower sodium and saturated fat intakes. Furthermore, UIFSM was associated with lower socioeconomic dietary inequities. However, although school meals were preferable to packed lunches in this analysis, they were not optimal, with high levels of processed and sugary items.

Conclusions

Food-assistance policies in the UK have the potential to improve the diet of not only low-income children, but all children through universal schemes. However, improvements need to be made to realise their full potential. Key recommendations include broadening the age and income eligibility criteria of Healthy Start and Free School Meal policies, so they reach more of the population and ensure continuity of assistance throughout childhood.

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I am so grateful to my fantastic team of supervisors for guiding me through this PhD: Eszter Vamos (*Imperial College London*), Chris Millett (*Imperial College London*) and Stephanie von Hinke (*University of Bristol*). I have also received support and advice from Kiara Chang (*Imperial College London*) and Anthony Laverty (*Imperial College London*).

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Declaration of originality

All the research in this thesis is my own. I have received support from my supervisors Eszter Vamos, Christopher Millett and Stephanie von Hinke. I am also grateful for the advice and input of Kiara Chang, Anthony Laverty, Jonathan Pearson-Stuttard, Martin White and Frank De Vocht, who have advised on methodology and policy implications at various points throughout my studentship. I also acknowledge the work of Erin Haney, whose contribution I detail at the start of Chapter 6. When I have reused other's work for illustrative purposes, I have appropriately referenced their work and sought permission, if required.

Copyright Declaration

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Abbreviations

ALSPAC	Avon Longitudinal Study of Parents and Children
ANOVA	Analysis of Variance
AOR	Adjusted Odds Ratio
CART	Classification and Regression Trees
CI	Confidence Interval
CPI	Consumer Price Index
CVV	Cash-value Voucher
DASH	Dietary Approaches to Stop Hypertension
DID	Differences-in-differences
DQI-A	Diet Quality Index – Adolescents
FFQ	Food Frequency Questionnaire
FSM	Free School Meals (means-tested)
FV	Fruit and Vegetables
HRP	Household Reference Person
HS	Healthy Start
HSE	Healthy Survey for England
IMD	Index of Multiple Deprivation
IPW	Inverse Probability Weights
IQR	Interquartile Range
LCFS	Living Costs and Food Survey
MCS	Millennium Cohort Study
MPF	Minimally processed food
NDNS	National Diet and Nutrition Survey
NSSEC	National Statistics Socio-Economic Class
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
OR	Odds Ratio
PSU	Primary Sampling Unit
RR	Risk Ratio
SD	Standard Deviation
SE	Standard Error
UIFSM	Universal Infant Free School Meals
UK	United Kingdom
UKHLS	United Kingdom Household Longitudinal Survey
UPF	Ultra-processed food
US	United States
VIF	Variation Inflation Factor
WFS	Welfare Food Scheme
WIC	Special Supplemental Nutrition Program for Women, Infants, and Children
YLL	Years Life Lost

Chapter 1. Background

On average, children in the UK do not attain the standard of a healthy diet. It is estimated that only 12% of British children aged 11-18 years meet the 5-a-day fruit and vegetable recommendation[1]. Additionally, sugar and saturated fat intakes are above the recommendations and ultra-processed foods account for 67% of their average dietary intake[2,3]. Yet it is in this context that socioeconomic inequalities in dietary intake are observed, with more deprived children even less likely to achieve a healthy diet[4,5]. Further to that, households with children are at greater risk of experiencing food insecurity than households without children, recent national estimates suggest up to 33% of households with children less than six years old have experienced some level of food insecurity[6].

Poor dietary intake in the UK has serious consequences for disease burden, contributing to nearly 15% of the attributable risk for years of life lost in England, but this burden is socially patterned with a higher risk in more deprived areas[7]. It is seen that diet-related inequalities in health are established at an early age. On joining primary school at ages 4-5 years there is a 7.3 percentage-point difference in the obesity prevalence between the most (13%) and least deprived (7%) children, however the difference doubles by the time they leave primary school at age 10-11 years, with 28% and 12% being obese, respectively[8]. This inequality persists and worsens throughout adulthood, with 36% of the most deprived adults being obese compared to 22% of the least deprived[9]. Obesity has many associated sequalae including but not limited to hypertension, diabetes, cardiovascular disease, cancer and musculoskeletal disorders, therefore obesity inequities increase the risk of other non-communicable diseases[10]. As it stands, the most deprived adults in England have a two-times increased likelihood of cancer mortality, a four-times increased likelihood of cardiovascular disease and a predicted 19-year difference in healthy life expectancy compared to the least deprived adults in England[11]. Furthermore, treating obesity and its related disorders puts a great strain on health resources. Its estimated treating obesity alone costs the NHS £18 billion a year, taking up 8% of GDP in the UK and having roughly the same economic impact as smoking and armed conflict[12].

The causes of dietary and health inequities are complex and multifactorial in nature. Factors which drive inequality act on multiple levels, including structural, societal, environmental, and individual[13]. Though, it is recognised that structural determinants of inequalities play a large role through generating social stratification in society, defining individual socioeconomic position and driving social gradients in both diet and health[14]. Put simply, wider structural determinants act to create unfair wage structures, meaning that not all wages in the UK cover the cost of living, whilst making unhealthy food cheaper, more accessible, and more available than less healthy food. Therefore, lower-income groups are driven towards unhealthy behaviours. It is imperative that public health policies intervene early to prevent the development of a cycle of inequality and improve diet and health outcomes for all children.

In this chapter, I will start by introducing the context of inequality in the UK and demonstrate the extent to which economic resources are unevenly distributed throughout society. I will then provide a detailed picture of dietary inequities in the UK, showing the degree to which diets are impacted and describe the prevalence of food insecurity in the UK. Following this I will explore the causes of dietary inequalities and food insecurity, using frameworks to demonstrate the interlinked web of causative factors. Then I will discuss the wide-ranging impacts of dietary inequalities, showing not only the health effects but also societal effects.

After laying a foundational understanding of the topic, I will consider what policy action is being undertaken in the UK to address the issue. I will make the case for intervening early in the life course. I will then go onto explore the food assistance policy landscape in the UK and describe two prominent food assistance policies at the centre of this thesis: Healthy Start and School Meal policies.

1.1 Inequality and dietary intake in the UK

1.1.1 Income inequality and poverty in the UK

Wealth and income in the UK are unevely distributed. It is estimated that the richest 1% of individuals hold around 20% of the total wealth in the country and the richest 10% of individuals control 50%[15]. Government estimates indicate that the wealth gap between the richest and the poorest in society has been growing; by March 2020 income inequality had reached a ten year high[15]. For example, mean total wealth in Great Britain increases exponentially between the lowest and the highest deciles. While the mean total wealth in the top two deciles is over one million pounds, the lowest decile has on average a debt for their financial (£-4,900) and property wealth (£-400) (Figure 1.1).

In the UK, relative poverty is defined as being below 60% of the median household income[15]. Across all households, relative poverty in the UK has remained stable over recent years at around 20% of the population. However, evidence indicates that poverty has been rising among certain groups. For example, the proportion of working households who experience poverty has increased, indicating that not all wages are not sufficient to protect from poverty[16]. Additionally, between the financial years of 2018/19 and 2019/20 there was a significant increase in the prevalence of children in relative poverty (before housing costs), from 20% to 23%[17](Figure 1.2). Rising household and childcare costs combined with reduced income support from the Government are factors which have contributed to households with children being increasingly likely to experience relative poverty[16.] This is further demonstrated as the prevalence of poverty after accounting for housing costs is higher than without housing costs (31% vs 23%, respectively), reflecting the increasingly unaffordable cost of living for families. As it stands, 3 in

10 children live in relative poverty in the UK[17]. The UK's child poverty rates are classified as 'Intermediate' by the OECD, ranking 14th out of the 37 OECD countries[18].

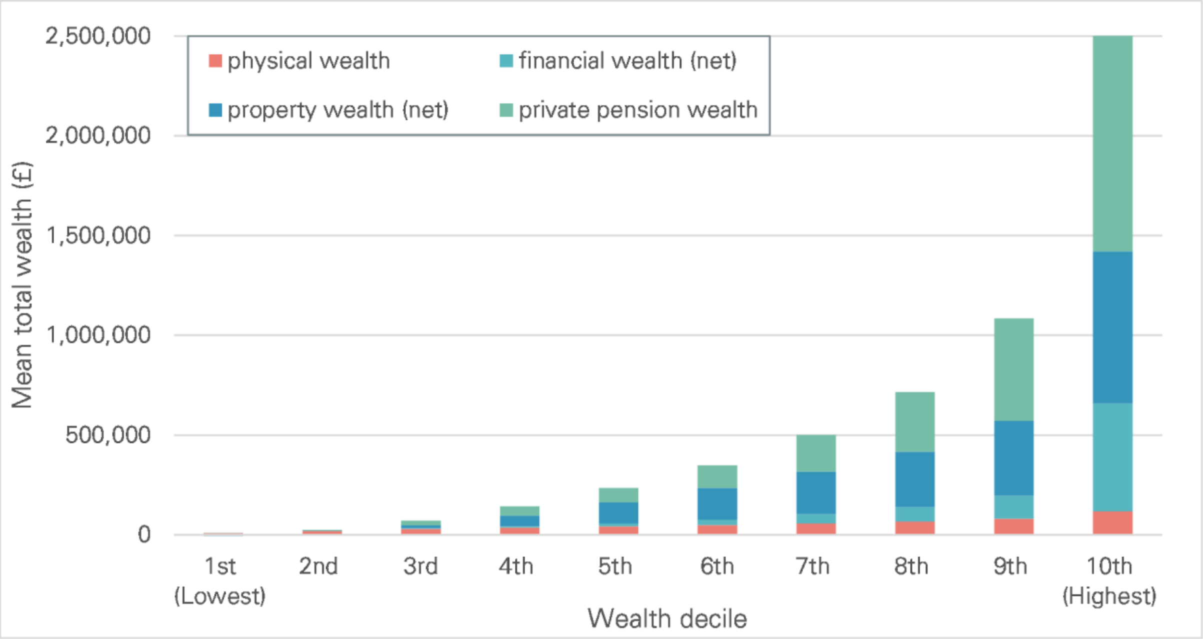

Figure 1.1 - Mean total wealth by component and wealth decile for Great Britain, April 2016 to March 2018.

Reproduced from ONS 2019[19]

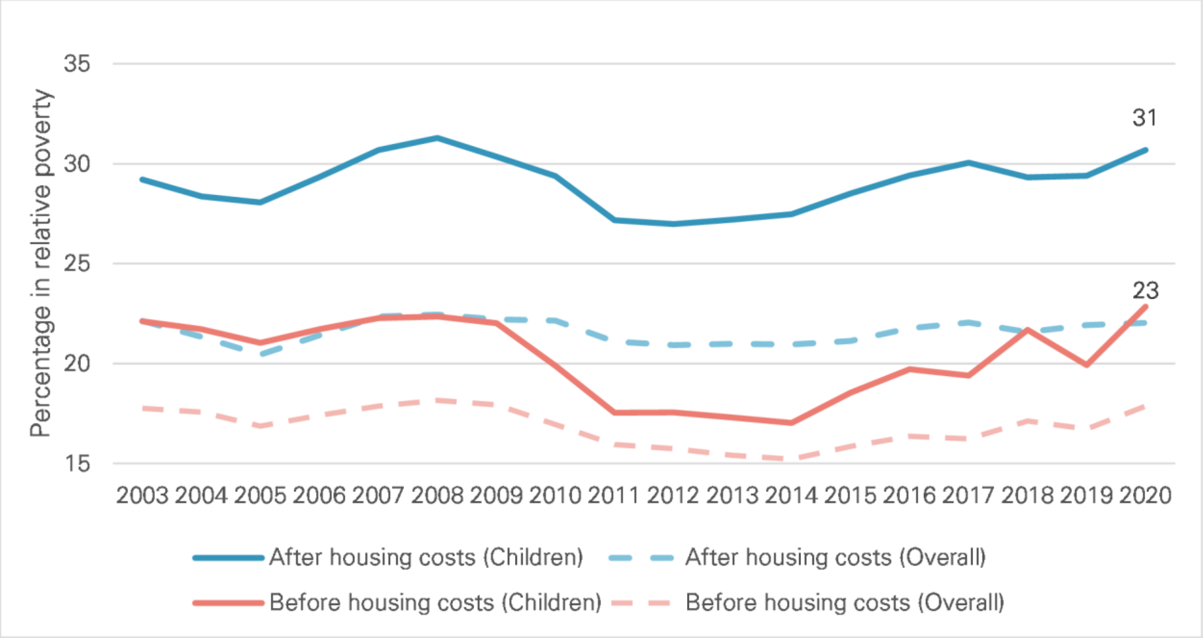

Figure 1.2 – Percentage of children in relative poverty in Great Britain compared to the average, before and after housing costs, 2002/03 – 2019/20.

Note: Years represent financial years. Reproduced from ONS 2021[17]

Living in poverty can have many serious consequences for children. The inability to afford quality housing, healthy food, fuel, public transport and social events prevents a child from having a socially acceptable standard of living and can have many wide-ranging effects[20]. Childhood poverty has been shown to be negatively associated with health, educational and social and emotional outcomes[21]. This thesis will focus on just one of the many consequences of poverty, the inability to afford and access a healthy diet.

1.1.2 Inequality in dietary intake

To explore the inequalities in achieving a healthy diet, it must first be determined what constitutes a ‘healthy’ diet. As nutritional science has developed over the last century, individual nutrients were isolated and associated with health outcomes[22]. Consequently, common rhetoric implicates certain nutrients as ‘bad’, such as saturated fat and sugar, and some as ‘good’, such as protein and vitamins. Research has determined optimal intake thresholds of these nutrients for health. While useful in quantitative research settings, this approach does not have utility in a real-world setting and does not reflect the way people eat. Subsequently, nutritional research focussed on food groups, highlighting the relative healthfulness of foods such as fruits, vegetables or sugar-sweetened beverages. Dietary guidelines in the UK are set using a combination of nutrient thresholds and portions of food groups[23]. Yet recently, concepts such as composite dietary scores and the degree of food processing have broadened the understanding on healthy eating, although this has not yet been factored into official advice. As such, it’s clear that there are multiple approaches to characterising dietary intake. Yet, the socioeconomic gradient in diet is ubiquitous and is evident in all approaches to describing dietary intake, as I will demonstrate in the following section.

Systematic reviews have summarised the socioeconomic gradient in dietary intake in high-income countries. One review, which is now outdated (containing data from 1990-2007) found strong and consistent evidence for a socioeconomic gradient in fruit and vegetable intake from European studies, but did not find consistency in other dietary indicators such as energy, fat and fibre and sugar-sweetened beverages[24]. Similarly, another systematic review of studies in Western Europe conducted between 1990-2011 concluded there was an overall positive association between socioeconomic position and intake of micronutrients such as, vitamin C, vitamin D and iron[25]. More recently, a pooled analysis across 12 European countries indicated that individuals with lower educational levels from high GDP countries had higher mean fat intakes and lower iron, folate and vitamin D intakes[26]. Although the evidence was less consistent for sugar intake. These systematic reviews give a useful picture of the association, highlighting that the socioeconomic gradient appears to be strongest for fruit, vegetables, and micronutrients, indicating more affluent people are more likely to eat a nutrient-dense diet. The evidence is less consistent for macronutrients such as fat and sugar. However, socioeconomic differences are inherently context-dependent and will change relating to the societal structure of a country. Therefore, it is important to examine these associations in the UK context.

We see evidence for socioeconomic differences in the types of foods that people purchase in the UK. Analysis of expenditure data has shown that low socioeconomic position households are more likely to purchase unhealthier versions of food products, such as foods which are energy dense and high in sugar, and are less likely to purchase wholemeal, fruit or vegetable products than high socioeconomic position households[27–31]. These findings have been shown to translate to what individuals report eating. Low socioeconomic groups consume less vegetables but more processed red meat and sweet foods such as cakes than higher socioeconomic position groups[32,33]. It is estimated adults in non-manual positions were 1.76 times more likely to meet fruit and vegetable recommendations in 2008/12 than adults in manual positions (OR 1.76; CI 1.35, 2.28), although this was an improvement from the inequality observed in the 1980s[34].

There are many important aspects of the diet to summarise which can often make the findings of multiple studies hard to consolidate. Composite dietary scores have been used to combine many dietary indicators into one value. Socioeconomic differences are clearly demonstrated in analyses using dietary scores. For instance, the Dietary Approaches to Stop Hypertension (DASH) score summarises dietary aspects of the DASH diet, which promotes high fruit and vegetable, wholemeal and low-fat dairy intake but low saturated fat and meat consumption. A higher DASH score has been associated with improved blood pressure[35]. There is consistent evidence that adults in a lower socioeconomic position had a lower DASH score[36,37]. Furthermore, reduced rank regression of the National Diet and Nutrition (NDNS) dataset, a nationally representative repeated cross-sectional dietary survey in the UK, concluded that obesogenic dietary patterns were more likely to be consumed by those from a manual occupation and low-income[38]. These composite scores are important as they directly associate socioeconomic gradient in dietary intake with negative health outcomes.

Another aspect of dietary intake which is relatively understudied is the degree of industrial food processing in the diet. Concern about high consumption of ultra-processed food (UPF) has developed over the previous 10 years, when the concept was formally defined[39]. The level of processing in the diet captures many negative aspects which have developed in western food culture. UPFs are packaged, ready-to-eat, hyperpalatable foods with little relation to whole foods or their original ingredients. High consumption of UPFs is associated with a higher intake of sugar, fat and salt and displaces foods which are dense in micronutrients[40]. Moreover, by their nature UPFs discourage societies from cooking, which is independently associated with reduced healthfulness of the diet[39,41,42]. Finally, UPFs have negative economic, environmental, and social consequences[42,43]. The consumption of UPF is also socially patterned. For example, the degree of processing in the diet was associated with low socioeconomic status in the NDNS[44], and negatively associated with cooking competence[41]. Moreover, a significant linear trend was found in the association between socioeconomic status and consumption of UPF, those in routine and manual positions consumed seven percentage-points more of their total energy intake as UPFs (57%) than higher managerial positions (50%)[45]. There has been comparatively little research into UPFs compared to other dietary indicators, the research base is growing as the field develops.

Inequality in diet is apparent at all life stages, with evidence that disparities in feeding patterns are present from birth. In a nationally representative birth cohort, the Millennium Cohort Study (MCS), it was demonstrated that mothers from low socioeconomic positions were four times less likely to breastfeed their children compared to mothers from high socioeconomic positions (OR 0.22; 95% CI 0.18,0.29)[46]. Although there is a trend that the socioeconomic differences have been narrowing between 2005-2013 in England, it remains an issue[47]. In a separate birth cohort based in the west of England, ALSPAC, there is also evidence of inequality in the initial foods given to children. At 6 months of age, low socioeconomic position infants were more likely to consume a diet characterised by biscuits, sweets and crisps than high socioeconomic position infants (β0.30; 95% CI 0.07,0.53)[48]. Furthermore, longitudinal data in Scotland show that reduced household income over the study period was negatively associated to fruit variety from 22 to 58 months of age but positively associated with unhealthy food consumption[49,50]. These patterns are also apparent in adolescence. Low maternal education was consistently associated with less healthy, obesogenic dietary patterns until age 13 years old in the ALSPAC cohort[51–53]. Similarly, income was negatively associated with consumption of sugar-sweetened beverages and fast food and positively associated with fruits and vegetables at age 14 in the MCS cohort[54]. This evidence clearly demonstrates that the disparity in dietary quality is apparent throughout childhood.

1.1.2.1 Food insecurity in the UK

Food insecurity is another lens from which to view dietary inequities in high-income settings, whereby access to adequate food is restricted due to limited resources. Food insecurity is commonly described as:

> "Limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways"[55]

Although definitions have varied, nearly all include the central concepts of "economic access, quality, quantity, duration and the social dimension"[56,57].

The experience of food insecurity can range from mild to severe[58]:

Mild food insecurity: Problems or worries about accessing enough food.

Moderate food insecurity: Reducing the quality, variety, or desirability of food, but not the quantity.

Severe food insecurity: Reducing the quantity of food because of lack of money or other resources and/or experiencing hunger.

Food insecurity in the UK is of a growing concern. National surveys in the UK between 2016-2019 have placed estimates of moderate or severe food insecurity at around 8% of households[6,58,59]. However, the burden is greater in households with children, the prevalence of any form of food insecurity is 18% in households without young children (<6 years) but is almost double at 33% in households with young children[6]. Furthermore, the probability of a low-income individual being food insecure in 2016 was 2-fold higher than in 2004, indicating that the prevalence worsened overtime (OR 2.38; 95% CI 1.87,3.04)[60].

Food bank usage figures have also been used to describe food insecurity in the country[61]. The Trussell Trust is the main provider of food banks in the UK, their usage figures give an indication of the rise in severe food insecurity in the UK. Since 2015/16 there has been an 128% increase in food parcel distribution from 1.1 million to 2.5 million[62]. Moreover, the figures indicate there was a 2.45-times increase in the number of children referred to the Trussell Trust food banks since 2014/15[62] (Figure 1.3). There are limitations with using this a data[61]; it is not nationally representative, and their usage figures are not on an individual level, so households could contribute to the figures more than once. Additionally, due to stigma not all food insecure households choose to use food banks, so the measure only reflects the most extreme cases of food insecurity.

A pattern emerges when these prevalence statistics are broken down by characteristics. In general food insecurity is associated with multiple markers of low socioeconomic position such as low income or education[58,60,63]. This is unsurprising as there is a direct link between income and the ability to afford food. However, it is concerning that certain characteristics, such as being disabled or having children, put a household at a greater risk of being food insecure[58,60,63]. Unlike income and education these characteristics are not in themselves a measure of socioeconomic position and reveal a context specific mechanism which places these households at a greater risk of food insecurity. Moreover, there is a clear association between food insecurity and certain life events, principally loss of work and accessing social security benefits[58,60]. For example, multiple studies have concluded that many of the food bank users surveyed were on state benefits [64,65] and 43% of individuals identified as food insecure in the most recent nationally representative survey in the UK were claiming Universal Credit[58].

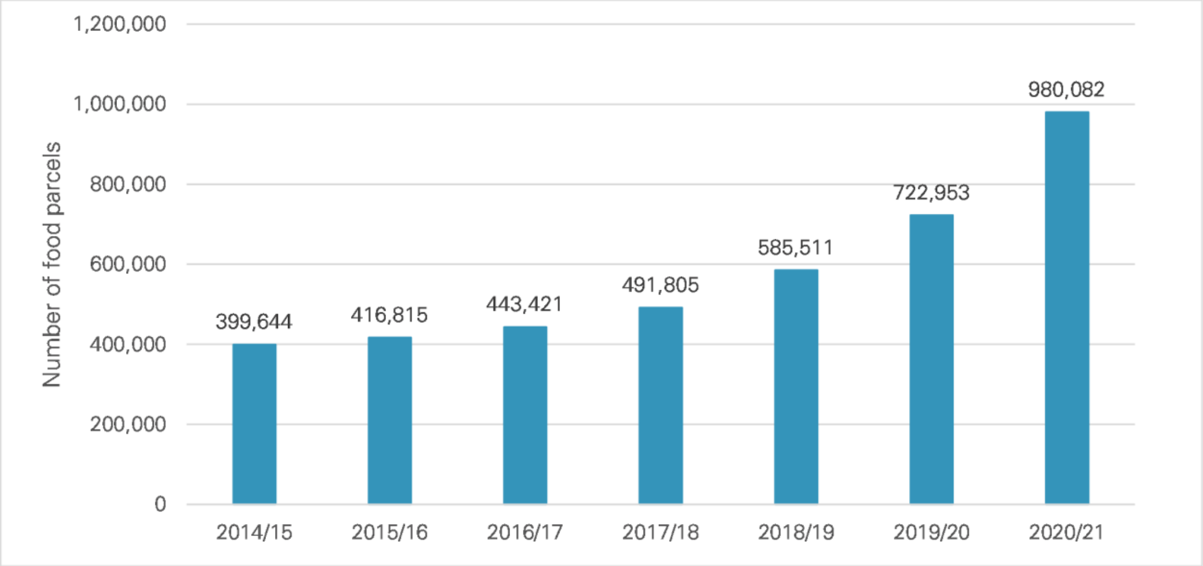

Figure 1.3 - Number of children referred to Trussell Trust food banks in the UK between 2014/15 - 2020/21

Reproduced from Trussell Trust[62]

1.1.2.2 Barriers to a healthy diet

The causal pathways to explain the social disparity in diet are numerous and multifactorial in nature. Diet is a cross-cutting issue; it is impacted by structural, political, cultural, economic, social and psychological factors[13]. Attempts to describe factors influencing dietary intake demonstrate the complexity of the issue. A model by Mozafarrin *et al*[13] elucidates the multiple levels from the individual to the global impacting dietary intake (Figure 1.4). Whereas Friel *et al*[66] illustrate the expansive pathways involved and describe how they contribute to four central domains: the accessibility, availability, acceptability, and affordability of healthy food (Figure 1.5). These four domains are used to demonstrate how the complex and interlinked factors can influence the equitable distribution of health food in society. I will use these four areas to discuss the barriers to a healthy diet in the UK.

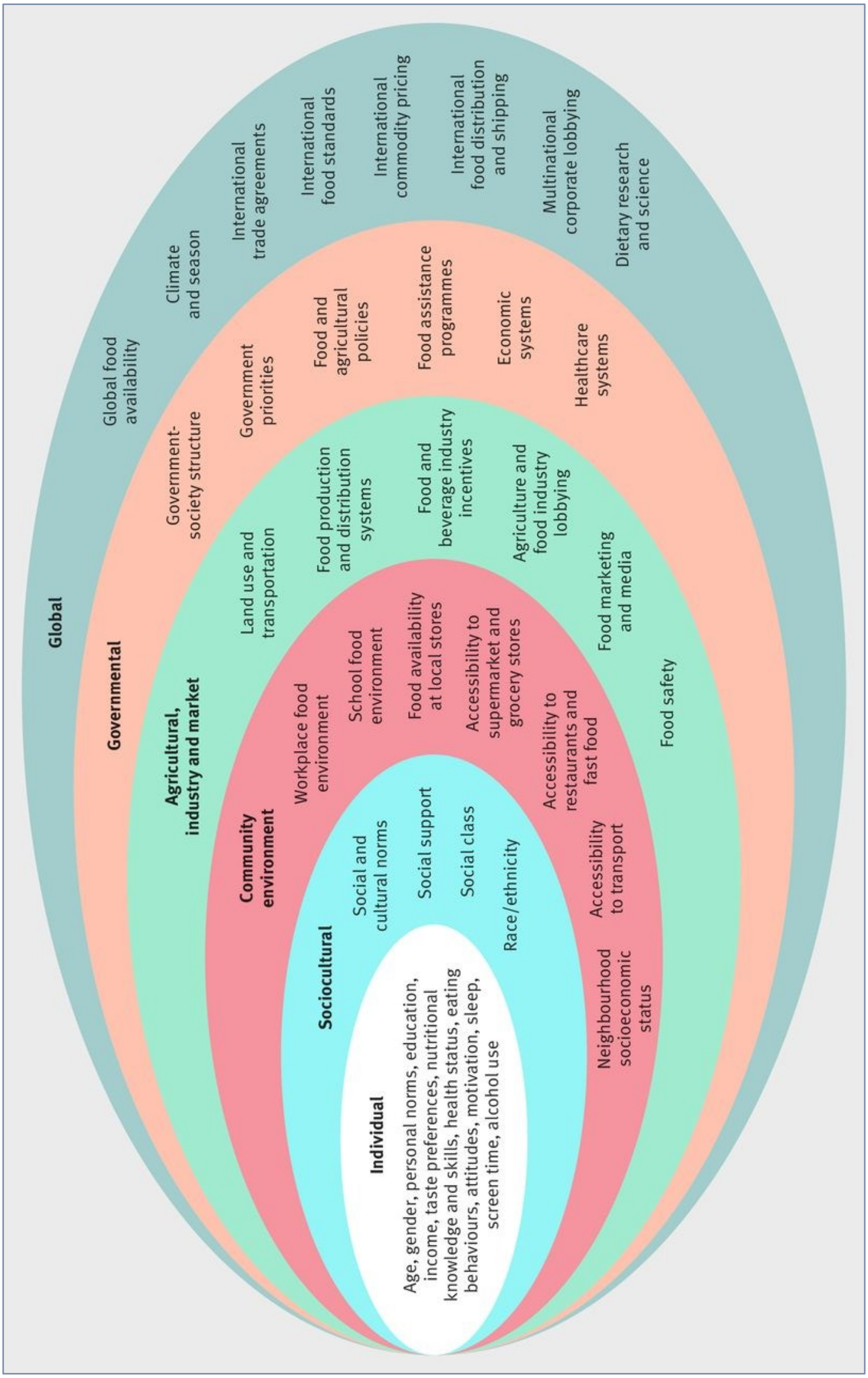

Figure 1.4 - The ecological model for barriers to healthy eating (Mozaffarian 2018) [13]

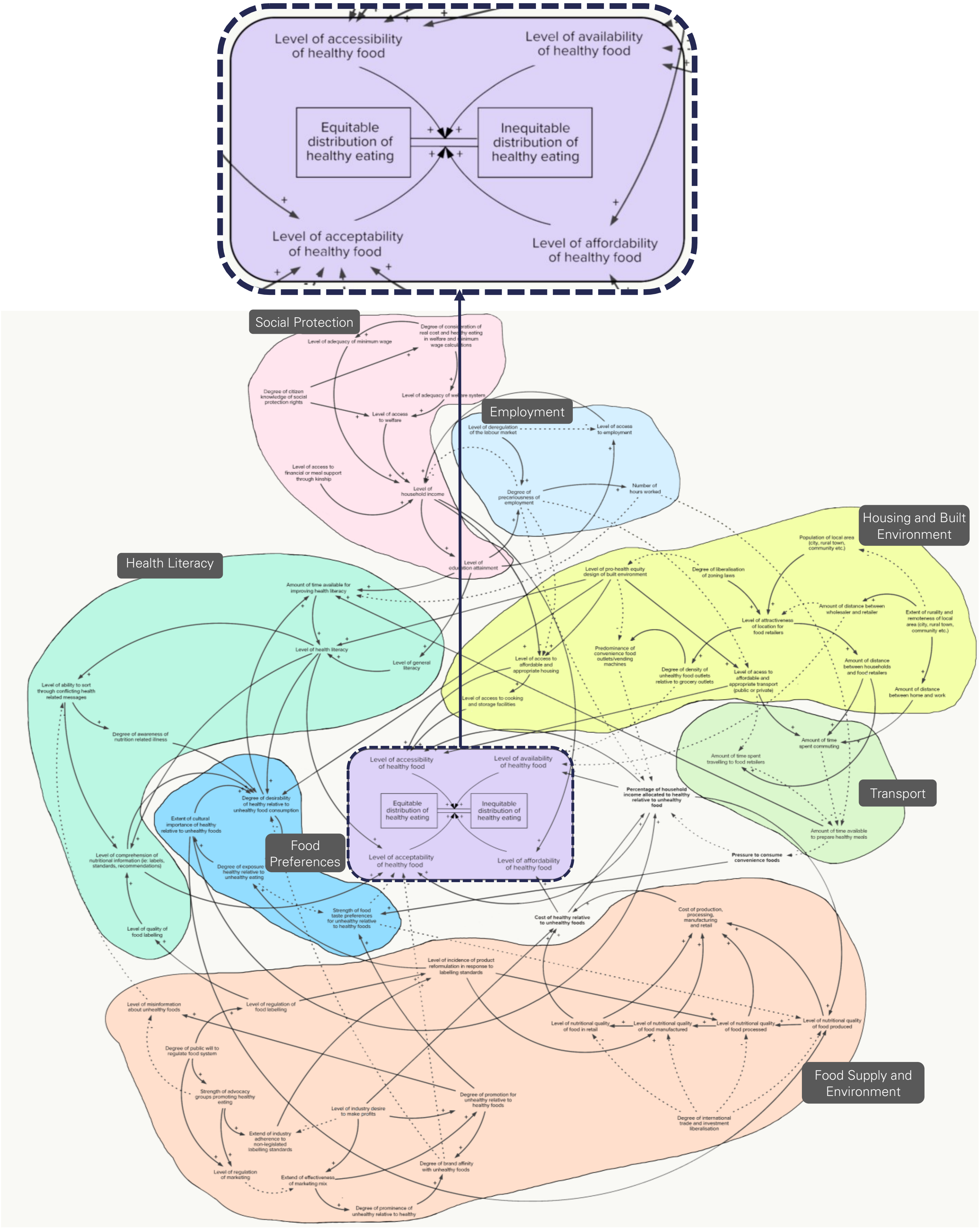

Figure 1.5 – HE^2 causal loop diagram on the multiple causes of inequities in healthy eating (Friel 2017)[66].

Please see a full-sized image at https://doi.org/10.1371/journal.pone.0188872.g004

1.1.2.2.1 Acceptability of healthy food

The individual taste preferences and the sociocultural community environment will determine what is acceptable for an individual to eat[67].

Taste preferences can have a large impact on a child's diet. Fussy eating in childhood is associated with a reduced dietary variety and a lower intake of vegetables[68]. Taste preferences develop early and are influenced by multiple factors[69]. Young children's initial preferences towards sweeter foods, aversion of bitter foods and fussy eating during infancy, termed neophobia, is thought to be caused by biological factors[69]. These preferences are posited to predispose young children towards accepting breast milk and avoiding potentially toxic foods, the preferences typically decline throughout adolescence. Although for some, genetic factors can impact their life-long taste preferences[70]. For example, some genetic mutations are linked to an increased sensitivity to bitter compounds, causing a dislike of bitter foods such as vegetables. However, development of taste preferences can also be impacted by parental behaviour. The mother's diet in the pre- and perinatal periods has been linked to a child's later acceptance of food, through the exposure to taste compounds in the womb and breastmilk[71]. Furthermore, through mirrored behaviour, when parents express enjoyment while eating food their children are more likely to consume that food, including vegetables[72,73]. Therefore, the development of taste preferences in childhood are a complex mix of biological, genetic, and learnt behaviours from their immediate family.

Social factors are another influence on dietary choices. In adolescence this can act as a barrier to healthy eating. Adolescent eating behaviour is affected by subjective peer-norms and has been linked to the formation of self-image and friendships[74]. This complex interaction of social relationships in adolescence is often linked to higher consumption of fast-foods[75]. Although, it must be recognised that food marketing and adverts play a key role in developing these social norms and preferences in children[75,76]. Children are highly susceptible to marketing practices. In young childhood, children are not aware they are being sold an item and the use of characters by food companies has been shown to increase children's preference to certain food items, often energy-dense and nutrient poor[77]. In adolescence marketing practices have worked to establish the association between social prestige and fast-food consumption[75,76].

Furthermore, ethnicity and culture play a large role in the acceptability of food[78,79]. Religion can be associated with prescribed dietary pattens and for some is associated with positive dietary and health outcomes[80]. Studies on migrant communities in western countries have revealed how dietary habits may change as individuals become assimilated into the culture of their host country[81]. This is termed as dietary acculturation and is typically associated with worse dietary intake for the migrant communities who adopt a western dietary pattern over the diet traditional to their home country[79]. However, dietary acculturation does not occur for all migrants. Communities that retain a strong connection with their cultural values have been shown to consume healthy diets despite their relatively low socioeconomic position in their host country. In the Netherlands, Dutch participants typically had lower dietary score than Surinamese, Moroccan or Turkish participants[82]. This study is exemplary that cultural values can strongly influence dietary practices and can override other influences such as socioeconomic status.

However, it is important to recognise the interconnection of these individual and social factors of food preferences to wider environmental and social determinants. Aside from genetic factors, all of the aforementioned influences on the acceptability of healthy food are in turn influenced by what healthy food is available, accessible, and affordable for that individual or social group[83,84]. For example, in Figure 1.5, food preferences and desirability of healthy foods are influenced by an individual's exposure to healthy food and the cultural importance of healthy versus unhealthy foods. However, these factors are in turn influenced by factors from their Food Supply and Environment, their Health Literacy and Housing and Built Environment. Although these factors influencing individual taste preferences are important to consider, they must be understood within a wider context.

Often the scientific and policy literature put a strong emphasis on an individual's food choice. This implies that the individual has the sole and ultimate responsibility for what they consume[85]. If this were true, it would make Mozaffarian's model much simpler (Figure 1.4), removing many of the outer circles. Indeed, dietary policies which aim to help individuals make healthier choices through education implicitly assume poor health literacy and place the burden of responsibility on the individual[13,85]. The two diagrams displayed in Figure 1.4 and Figure 1.5 contradict that concept and posit that although the individual is central in their dietary habits, there are multiple factors that predetermine what choices are available for an individual to make. Although dietary knowledge is socially patterned, this does not explain the entire social gradient nor is it the most influential mediator[86,87]. Qualitative research with low-income individuals demonstrated that they have reduced resources for cooking[88], not a lack of knowledge or skills[89]. In this way, education-based interventions have been shown to drive inequalities in the diet, as the intervention requires a high amount of individual agency. These are unlikely to be successful as they do not consider that the resources required to prepare healthy food are also socially patterned[13,85,90]. Therefore, although an individual's actions are central, it is important to consider what factors are determining the choices that are available to that individual.

1.1.2.2.2 Availability and accessibility of healthy food

An individual's environment also influences their dietary intake. The concept of a 'food environment' can be nebulous and all-encompassing but a simple definition proposed that food environments are "*the interface that mediates people's food acquisition and consumption within the wider food system*"[91]. Through this concept of food environments, the wider influences on dietary intake can be considered.

The access to and availability of healthy food in an individual's local area are determined by factors beyond their control. Regardless of their intention or desire to consume healthy food, their food environment might make this difficult to achieve. In Mozaffarian's model (Figure 1.4), this includes the aspects in the "community environment" level, such as "access to supermarkets" and "neighbourhood socioeconomic status".

For example, the distribution of healthy and unhealthy shops and restaurants in a neighbourhood has been shown to be associated with markers of deprivation. A longitudinal study in Norfolk indicated that supermarket presence was not associated with area-level deprivation but fast-food outlets were more densely located in low socioeconomic areas and increased between 1990-2008[92]. There has been particular concern over children's exposure to fast-food outlets and their proximity to school premises, as researchers found that fast-food exposure near schools has been increasing overtime and is linked to area-level deprivation[93,94]. However, the link between fast-food exposure near schools and outcomes such as diet or obesity appears to be weak[93,95–97]. Although the inconsistency might be partly due to the methodological complexities of studying area-level exposures[98]. It highlights that the food environment is not strongly independently associated with inequalities in dietary intake, but one of many contributing factors which should be considered. For example, it was shown that exposure to fast-food outlets alone was not associated to diet and obesity in a sample of nearly 6,000 adults in Cambridgeshire, but it did amplify existing inequalities in diet and obesity[99]. In this study, associations between fast-food exposure and obesity were only significant for the least educated group. Similarly, in an analysis of over 50,000 adults, the association between fast-food exposure and obesity was strongest when household-income was considered; those with the lowest income and the highest fast-food exposure were at the greatest risk of obesity (OR 2.43; 95% CI 2.09, 2.84)[100]. Additionally, when the price of a supermarket was taken into account, this was found to have a greater association to dietary quality than geographic accessibility alone[101]. In summary, it appears access and availability to food in the local environment is a barrier to a healthy diet but one which acts to amplify existing inequalities. The evidence of an independent association in the UK is weak. Factors such as dietary costs and socioeconomic position need to be considered alongside environmental factors[102]

1.1.2.2.3 Affordability of food.

The affordability of food is a critical barrier to a healthy diet. Healthy food is more expensive than less healthy food[103]. Despite the simplicity of the statement, this fact has been difficult to determine. Foods which are commonly accepted to be healthier, such as fruit and vegetables, have lower energy density but a higher micronutrient content compared to less healthy foods such as fast-food and confectionary. Therefore, whether the price is given by its energy (£/Kcal) or its weight (£/g) will vary how expensive 'healthy' foods appear relative to 'unhealthy' foods[104]. However, a systematic review of the literature determined that healthy foods, whether compared to a similar less healthy product or viewed as an entire dietary pattern were more expensive, regardless of the metric used [105].

Moreover, not only is healthy food more expensive, but it has also become relatively more expensive overtime. Over the past twenty years in the UK, food price inflation has made all categories of food relatively more expensive (Figure 1.6)[106]. However, this was shown to have been disproportionally higher for healthy foods such as fruit and vegetables compared to less healthy groups such as foods high in fat and sugar; the price rose £0.17/1000kcal per year for healthy groups and £0.10/1000kcal per year for less healthy groups[107].

However, this is exacerbated for those on the lowest income, in which wage depreciation over the same time-period has not recovered from the 2002/03 levels (Figure 1.6). Average income for the lowest quintile fell by 12% but food prices rose 3.5%[106]. As such, the lowest income households on an absolute scale, purchase less food, but this constitutes relatively more of their income compared to higher income households[108]. Indeed, it was observed that over the past 10 years, average spending on fruit and vegetables rose in the average UK household (1% and 3%, for fruit and vegetables respectively), but fell for households in the lowest income decile (-6% and -3%, respectively)[106]. Furthermore, this association has been observed across Europe and is directly associated with the prevalence of food insecurity. It was found that for every 1% rise in food price inflation above wage inflation there was an associated 0.07 percentage point rise in food insecurity across 21 European countries between 2004-2012[109].

Figure 1.6 - Change in average income after housing costs for the lowest quintile and price of food and drink from 2002 in the UK.

Reproduced from DEFRA[106]

Unfortunately, there are indications that food price inflation will continue to worsen in coming years. The UK imports a large proportion of its food, 90% of fruit and 45% of vegetables, and has a heavy dependance of European labourers in the agricultural sector[110,111]. Consequently, Brexit is likely to both increase food prices through increased tarrifs and reduce accessibility through trade blocks and reduced labour, further exacerbating food insecurity[110,112]. At the time of writing, there were early indications of Brexit-related food supply chain issues impacting food costs, with estimates that this could rise to 10% by 2023[113]

In this context, the size of the financial barrier to a healthy diet is evident. It has been estimated that the lowest income households would need to spend over 70% of their disposable income to meet all of the UK government's dietary recommendations of the Eatwell Guide[114] and that diets which meet 6 or more of the recommendations were 29% more expensive[115]. Other definitions of a healthy diet, including the DASH and Mediterranean diet, were also found to have higher dietary costs in samples of UK adults[36,116,117]. Interestingly, it was observed that socioeconomic status was a mediator to the association between dietary costs and dietary patten. There were greater differences in the cost of attaining a healthy diet in the lower socioeconomic groups compared to the higher socioeconomic groups[117]. This suggests that the cost of a healthy diet is a greater barrier for people in low socioeconomic positions than higher socioeconomic positions[28]. This has been confirmed through qualitative interviews, in which price was shown to be a greater determinant of choice for low-income individuals than high-income individuals[118,119]. To compound this issue, unprocessed and home-cooked food, which is typically healthier, becomes more expensive when the time to prepare food is taken into account. It becomes even less economically viable for low-income households to dedicate time to preparing healthy food when this is considered[120,121].

This can also be demonstrated by examining low-income household's price sensitivity and response to economic shocks[121]. A study which analysed the impact of the 2008 recession on dietary intake determined that low-income households, especially ones with children, were more likely to reduce their intake of fruit and vegetables and increase their intake of processed snack foods[122]. A finding which was confirmed in a systematic review[123]. Moreover, a meta-analysis of studies analysing food prices and consumption determined that in all countries studied, lower income households were more price sensitive than higher income households[124].

Economic shocks, have also been shown to be associated with food insecurity. For example, across Europe a sharp rise in food insecurity, a reversal of a previously downward trend, was associated with the onset of the global economic recession in 2008 and a period of austerity[125]. However, the recession did not have a similar impact on food insecurity across individual European countries. Whereas the overall trend was of an increase, for some countries such as Portugal, there was a decrease in food insecurity. This lead to researchers to posit that social protection policies can mediate the impact of macroeconomic changes on individual experience of food insecurity[125,126]. An analysis of 21 European countries observed that the association between falling wages and food insecurity was significantly impacted by social protection[126]. Government spending on housing, unemployment, disability, family, and sickness policies was effective at reducing the association between increasing unemployment and food insecurity. Moreover, across 148 countries income support policies for families were associated with a lower prevalence of food insecurity[127].

The rise in food insecurity and foodbank use in the UK in welfare benefit claimants reflects a failure of the state to protect the most vulnerable in our society from macroeconomic shocks. Not only does the system fail to protect, but there is also evidence that it causes a rise in food insecurity. Social security benefits in the UK are now paid through one system, Universal Credit, which was phased in slowly across the UK. It has been demonstrated that a year after the introduction of Universal Credit in a region, food banks see a 52% increase in demand compared to regions which have had Universal Credit for less than 3 months[128]. Indeed, governmental changes to spending and welfare have consistently been associated with increased food insecurity, food bank use and increased stress and financial strain for low-income individuals[129–131]. The extent of this issue was noted by the UN’s Special Rapporteur on extreme poverty and human rights on their visit to the UK in 2019[132].

More recently, the COVID-19 pandemic has been another example of a large economic shock which has had a significant impact on food insecurity in the UK. A nationally representative survey in the first two weeks of the first national lockdown (March-April 2020) estimated moderate to severe levels of food insecurity quadrupled[133,134] and demand for emergency food aid rose[135,136]. Unlike other economic shocks, physical lack of access to food due to self-isolating or food shortages contributed to food insecurity, an estimated 40% of the observed association[134,137]. However, financial insecurity was shown to be the greatest influence. There was a greater dependency on welfare benefits during this period[138]. Government schemes to support low-income children and the clinically vulnerable were criticised for their insufficiency, putting these groups at a particular risk of food insecurity during the pandemic [61,138,139]

1.1.2.2.4 Summary of the barriers to a healthy diet

In summary, there are multiple intersecting influences which contribute to dietary intake, these include factors which affect the acceptability, accessibility, availability, and affordability of healthy food. No one factor in isolation can explain the between-person variation in dietary intake or the socioeconomic gradient in dietary intake. Furthermore, although measures of socioeconomic status are strongly associated with dietary intake, these factors are not deterministic. Due to the complex web of influences on diet, not all individuals will be in keeping with the trend. In balance, however, there is strong evidence that affordability of food has a large influence on the diet of low-income households, especially those with children. A recent confluence of rising food prices with reduced wages has been one factor which has made food less affordable, particularly for those on the lowest income. The continuing pressure of Brexit and the COVID-19 pandemic are a growing concern. Without permanent and improved social security protection or addressing the price differential between healthy and unhealthy food, the issue of diet inequities and food insecurity in the UK will only deepen.

1.1.3 Diet-related inequality in health outcomes

There is a well-established link between diet and health[140]. It is important to note that are multiple causes of ill health, some of which are socially patterned such as exercise and environmental exposures, and others which are not such as genetics. However, in this section I will only consider the influence diet on health. The Global Burden of Disease study estimated that in 2016, dietary factors contributed 14.4% of the attributable risk for years of life lost (YLL) in England, but found the burden was varied by area-level deprivation[7]. For example, the age-standardised attributable risk for YLL due to dietary factors in the most deprived local authority was over 1,500 YLL per 100,000 population but was less than 900 YLL per 100,000 population in the least deprived local authorities. Therefore, the observed socioeconomic gradient in dietary intake has negative consequences for health inequities.

Dietary inequities are associated with increased weight for lower-income populations. Data from the MCS birth cohort reveal that inequalities in childhood obesity were present from the age of 5[141]. Children in the lowest quintile of income had a 2-fold (95% CI 1.4,2.8) increase in obesity at age 5 and a 3-fold (95% CI 2.0,4.5) increased risk by age 11 than children in the highest quintile. Dietary factors, along with physical activity, were the greatest mediators to this association, a finding which continued into adolescence[54]. Similar findings were observed in the ALSPAC birth cohort where socially patterned, energy dense diets were associated with increasing fat mass from mid-childhood to adolescence[142]. Furthermore, over 10 years of follow-up it was demonstrated that high ultra-processed food consumption in the ALSPAC cohort was associated an increased trajectory of weight gain from childhood to early adulthood[143]. Resultantly, the diet-related socioeconomic differences in BMI that are apparent from age 7 have been shown to persist through to adulthood and have been widening overtime, as shown in multiple birth cohorts[144,145].

The increased likelihood of obesity for the most deprived children puts them at increased risk of non-communicable diseases in adulthood. Analysis of three birth cohorts in the UK indicate that persistent obesity from childhood to adulthood was associated with a 2.5 fold increase in the odds of hypertension (OR 2.56; 95% CI 1.40, 4.68), 12 fold increase in type-2 diabetes (OR 12.6; 95% CI 6.6, 24.0) and a 6 fold increase in the odds of coronary heart disease (OR 6.62; 95% CI 1.94, 22.65)[146]. As such, the sequela of poor dietary patterns and obesity, such as type 2 diabetes, cardiovascular disease and cancer also display socioeconomic differences. In ALSPAC, socioeconomic gradients were observed in a number of markers of cardiovascular disease, including blood lipids, c-reactive protein and blood pressure, as early as 10 years old[147]. Resultantly, the most deprived adults in England have a two-times increased likelihood of cancer mortality, a four-times increased likelihood of cardiovascular disease and a predicted 19-year difference in healthy life expectancy compared to the least deprived adults in England[11]. There are multiple factors which contribute to the persistence of this health inequity throughout the life course, health behaviours such as diet are just one contributing factor. However, it appears that the mediating impact of health behaviours on the morbidity and mortality of non-communicable disease may be more apparent for low socioeconomic individuals. In a longitudinal study of almost 400,000 UK adults, the protective effect of healthy behaviours on cardiovascular disease incidence, mortality and all-cause mortality were greater for low socioeconomic individuals compared to those in higher positions[148]. The negative impacts of unhealthy behavioural factors were also found to be more severe[149], indicating that low-income individuals are more vulnerable to the consequences of behavioural factors. This is likely due to accumulated disadvantage through the life causing faster disease progression[150].

Inequalities in dietary intake also has a strong association in poor dental health. Repeated cross-sectional surveys in the UK have shown a downward trend in dental caries for all children between 2003-13[151]. However, despite the improvement, children from a deprived background were still twice as likely to have dental caries than less deprived children at age 15 (OR 2.28; 95% CI 1.98, 2.63). An association which has been shown to continue to later life [152].

Obesity is also linked with poor mental health. Researchers have noted a bi-directional relationship between depression and obesity whereby dietary factors and obesity increase the risk of poor mental health, but also poor mental health is also associated with changing dietary habits and obesity[153]. For low-income individuals this is compounded by the other stresses, such as the psychological distress related to experiencing food insecurity[154].

As it stands, low-income children are more likely to have an unhealthy diet, be overweight from an early age and live less of their life in good physical or mental health. So, diet-related ill health has a large individual cost, but it also carries a large societal cost. The economic consequences of treating obesity and non-communicable diseases are huge. Obesity alone costs the NHS £6.1bn/year[155], the cost is exacerbated as the price of treating a patient increases with their BMI[12] . Yet, diseases associated with obesity increase this bill further; treating cancer costs the NHS £5.6bn/year, cardiovascular disease £9bn/year and type 2 diabetes costs £8.8bn/year[156]. Additionally, obesity and diet related ill health can negatively impact the labour market through absenteeism and low employment[157] and increase social care cost due to greater care needs[158].

1.2 Food assistance in the UK

The current state of socioeconomic inequality contributes to dietary inequality and has serious consequences for health and wellbeing. Actions to reduce dietary inequalities in the UK will be discussed below. First, I will present an argument for why it is important to consider policy action early in the life course.

1.2.1 Why focus on mothers and children; the case for investing early.

The Developmental Origins of Disease hypothesis[159–161] centred research around the 'first thousand days of life'[162] and highlighted how critical the in-utero and post-partum periods are for healthy child development. Insufficient nutrition during key periods of development are thought to permanently alter the cellular structure and metabolic functioning of the body, predisposing an individual to disease[160]. As such, dietary intake in critical windows of development has been shown to have long-lasting associations with health. For example, in a longitudinal birth cohort in the UK, modifiable early-life risk factors occurring before and during pregnancy such as low maternal vitamin D status and excess gestational weight gain were associated with child obesity. Children who experienced multiple risk factors in pregnancy had a four-fold increased risk of being obese or overweight at the age of six years compared to children who did not experience these risk factors (RR 4.65; 95% CI 2.29, 9.43)[163]. In ALSPAC, unhealthy dietary habits in pregnancy were associated with a 2 fold increase in obesity at age 15 years (OR 2.02; 95% C: 1.37, 3.01)[164]. Furthermore, natural experiments have examined the longitudinal impact of experiencing famine during pregnancy. These studies demonstrate that children who were exposed to famine in-utero were at increased risk of non-communicable diseases in later life, including diabetes and coronary heart disease[165–167]. Although malnutrition to this extent will be extremely rare in the UK today, this example demonstrates that in-utero nutrition can have far reaching consequences for health.

Furthermore, infant feeding practices such as breastfeeding are also associated with later health outcomes. A meta-analysis of 25 studies concluded that breastfeeding was associated with a reduced risk of childhood obesity (OR 0.78; 95% CI 0.74, 0.81)[168]. As obesity in childhood itself is a predictor of later disease [144,169], it is important to avoid early onset of obesity. Other examples of good nutrition in childhood are shown to be associated with reduced morbidity and mortality in later life. Increased fruit and vegetable intake in early life is linked to reduced incident cancer[170] and cardio-vascular disease morality[171].

Improving nutrition during this period has impacts beyond health. Brain development during early childhood is sensitive and has been shown to impact cognition in both early and later life[172]. For example, data indicates that longer breastfeeding duration was associated with more favourable behavioural development by the age of 5 years old[173] Moreover, analysis of two birth cohorts link breastfeeding with higher child IQ[174]. An effect which is shown to continue to educational attainment at the age of 16 years[175]. The positive effects of breastfeeding are also present at a societal level, an estimated 1% increase in breast-feeding rates would be worth over £33.6 million in additional economic output throughout the working life of the cohort.

Furthermore, interventions during this period are more likely to be successful. Evidence indicates that women are more receptive to health messaging in pregnancy[176–178]. Moreover, dietary habits which are established in early childhood have been shown to track to adulthood[48,179–183]. Therefore, influencing diet at an earlier point will more likely have permanent and long-lasting outcomes. For these reasons, it has been shown that the earlier an intervention occurs in the life course the greater the potential for impact and prevention of the accumulation of health inequalities[184].The benefits are felt not just for health, but also on the cost-effectiveness of the intervention, which provide greater returns on investment [186].

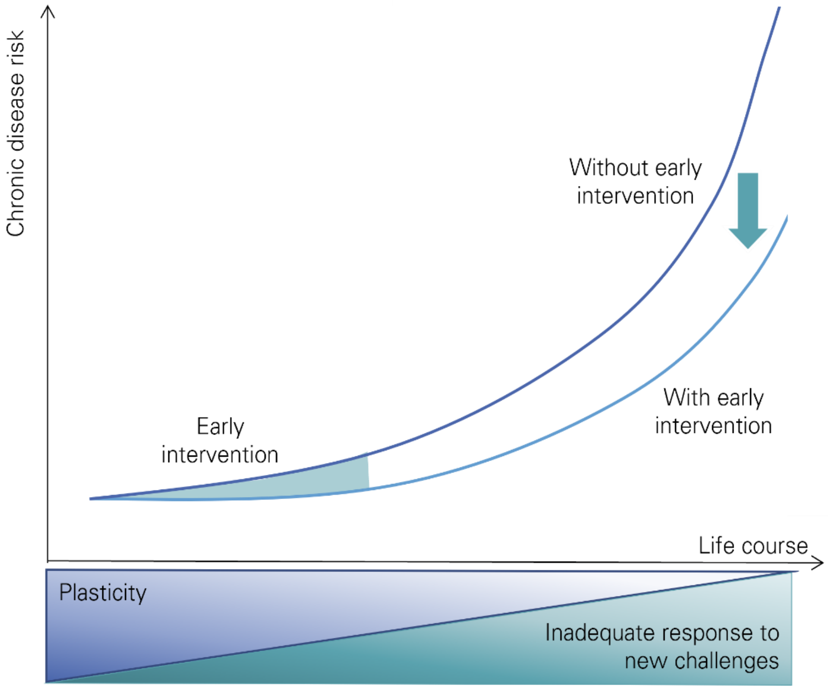

Figure 1.7 - Life course approach to reducing risk of chronic disease through intervention early in the life course.

Note: Reproduced from Godfrey, Gluckman & Hanson, 2010[185]. In this diagram early interventions have a positive effect at reducing risk of chronic disease as plasticity and positive responses to new challenges decrease across the life course and negative responses accumulate.

1.2.2 Policy options for reducing dietary inequalities

Policies to reduce dietary inequities can occur on multiple levels, such as on the individual or societal level. They can have multiple formats, such as educational or fiscal, and can be targeted, such as towards children, or be universal. Moreover, policies can differ in whether they are specific or sensitive to dietary inequalities. The primary aim of policies which are specific is to reduce dietary inequalities while sensitive policies have an indirect impact on dietary inequalities, without stating it as a primary aim[187]. The policy types are summarised in Table 1.1.

As mentioned in Section 1.1.2.2, policies intended to improve the knowledge or skills of a population are highly agentic and often reinforce socioeconomic inequalities[85,90]. However, educational interventions have been targeted specifically at low-income populations. Although they have shown short-term success, their impact is limited long term as they do not address the access and affordability of food[188].

Food assistance programmes are specific policies addressing dietary inequalities, which can take two formats: ‘in-kind’ assistance or cash transfers. Nearly all food assistance in the UK is ‘in-kind’, involving food packages or cash-value vouchers (CVV). In-kind food assistance programmes that supply food, such as food banks, attempt to address the issue of food insecurity in the most direct route possible. These programmes are beneficial as they provide an immediate solution in emergency situations, yet they have many criticisms. Firstly, the programmes are often run by large charitable organisations to a targeted group. Therefore, many decisions around food acquisition are removed from the recipient, such as the timing, type and quantity of the food they receive[189,190]. Decisions which are an essential aspect of acquiring food in a dignified and socially acceptable way[191,192]. As such, these forms of food assistance are often associated with high levels of stigma[193]. Secondly, it has been argued that these policies do little to address the root cause of food insecurity or dietary inequities. Another form of in-kind food assistance are conditional cash-value vouchers, which give the beneficiary greater choice on where, when and what they purchase, compared to food packages[191]. However, the benefit is still conditional. Typically, the voucher is limited to healthy foods and restricts harmful commodities such as alcohol. The utility of these conditions is a contentious topic[194]. For some, it is viewed that the conditions are essential to ensure the intended programme effect (i.e. increase fruit and vegetable intake) and avoid misspending[195]. However, others argue the conditions are implicitly condescending, insinuating a lack of trust in the target population[191].

Policies which are sensitive to dietary inequalities typically occur upstream, at a governmental or societal level. For example, policies which make sugar-sweetened beverages less available through reformulation or affordable through taxation will have a greater impact in populations with high consumption, such as more deprived groups[13]. However, as mentioned previously (Section 1.1.2.2), a critical barrier to a healthy diet is the rising cost of living and specifically the rising cost of food. Consequently, approaches which are ‘cash-first’ through either increasing welfare benefits or providing cash transfers are an increasingly popular policy approach to addressing social inequalities in dietary intake through their ethical, compassionate and permanent approach[191,196]. If individuals on welfare benefits disproportionally need to rely on emergency food assistance, it is clear that the UK welfare system does not give beneficiaries an adequate standard of living[190]. For example, Scotland is increasingly taking a cash-first approach[197]. Due to the complexity of the issue there is no one solution to dietary inequities[84,90]. It is likely that multiple approaches occurring on multiple levels will be needed.

Table 1.1 - Categorisation of policies to reduce dietary inequalities.

LEVEL	AIM	TARGET	POLICY
Individual	Dietary inequality specific	Targeted	Nutrition education and skill building programmes *HENRY (Healthy Eating and Nutrition for the Really Young)*
	Dietary inequality sensitive	Universal	Public awareness campaigns *5-a-day, Change 4 Life*
Social and community	Dietary inequality specific	Targeted	In-kind food assistance - food *Food banks, meals-on-wheels* School food programmes *Means-tested free school meals*
		Universal	School food programmes *Universal free school meals, school milk, fruit and vegetables*
Political, socio-economic, and cultural	Dietary inequality specific	Targeted	In-kind food assistance - vouchers *Healthy start vouchers*
	Dietary inequality sensitive	Universal	Reformulation *Salt reformulation* Taxes on unhealthy foods *Soft Drinks Industry Levy*

Note: Categories are influenced from the work of Peeters & Blake [84] and Friel *et al* [187]. UK examples of polices are given in blue italics.

This thesis will focus on policies which are specific to dietary inequalities in the UK. Two prominent examples of national food assistance policies in the UK are (i) Healthy Start food vouchers and (ii) school-based food assistance, such as school meal policies. Food banks are run by charitable organisations so are not Government policy. Also, upstream policies in the UK are not specific to addressing dietary inequalities. Both Healthy Start and school-based food assistance aim to improve the dietary intake of young children and will be discussed in greater detail in the following sections after a discussion on the factors which influence the policy process.

1.2.3 Policy process and factors that influence policy action

There are multiple possible policies to address dietary inequalities in society. However, whether a certain policy approach is taken by a government, if any, is highly complex and variable. Political theories have attempted to describe the policy process, whereby the convergence of multiple factors at different stages will influence policy formation.

One theory which is regularly referenced is the Multiple Streams Framework[198] (Figure 1.8). The theory posits that there are three parallel yet mostly independent streams: problems, policy, and politics. Within these streams there may be many competing problems and policy solutions, which problems are given the most importance at any one point will depend on a policy actor's perspective and the context of the time. However, it is only when the three streams of a particular issue combine that the policy window for action will appear. This theory is useful as it serves as a reminder that although researchers may consider dietary inequalities to be an important ongoing issue, wider recognition of the problem timed with relevant and feasible policy proposals is needed to put the issue on the political agenda and result in policy action.

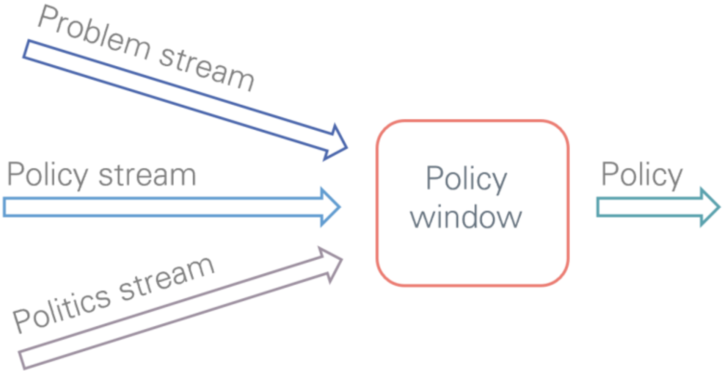

Figure 1.8 – Multiple Streams Framework[198]

A recent example is useful in exemplifying this framework. In 2020, the value of the Healthy Start voucher scheme was raised (please see Section 1.2.4 for an in-depth description of Healthy Start). The suggestion that the voucher value should be raised was common among practitioners working on Healthy Start[199]. However, it was not until there was public concern over food insecurity in children during the COVID-19 pandemic, triggered by public campaigns by the footballer Marcus Rashford[200], , that the issue was put on the political agenda. The policy suggestion to increase Healthy Start had been argued in the widely regarded National Food Strategy report[12] and was used as one of the Government's policy responses to the issue.

A secondary framework which is useful for understanding policy formation is the Policy Skills Framework[201] (Figure 1.9). Similarly, to the Multiple Streams Framework this framework highlights that evidence is only one aspect of successful policy formation. However, unlike the Multiple Streams

Framework this framework emphasises the importance of considering how a policy will be delivered. Policy solutions must be feasible within the existing political structure and budget for them to be considered as viable options by civil servants and politicians. Financial and practical aspects of delivering a policy may be a key limitation in its implementation.

Therefore, policies should always be considered within the context of their time. The political, economic, and social environment surrounding a policy are vital for understanding why a certain policy approach was chosen and how sustainable it is likely to be in the future.

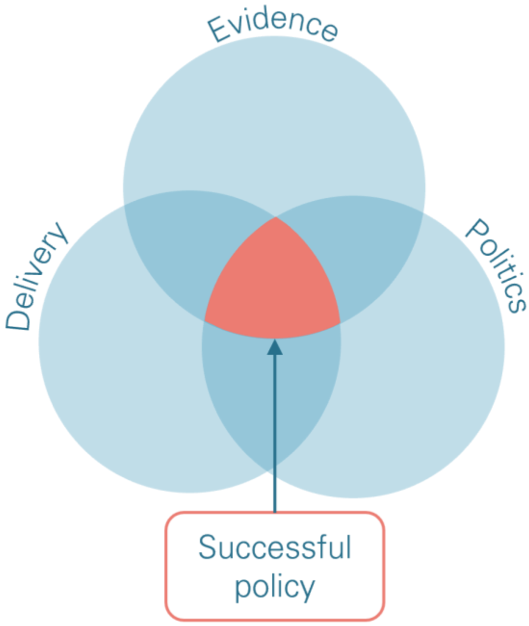

Figure 1.9 – Policy Skills Framework[201]

1.2.4 Healthy Start

The first food assistance programme under consideration in this thesis is the Healthy Start scheme. The Healthy Start scheme is a means-tested, in-kind benefit in the UK. Families with a pregnant woman or child less than four years old who claim welfare benefits are provided with cash-value vouchers which can be redeemed for fruit, vegetables, infant formula, and cow's milk. The scheme was introduced in 2006 as a reform of a previous policy, the Welfare Food Scheme. The reform was promised in a NHS Plan[202] released in 2000 in response to the Acheson report, which placed an impetus on reducing inequalities in child and maternal health[203,204]. As such the Welfare Food Scheme, which provided tokens for milk and infant formula, was expanded to include a broader range of foods.

The stated aims of Healthy Start are to "*provide a nutritional safety net to low-income families*". However, the aims of Healthy Start are unclear and commonly misunderstood among health professionals[205]. There is an implicit aim that the programme is intended to increase fruit and vegetable intake among low-income families, due to the broadening of foods from the Welfare Food Scheme. This is alluded to inconsistently among policy documents. Alternative descriptions of the policy aim include *"to ensure that children in poverty have access to a healthy diet, [with] increased support for parenting and breastfeeding"*[206] and *"that women and children most in need of additional support because they have very low incomes and are at risk of poor nutritional health can use the voucher towards the cost of their own and their child's dietary needs, and increase their intake of fruit and vegetables."*[207]. In an early policy document, it is clear that the policy aims are confined by the budget of the policy (Figure 1.10)[208], which might reveal why the policy does not explicitly aim to increase fruit and vegetable intake in the beneficiaries.

> "The purpose and intended effect of the Regulations is to:
>
> I. Reform the current Welfare Food Scheme (WFS) to better meet the nutritional needs of beneficiaries, within existing budgets.
>
> II. To use the resources of the WFS more effectively to ensure that children in poverty have access to a ''healthy'' diet and to provide increased support for breastfeeding and parenting (NHS Plan, 2000).
>
> III. To provide a nutritional safeguard for those pregnant women and children in disadvantaged families.
>
> IV. To increase the flexibility of the WFS to better reflect current dietary requirements.
>
> V. To forge closer links with the NHS to ensure that beneficiaries have access to information and advice about healthy eating and living.
>
> VI. To improve the health outcomes of disadvantaged families
>
> VII. To contribute to the reduction in childhood obesity by supporting low-income families to make informed choices about eating a varied and healthy diet. "

Figure 1.10 - Purpose and intended effect of Healthy Start as stated in a 2005 explanatory memorandum[208]

Healthy Start eligibility is conditional on a household's income and composition. It is only available to pregnant women (10 weeks gestation and over) and children 0-3 years. Additionally, it is a passported benefit, meaning only those who are currently claiming welfare benefits are eligible to the scheme (see Table 1.2. for details). Only very low-income households, typically out-of-work, are eligible for the scheme. An exception is pregnant women under the age of 18, who are eligible regardless of their income. Recently, households who have no recourse to public funds were also deemed eligible, following a legal challenge[209]. Until April 2020, Healthy Start participants were required to get their application approved by a health professional, to confirm the pregnancy.

The scheme provides cash-value vouchers which can be exchanged for food. The vouchers are worth

£4.25 per week per eligible beneficiary. To account for the cost of infant formula, two vouchers are given to children less than one year old. The vouchers can be spent on fruit and vegetables, infant formula, or cow's milk, with some conditions (see Table 1.2). The vouchers, which are received in the post every month, can be redeemed at participating retailers, including all major supermarkets.

Table 1.2 - Healthy Start programme eligibility criteria and provision.

BENEFICIARY	ELIGIBILITY REQUIREMENT	VALUE	LIST OF ITEMS ACCEPTED
Pregnant woman aged <18 years	No requirement.	£4.25/week	**Fruit, vegetables, and legumes** Can be fresh, frozen or tinned but does not include foods to which fat, salt, sugar, flavouring or any other ingredients have been added **Liquid cow's milk:** not including milk to or from which chemicals, vitamins, flavours, or colours have been added or removed **Infant formula:** From birth – one year, cow's milk formula
Pregnant woman aged 18+ years	(i) Someone in household has: income support an income-based jobseeker's allowance universal credit and has earned income of £408 or less child tax credit and household income below £16,190* no recourse to public funds (after June 2021) and (ii) Application approved by health professional (before April 2020)	£4.25/week	
A child aged < one year		£8.50/week	
A child aged 1-3 years		£4.25/week	

*Tax credit threshold: 2005 - £13,190; 2006 - £14,155; 2007 - £14,495; 2008 - £15,575; 2009 - £16,040; 2010-19 - £16,190

There have been changes to the policy since its introduction, which are detailed in Figure 1.11. Firstly, the breadth of items which could be purchased has been expanded, including plain frozen and tinned fruit, vegetables, and legumes. Secondly, the value of the voucher was increased twice, from £2.90 to £3.10 in 2009 and to £4.25 in 2021. Also, by the end of 2021, the scheme will be digitised. Participants will receive a digital payment card instead of paper vouchers and will be able to apply for the scheme online.

In 2019, the devolved Scottish Government replaced Healthy Start with Best Start Foods[210]. The Best Start Food policy had the same skeleton of the Healthy Start scheme but had some key reforms. The scheme was digitised, the voucher value was raised to £4.25, eggs and pulses were included and the age range of eligibility for children was narrowed to only include children 0-2 years. The income eligibility remained similar.

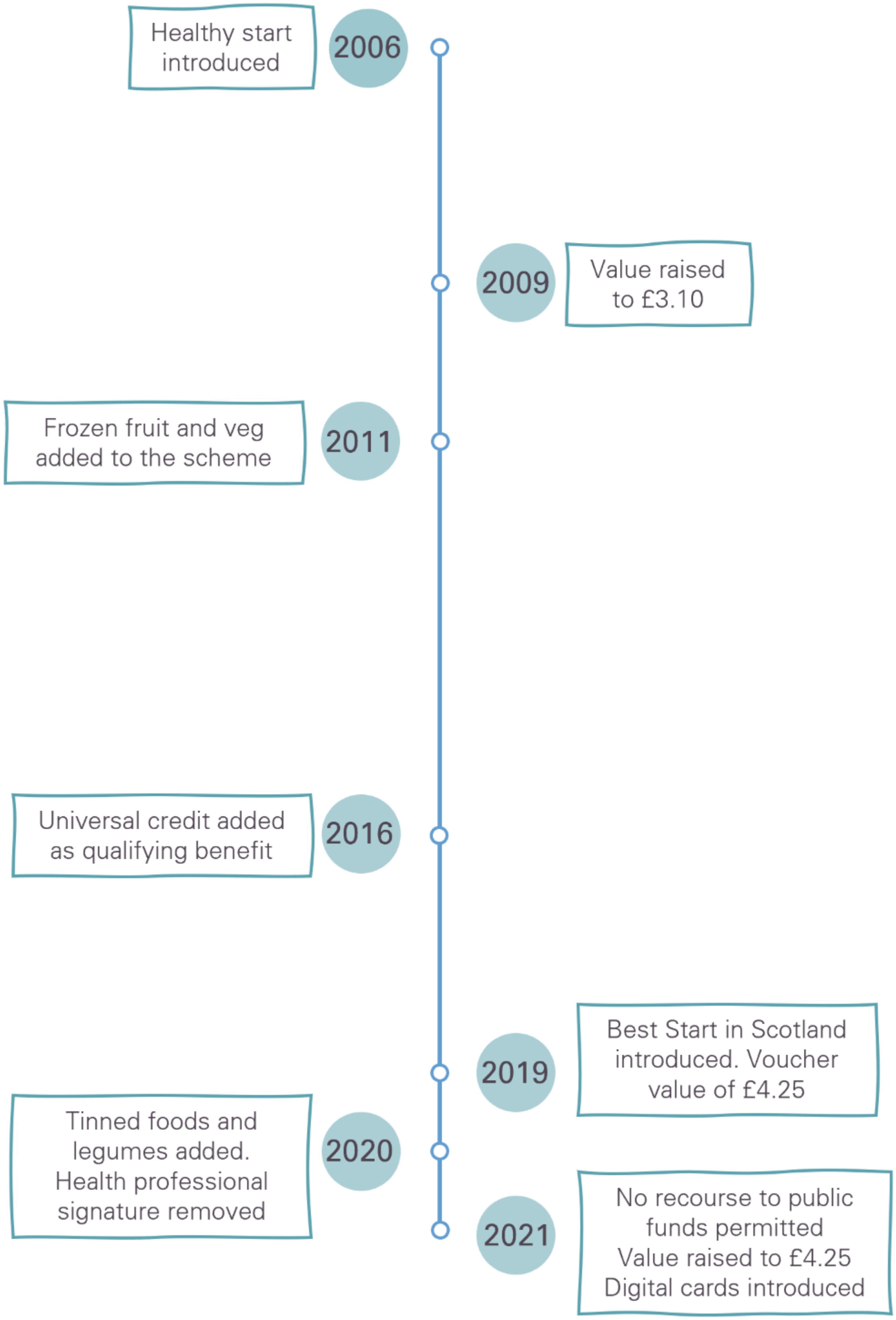

Figure 1.11 - Timeline of the Healthy Start scheme

1.2.4.1 Healthy Start uptake

Currently, Healthy Start reaches around 300,000 families in the UK. Uptake of the scheme is low, the average uptake across the UK is 55%[211]. Therefore, up to 200,000 families are eligible but not participating. There is regional variation in the uptake of the scheme. The most recent figures suggest there is a 13-percentage-point difference across England, with a high of 65% in Northeast England and a low of 52% in East England. Both the absolute number of households eligible for Healthy Start and the number participating have been falling since 2011 (Figure 1.12).

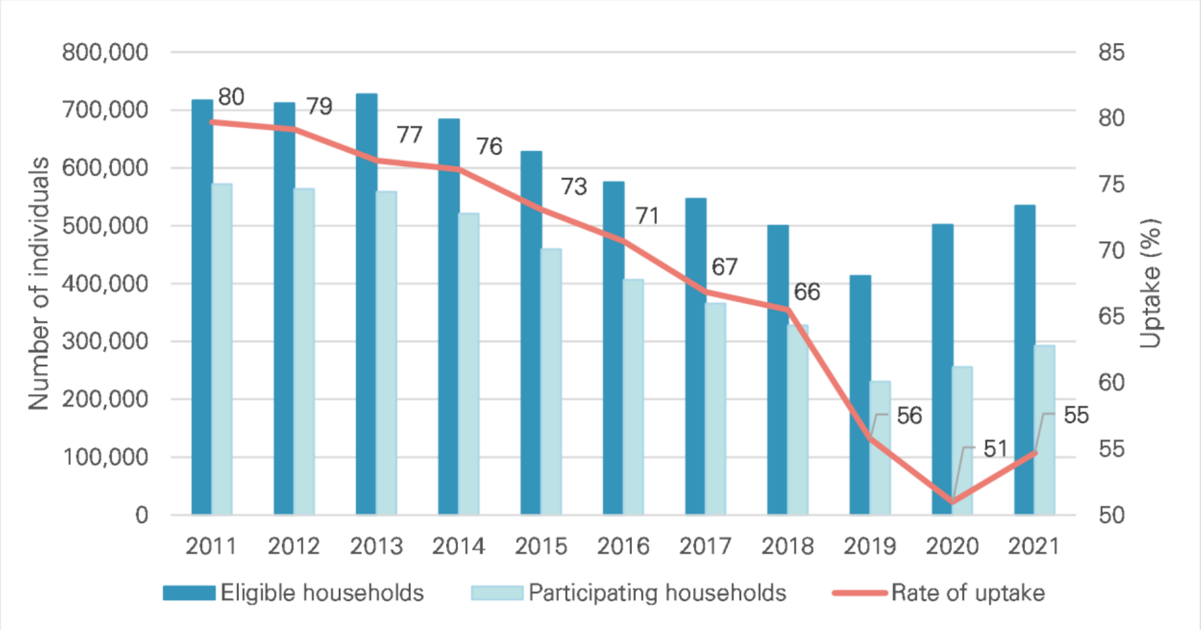

Figure 1.12 - The number of Healthy Start eligible and participating households in the UK and the rate of uptake between 2011-2021[211,212]

Note: Years 2011-2018 taken from Crawley[212]. Years 2019-2021 taken from Healthy Start website. Year 2021 averaged until 25th April.

Changes to the welfare benefit system, such as the introduction of Universal Credit in 2013, have meant a reduction in the absolute number of households eligible for Healthy Start[207,212]. Reasons for a fall in Healthy Start uptake are unclear and have not as yet been fully elucidated[212.] However, the dramatic drop in uptake in 2020 is likely a consequence of the COVID-19 pandemic. There was an increase in newly eligible households, but these are likely to be from communities who were not familiar with the benefit system and might not have heard of Healthy Start. Moreover, reduced contact with health services during this time could explain the fall in uptake.

The literature evaluating the uptake and impact of the Healthy Start scheme will be discussed in Chapter 2.

1.2.4.2 Comparisons with international policies: Special Supplemental Nutrition Program for Women, Infants, and Children

The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) is a federal nutrition assistance programme in America introduced in 1974[213]. The policy is the closest available comparison of a food assistance programme to Healthy Start, as they aim to serve a similar demographic through a similar policy approach

The programme serves pregnant, breastfeeding, postpartum women, infants and children 0-5 years[214]. However, to be eligible their household income must fall at or below 185% of the US poverty level and they must be determined to be at "nutritional risk" by a health professional. This equates to over a quarter of pregnant women and over half the infants in the US[214].

As part of the programme, participating families are given an age-specific food package and a cash-value voucher. The food packages include healthy food items such as infant cereal, juice, eggs, milk, cheese, peanut butter, beans/peas, canned fish and other whole-grain foods[213]. The cash-value vouchers are worth between $8-$11/month per participant depending on their age and can only be spent on fruit and vegetables.

While the WIC programme is similar to Healthy Start in its approach to addressing nutritional intakes in low-income mothers and children, there are a few key differences. A comparison between the two programmes is presented in Table 1.3

Table 1.3 - Comparison between Healthy Start and WIC

	HEALTHY START	WIC
Eligibility	Pregnant women, children 0-3 years	Pregnant women, post-partum women children 0-5 years
Income requirement	Receive income-related state benefits	Household income <185% of poverty line
Benefit	£4.25/week* CVV per participant fruit, vegetables, pulses, cow's milk, infant formula	$8-11/month CVV per participant fruit and vegetables + Food package Example: 3 gallons of milk; 1 pound of cheese; 1 dozen eggs; 36 ounces of cereal; 18-ounce jar of peanut butter, 4 cans beans/peas;2 bottles 64-ounce juice; 2 pounds whole grains (breads, tortillas, brown rice or oatmeal[215]
Total value per participant per month	£18.41/month ($25/month)	$61.24/month[216]

Note: CVV – Cash value voucher

Key differences between the programmes include:

WIC has a wider eligibility threshold. The programme reaches a greater proportion of the population than Healthy Start, for a greater period of the child's life.

WIC benefit is larger. Although the CVV of Healthy Start is greater than WIC, the total value per participant is greater in WIC due to the added benefit of the food packages.

Evaluations of WIC have indicated it is associated with improvements in maternal and infant dietary intake[214,217,218], improved pregnancy outcomes[219] and improved markers of infant health[220]. Further comparison of Healthy Start and WIC considering the findings of this thesis will be given in the Discussion (Section 11.3)

1.2.5 School meal policies in the UK

School based food assistance will be the secondary food assistance policy under consideration in this thesis. Currently there are a few school-based food assistance policies in the UK: means tested Free School Meals; Universal Infant Free School meals and the School Fruit and Vegetable scheme. Recently a Holiday Activities and Food programme was also introduced in 2021. This thesis will focus on the free school meal schemes as they are well-established, large scale and specific to low-income children. However, a discussion on free school meals cannot be separated from the overall provision of food in schools. The success of free school meal policies is influenced by the availability, quality, and acceptability of school meals.

1.2.5.1 History of school food in the UK

There has been a great deal of variation in the provision of school food over time. The topic is often highly politicised, emotive and has been subject to sweeping policy changes.

Pre 1940s

In Manchester 1987 a school began to provide free school meals to their pupils in recognition of the food poverty and malnourishment in their cohort. The school inspired similar action across the country, however the motivation and responsibility to provide meals was on individual schools, there was no law mandating school food provision[221]. Although the potential of free school meals as a public health tool was recognised in the academic literature as early as 1936[222].

1940s

The Education Act in 1944 made the provision of school meals and milk a statutory obligation for local authorities. The law set minimum nutritional requirements for the school food and determined that it would be free to poorer children and at a heavily subsidised value for the remainder[221,223,224]

1980s

Margret Thatcher's government made large changes to school food provision including: minimum nutrition requirement was removed; universal free milk was removed; competitive tendering was introduced and eligibility for free school meals was narrowed[221]. This led to a reduction in the quality of school meals, increased marketing of processed, fast foods in schools; increased prices and reduced uptake of school meals[223,225].

2000s

In 2001, food and nutrient standards were introduced in the UK, with each country taking a similar but slightly different approach. Yet these were not seen to have a large impact. In 2005, the School Foods Trust recommended new standards, in reaction to a widely popular TV show on school food by Jamie Oliver[226], which were phased in between 2006-2009[221].

2010s

The School Food Plan report was released in 2013 and recommended a range of steps to increase school meal uptake and quality, including changing from nutrient based standards to food based standards[227]. The food-based standards were introduced in 2015. Additionally, free school meals were made universal to all infant schoolchildren in September 2014 in England and January 2015 in Scotland.

1.2.5.2 School Food Standards

The nutritional quality of school food is a topic which has garnered strong public reactions over the past twenty years [228–230]. As a consequence, school food standards were brought in to regulate and maintain a minimum standard of food across schools. The current food-based standards are summarised in Table 1.4.

It is mandatory that all local authority-maintained schools abide by the School Food Standards across the school day. However, academies which were formed after 2010 are not legally bound by the standards and can follow on a voluntary basis, this is estimated to make up two thirds of all secondary schools[231,232]. In addition, the School Food Standards are not monitored in England. Consequently, there is not good data on the extent to which the standards are implemented in schools. There are some indications that there is a high variation in the application of the School Food Standards, which is highly determined by the commitment to healthy food from the School's leadership[233]. For example, an observational study in Northern Irish primary schools indicated there was differences between a school's food policy and the food served[234]. Moreover, in a sample of London schools its estimated up to 60% were failing to comply with the standards[233].

Despite this, evidence shows that introduction of School Food Standards did improve dietary quality of school food, especially when compared against the nutritional quality of school food before 2006[235–241]. School meals were not meeting healthy eating guidance before the guidelines[242] or in the 1980s[243]. In repeated cross-sectional studies from both primary[235,240,244] and secondary schools[236,241], the overall nutritional profile of school food improved after the introduction of the 2006 School Food Standards. Moreover, changes were equitable across different socioeconomic groups[244], with some research indicating that lower-income free school meal eligible children were more likely to choose the healthier option[245] . The positive impact of the School Food Standards were also shown in children's total diet across the day, indicating that regulating school food has the potential to impact population-level dietary intake [240].

Table 1.4 - Summary of food-based School Food Standards[227]

GROUP	SCHOOL FOOD STANDARDS' RECOMMENDATION
Fruit and vegetables	One or more portion of fruit and vegetables every day The majority of desserts should contain at least 50% fruit Three different fruits and vegetables on offer each week
Milk and dairy	A portion available every day Use low fat milk
Starchy foods	One wholegrain option a week One portion available every day Three options throughout the week Limited cooked in fat
Meat, fish, eggs, beans	A portion available every day Fish at least once a week Limited breaded products
Healthier drinks	Only permitted drinks are water, lower fat milk and fruit juice
Food high in fat, sugar, and salt	Limited deep-fried, breaded, pastry options in the week. No confectionary, chocolate or snacks with added sugar or salt. Desserts, biscuits, and cakes are allowed.

Mandatory School Food Standards are essential to make healthier food more available, accessible, and affordable. Lack of regulation led to unhealthy options being the easier, cheaper choices for schools and their pupils[221]. The combination of voluntary guidelines combined with competitive tendering for catering services allowed market forces to influence the food served at school. They were driven to less healthy, preprepared and processed food due to their comparative lower costs. Given the choice, children show a preference for highly palatable but less healthy foods and are influenced by price [245,246]. Therefore, if unhealthy cheap food is given as an option at schools, it will be chosen and disproportionally by low-income children. School Food Standards regulate the options, making healthier school meals the easier choice for all children, regardless of income.

1.2.5.3 Means-tested free school meals

As mentioned above, low-income children in the UK have been entitled to a free lunch whilst at school from 1944. The eligibility for the scheme has changed overtime. Similarly to Healthy Start, free school meals are a passported benefit, eligibility is determined through receiving the same welfare benefits, which are detailed in Table 1.2. In addition to this list, children whose families receive Support under Part VI of the Immigration and Asylum Act 1999 have been eligible for a means tested free school meal from 2004[247].

Pre-pandemic government reports show that 17.3% of pupils in England were eligible for free school meals, amounting to over 1.4 million children[247]. The number of eligible children has been rising, in line with increases in child poverty (Section 1.1.1), but there was a steep incline in 2020 due to the COVID-19 pandemic[248]. In January 2021, 21% of all schoolchildren were estimated to be eligible for free school meals, of which 42% of this number were newly eligible.

A flat rate of £2.30 is given to each eligible child per day. However, the cost of delivering school meals varies regionally and this has been shown to not cover the average cost of a school meal in all schools[249].

Literature evaluating the uptake and impact of school meal policies will be discussed in Section 2.2.2.

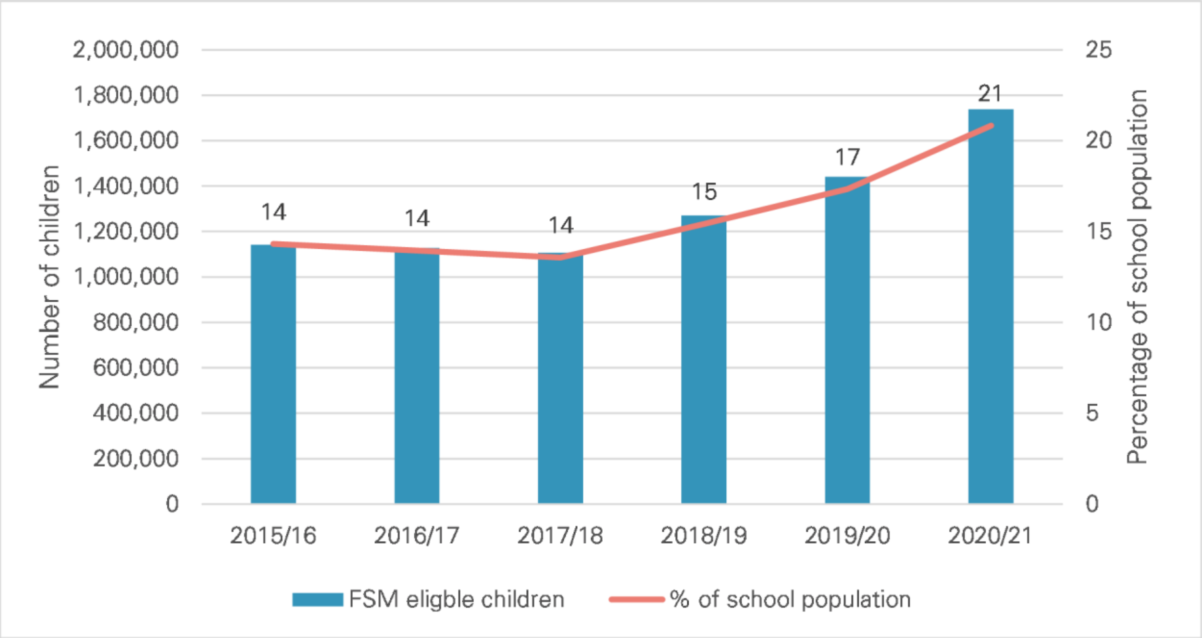

Figure 1.13 - Number of free school meal eligible children in the UK between 2015-2021[248]

1.2.5.4 Universal Infant free school meals

In September 2014, the Universal Infant Free School Meal Scheme was introduced in England. This extended the eligibility to all infant school children, regardless of their family's income. This includes children in the first three years of school, or ages 4-7 years. Scotland introduced the policy from January 2015. From this point onwards in the thesis, the means-tested free school meal scheme will be referred to as FSM and the universal infant free school meal will be referred to as UIFSM.

The UIFSM stated policy aims are[250]:

- To improve educational attainment and children's social skills and behaviour.
- To ensure that children have access to at least one healthy meal each day and support the development of long-term healthy eating habits.
- To help families with the cost of living, and
- To remove disincentives to work.

Schools are provided with £2.30 per pupil to cover the costs of the programme, or £400 per pupil per year [250], a value based on a survey conducted in 2011. At the time researchers questioned whether this would be enough to cover the costs of the programme[251]. The value has only been increased once since its introduction, to £2.34 in 2021, despite rising inflation and pressures to the food system such as Brexit[252]. It is estimated that if this continues, by 2023/24 the scheme could cost an additional £109 million to schools above the funding they receive[250].

National estimates indicates average uptake is high, from 85% in 2015 to 88% in 2020/21 which equates to 1.7 million infant schoolchildren having a free lunch [247]. Literature evaluating the uptake and impact UIFSM will be discussed in Section 2.2.3

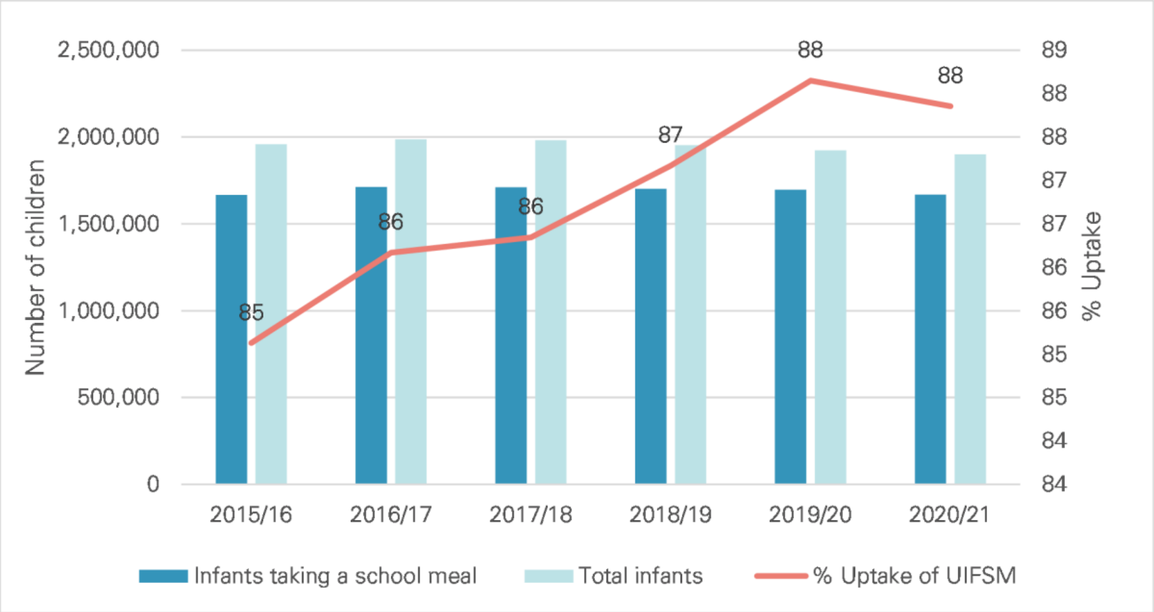

Figure 1.14 - Uptake of the Universal Infant Free School Meal Scheme in England between 2015/16 and 2020/21[247]

1.2.5.5 Comparisons with international school meal policies

National school meal programmes are common around the world, with an estimated 388 million children covered by a programme worldwide. Coverage of school meal programmes across countries varies by income level, with high income countries achieving 78% coverage and low-income countries achieving 20% coverage[253]. Although school meal policies are common, the extent to which they are free at the point of use varies. A non-exhaustive example of school meal policies around the world is presented in Table 1.5. It is rare that a high-income country did not have a national school meal policy. Norway, Denmark, and Canada exist as some exceptions, where it is normal for children to bring packed lunches or school meal programmes are organised regionally. The most common school meal policy is to give subsidized or free meals on a means-tested basis. This is similar to the FSM policy in the UK for children over 8 years old. Universal free school meals were first introduced in 1943 in Finland, with Sweden joining two years later[254]. Since then, a few countries around the world have implemented a universal free school meal policy. It is notable that universal policies are not only implemented in high-income countries, with examples in India and Brazil.

Table 1.5 – Examples of school meal policies around the world[254–256]

UNIVERSAL	MEANS-TESTED FREE OR SUBSIDIZED MEALS	NO NATIONAL SCHEME
Finland	England + Scotland *Ages 8-18 years*	Norway
Sweden	China *For rural students*	Denmark
India	Japan	Canada *Variation regionally*
South Korea	Lithuania	
Brazil	Slovakia	
England + Scotland *Ages 4-7 years*	Italy	
United States *Schools in low-income neighbourhoods only otherwise means-tested.*	Spain	
	France	
	Portugal	

In this way, England and Scotland are among a few countries which have more generous school meal policies. Universal free school meal policies have been shown to have a positive impact on school attendance, dietary intake and health outcomes[254]. Further comparison of the UIFSM scheme compared to other international school meal policies will be given in the Discussion (Section 11.3), in consideration of the findings of this thesis.

1.3 Chapter conclusions

In this chapter, I have discussed the dietary inequalities in the UK and the importance of intervening early in life to prevent such inequities and their associated harm. Additionally, I introduced the Healthy Start and school meal policies, which will be the focus of this thesis. In the next chapter, I will go onto review the current evidence on these policies, before highlighting the gaps in the literature.

Chapter 2. Literature review

In this chapter I will present the literature evaluating Healthy Start and school meal policies in the UK. First the qualitative and quantitative evidence on the Healthy Start scheme will be presented. Second, the evidence on the quality of school meals, the FSM and the UIFSM scheme will be discussed.

2.1 Healthy Start

2.1.1 Qualitative evaluations of Healthy Start

There has been expansive qualitative evaluation of Healthy Start. Qualitative reviews have spanned years 2011[257] to 2017[258], have included a total of 1,516 participants who consist of healthy start eligible families, health professionals and retailers. A range of methods were used including one-on-one interviews, focus groups and online consultations. A summary of the methodologies is given in Table 2.1.

Table 2.1 - Summary of qualitative studies evaluating Healthy Start.

AUTHOR	YEAR	LOCATION	SAMPLE SIZE	PARTICIPANTS	METHOD
Relton[259]	2019	UK (4 sites)	*n*=363	Healthcare professionals	Free-text survey responses
Ohly[258]	2018	North-West England (2 sites)	*n*=11	Healthy Start eligible women (users and non-users)	Semi-structured interviews
Browne[260]	2016	Scotland	*n*=40	Healthy Start eligible women (users and non-users)	Semi-structured interviews
Khanom[119]	2015	Wales	*n*=61	Parents in Wales (Growing Up in Wales cohort)	Semi-structured interviews
McFadden[199] [261]	2014	Yorkshire and London	*n*=49 (Focus group), *n*=619 (consultation), *n*=109 (workshops)	Health practitioners and Healthy Start eligible families	Focus group, online consultation, participatory and cross-sectoral workshops.
Lucas[262263]	2013	England (13 sites)	*n*=65 (professionals), *n*=107 (parents), *n*=20 (retailers)	Healthcare professionals, Healthy Start eligible families and retailers,	Interviews
Department of Health [257]	2012	England	*n*=72	Retailers	Interviews

Emergent themes from across the research have been summarised in Table 2.2. Themes include the scheme's eligibility, uptake, implementation, how the vouchers are used and the voucher value.

Table 2.2 - Summary of themes from Healthy Start qualitative research.

THEME	FINDINGS
ELIGIBILITY	➢ Eligibility criteria caused confusion [261,263] ➢ The low threshold for eligibility results in many low-income families missing out on the benefit [119,261,263] ➢ Families with unsure migration status are excluded from the scheme but are one of the most vulnerable groups in society [263]
UPTAKE AND AWARENESS	*Low awareness* ➢ Many eligible families are unaware of the scheme [259–261]. ➢ Awareness is particularly poor among pregnant women [260]. *Over-reliance on healthcare practitioners* ➢ Overreliance on practitioners to promote Healthy Start, results in them acting as gatekeepers to the programme [261,263] ➢ Not all practitioners are adequately trained on Healthy Start [258,261,263] ➢ Healthy Start is deprioritised in antenatal appointments as practitioners have too much information to give [261]. ➢ Practitioners struggle to identify eligible families [261,263] *Regional variation in Healthy Start promotion* ➢ Healthy Start is inconsistently promoted across regions [261]. Promotions are often targeted to low-income women only [261] ➢ Uptake data was not readily available to all practitioners and coordinators [263]
ADMINISTRATION	➢ Healthy Start information is not provided in enough languages[261,263] ➢ Application process is overly complicated, The requirement of a counter-signature created an administrative barrier [261,263] ➢ There is a charge to call the helpline to notify the birth of the child, which causes an unnecessary discontinuation of vouchers and financial cost [261,263]
USE OF VOUCHERS	*Intended uses.* ➢ Participants use the vouchers to increase the amount of healthy food they buy, enabling to buy more target-items than they would have otherwise [258,261,263] ➢ Family context changed who benefited from the vouchers, with some women choosing to share the additional food between the family [258,261], but some reserving the additional food for eligible household members only [261]. *Unintended uses* ➢ Vouchers are used as financial assistance and not to increase food purchases [258,261,263] to stockpile infant formula [258] or are spent on non-target items [261].
VOUCHER VALUE	➢ Monetary value of the voucher is too low, it does not cover the rising cost of infant formula or fruit and vegetables [261,263] ➢ Does not take into account family size, resulting in relatively less benefit for larger families
RETAILERS	➢ Some stigma attached to using vouchers in shops for many participants [261,263] ➢ Practitioners and participants were unsure where to use vouchers aside from supermarkets [261]

THEME	FINDINGS
	➢ Retailers generally understood the scheme and smaller retailers participated to help low-income families, a minority of retailers allow non-target item to be purchased [257,263] ➢ Fixed value paper voucher format can result in underspend being lost to the participant [261,263]
VIEWS ON THE SCHEME	➢ Vouchers are valued by participants [119,260,261]. ➢ Practitioners were concerned the voucher encouraged formula feeding but participants had mixed views on whether the scheme encouraged their infant feeding choices. [261] ➢ A minority of participants view the programme as just for women who are not breastfeeding [261,263]

2.1.1.1 *Discussion of Healthy Start qualitative research*

In combination, the qualitative evaluations which have been conducted give a detailed understanding of the programme, casting a light onto the perspectives of all stakeholders involved in the scheme. The qualitative research highlights both areas of success and limitation. Many common themes emerged, the plurality of themes across the studies adds to the strength of these findings. In particular the following themes were mentioned consistently:

Impact of the voucher on household purchases

In all studies, participants reported either using the vouchers to buy more fruit and vegetables than usual or used them as financial assistance, reducing the cost of their typical shop. These findings indicate that the vouchers are not consistently used to increase fruit and vegetable purchases, revealing multiple possible mechanisms of the vouchers.

Poor awareness of the scheme

Low awareness of the scheme was common in both the wider population and eligible groups, signalling poor promotion of the scheme. Pregnant women were identified as a group which commonly only became aware of the scheme after they gave birth. This is a key reason behind the low uptake of Healthy Start.

Practitioners as gatekeepers

Promotion of the scheme is inconsistent across the country and heavily depends on health practitioners to make eligible families aware of the scheme and to co-sign their application. This often involves health practitioners making assumptions on eligibility. Consequently, any issues such as lack of training or competing priorities in antenatal visits will have a large impact on families participating in the scheme. For these reasons, pregnant women, women in work or in less deprived areas are less likely to be aware of the scheme. This is another critical reason for low uptake of the Healthy Start programme

There was only one theme where the studies were in contradiction. McFadden *et al*[261] reported practitioners did not think Healthy Start helps to identify additional vulnerable families to local health services. Whereas Lucas *et al*[263] report the opposite, indicating it helps to funnel families to services they would not be exposed to otherwise. The difference further demonstrates that local public health teams can vary substantially across the country.

Whereas the majority of the research focused on impacts of the scheme, Ohly *et al*[258] conclude that contextual factors are an important consideration and can explain the differing programme effects. Ohly summarises that if the participants value healthy eating, are motivated by health benefits and intend to breastfeed they are more likely to use the voucher to improve dietary intake. Other contextual factors such as family size and financial strain are important limitations to the programme effect which should be considered by policy makers as they are critical programme's impact.

Due to the clarity of the findings, key implications from the research can be easily identified:

- The voucher value should be increased, to cover rising food costs[258]
- Widen eligibility criteria for Healthy Start, including children up until their fifth birthday, families with no recourse to public funds and low-income families in work.
- To increase uptake:
  - Action is needed to increase the nationwide, universal awareness of the scheme, promotion should not just be targeted at low-income groups [261]
  - Consistent training for health professionals across the country is needed and remove the need for a counter-signature on the application[258,261]

The qualitative studies were all conducted before 2018. Resultantly, recent changes to the scheme regarding the voucher format, value and expanded eligibility now mean that these discussion points have become outdated and many of the key recommendations have been met. Future qualitative research should aim to determine how these changes affect the participant's experience of the scheme.

2.1.2 Quantitative evaluations of Healthy Start

There are comparatively less quantitative studies on Healthy Start compared to the qualitative literature. Studies which have evaluated the impact on food purchases, dietary intake, breastfeeding and programme uptake will be discussed in the following sections.

2.1.2.1 Impact of Healthy Start on household purchases.

Analysis of longitudinal purchase data (2004-08) aimed to assess whether introduction of the Healthy Start scheme in 2006 impacted food purchases among low-income households (*n*=296)[264]. The study used hours worked (<8 hours) and child age (<4 years) to estimate which households were eligible for Healthy Start. Food purchases in these households were compared against equally low-income households with ineligible children (4-8 years), using a difference-in-differences approach. Spending on fruit and vegetables was found to increase 15.5% among eligible households after the introduction of Healthy Start, compared to ineligible households. This increase is equivalent to £2.43/month (Standard Error [SE] 0.06) or 1.79 kg/month (SE 0.65). Moreover, the voucher was found to be more effective than the equivalent cash value, as spending on fruit and vegetables increased by 14 pence for every £1 of the Healthy Start voucher. Analysis of the nutritional content of purchases revealed that there was an improvement in key micronutrients, including fibre, vitamin A and iron. An increase was not shown for less healthy nutrients including sugar and saturated fatty acid. Additionally, the paper demonstrated that households which spent at least the voucher value on fruit and vegetables before the scheme was introduced did not increase their spending. The authors conclude this shows the voucher works solely by providing an economic incentive, rather than through an additional health promotion mechanism. The paper provides strong evidence that the Healthy Start scheme increases spending and quantity of fruit and vegetable purchases among low-income households. Yet, it must be noted that the effect size estimated is small. If the average increase in fruit and vegetables is divided by the average household size (*n*=4) it equates to an increase of 5.6 portions of fruit and vegetables per individual per month (447g). In reality however, it cannot be known how the food is divided in the household, another limitation of this study. Moreover, the paper is limited by a lack of direct observation of Healthy Start participation. The estimation of eligibility through hours worked will result in the introduction of misclassification bias. As such, the study provides data on the effectiveness of the Healthy Start programme in the population, or the 'intention-to-treat' effect. However, it does not give information of the efficacy of the scheme within the target population, which is also needed to evaluate the programme.

The final important consideration is the timing of this study, which evaluated the impact of the programme in its first two years (2006-08). Since this period, the value of the Healthy Start voucher did not rise in line with inflation (Figure 2.1). Resultantly these findings might not reflect the programme impact in later years.

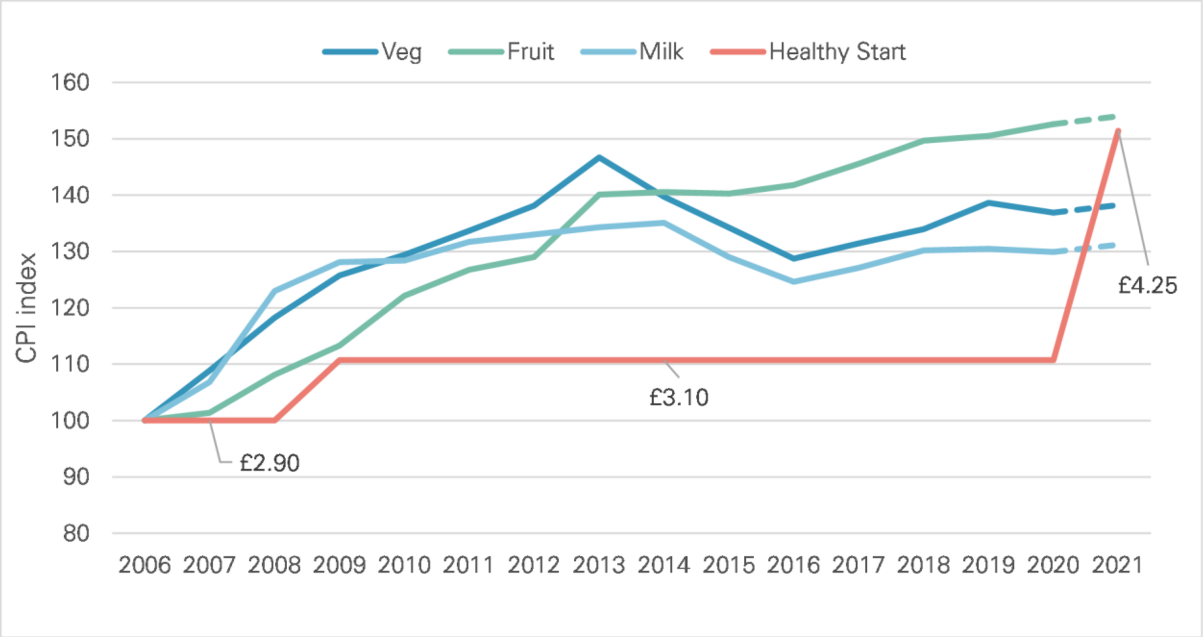

Figure 2.1 – Inflation in the price of vegetables, fruit, milk and Healthy Start vouchers between 2006-2021, relative to their 2006 value.

Note: CPI index were taken from Office for National Statistics. Dashed lines indicate where trends were estimated to illustrate the impact of the 2021 Healthy Start Voucher value increase

2.1.2.2 Impact of Healthy Start on dietary intake.

To date, only two studies have evaluated the impact of Healthy Start on dietary intake.

A before-and-after study was conducted in Sheffield comparing the dietary intakes of women on the previous Welfare Food Scheme (WFS) to women on Healthy Start when it was introduced[265]. Pregnant (*n*=170) and post-partum (*n*=142) women were recruited from a hospital, their dietary data were collected through a Food Frequency Questionnaire in 2005-06 for the WFS and 2006 for the Healthy Start scheme. In comparison to WFS, pregnant and post-partum women on Healthy Start had improved nutritional intakes of key micronutrients, including calcium, iron, folate, and vitamin C. The study also found that Healthy Start women were more likely to achieve the 5-a-day dietary recommendation as they had higher mean intake of fruit and vegetables. However, Healthy Start women were also found to have higher intake of total energy and unhealthy food groups. In a follow-up, the between group differences were found to sustain to 12 weeks post-partum[266]. The study concluded that Healthy Start was more effective than WFS in improving the diet quality of low-income women, but I propose that due to limitations, the results should be viewed with caution. The before-and-after study design does not appropriately control for confounders. For example, the WFS group had a significantly lower BMI than the Healthy Start group and the analysis did not adjust for total energy intake. In combination, it is possible that the increased nutritional intakes observed in the Healthy Start group are the result of systematic difference in total food intake between the groups. Additionally, the study is small-scale with strict inclusion criteria, limiting the representativeness and generalisability of the study. The sampling frame excludes ethnic minority groups, who are an important demographic as they are over-represented in the Healthy Start scheme. As such, the conclusions which can be made from the study are very limited.

Four cycles of Health Survey England data (*n*=84,278, years 2001-2014) were analysed to examine trends in individual fruit and vegetable consumption over-time[267]. The study compared fruit and vegetable consumption among Healthy Start eligible individuals against three non-eligible control groups. The control groups were comprised of people who lived in households that were either: (i) eligible by income but had no eligible household member; (ii) eligible by household member, but not by income or (iii) ineligible by both household member and income. In similarity to Griffith *et al*[264], Healthy Start participation was not directly measured in this study but assumed through income and benefit data, resultantly the paper also studies the 'intention-to-treat' effect. The study did not find a significant interaction between time-period and Healthy Start eligibility group, indicating that the introduction of Healthy Start in 2006 was not associated with a greater increase in fruit and vegetable intake for the target group. As the low-income groups in the sample had the lowest fruit and vegetable intake, the study supports the postulation that Healthy Start does not adequately overcome the negative impact of poverty[268,269]. A major limitation of the study is that the fruit and vegetable consumption of young children (<5 years) was not measured, meaning that the study sample, aside from pregnant women, includes mainly non-target household members. Consequently, there is an assumption that food purchased with the vouchers is shared among household members, yet there is some qualitative evidence which contradicts this assumption[261]. A lack of significant effect in this study might not reflect a true null impact of the Healthy Start scheme in its target population of young children.

In summary, quantitative evidence evaluating the impact of the Healthy Start vouchers on dietary intake is weak. Both studies were affected by serious limitations which impacted the veracity of their findings. There is currently not enough evidence to make a conclusion on the impact of Healthy Start vouchers on dietary intake. A nationally representative study which has been adequately designed to evaluate this association in the target population, specifically including children less than four years old, is needed.

2.1.2.3 Impact of Healthy Start on breastfeeding

A nationally representative cross-sectional survey, the Diet and Nutrition Survey of Infants and Young Children (DNSIYC), was conducted in 2011 and collected data on Healthy Start participation[270]. It found that children on the Healthy Start scheme were more likely to be formula fed and have a lower mean intake of fruit and vegetables at 4-11 months (37g difference) and 12-18 months (47g difference), than the general sample. However, the analysis which used bivariate statistical methods to test Healthy Start children against the general sample did not make a valid comparison. The general sample was of a higher socioeconomic class, so without a more comprehensive statistical analysis, it is unclear whether the association is attributable to a confounding effect of socioeconomic factors. Arguably, it gives an indication that the Healthy Start programme does not effectively counteract the association of low socioeconomic status with infant feeding outcomes

Natural experiment methods were used to analyse a longitudinal survey in Scotland, Growing Up in Scotland[271]. The study used propensity score matching and compared the breast-feeding initiation and duration of Healthy Start participants to eligible non-participants (*n*=412 matches) and nearly eligible participants (*n*=505 matches). No difference was found in the breast-feeding initiation of participating and eligible non-participating groups (53% and 53%, respectively; P=0.99) or with nearly-eligible participants (62% P=0.19). Similarly, there was no difference in breastfeeding duration. Unlike the DNSIYC, this analysis uses a strong, natural experiment study design. These results accounted for selection bias and confounding factors of socioeconomic status. Therefore, this study gives a strong indication that the Healthy Start scheme does not discourage breastfeeding, a concern of some practitioners[199,263]. However, the results from Scotland may not be comparable to the rest of the UK. National estimates for 2019/2020 indicate average breastfeeding rates although similar, were slightly higher in England (48.2%; CI 47.9,48.5%)[272] than in Scotland (43.9%; CI 43.8,44.1)[273].

2.1.2.4 Healthy Start programme uptake

An intervention aiming to improve Healthy Start uptake was conducted in Scotland[274]. Interactions between a midwife and an eligible pregnant woman in the first antenatal visit were studied. This process identified barriers for both the midwife and an eligible pregnant woman in the application process. It was found the midwife had key misunderstandings about their role in the application process, which a survey revealed was common among other midwives, and participants needed greater support in the application process. Subsequently, training was given to midwives and Legal Aid support was secured for applicants. In the weeks following this intervention there was a 13.3% rise in voucher receipt in the local area, while there was a 8.4% decline in the rest of Scotland. This study lacked a rigorous design, and as such many factors limit the validity of these results. For example, a control group and statistical analysis were not employed to rule out chance or confounding. However, the intervention involved a high level of stakeholder involvement employing qualitative methods to create an intervention to improve Healthy Start uptake. It is the first study to indicate that Healthy Start uptake may be modifiable through practitioner training and providing application support to participants. These findings could be used as a basis for further action to improve Healthy Start uptake and give some quantitative support to the hypothesis that training of health professionals and issues with the application process are drivers of low programme uptake. This is consistent with qualitative research showing that practitioners may have acted has a gatekeeper to the programme. Now that the requirement for a signature has been removed, there may be an increase in Healthy Start uptake. Yet it could have the opposite effect as health professionals were also the main way beneficiaries became aware of the scheme. There has been no quantitative assessment of awareness of the Healthy Start scheme to date, this should be a future avenue of research.

2.1.2.5 Discussion of Healthy Start quantitative research

In summary, quantitative evaluations on the impact of Healthy Start on a range of outcomes are limited. When only the higher quality evaluations are considered, it appears the Healthy Start scheme may not disincentivise breastfeeding[275]; but that the effect on fruit and vegetables is mixed. One study indicated there was an increase in household fruit and vegetable purchases[264], but another indicated there was not an increase in fruit and vegetable intake from people in Healthy Start eligible households[267], compared to controls. A factor which limits the availability and quality of quantitative evaluations of Healthy Start is a dearth of data on participants. Of the three studies mentioned, only one had data on which participants received Healthy Start[271], the others assumed Healthy Start eligibility[264,267]. Moreover, studies to date have focused only on household purchases and dietary intakes. Critical questions on whether Healthy Start affects key maternal and child health outcomes remain, although issues with data availability make these questions hard to answer.

2.2 School meal policies

In this section, literature on school meal policies will be discussed. As mentioned in the introduction, the dietary quality of school food is a central mechanism of free school meals. Therefore, in order to thoroughly examine the impact of free school meal schemes, the literature evaluating the quality of school meals will be reviewed. Then qualitative and quantitative literature on FSM and UIFSM will be discussed.

2.2.1 School meals vs packed lunches

Children in the UK have an alternative to school meals, they can bring food from home, referred to as a ‘packed lunch’. It is necessary to compare the dietary quality of school meals over packed lunches, to understand the benefit of school meals over the alternative option. Evidence from primary and secondary schools will be presented separately.

2.2.1.1 Primary schoolchildren

A meta-analysis of studies published before 2007 pooled estimates of packed lunches and school meals in primary school children, finding packed lunches were higher in energy, sugar, saturated fat, and sodium[276]. These studies were conducted before standards were introduced. As the standards were shown to improve school meal quality, discussed in Section 1.2.5.2, the association may now be outdated. Subsequent studies comparing school meals and packed lunches after the 2006 School Food Standards are summarised in Table 2.3.

Table 2.3 - Summary of studies comparing school meals and packed lunches in primary schoolchildren in the UK.

AUTHOR	YEAR	LOCATION	SAMPLE SIZE	FOOD GROUPS OUTCOMES*	NUTRIENT OUTCOMES*
Stevens and Nelson[277]	2003-05	UK	*n*=311	⇧ Starchy foods, chips, puddings, vegetables, and baked beans	⇧ Folate
				⇩ Cheese, yoghurt, confectionary, savoury snacks and soft drinks	⇩ Sodium, sugar and fat
Golley[237]	2007	Sheffield	*n*=125	⇧ Vegetables, cakes, and biscuits	⇧ Protein, vitamin A, fibre, folate, iron and zinc
				⇩ Fruit, meat products confectionary, savoury snacks, and soft drinks	⇩ Energy, fat, and saturated fat
Pearce[278]	2009	England	*n*=10,002	⇧ Vegetables, salad, water	⇧ Protein, vitamin A, fibre, folate, and zinc
				⇩ Fruit, meat products, dairy, confectionary, savoury snacks, and soft drinks	⇩ Fat, saturated fat, sugars, sodium, calcium, vitamin C and iron
Harrison[279]	2007	Norfolk	*n*=1,625	⇧ Vegetables, starchy foods, chips, sweet snacks, and milk	⇧ Protein and fibre
				⇩ Bread, confectionary, savoury snacks, and fruit	⇩ Energy density
Evans[280]	2007	England	*n*=2,709	⇧ Vegetables, starchy foods, chips, pudding, and water	⇧ Protein, fibre, folate and iron
				⇩ Bread, sweet and savoury snacks, cheese, ham, yoghurt, and soft drinks	⇩ Sugars, sodium

⇧ Significantly higher in school meals compared to packed lunches ($P<0.05$)

⇩ Significantly lower in school meals compared to packed lunches ($P<0.05$)

* School meals vs packed lunches

In general, the studies confirm that the food and nutritional profile of school meals were healthier than packed lunches. Findings indicated that school meals were more likely to meet School Food Standards. Across the five studies, for the food group outcomes, school meals had a higher intake of vegetables

(5/5 studies), starchy foods (3/5) and puddings (4/5), but a lower intake of savoury snacks and confectionary (5/5), soft drinks (4/5), dairy (3/5) and fruit (3/5) compared to packed lunches. When nutrient outcomes were reviewed there was a consistent higher level of protein, fibre, and folate (4/5, respectively) in school meals. Additionally, there was evidence of lower levels of fat (3/5), sugars (3/5), sodium (3/5) compared to packed lunches, but these were less consistent between studies. Differences in iron levels were in contradiction, with Pearce *et al*[278] finding a lower levels but Golley *et al*[237] and Evans *et al*[280] finding higher levels in school meals compared to packed lunches. Finally, there was evidence that lunchtime school meals positively impacted on their total daily diet[279]. This was confirmed in a repeated cross-sectional study in Newcastle, which compared school lunch type and examined how deprivation impacted lunchtime and total diet intakes over time[244]. The study concluded that school meals were associated with reduced inequalities in sugar and vitamin C intake in the total diet between the least and most deprived children.

It is notable that not all the differences between school meals and packed lunches were favourable to school meals. For example, school meals commonly contained less fruit than packed lunches[237,278,279]. Also, although a lower level of savoury snacks and confectionary was observed consistently in school meals, there was a higher level of puddings and chips in school meals compared to packed lunches[237,277,279,280]. Moreover, changes in macronutrients were not consistent. Although reductions in consuming some unhealthy food groups were observed, it is essential to see a uniform reduction in fat and sugar intakes to help children improve their overall dietary intakes and ensure that the sources of sugar and saturated fat are being reduced and not replaced.

Some of the studies were limited by small sample sizes[237,277] and their geography[237,279], possibly impacting the representativeness of the findings. But these studies were supported by the larger studies which were geographically representative of England[278] and demonstrated broadly similar findings. All of the studies were conducted before 2009, consequently the findings might not reflect changes from the food-based School Food Standards introduced in 2015. Additionally, only one, small-scale study covered areas of the UK outside of England[277], so there is a lack of studies representing Scotland, Wales and Northern Ireland.

2.2.1.2 Secondary schoolchildren

Studies comparing the nutritional quality of school meals and packed lunches in secondary school children are summarised in Table 2.4 . Compared to the studies in primary schoolchildren, the findings are less consistent in older children.

Table 2.4 - Summary of studies comparing school meals and packed lunches in secondary schoolchildren in the UK.

AUTHOR	YEAR	LOCATION	SAMPLE SIZE	FOOD GROUPS OUTCOMES*	NUTRIENT OUTCOMES*
Prynne[281]	2005-07	Cambridgeshire	*n*=757	⇧ Starchy foods, puddings, meat and fish, vegetables	⇧ Saturated fat, sodium
				⇩ Bread, dairy, fruit, confectionary, savoury snacks and soft drinks	⇩ Protein, iron (B), folate,
Pearce[282]	2008	Sheffield, Manchester, Leicester City and Essex	*n*=497	⇧ Starchy foods, chips puddings, meat and fish, vegetables, fruit, soft drinks	⇧ Energy, protein, carbohydrate, fibre, vitamin C, folate, iron and zinc.
				⇩ Dairy, meat products confectionary	⇩ % Energy from sugar, % energy saturated fat
Spence[241]	1999-2000 and 2009-10	Northumberland	*n*=298, *n*=215	N/A**	⇩ Energy, % energy saturated fat, sodium, vitamin C and calcium
Stevens[283].	2010-11	England	*n*=7,730	⇧ Starchy foods, chips, vegetables, desserts, water,	⇧ Energy, carbohydrate, protein fibre, vitamin A, folate, iron and zinc
				⇩ Sandwiches, fruit, confectionary, savoury snacks and soft drinks	⇩ Sodium, % energy fat

⇧ Significantly higher in school meals compared to packed lunches (*P<0.05)*

⇩ Significantly lower in school meals compared to packed lunches (*P*<0.05)
* School meals vs packed lunches; ** Food group outcomes not studied

The studies show a difference in consuming foods consistent with the typical differences between hot school meals and cold packed lunch foods. School meals consistently had higher starchy foods, chips, vegetables, and puddings (3/3 studies) and confectionary (3/3 studies). Compared to primary schoolchildren there was not a consistent difference in dairy products, soft drinks or savoury snacks in secondary school children, with one study finding a higher intake of soft drinks in school meals[282]. The only consistent change in nutrient outcomes was a lower percent of energy from fat in school meals (3/4 studies). Impact on micronutrients were mixed with two studies finding a higher level in micronutrient intake in school meals[282,283], but one study found a decrease[241]. However, the difference in methodology may explain this finding. Spence *et al*[241] analysed both a smaller sample of participants and a smaller geographical area than the other two studies. Prynne *et al*[281] found a concerning higher intake of saturated fat and sodium but lower intake of protein, iron and folate in school meals, in contradiction with the other studies. However, this study was conducted before the nutrient-based standards were introduced. In summary, studies in secondary school indicate a slightly improved nutritional profile for school meals when compared against packed lunches but the evidence is not consistent. It was highlighted in one study that neither meal type met the standards[283], indicating that the quality of school meals in secondary school may be worse than primary schools. However, no studies have directly explored this hypothesis.

Similarly with primary schoolchildren, studies have indicated that differences between school lunch type are evident in the total dietary intake. Spence *et al*[241] additionally compared the impact on total dietary intake, concluding secondary schoolchildren consuming a school meal had a slightly lower daily saturated fat, sugar and sodium intake. Additionally, in a pooled cross-sectional study of NDNS data (2008-2016), the overall daily diet quality of adolescents, compared using the DQI-A index, was higher if they took a school meal compared to a packed lunch or bought from an external shop/café[284].

Studies evaluating the relationship in secondary schoolchildren are also outdated, with no studies performed after 2011, and lack representativeness of the UK as no studies were outside of England.

2.2.1.3 Studies on school lunch type

The studies presented so far have directly compared the nutritional content of school meals and packed lunches. However, a range of studies have focused on each lunch type separately. Although these studies are limited as they do not make a direct comparison between lunch type, they make some important additions to the understanding on the relative healthfulness of school meals compared to packed lunches.

2.2.1.3.1 Meeting school food standards

Two cross-sectional studies have quantified the prevalence of packed lunches meeting the School Food Standards[285,286]. As the School Food Standards do not apply to packed lunches, the aim was to explore how consistent they are with the standards. The studies were conducted in 2006 and 2016, and included 1,148 and 323 children aged 8-9 years, in each phase respectively, from schools across England. The study concluded that packed lunches have improved over time, with a reduction in the frequency of confectionary and soft drinks and an increase in the likelihood of meeting individual nutrient standards, such as for sugars, vitamin A and C. Despite this, achievement of all the food standards was very low and showed little improvement over time, only 1.6% packed lunches met all standards in 2016. This figure is alarming and is frequently cited to support the argument that more children should consume school meals. However, no study to date has given an equivalent comparison in school meals. Although the standards should be mandatory, reports indicate some school food does not meet these standards, as mentioned in Section 1.2.5.2. It is reasonable to assume that more than 1% of school meals would meet all the food standards, but without an equivalent study in school meals, it is difficult to compare and interpret these findings.

2.2.1.3.2 Interventions to improve lunchtime intake

Reports on the quality of packed lunches have led for calls for greater regulation on packed lunches. However, evidently this would have to take a different form to regulation on school meals and would need to be implemented at the school-level. As such packed-lunch policies have a high variation between schools[227]. Interventions conducted in Derby[287] and Leeds[288] aimed to improve the nutritional content of packed lunches through providing additional educational information and lunchbox equipment to parents. However, in both studies there was a minimal sustained improvement in the nutritional content of the intervention's packed lunches compared to the control group at follow-up.

Comparatively, interventions which have used nudging tactics to change the food choice architecture in a school setting have shown positive results. For example, an intervention in a secondary school in Yorkshire changed the labelling, positioning and presentation of plant-based food and monitored how these changes influenced food purchasing over six weeks[289]. Analysis of 218,796 transactions suggested there was a 2.5 times increased likelihood that students would select plant-based food items after the intervention. However, this study did not have a control school. A similar intervention was conducted in primary schools in Wales, but randomly allocated schools to the intervention and the control (n=2, respectively)[290]. Over three weeks, changes such as improving the labelling and presentation of healthy food, were associated with an increased fruit, vitamin C and fibre intake in the intervention group compared to the control.

Consequently, improving the food environment to positively influence food choices can be an effective way of increasing the nutritional quality of school meals, but not packed lunches[291]. As the appeal of the school food environment has been shown to be important to children, this is an critical pathway to improving dietary intake [227,292].

These studies in combination with the literature showing that School Food Standards improve the nutritional content of school meals, indicate that it is easier and more effective to improve the nutritional intake of school meals than packed lunches. This may explain why the literature indicates that school meals are healthier and gives further support to the argument that school meals are preferable to packed lunches.

2.2.1.4 Discussion of school food quality research

To date there has been extensive literature comparing the nutritional content of school meals and packed lunches in the UK. The balance of evidence indicates that school meals have a preferable nutritional profile than packed lunches overall. Although school meals are not yet optimal. Moreover, the literature indicates the difference is greater in primary schools, which may indicate that the association changes as children age. This has not been directly studied, more evidence is needed to confirm this hypothesis.

Although a large total number of pupils have been assessed, the literature has been focused in England, with no study representing all areas of the UK. Moreover, there is a dearth of studies after the food-based standards were introduced in 2015. Consequently, these findings may no longer be relevant. Finally, to date studies have only compared school lunches and packed lunches using two forms of dietary indicators: nutrient content and food groups consumed. As discussed earlier, the level of UPF in children's diet is of growing concern. It would be important to quantify the level of intake of UPF in school lunches, which is currently unknown in the UK. As a study in Brazil indicated that adolescents who were not receiving the Brazilian School Food Programme were more likely to consume UPFs [293], it is likely that a similar association would be found in UK schools.

2.2.2 Free school meals

Free school meals aim to provide the most deprived school children with food, acting to reduce their food insecurity, other benefits are said to include improved health, behaviour, and education. However, literature examining either the uptake or impact of the FSM policy is limited. The FSM policy is a long-standing policy which is present every year of children's schooling, therefore opportunities for a natural experiment evaluating the scheme are limited. The majority of FSM literature uses the policy as a marker of deprivation, rather than an example of a public health policy[294]. Here studies on the FSM take-up and impact on dietary and health outcomes are presented.

2.2.2.1 FSM uptake

Around 10-20% of FSM-eligible children choose not to use their FSM entitlement. Studies exploring reasons for not claiming FSMs have revealed that stigma is a major barrier to the benefit. Sources of stigma are situations where the child is made to feel different, such as needing to verbally identify as FSM-eligible at the till or by not being able to leave school and buy lunch at an external shop or café[295–297]. Anonymised payment systems are proposed as a way to reduce stigma, but it only addresses one source of stigma. It does not enable secondary school children to leave the school premises for lunch[298,299]. For this reason, stigma of receiving FSM is greater for secondary school children[297]. Additionally, other aspects of the school food environment, such as the price and quality of the food along with the social aspects of dining have been shown to affect FSM take-up[297]. In a multi-level evaluation of Scottish data, FSM take-up increased with the level of overall school meal take-up and the proportion of FSM-eligible pupils in the school, indicating that peer-effect may have an important role in FSM uptake[300]. Moreover, case studies in 2001 identified that the FSM allowance was not enough to purchase a healthy well-balanced school meal[295], a finding which was confirmed in a survey of FSM-eligible children in 2012[249]. Indicating that the FSM benefit was not successful at removing income inequality in the school canteen. In summary, FSM must be an appetising, fulfilling and socially acceptable option for low-income children to ensure a high take-up of the scheme.

2.2.2.2 FSM impact on diet and health outcomes

There are few studies which explore if the FSM scheme impacted the nutritional intake or health outcomes of low-income children. The majority of studies available are not appropriately designed to evaluate the scheme as they do not use comparable control groups. Rather, there are many studies which compare FSM-eligible children to non-FSM eligible children, without appropriately accounting for differences in socioeconomic position.

For instance, studies conducted between 1979-89 observed that FSM-eligible children in England and Wales were of a lower height and weight than the rest of the school population[301–304]. By 1994, evidence indicates this association was reversing and now it is seen that FSM-eligible children are now more likely to be overweight[304,305]. It is clear that in these studies FSM-eligibility is acting as a proxy indicator for low socioeconomic position and the association reflects the overall trend in weight for low-income populations in England overtime[145]. A similar association is observed in literature comparing the dietary intake of FSM-eligible children. In an analysis of a 1997 national dietary survey of young children, it was concluded that FSM-eligible children had a worse nutritional profile than non-FSM children[242]. However, it was also observed that this closely reflected the differences observed by income. Further demonstrating that without an appropriate comparison group, these differences describe socioeconomic inequalities and not the impact of the policy.

However, in a nationally representative cross-sectional survey of low-income individuals conducted between 2003-05, it was observed that a FSM was of a higher dietary quality than a packed lunch in a sample of low-income children[277]. This is the best evidence available to indicate what impact the FSM policy has on the nutritional intake of low-income children, suggesting it protects low-income children from taking a poor-quality packed lunch. As the study is cross-sectional it cannot provide evidence towards a causal association of the FSM programme impact.

However, FSM policy changes in the 1980s were exploited to evaluate the impact of the programme. In 1988 families who received Family Credit (later replaced by Working Tax Credits) lost their right to FSM but received 65p per school day in compensation. A national study of 7,000 English Primary schoolchildren in 1982-92 was analysed to evaluate the impact of this change in FSM eligibility on the take-up of school meals, compared to other children who remained eligible[270]. It was observed that in the years 1985-87, children eligible for Family Credit had an average school meal take-up over 80%, this was compared to 90% in the Income Support eligible group and 60% in the children who received no benefits. However, in the years after the eligibility changes, there was a greater drop in school meal take-up in the Family Credit group (-33 percentage-points[pp]), than the Income Support group (-2.5 pp) or No Benefit group (-7.7 pp). In addition to this, a small-scale study in Southampton (*n*=199) evaluated how this policy change impacted dietary intake[306]. The shift from consuming FSM to packed lunches was associated with a lower consumption of burgers, pies, chips and ice-cream, and higher consumption of crisps, sandwiches, and fruit. These studies are now outdated; there have since been large changes in the school food environment, price of food and benefit system since these studies were conducted. Yet, the findings give a useful indication to the price sensitivity of low-income families and the potential of the FSM scheme to impact the dietary intake of low-income children.

Lastly, study of FSM-eligible children during school holidays can reveal the short-term impact of the removal of the scheme. It is estimated that up to 3 million children are at risk of food insecurity during the school holidays as a result of not receiving their FSM[307]. Qualitative studies reveal that families struggle to afford food in the school holidays, adopting strategies such as not paying bills, reducing parental nutritional intake to prioritise food for the children, buying cheaper foods and stockpiling before the holiday[308]. Increased food insecurity during school holidays reflects the impact of the scheme, although no study to date has quantitively evaluated this impact.

2.2.2.3 Discussion of Free School Meal research

Studies evaluating the impact of the FSM scheme are limited. Qualitative studies identify the stigma associated with the scheme, but few studies have explored the impact on FSM dietary intake. Literature indicates that the programme may protect low-income children from a poor-quality packed lunch and improves a family's food security, yet due to the difficulty of studying the well-established programme, these studies are limited in their design.

2.2.3 Universal Infant Free School Meals

This section will present research on the implementation of UIFSM scheme and its impact on school meal uptake, dietary intake, educational attainment, and health outcomes. Comparatively to the FSM, there has been greater opportunity to evaluate the impact of the more recently established school meal scheme.

2.2.3.1 Qualitative evaluations of UIFSM

The qualitative literature which evaluated the implementation of UIFSM in England and Scotland included a wide range of stakeholder voices, such as catering staff, school leaders, parents, and pupils. Qualitative studies have been conducted to assess the implementation of the UIFSM scheme and its perceived impact from key stakeholders. The studies are described in Table 2.5.

Table 2.5 - Summary of qualitative studies evaluating Universal Infant Free School Meals

AUTHOR	YEAR	LOCATION	SAMPLE SIZE	PARTICIPANTS	METHOD
Day[309]	2014	North England	*n=139*	Pupils, catering managers and head teachers	Focus groups and interviews
Goodchild[310]	2015	Leicester, England	*n*=676	Parents and school leaders	Survey
Sellen[250]	2017	England	*n*=986	Pupils, parents, educational staff, school leaders and catering staff	Case study visits, survey, and interviews
Chambers[311]	2015	Scotland	*n*=49	Local-authority and school stakeholders	Case study

Emergent themes from across the research have been summarised in Table 2.6. Themes include the policy's implementation, stakeholder's viewpoint, and their perceived outcomes of the policy.

Table 2.6 - Summary of themes from Universal Infant Free School Meals qualitative research.

THEME	FINDINGS
IMPLEMENTATION	➢ Increased funding allowed for more staff and equipment, allowing for a smooth implementation of UIFSM in many schools [311] ➢ UIFSM caused changes in lunchtime provision for all schools but only some schools reported having limited time or space to serve all children [250,309,311] ➢ UIFSM caused increased workload for both catering and education staff [311] ➢ The success and promotion of the scheme was dependent on buy-in from school-leaders [311]
STAKEHOLDER VIEWPOINTS	*Catering staff* ➢ UIFSM ensures sustainability of school food systems, possibly encouraging school meal uptake in later school years [311] ➢ Catering staff felt there was a lack of communication between them and educational staff ➢ Viewed as a chance to improve the school food environment [309] *School leaders and education staff* ➢ Mixed support from school leaders o UIFSM requires unnecessary time and money input to provide lunch to children who mostly could afford to pay when those resources are scarce in the educational sector[311]

	○ Some recognise that the scheme benefits children who just miss out on the means-tested scheme [311] *Parents* ➢ Parents were mostly in support of the scheme, reporting it saves them money[250] ➢ Parents of children who don't use the scheme report being concerned over food quality and quantity [310] *Pupils* ➢ The food needs to be appealing and have a wide variety of choice to encourage take-up [250] ➢ Children need assistance and encouragement in choosing healthy options [309]
OUTCOMES	➢ UIFSM helps to improve healthy eating policies in schools [250] ➢ It was felt there were positive social outcomes from children eating communally [311] ➢ Also perceived that there was improved behaviour and eating etiquette [250]

Overall, the implementation of the scheme was successful and was mostly viewed positively by stakeholders. All schools noted that the scheme caused significant changes to the lunchtime service. In some schools this was reported as a positive change, inspiring a healthier food policy and improved dining experience for the pupils [250]. However, some schools reported that this scheme caused them to reach the limits of their capacity, reporting they lacked the space to cater for all their pupils[250,309,311]

It is notable that support for the scheme was mixed between school leaders [250,311]. School leaders who did not support the scheme considered that in a context of persistently under-funded educational budgets, UIFSM was an unnecessary use of public funds when most of the children in their school could afford to pay. On the other hand, some school leaders recognised the benefit of the scheme to serve children whose parents were low-income but in work. As the success of the scheme was perceived to be dependent on the positive commitment from school leadership. It is vital that school leaders feel they have the necessary resources to implement the scheme. Otherwise lack of support from school leaders was seen as a key barrier to the policy's long-term success.

2.2.3.2 *Impact of UIFSM on school meal uptake*

Two pilot studies were conducted to test the implementation of UIFSM. In Scotland in 2006/07, UIFSM was implemented in five local authorities in Scotland (East Ayrshire, Fife, Glasgow, Scottish Borders and West Dunbartonshire), the results were analysed in a before-after analysis[312]. In England in 2009-2011 a trial implemented UIFSM in two local authorities (Newham and Durham) and extended the FSM entitlement in another local authority (Wolverhampton)[313].

The uptake of school meals in both pilots were similar. In Scotland, there was a 22pp increase in all infant schoolchildren taking a school meal during the pilot compared with before (before 53%; after

75%). In England there was a 28pp increase in pilot areas compared to the control area (control 66%; intervention 94%). These values were broken down by FSM-eligibility. Due to a lower school meal-uptake before the pilots were introduced, there was a larger increase in school meal uptake in non-FSM eligible children. In Scotland, a 28pp increase was observed in non-FSM-eligible children (from 41% to 69%), in England there was a 35pp increase (from around 50% to around 90%). Uptake in FSM eligible children was lower in both Scotland (4 pp) and England (16 pp), however as the pre-intervention uptake levels were over 85% in both cases, it is expected the uptake would be proportionally lower.

Further analysis of the Scottish trial quantified the positive peer-effects for FSM-eligible children as part of the universal scheme[314]. The analysis estimated that due to positive peer effects, a 10% rise in peer-group school meal uptake would lower non-participation from FSM-eligible children by 3.3-4.0%. Therefore, this study confirmed that although the scheme was universal, it had specific benefits in improving school meal uptake in the most disadvantaged children. The mechanism of this effect was posited to be through reducing social exclusion, as children taking packed lunches were not physically separated from those taking school meals, increasing the social desirability or perceived attractiveness of school meals. Interestingly, the paper demonstrated that the effect was not through reduced stigma of being identified as FSM-eligible when paying, as participation rates were similar in schools with and without anonymised payment systems.

Although these pilot studies are revealing and give a good indication of the possible impact of a universal scheme, they are limited in many ways. The Scottish pilot was conducted for a short amount of time (nine months) and although they used a representative sample of local areas to get a mix of deprivations, the study did not use a control area. Conversely, the English pilot used a control area and was implemented for two years, the study was limited by its geographical representation. As such it is important to compare these with national estimates of uptake since the UIFSM scheme has been introduced.

The first estimate of programme impact on school meal uptake after the scheme was introduced was derived from an evaluation of a nationally representative expenditure survey in the UK, the Living Costs and Food Survey (LCFS)[250]. In this dataset, families were asked how many school meals their child had on the previous week. For infant schoolchildren, there was a significant increase in the proportion taking at least one school meal compared to older children (Figure 2.2). However, this value does not account for families who were surveyed during school holidays. After the analysis was adjusted to account for responses during school holidays, it was estimated that school meal uptake rose from 38% in 2013/14 to 80% in 2015/16.

The second estimate is derived from school census data, whereby school meal uptake is surveyed on one day of the year. Although this statistic has a high coverage of English schools, this value is not representative of school meal uptake across the year. The estimates show a large increase in school meal uptake in non-FSM-eligible children, a rise from 30% in 2013/14 to 85% in 2014/15[315]. Findings which are similar to the estimates by Sellen *et al*[250]. However, there was little difference in FSM-eligible children's school meal uptake, which remains relatively constant, rising 2pp to 87%, indicating the analysis by Holford *et al* may have slightly overestimated the peer-effects for FSM-eligible children[314] On a larger scale, the hypotheses of reduction of stigma and peer-effects might not be relevant due to the high variation of food environments across schools.

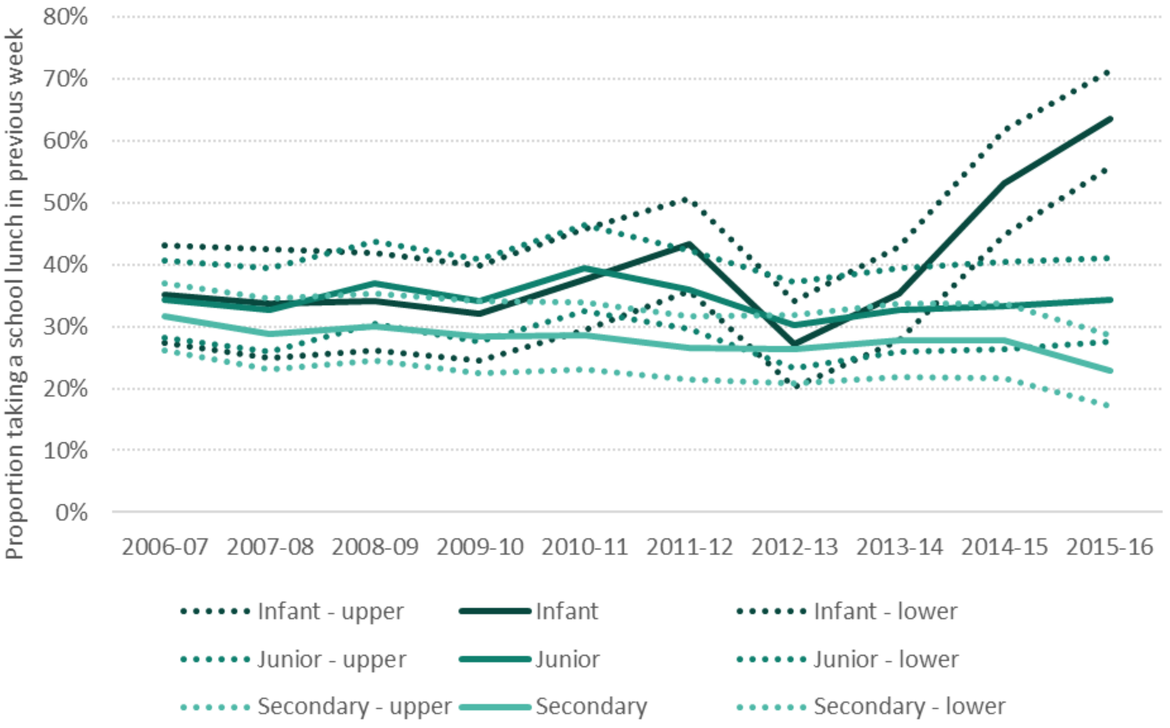

Figure 2.2 - Estimated proportion of children in England attending state schools taking at least one school lunch in the last week.

Source: Sellen [250]

A cross-sectional survey of parents in Leicester after UIFSM was implemented sought to characterise factors associated with UIFSM uptake[310]. It was observed that of 676 parents surveyed, 23.5% did not use UIFSM and that this group was more likely to be White British, have English as a first language or of a higher socioeconomic class. The principal reason for not using UIFSM were concerns of school food quality. Although these views may be only representative to this regional area, the study provides vital insight into reasons for non-engagement in UIFSM. This is congruent with qualitative findings from the Scottish pilot that noted more affluent parents were concerned the school meals were less healthy than the packed lunches they previously provided [250].

2.2.3.3 Dietary intake outcomes

The English pilot study reported a significant impact of UIFSM on the food groups consumed in intervention areas compared to the comparison areas[313]. There was a reduction in foods which are typically associated with a packed lunch and an increase in foods typically associated with a cooked school meal, consistent with the research described in Section 2.2.1. There was a significant increase in starchy foods, chips, vegetables and any hot food and a reduction in consuming crisps, fruit, and sandwiches (Figure 2.3). It was noted that differences in consuming a hot meal or fruit and vegetables were not seen across the day, indicating intakes were not compensated at later points in the day. As school meal uptake increased, it is not surprising that the differences in food groups are consistent with previous research. This study did not explore if change in food groups consumed impacted nutrient intake. For example, it would be important to evaluate whether any improvements in fat consumption from the reduction in consuming crisps are offset by the observed increased in consuming chips. The results also do not capture the quantity of a food group consumed, which is important for frequently consumed foods such as fruit and vegetables. Moreover, as mentioned previously this study is limited in its representation of the country. Although two pilot and comparison areas were chosen, there may be differences across the country. The dietary measure reflects only the most recent school day and may not be representative of the total lunchtime intake across the week.

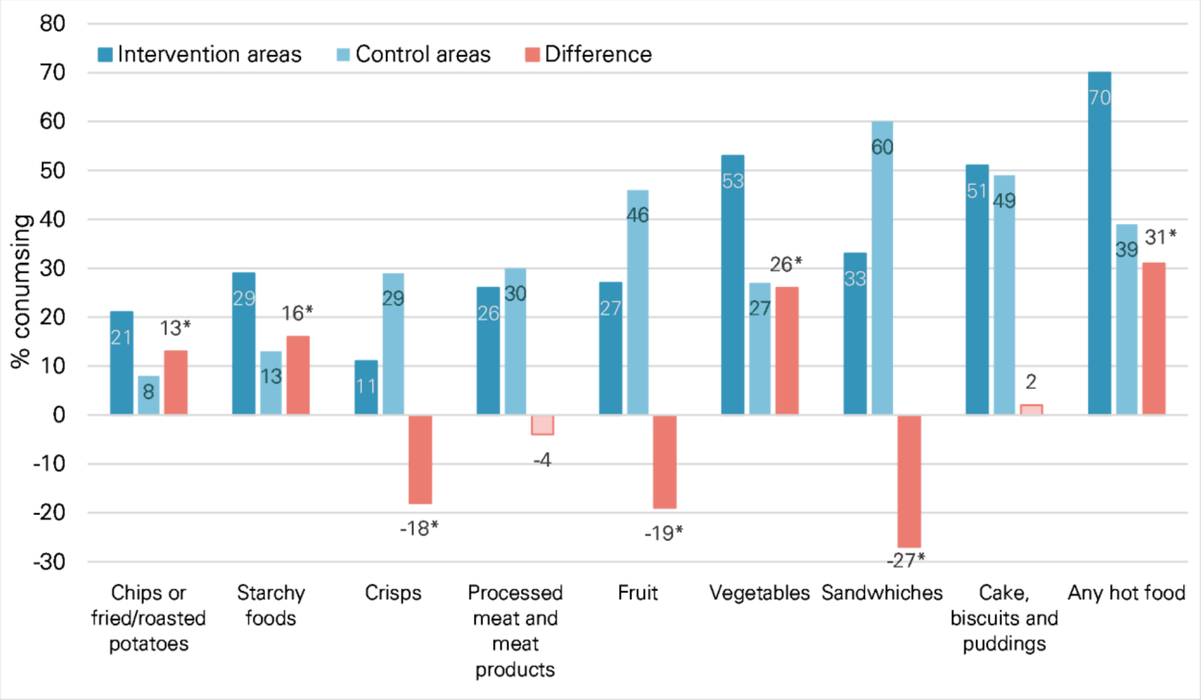

Figure 2.3 - Consumption of food groups in the most recent lunchtime in intervention and control areas in the English UIFSM pilot scheme.

Note: * P<0.05. Reproduced from Kitchen[313]

A repeated cross-sectional study evaluating the impact of UIFSM was also conducted in Northeast England[316]. The small-scale pilot study (pre-UIFSM *n*=112 2008-09; post-UIFSM *n*=84 2017-18) used a convenience sample to survey the lunchtime intake of foods and nutrients in pupils from two schools. After UIFSM there was a significant reduction in the percent of energy from sugars (-4.6%; CI-6.3, -2.9) and a decrease in the number of portion of biscuits consumed (-0.4; CI -0.5, -0.3). However, in one of the schools studied, an increase in cake portions consumed was observed. Additionally, there was evidence of a lower intake of % energy of fat and sodium, although the statistical significance of this change was not provided. This study has many limitations which limit the generalisability and validity of these findings. The small sample and limited geographical location limit the generalisability beyond the Northeast of England, which is a typically more deprived area of England. Moreover, no control was used in the study, therefore the study cannot account for other important changes which occurred over the study period, such as changes in School Food Standards in 2015.

2.2.3.4 Health outcomes

The English UIFSM pilot measured height and weight during the interview[313]. The study found no evidence of a difference in the prevalence of overweight or obesity in pilot areas compared to similar children in control areas. The authors posited that either the study period was not long enough to view weight changes or the UIFSM did not cause significant changes in calorie consumption. However, this is in contrast to the findings of an analysis of the National Child Measurement Programme data[315]. The dataset is a repeated cross-sectional survey of over 90% of English primary schoolchildren. The study aims to get a snapshot of the height and weight of English schoolchildren as they enter (ages 4-5 years) and leave (ages 10-11 years) Primary school. In the analysis, the time in the year which Reception schoolchildren had their anthropometric measurements taken was used to estimate the length of exposure to the UIFSM scheme. Children who had their measurements taken in the start of the school year (September) were considered as less exposed than children who had their measurements taken at the end of the school year (June). Measurements in years post-UIFSM (2014/15-2017/18) were compared to measurements in the same months in previous years (2008/09- 2013/14). The study found that children who had a greater exposure to UIFSM were more likely to be a healthy weight (1.2%), less likely to be obese (0.7%) and have a lower BMI (-4.3%) than children who were less exposed and compared to previous years. There was evidence of a dose effect, with benefits apparent from the November half-term block (Figure 2.4).

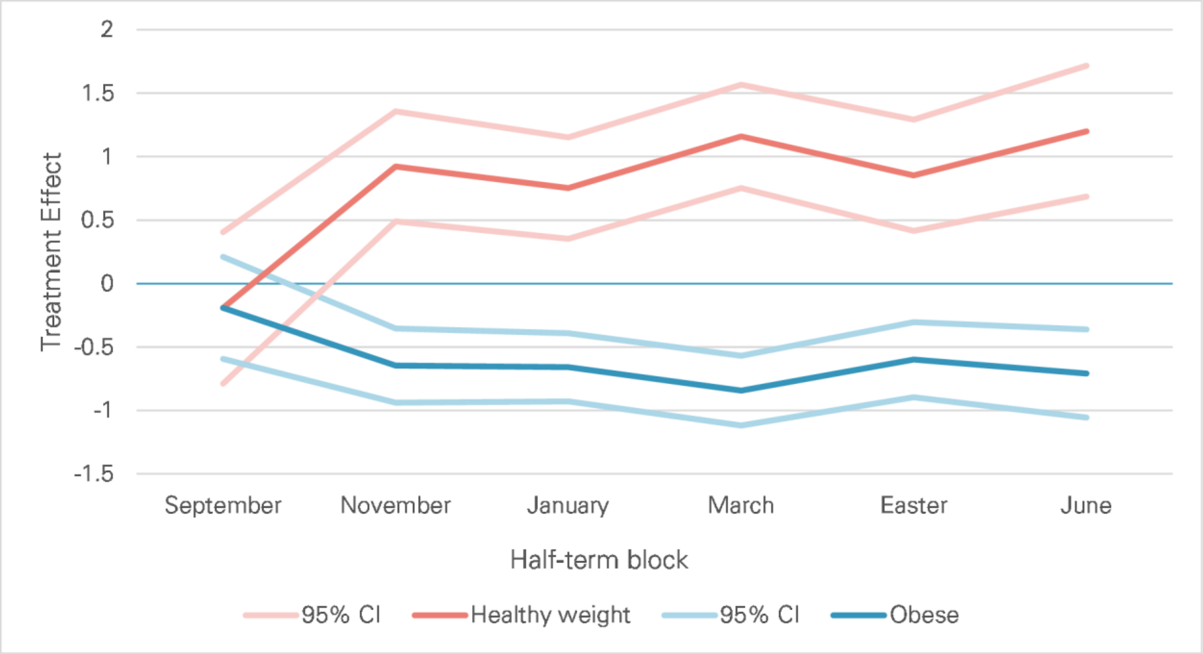

Figure 2.4 - Treatment effects of UIFSM by half-term block on the prevalence of healthy weight and obese children in Reception (4-5 years)

Note: Reproduced from Holford & Rabe[315]

The authors highlight the rarity of observing changes in bodyweight on this scale from a school-level intervention[315]. Although modest, the findings highlight the potential of the programme to improve health at a national level. There are two possible mechanisms for this effect. The scheme could have a direct impact by improving energy intake at lunchtime. Alternatively, the scheme could have an indirect effect through improving the financial situation of the household.

Moreover, the study provides evidence that the UIFSM programme can benefit a wide range of children from socioeconomic backgrounds. When the analyses were stratified by % FSM eligibility of the school, treatment effects were seen in all but the highest and lowest groups. It is likely the highest group, which had a larger FSM-eligible population, were less impacted by the scheme and experienced a reduced effect. Conversely, children in the most affluent group likely had a high-quality packed lunch and were least likely to take-up the scheme, so were similarly less affected by UIFSM. This finding emphasises the broad range of children which can benefit from dietary interventions, challenging previous perceptions that only very low-income children have poor diets.

The analysis employed a strong study design, with the benefit of a large sample size (154,169 data points from 17,776 schools) which is nationally representative. Therefore, the findings present a more valid and reliable estimate of the policy impact on child weight compared to the English UIFSM pilot. However, although promising, the findings cannot be extrapolated beyond reception year students. As we know that children typically gain weight throughout primary school[8], it is unclear whether this effect would be consistent in later school years.

2.2.3.5 Educational outcomes

The English UIFSM pilot also analysed the impact on attainment in school[313]. This was assessed using a composite 'attainment' score, describing reaching the expected level in a range of subjects including maths, reading, writing, science, speaking and listening. There was a statistically significant increase in the overall attainment score in one of the pilot areas at key stage (KS) 1 and in both pilot areas at KS2, when compared against similar children in control areas. Subgroup analyses indicate the effect of UIFSM were greater in children who were not previously eligible for FSM, in similarity to body weight outcomes (Figure 2.5 and Figure 2.6). This is expected, as FSM-eligible children had little change in school meal uptake, it is reasonable to assume the effect of a school meal on education attainment was already observed at baseline. The biggest effect is seen in the group who were previously unexposed and had the biggest change in their lunch, children who were nearly eligible for FSM at baseline. In pilot area B, there was a greater rise in the maths and writing attainment of these nearly eligible children than any other group. Similarly, children whose prior attainment at baseline was the lowest saw the greatest improvement during the intervention. Although this was only seen in one of the pilot areas, this finding indicates that the UIFSM could have the greatest benefits for low-income children who miss out on FSM. Further research is needed to explore if this has benefits in a nationally representative sample.

Figure 2.5 - Impact on educational attainment at Key Stage 1 in pilot area A of the English UIFSM pilot.

Note: *P<0.05 and shaded bars. FSM eligible – Children eligible for means-tested FSM at baseline; Nearly FSM eligible – low-income children not eligible for a means-tested FSM; Non-FSM eligible – all children not eligible for a means-tested FSM at baseline. Reproduced from Kitchen[313]

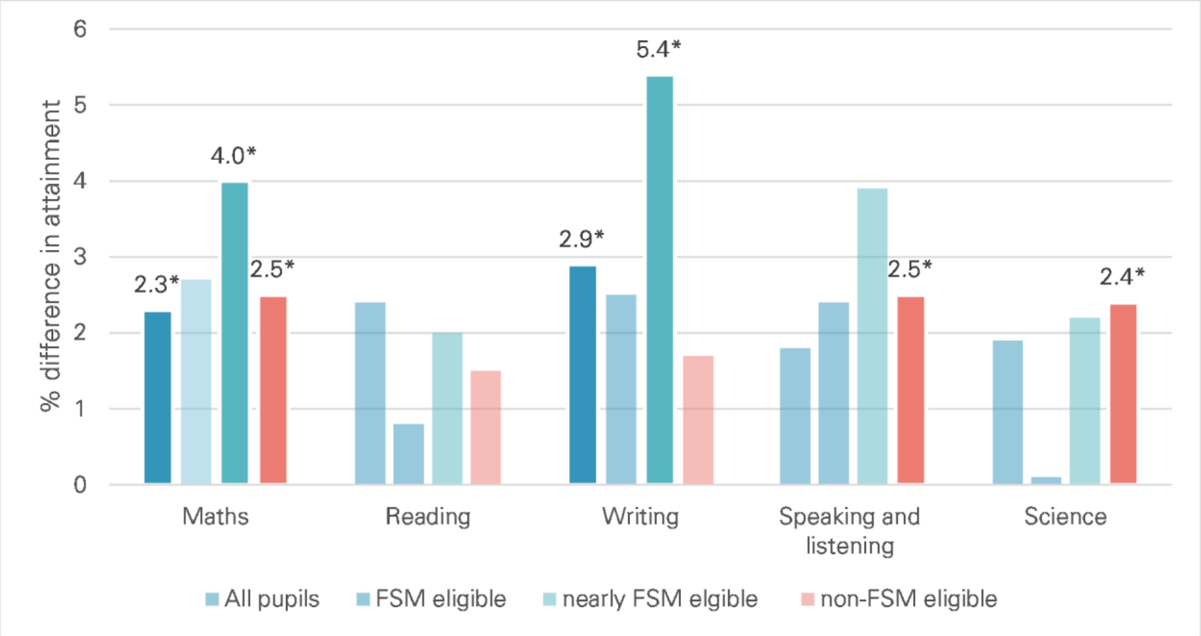

Figure 2.6 - Impact on educational attainment at Key Stage 1 in pilot area A of the English UIFSM pilot

Note: *P<0.05 and shaded bars. FSM eligible – Children eligible for means-tested FSM at baseline. Nearly FSM eligible – low-income children not eligible for a means-tested FSM. Non-FSM eligible – all children not eligible for a means-tested FSM at baseline. Reproduced from Kitchen[313]

2.2.3.6 Economic outcomes

One of the aims of UIFSM is to help families save money. Cost-effectiveness analysis performed by Sellen *et al*[250] determined there was a high cost-effectiveness of the intervention. This was due to the economies of scale of food production and the consideration that most of the cost would be passed onto families, 85% of the estimated £5,128 million of Government costs. Indicating the programme is achieving this aim.

Moreover, modelling conducted on data from 2002 challenged the perception that it is mostly middle-class who families benefit from the scheme[317]. As the FSM scheme is a passported benefit, only those who receive out-of-work social security benefits are eligible for FSM. Therefore, if you were to divide the school population by their equivalised household income, not all the children in the lowest deciles would be eligible for FSM. The researchers estimated the income gains expected from different policy scenarios: (i) no FSM scheme; (ii) means-tested FSM scheme and (iii) universal FSM scheme. It was observed that moving from a means-tested scheme to a universal scheme would save families between £2.67-£6.46 per month (Table 2.7). Interestingly, there was not a socioeconomic gradient in the absolute income gains. Households between the first and ninth deciles experience a similar absolute saving, which oscillates between £3.26-£6.46. But importantly, the proportional gain of the household income did show a gradient, with the lowest income households having the largest proportional gain from the scheme. This analysis reveals there are many low-income households which are excluded from food assistance due to the passported nature of the means-tested system. There are many limitations in this analysis which make it difficult to extrapolate these findings to the present day. Food price inflation, changes in the social security system and wage deflation will all modify this observed association in the present day. Considering these limitations however, this analysis still provides a useful reminder that a universal scheme could proportionally benefit low-income families more than higher income families, despite them all receiving similar absolute income savings.

Table 2.7 - Income gains expected from moving from a mean-tested FSM scheme to a Universal scheme in 2002.

Decile of household income	% gain	£ (per household per month)
1	2.141	5.71
2	0.455	3.26
3	0.363	3.46
4	0.410	4.82
5	0.415	5.87
6	0.376	6.46
7	0.314	6.46
8	0.250	6.24
9	0.161	5.08
10	0.052	2.67

Reproduced from Morelli and Seaman [317]

2.2.3.7 Discussion of Universal Infant Free School Meal research

In summary, the introduction of the UIFSM scheme in England and Scotland was popular and was associated with a high uptake of school meals. Qualitative research has highlighted both strengths and limitations of the scheme, suggesting that although the scheme as brought about positive changes, without sufficient support from school leaders and an appealing school food quality, the scheme is vulnerable. Quantitative evidence evaluating the scheme is currently very limited. A high-quality study provided strong evidence that the UIFSM was associated with modest improvements in weight status for children in their first school year. But there is a dearth of nationally representative studies evaluating the impact on dietary and educational outcomes, with most of the evidence from one pilot study in England. Moreover, key dietary indicators were not included in the pilot study, therefore it is currently unknown how the scheme impacts the nutritional intake or consumption of UPFs at lunchtime or across the day. Lastly, the scheme appears to have important differences across the socioeconomic spectrum. There is little change in school meal uptake, weight status or educational attainment for children previously eligible for FSM. But for non-FSM eligible children, there was improvements in weight status and education attainment for all but the most affluent, indicating that UIFSM could help to reduce the socioeconomic gap across the entire gradient.

Chapter 3. Rationale, aim and objectives

3.1 Summary of introductory chapters and rationale for thesis

There are concerning levels of income inequality and poverty in the UK, with evidence that households with children are vulnerable to experiencing poverty[16,127]. One of multiple negative consequences of poverty, is the inability to afford and access food. Disproportionate pricing of healthier food compared to unhealthy foods[107] creates an economic barrier to a healthy diet and is one factor which contributes to the socioeconomic gradient in the dietary intake of both adults and children[187]. Diet is a strong determinant for health outcomes[7], therefore the observed diet inequities are one factor which drives observed health inequalities.

Action needs to be taken to reduce inequalities in diet, reduce the intake of UPFs, and prevent further widening of health inequities. There is strong evidence that the early-life period is an effective time to intervene to improve life-long dietary intake, health and reduce socioeconomic inequalities[184]. The UK has two policies which are specific to food insecurity in children: the Healthy Start scheme and school meal policies. However, both examples of food assistance policies in the UK are under evaluated with gaps in our understanding of their impact. The evidence gaps and rationale for research are as follows:

Healthy Start

Qualitative research has highlighted that Healthy Start uptake is affected by household characteristics, such as pregnancy status and location. Yet the extent to which household characteristics determine Healthy Start uptake among an eligible population has not been quantified. Understanding how greatly sociodemographic factors are associated with uptake will help to inform policy makers on the groups in the population which need greater support in accessing the scheme.

It is equivocal whether Healthy Start has a significant impact on the purchasing behaviours, dietary intake or health outcomes in participants compared to non-participants. Previous studies have compared an eligible population against an ineligible comparison group, showing the 'intention-to-treat' effect. Estimates of the Healthy Start impact within the eligible population are needed to decipher whether the programme is effective and provide greater information on how the policy is functioning within the target group.

Quality of school food

To determine how school meal policies affect the nutrition of low-income children, we must first understand the quality of school food. Quantitative studies comparing the quality of school meals against packed lunches provided evidence that school meals were typically the healthier option. However, the evidence is limited in several ways, leaving key questions unanswered.

Firstly, no study has been conducted after the food-based school food standards were introduced in 2015, meaning the findings may be outdated for the current school food service. Secondly, the current literature has not compared across primary and secondary schools. The benefit of having a school meal appears to be reduced in secondary school students, however this has not been quantitatively explored. There would be important implications for the effectiveness of school meal policies in secondary school children if their school meal quality is reduced. Thirdly, the studies have also limited in their geographical representation of the UK, with no studies covering Scotland, Wales, and Northern Ireland. Finally, to date, no study has described the intake of UPF in the school setting. It is hypothesised that school meals would reduce the intake of UPF, which could be an important yet unexplored dimension in school food. The degree of UPF exposure at school needs to be quantified to understand if this should be of public concern.

School meal schemes

There is a dearth of quantitative evidence on both FSM and UIFSM, resulting in a limited understanding on how the schemes impact food security and dietary intake.

Aside from a large-scale study on the impact of the policy on bodyweight outcomes, most of the understanding of the UIFSM scheme comes from a pilot study. The pilot study was limited in the geographical representation and the dietary indicators used. Consequently, little is known on the population-level impact of the UIFSM policy. As the policy is highly contentious, with calls for it either to be scrapped[318] or widened[319], greater understanding and evidence on the policy's effectiveness is needed.

In comparison to UIFSM, there is limited opportunity to evaluate the well-established FSM scheme. However, interruptions in the policy, such as the COVID-19 lockdown, provide an opportunity to evaluate the scheme. The COVID-pandemic and its catastrophic impact on daily life was an unforeseen event in my studentship. However, it provided a critical opportunity to meaningfully assess the impact of the COVID-19 lockdown on the FSM scheme.

3.2 Aim

This thesis aims to evaluate the impact of the nutrition welfare policies on measures of dietary intake in British children.

3.3 Objectives

Specific research objectives include:

- ➢ Examine the impact of the Healthy Start programme on household purchasing behaviours between 2010-2016 in a nationally representative sample of British households.
    a. To describe the geographical and social determinants of Healthy Start uptake.
    b. To determine whether Healthy Start participation is associated with differences in spending and quantity of fruit and vegetables and total food purchases among households who are Healthy Start participants, eligible non-participants, nearly eligible non-participants and ineligible non-participants.

- ➢ Examine the impact of school meal policies on dietary intake in a nationally representative sample of primary schoolchildren between 2010-2017.
    c. Quantify differences in food and nutrient content of school meals and packed lunches among primary and secondary schoolchildren in the UK
    d. Explore differences in the ultra-processed food content between school meals and packed lunches among primary and secondary schoolchildren in the UK
    e. Examine if the introduction of the Universal Infant Free School Meal policy in 2014 was associated with improved dietary intake among infant schoolchildren (4-7 years) compared to junior schoolchildren (8-11 years).
    f. Examine if the introduction of the Universal Infant Free School Meal policy in 2014 was associated with differences in ultra-processed food consumption among infant schoolchildren compared to junior schoolchildren.
    g. Determine whether Free School Meal access was affected during the COVID-19 ‘lockdown’ and describe which sociodemographic factors were associated with Free School Meal access.

Chapter 4. Methods

In this overall methods section, I will discuss common methodology across the thesis including the data sources and outcome measures.

4.1 Data sources

I will use routine data sources to quantitatively evaluate the nutrition welfare policies in this thesis. I summarise all the relevant datasets in Table 4.1 which could be used to evaluate the programmes and whether they are suitable to use for these research objectives. Additionally, the dataset must collect information during the time-period of the policy, datasets that don't include the right timeframe are not presented in Table 4.1. For this reason, high-quality longitudinal birth cohorts such as the MCS and ALSPAC were excluded as the children were too old to have received either Healthy Start or Universal Infant Free School meals.

Healthy Start

The critical requirement of the data source for this research objective was that it measured Healthy Start participation. As identified in Section 2.1, previous literature on Healthy Start used the eligibility for the programme as the exposure in their evaluation. To extend upon the previous research and add value to the literature, measurement of Healthy Start participation is needed. However, to identify a suitable comparison group in the analysis the data source must also collect information on welfare benefits and household characteristics such as children's age and women's pregnancy status to identify all Healthy Start eligible households. Finally, the data source must have a relevant outcome measure which can act as a proxy measure of dietary intake. Further discussion of dietary assessments is given in Section 4.3 and dietary outcome variables in Section 4.4

It can be seen in Table 4.1 that the only dataset which met these criteria was the Living Costs and Food Survey. The dataset contained information on Healthy Start participation, collected enough information on household composition and income to determine eligible households and through collecting information on household food purchases had a proxy measure for dietary intake. A limitation of the dataset is that it didn't measure individual-level dietary intake and data on Healthy Start participation was measured only from 2010 onwards.

School meal policies

To evaluate the impact of school meal policies on lunchtime dietary intake, a dataset must collect detailed dietary information of a school lunchtime and record what meal type (school meal or a packed lunch) was consumed. It is uncommon that routine datasets have detailed dietary information, as this is burdensome data to collect and analyse. Furthermore, as typically only the dietary diary assessment method records time and location, it is also uncommon that detailed dietary information can be analysed by time and location. Therefore, this level of granularity is rare in routine data. To assess socioeconomic inequalities in the programme impact, the data must also contain sufficient information on the participant's income and social status. Finally, to evaluate the introduction of UIFSM, the data set must have information before and after the implantation of the policy.

It can be seen in Table 4.1 that the only dataset which met these criteria was the National Diet and Nutrition Survey. The dietary information was detailed enough to have the time and location of each eating event, furthermore data was recorded over a sufficient timespan to evaluate school meal policies.

The dataset methodology and dietary assessment methods will be discussed later in the Methods chapter.

4.1.1 Ethical approval

Imperial College Research Ethics Committee (ICREC) have confirmed that ethical approval was not required for any of the research projects in this thesis. All projects involved a secondary analysis of a publicly available dataset, accessed via the UK data service.

Table 4.1 - Potential datasets to be used for secondary analysis and their strengths and limitations

DATASET	DESCRIPTION	HEALTHY START VARIABLES	SCHOOL MEAL VARIABLES	STRENGTHS	LIMITATIONS
Living Costs and Food Survey (LCFS) 2001-2017	Annual survey of British households that collects income and expenditure data. (*n*= 5,000 annually)	☑ HS eligibility ☑ HS receipt ☑ Outcome data ☑ Covariates	☑ FSM eligibility ☑ School meal use ☑ Outcome data ☑ Covariates	Nationally representative HS participation measured Food purchasing data (£ and Kg) FSM eligibility and school meal uptake measured	Time-series (not longitudinal) Household-level No dietary intake or health outcome
Diet and Nutrition Survey of infants and young children 2011	One-time cross-sectional survey of children 4-18 months collecting diet data (*n*=2,683)	☑ HS eligibility ☑ HS receipt ☑ Outcome ☑ Covariates	☒ FSM eligibility ☒ School meal use ☒ Outcome data ☒ Covariates	Detailed dietary intake and anthropometry data HS participation measured	Small sample size Cross-sectional Reduced age range Not school aged
Growing up in Scotland 2010-2018	Longitudinal study of Scottish children collecting health data (*n*=6,000)	☑ HS eligibility ☑ HS receipt ☑ Outcome ☑ Covariates	☒ FSM eligibility ☒ School meal use ☒ Outcome data ☒ Covariates	Detailed dietary intake and health data HS participation measured	Specific to Scotland In use by another research team
National Diet and Nutrition Survey 2008- 2017	Repeated survey of children and adults collecting diet data (*n*=~2,000 / survey)	☑ HS eligibility ☒ HS receipt ☑ Outcome data ☑ Covariates	☑ FSM eligibility ☑ School meal data ☑ Outcome data ☑ Covariates	Detailed dietary intake and anthropometry data School meal measured	Small sample size Cross-sectional HS participation not measured
Infant Feeding Survey 2010	Cross-sectional survey of mother and infants until 9 months collecting infant feeding data (*n*=~10,000)	☒ HS eligibility ☑ HS receipt ☒ Outcome ☑ Covariates	☒ FSM eligibility ☒ School meal use ☒ Outcome data ☒ Covariates	HS participation measured Infant feeding data	Cross-sectional Limited age range (< 9 months) No income data to assess eligibility Not school aged

Table 4.2 – Dietary assessment methods used in a selection of datasets and their strengths and limitations[320,321]

DATASET	DIETARY ASSESMENT METHOD	TIME SPAN	LEVEL OF ANALYSIS	STRENGTHS	LIMITATIONS
Living Costs and Food Survey (LCFS) 2001-2017	Expenditure diary recording the cost and weight of all food bought inside and outside of the house	Two-weeks averaged to one week	Household	Gives information on economic aspects of the diet Reflection on household intake	Not all food consumed may be recorded i.e. friend's house Unsure of household division of food Not all food bought will be consumed (household wastage)
Diet and Nutrition Survey of infants and young children 2011	Estimated diary recording the weight, type, location of all eating events	Four days	Individual	Detailed information on all foods consumed Validated methodology in young children	Limited timespan Self-reporting bias is high
Growing up in Scotland 2010-2018	Interview on frequency of consumption and dietary habits (Maternal recall)	One – seven days	Individual	Repeated dietary measures	Reporting bias is likely Lacks quantitative detail Limited range of outcomes
National Diet and Nutrition Survey 2008- 2017	Estimated diary recording the weight, type, location of all eating events	Four days	Individual	Detailed information on all foods consumed Validated methodology in young children	Limited timespan Self-reporting bias is high Proxy used for young children but not older.
Infant Feeding Survey 2010	Interview on breastfeeding and complimentary foods (Maternal recall)	9 months	Individual	Spans initial feeding practices for children, BF initiation and duration	Lacks detail on complimentary foods

4.1.2 Living Costs and Food Survey

The Living Costs and Food Survey (LCFS) is an annual cross-sectional survey of UK households which collects detailed income, expenditure, and sociodemographic data. Data have been collected from 2003 to 2018, with around 5,000 households surveyed per year. The LCFS dataset was found to have the most unexplored potential for evaluating the Healthy Start programme. The dataset directly measures Healthy Start participation from 2010 onwards and has detailed income and household characteristics data to accurately define Healthy Start eligibility. Expenditure and quantity of food purchases can be used as an outcome. However, there was no information on health outcomes or individual level consumption. Although this dataset collects information on school meal uptake, this has previously been analysed[250], therefore this dataset only has a use for evaluating Healthy Start and not school meal policies.

4.1.2.1 Dataset methodology

The LCFS used a multi-stage stratified random sample with clustering design to draw a representative sample of houses for the survey. Postcodes, from the Postcode Address File (maintained by the post office), were eligible if they contained a private household. The two-stage sample design used postcode sectors as the Primary Sampling Units (PSUs) which were drawn from a list of areas which were stratified by region, NS-SEC and car ownership.

Invited households were asked to complete an interview and a household expenditure diary. The interview consists of two sections: a general section completed by the Household Reference Person (HRP) and an individual section completed by each household member. Sociodemographic characteristics are collected in the general section. To ensure that the information given is accurate, interviewers are instructed to ask respondents to check documentation to confirm their responses, where relevant. Best estimates are recorded and sometimes used to impute missing data from 'don't know' responses. Proxy reviews for household members are permitted if a household member is not present, the level of proxy interviews have been rising, currently at 27%. Proxy interviews increase sample size and precision yet may reduce accuracy of the data. Expenditure diaries are given to every household member over the age of 7 years. Over a two-week period, they are asked to record all of their purchases including all food and drink. The weight and price of food purchased is recorded in the diary. All payment methods, including using a voucher are valid.

4.1.2.2 Dataset preparation

The quantity of household food purchases was not held in the LCFS dataset. Although collected in the same expenditure diary, they were stored in the Family Food database. The quantity data were extracted from the Family Food Microsoft Access database and combined with the LCFS database on Stata using household case number to merge the datasets.

4.1.3 National Diet and Nutrition Survey

The NDNS is also a repeated cross-sectional nationally representative survey in the UK. The survey aims to collect a ‘snapshot’ of the UK’s diet through surveying 1,000 adults and children per year. This dataset did not collect information on Healthy Start but contains all the correct information to evaluate school food policies. This data addresses key limitations in previous literature as it collects information after 2015, has detailed information on the dietary intake of school lunchtimes and can be used to compare the school lunches of both primary and secondary schoolchildren.

4.1.3.1 Dataset methodology

The NDNS similarly use a clustered random sampling methodology, drawing postcodes from the Postcode Address File, also clustered into PSUs. In each selected household, one adult and one child were invited to participate in the survey, although to get an equal number of children to adults, in some households just one child was asked to participate.

Participants were asked to complete an interview and a four-day estimated food diary. The interview collected sociodemographic information, dietary habits, and anthropomorphic measurements. The four-day diary was instructed to be completed on four consecutive days including at least one weekend day. Participants were asked to record the day, time, location, and portion size of everything they ate and drank over the study period. The food diaries of children less than 12 years old were completed by a carer. If at school, this was completed by school staff.

4.1.3.2 Dataset preparation

The NDNS provide the raw food-level data for each participant alongside aggregated averages by day and by person. To evaluate the impact of school meal policies, only food items consumed at a school premises at lunchtime were required. Consequently, to prepare the dataset for analysis I included only items consumed at a school premises, during lunchtime on a weekday. Due to the location of the item being recorded in the diary, and by using the age of the participant, the time and day of the eating event, I could be confident that these food items were consumed by a school pupil for their lunchtime meal. I then summed the outcome variables to get a total value per lunch and made an average per person. Some participants recorded more than one school lunch, ranging between one and four lunches.

4.1.3.3 Multiple imputation of income

There was a high proportion of participants who had missing household income data. As this variable was a central to all analyses, I used multiple imputation to account for the missing data. I assumed that the data were missing-at-random. Although this is a fundamentally untestable assumption[322], I determined that key outcome measures were not significantly different between those who had missing income data and those who did not. Moreover, I reasoned that including multiple other socioeconomic variables would help to account for the missing data.

The classification and regression trees (CART) method for multiple imputation was used. Standard approaches to multiple imputation estimate the value using linear regression models using a set of predictor variables. However, the household income variable in the NDNS was collected as a multi-categorical variable, with 13 ranges of income from £0-£5,000 to >£100,000. To equivalise the variable, the NDNS researchers took the mid-point of these ranges and divided them by an equivalence score, to adjust for the number and ages of people in their household. The result being that although the variable was continuous, it only had 547 unique values, with clusters at certain points. As a result, there was not enough variation in the values to perform the multiple imputation using linear regression methods, so CART was used which is better suited to multiple categorical variables. The CART method repeatedly partitions the data into small units conditional on predictor variables, creating small groups with homogenous outcome distributions which are used estimate the outcome variable[323]. The pooled average imputed value from ten iterations of the model were used. The following predictor variables were used in the imputation models: number of adults in household; household tenure; work status of HRP; ethnicity; region; sex of HRP; age of HRP; year; household size; social class; benefit status and index of multiple deprivation.

4.2 Study design

Cross-sectional and difference-in-differences study designs were used in the thesis to evaluate the research objectives. In this section I will explain why these study designs were the most appropriate option with the available data.

4.2.1 Cross-sectional studies

Analyses evaluating Healthy Start (Chapter 5) and the quality of school meals (Chapter 6 and Chapter 7) used a cross-sectional study design. Although there were multiple time points of data collected in both the LCFS and the NDNS datasets, cross-sectional study designs were the only appropriate option for the analyses.

Healthy Start

LCFS data are available from 2003 and Healthy Start was introduced in 2006, yet Healthy Start participation was only measured in LCFS from 2010 onwards (see Figure 4.1). Therefore, for the years 2006-2009 I could not determine Healthy Start participants from eligible non-participants, a key novel aspect of my analyses. This prevented me from evaluating the impact of the programme from its introduction using a before-after analysis or interrupted time-series analysis, as I did not have a baseline measurement for Healthy Start participants.

Another limiting factor was the sample size of Healthy Start eligible households collected in each survey year was low, reflecting the low prevalence of Healthy Start eligible households in the UK. The highest level was 144 households in 2011, falling to 70 households in 2016 (see Figure 4.2). The low annual sample size of households precluded an analysis with multiple timepoints. therefore, a cross-sectional study design was used, pooling years to retain sample size and statistical power

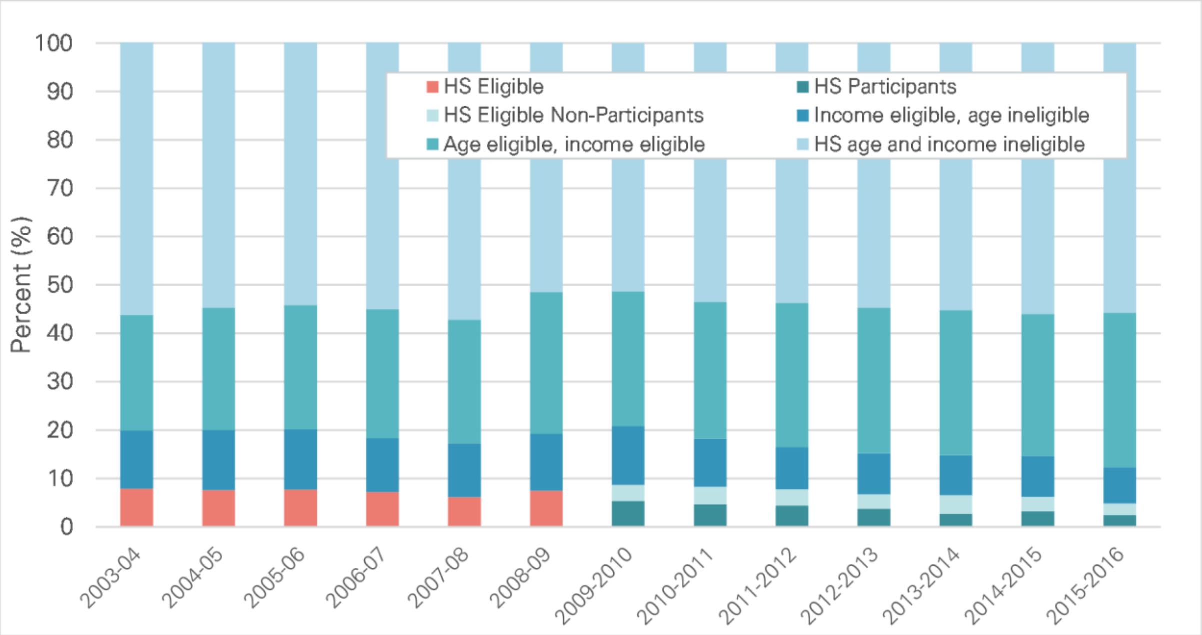

Figure 4.1 - Prevalence of Healthy Start eligible groups in the Living Costs and Survey dataset, survey years 2003-2016

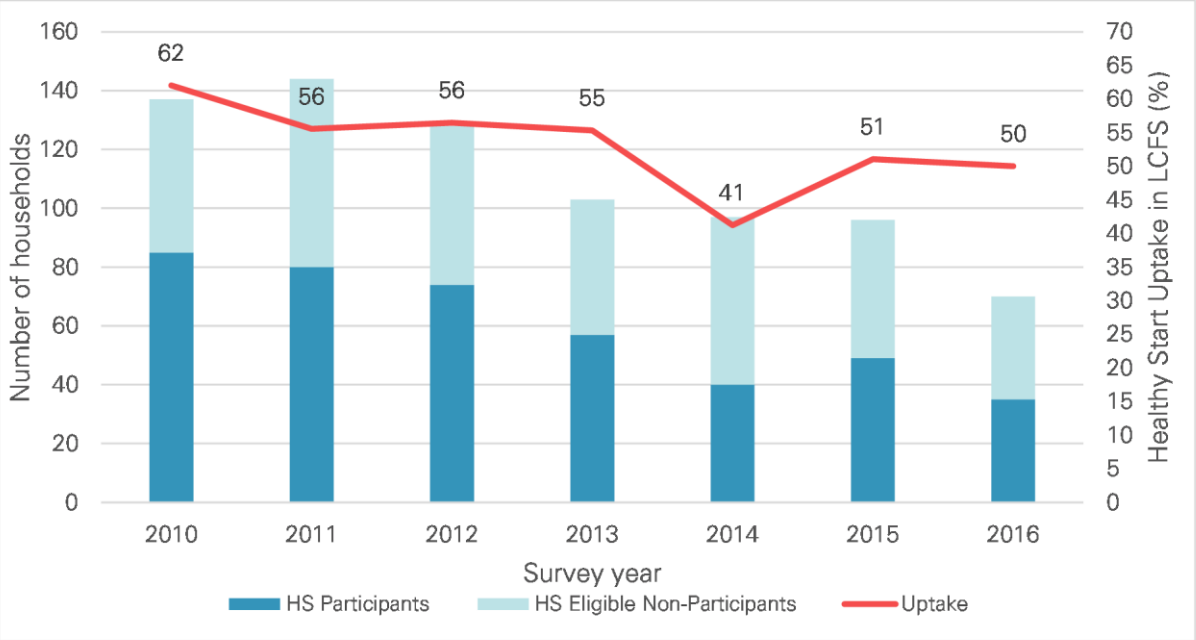

Figure 4.2 – Number of Healthy start eligible participating and non-participating households in the Living Cost and Food Survey dataset (Years 2010-2016) and the estimate Healthy Start uptake.

Quality of school food

In the NDNS, the annual sample size of school aged children who had recorded their lunch whilst at school was low, which precluded an analysis using multiple timepoints (See Table 4.3). All survey years were pooled to retain sample size and statistical power in analyses.

Table 4.3 - Annual sample size of school-aged children and prevalence in total sample in the National Diet and Nutrition Survey years 2008-2017 who recorded a school lunchtime intake

Survey year	Number	Percent
Year 1 (2008-2009)	411	12.4
Year 2 (2009-2010)	411	12.4
Year 3 (2010-2011)	386	11.7
Year 4 (2011-2012)	457	13.8
Year 5 (2012-2013)	271	8.2
Year 6 (2013-2014)	381	11.5
Year 7 (2014-2015)	303	9.1
Year 8 (2015-2016)	346	10.5
Year 9 (2016-2017)	337	10.2

Cross-sectional study designs are useful for describing associations between exposure and outcomes. However, there is a high chance of confounding as the study design cannot establish a temporal sequence to the association, so they cannot provide evidence of a causal relationship. In all analyses, time-period was included in the statistical models to account for variation which may have occurred over time. Further discussion of the limitation of pooling data into a cross-sectional study design is given in Section 11.2.

4.2.2 Difference-in-difference analysis

To evaluate the impact of the UIFSM policy on dietary quality (Chapter 8 and Chapter 9), I conducted a natural experiment evaluation using a difference-in-differences (DID) approach[324]. Natural experiments are beneficial as they allow the evaluation of an intervention using observational data in situations which cannot be studied experimentally, for a range of reasons. In this situation, it allows for a retrospective evaluation of a policy[324]. A DID study compares changes in an outcome between two groups of people, exposed and unexposed, at two time points, pre- and post-intervention (see Figure 4.3). In this way, the study controls for unobserved, time invariant differences between groups that are present at baseline and for time variant differences that occur over the study period and are common to both groups[325]. The assumption is made that the two groups have parallel trends, permitting the post-intervention outcome in the control group to estimate the outcome in the intervention group, had they not been exposed to the intervention.

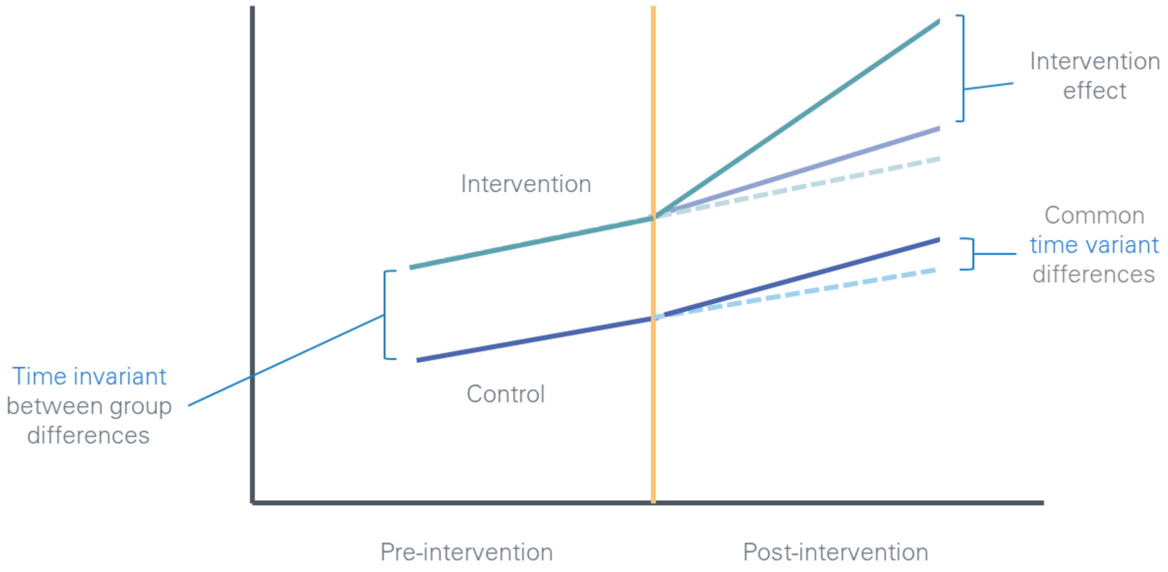

Figure 4.3 – Example of difference-in-differences study design

The strengths of using a DID design is that if the assumptions are met you can obtain a causal effect of a policy from observational data[326]. Furthermore, the comparisons groups can be at different baseline levels of the outcome variable as the estimate focuses on change in the outcome not absolute levels. However, it is impossible to fully test the parallel trends assumption and the study design is not suitable if the comparison groups change overtime. This study design is preferable to a before/after study design and a cross-sectional study design. However, it does not provide as the same strength of evidence as a randomised controlled trial.

4.3 Dietary assessment methods

Two dietary assessment methods used to collect the dietary data in this thesis were food expenditure diaries and estimated four-day dietary diaries. In this section, I will discuss these two assessment methods and compare their strengths and limitations before considering other dietary assessment methods. Additionally, I will discuss a common limitation of dietary assessment, misreporting, and how I corrected for this limitation in the research.

4.3.1 Food expenditure diary

Food expenditure diaries record all food purchased at the household level, including at shops and eating establishments. The method can give a useful reflection on household purchasing and dietary habits. Studies have demonstrated that dietary quality assessed though expenditure diaries is comparable with a 24-hour recall[327]. Young children do not have independent control over their diet, so it is important to consider the dietary habits of the entire household. Furthermore, the Healthy Start voucher may or may not be shared throughout the household, so analysing the diet on a household level is more likely to capture total effect. Furthermore, unlike other dietary assessment measures, this approach also links a proxy of dietary intake with the monetary value of the food. The method covers a reasonable amount of time, so will include most common dietary habits, but may not accurately record less frequently or bulk-purchased items. The LCFS methodology ensures even distribution throughout the year, to capture seasonal impacts on purchasing habits.

However, this assessment method is not a direct measure of individual dietary intake. Food may be wasted and not evenly shared between household members. As such it is not a reflection on actual intake. Furthermore, the diary will not include food which is consumed but not purchased within the study period such as food consumed at a friend's house or eating long-life food from the cupboards. The method is prone to reactivity and social desirability bias, in that the participants might change their purchasing habits through the knowledge of being recorded.

Although the food expenditure diaries were confirmed with receipts, there is likelihood for measurement bias through this method. To reduce participant burden, barcode scanners are used by some studies to speed recording of items purchased, this would also allow for fast association of back-of-pack nutrition data.

4.3.2 Estimated dietary diary

The weighed dietary diary was often considered as a gold standard among the options for self-reported dietary assessment[328]. The method records a large amount of detail which is useful for getting a granular picture of the food and nutrient content of the diet[321]. Additionally, depending on the length of the diet, the dietary diary can capture the within-person variation in the diet, especially if both weekday and weekends are included. Furthermore, NDNS methodology evenly spaces dietary assessment to account for seasonal variation in intake[329]. However, food eaten less than weekly may not be accurately recorded[320]. Other benefits of this methods are that it does not require participant's memory and can be filled in by a proxy reporter, which is important for studying young children[330].

However, this method can be highly burdensome for the participant[320,321]. Weighing all food eaten is impractical for food eaten outside of the house and may lead to errors in recording. Subconsciously or otherwise, participants may alter their diet for the days recorded or be less likely to record unhealthy items they consume (reactivity and social desirability bias). To reduce participant burden, the number of days recorded can be reduced and estimated weights can be used, using household measures which are standardized through participant training. The NDNS validated this approach against other dietary assessment methods.

Dietary diaries are burdensome for both the participant and the research team, they require the participant to be literate and are prone to reactivity bias. Other forms of dietary assessment methods have been developed to counteract these limitations[320,321]. For example, 24-hour dietary recalls involve a trained nutritionist or online programme asking an individual about their diet over the previous 24 hours. The dietary information recorded can be highly detailed. The recall may be random, to prevent participants consciously altering their dietary intake, and is less burdensome for the participant. However, the method depends on the participant's memory and is still prone to selective reporting of food items. The method also may not accurately record foods which are eaten infrequently and unless the dietary recall is repeated on multiple days, the result may not be generalisable to the total diet. Food Frequency Questionnaires (FFQ) are more appropriate at capturing the total dietary pattern, including frequently consumed foods. In an FFQ participants are required to estimate how frequently they consume each item from a list of foods. This method is less burdensome, yet it requires participant memory, is not accurate for recording portion sizes and requires a complete and comprehensive list of food items, which is highly unlikely to be relevant to all people in an ethnically diverse population.

The estimated food diary has been validated against other forms of dietary intake method[321,331] and is appropriate for recording the diet of a young population, therefore it is reasonable to conclude that this is an appropriate dietary assessment method for the research question.

4.3.3 Energy misreporting

Self-reported dietary assessment methods are prone to misreporting, due to reactivity and social desirability bias[320,321]. All forms of dietary assessment have been shown to be associated with misreporting of energy intake when compared to the doubly labelled water (DLW) technique, which is an objective biomarker of energy requirement [328,330]. For example, NDNS compared reported energy intake and energy requirements measured through DLW in survey years 1-3, finding that children aged 4-10 years underreported their energy intake by 11-13% and children aged 11-15 years underreported their energy intake by 24-28%, compared to their estimated energy requirement[332]. As it is known that reporting is systematically different for certain foods or individuals, such as unhealthy foods or obese individuals, dietary misreporting can seriously impact the validity of dietary analyses if not addressed[328,333].

The DLW technique is expensive and could only be performed on a subset of NDNS participants. Methods of identifying possible energy intake misreporters have been developed to address information bias in self-reported dietary data. Simple cut-offs for implausible energy intake (<500 kcal/day and >3500kcal/day) have been proposed, however this approach is not sensitive to variation in energy requirement between people and is only suitable for an adult population[334]. More sensitive methods estimate energy requirements through calculating each participant's basal metabolic requirement using the Schofield equations and an estimate of their activity level. The Goldberg cut-offs compare the ratio of reported energy intake to estimated energy requirements and identify levels which are feasibly high or low, within a 95% confidence interval[320,328,335]. The Goldberg method has been adapted for use in children[336]. This method has flaws[320,337], it is dependent on the quality of dietary data, and is more accurate with individual dietary data and numerous dietary days recorded. One study suggested the method only identifies 50% of under-reporters. However, the method serves as a useful technique of identifying some implausible dietary intakes in the dataset in absence of DLW data.

4.4 Dietary outcome variables

As mentioned in the introduction, there are many approaches to analysing dietary intake. Diets can be considered by their nutrient content, the foods in their diet, as a dietary pattern and by the level of industrial food processing. Each approach has strengths and limitations, which will be discussed below.

4.4.1.1 Nutrient content

Assessing the nutrient content of food is a classic way of analysing the diet. The benefits of this approach are that it relates directly to health impacts, it is widely comparable to the literature and many dietary guidelines use nutrient thresholds to set standards. Therefore, by using nutrient outcomes the analysis is comparable to both previous literature and Government dietary guidelines. However, the nutrient content of food is invisible, as we eat food not individual nutrients, this outcome variable is difficult to interpret in a real-world setting. Although technically useful, nutrients should not be analysed in isolation

4.4.1.2 Food groups

Many guidelines and standards are also given by food groups, due to the issue of interpreting nutrient values. For example, the guidance to eat 5 portions of fruit and vegetables a day or the 2015 School Food Standards, which are food based. These are typically based upon the botanical grouping of foods such as dairy, cereals and meat. Therefore, an analysis of food groups consumed is useful alongside the nutrient content to help interpret the findings. However, analysing all the relevant nutrient and food groups variables results in many outcomes to interpret.

4.4.1.3 Dietary patterns

Composite scores can be useful to describe overall dietary patterns. There have been a number of indices which have been adapted and validated for children and adolescents[338]. However, these have been designed to analyse whole dietary patterns, rather than one meal. Moreover, there is not frequent use of these scores in the UK context. Therefore, it was decided a composite score was not appropriate in this context.

4.4.1.4 Level *of processing (NOVA)*

The NOVA food classification system is the predominant way of categorising the degree of industrial processing in food. It uses four food groups to categorise food, which are presented in Table 4.4.

Table 4.4 - Description of NOVA food classification

NOVA GROUP	DESCRIPTION
GROUP 1 Unprocessed or minimally processed foods *Fresh, frozen, or dried fruit and vegetables, pasteurised milk, plain yoghurt, flour, whole grains, pasta and tea or coffee.*	Unprocessed food is the edible part of plants, animals, or fungi after they are removed from their origin. Often food requires small amounts of processing to be edible this may include removal of inedible parts; drying; grinding; boiling; roasting' pasteurisation and squeezing. If the processes are not industrial and do not add additional ingredients (oil, salt and fat) then the product is considered minimally processed
GROUP 2 Processed culinary ingredients *Butter, vegetable oil, syrup, salt*	Products obtained from minimally processed foods which undergo industrial processes such as milling, refining or extracting to create culinary ingredients. These foods, such as oils, sugar, honey and salt are used to prepare group 1 foods.
GROUP 3 Processed foods *Canned or brined vegetables, jam, salted fish, smoked meats, cheese.*	Products (but not meals), which are produced by adding culinary ingredients to minimally processed foods. The processes such as canning, salting, cooking with ingredients such as salt, sugar and oil will make the product have an increased shelf life and modify the taste and texture of the food.
GROUP 4 Ultra-Processed foods *Carbonated drinks, confectionary, ice-cream, breakfast cereals, ready-to-heat meals, sausages, reconstituted meat products, infant formula, mass-produced bread.*	Products which have gone industrial level processing, have been combined with artificial ingredients and are typically unrecognisable from their minimally processed origin. Typically, these are products which could not be made in a domestic kitchen and come pre-packaged and ready-to-eat. Ultra-processing techniques include fractioning, extrusion, pre-frying, hydrogenation, and moulding. Artificial ingredients include hydrogenated oils, high-fructose corn syrup, emulsifiers, flavourings, and preservatives.

Note: Adapted from Monteiro[339]

As mentioned in the introduction, the level of processing captures many important aspects of the diet not captured in the previous dietary indicators. For example, standard food groups use in nutritional sciences would group items such as grilled chicken and a chicken nugget together and French fries with jacket potatoes (see Figure 4.4). The UPF version of a product is likely to be higher in fat, salt and sugar[42]. Aside from the nutritional content, the ultra-processed version will have a modified texture which can have negative consequences for digestion and blood sugar levels[340,341]. It is also more likely to contain additional additives. For these reasons, the degree of processing is a dimension of dietary intake which is important to quantify and has so far not been described in UK school food.

Classification of food items in years 1-8 of the NDNS was performed by colleagues and shared for this project[45]. Uncoded items in year 9 of the NDNS were independently coded by me and another colleague, using the food name, food group and eating location to categorise food items into the four NOVA groups. Any disagreements in coding were discussed and mutually agreed upon.

Figure 4.4 - Examples of minimally (left) and ultra-processed (right) chicken products

Note: Photos by Nathan Dumlao and Fernando Andrade from Unsplash.com

4.5 Statistical analyses

In this section I will discuss some of the main considerations made in the statistical analyses across the research in this thesis.

4.5.1 Analysing non-normally distributed outcome data.

The expenditure, food group and industrial processing outcome variables analysed in this study were all right skewed, with an inflation of zero-vales (See Figure 4.5). This is linked to the frequency of food consumption. Variation in dietary pattern between people results in a high frequency of zero-values as individuals choose not to consume a food group. The only variables found to be normally distributed were macronutrient variables, as they were consistent components of all participants' diets. Linear regression models assume that the errors in the model are normally distributed and that there is an linear association between the dependant and independent variables[342]. The skewed distribution in many of the outcome variables resulted in the residuals having a non-normal distribution. In this case the estimates from a linear regression would have been biased as the assumption of normality was violated[343]. Therefore, alternative approaches to analysing the data were explored.

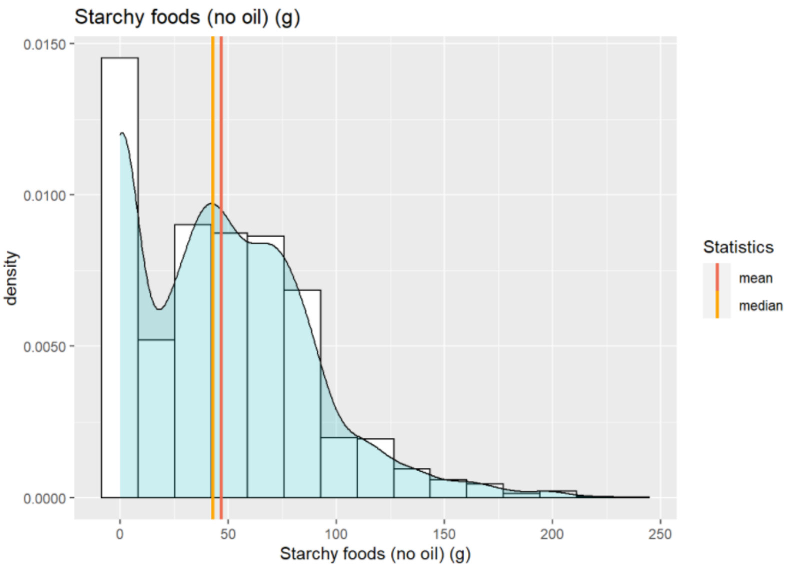

Figure 4.5 - Distribution of an outcome variable (Starchy foods [g/lunch]) among schoolchildren in the National Diet and Nutrition Survey (2010-2017)

4.5.1.1 Data transformation

A common approach to addressing this issue is to statistically transform the data, such as a logarithmic transformation, to give the data a normal distribution. Although this may work for some non-normal distributions, when there is a large inflation of zero values, transformation does not have the desired effect of making the distribution of residuals normal[344]. Another issue is that transformation changes the scale of the coefficients, complicating the interpretation of the results. It was important the results were interpretable for a wide audience, including policy makers. Furthermore, as back transformation can result in bias[342], it was decided data transformation was not an appropriate approach to analysing the data.

4.5.1.2 Quantile regression

Linear regression models the association between the dependant and independent variables using the conditional mean function[343,345]. However, quantile regression models the relationship using the conditional quantile function, and as such has no distributional assumptions. Therefore, quantile regression, unlike linear regression, is not impacted by extreme outlying values. A secondary benefit of quantile regression is that any quantile (e.g. 25th, 50th or 75th) can be used, allowing for the relationship between the dependant and independent variables to be assessed at different points along the distribution of the dependant variable.

It was decided that for the analyses in 0, the outlying values in the expenditure data would have biased the estimates from a linear regression. Furthermore, as expenditure on food items can vary greatly within a group, it was important to model the association at higher and lower distributions of food expenditure. Finally, using quantile regression allowed for the scale of the coefficients to remain as £/week, so the results remained easily interpretable to the audience.

4.5.1.3 Logistic regression

Dichotomising the outcome variable and performing logistic regression is another approach to analysing non-normally distributed data[344]. The approach removes any assumptions on the data distribution and the coefficients are easily interpreted as odds ratios. Yet, this approach is sometimes criticised due to the loss of information by categorising the continuous outcome variable[344]. However, in Chapter 6, dichotomising the outcome variables was aligned with dietary recommendations for school children's lunchtime intake. Therefore, in this case loss of information was outweighed by the added interpretability and relevance to policy.

4.5.1.4 Two-stage hurdle models

The use of a DID study design in Chapter 8 and Chapter 9 complicated the approach to analysing non-normally distributed data. Both quantile regression and linear regression cannot be used in a DID analysis. In a logistic regression, the DID estimator would be a ratio of two odds ratio, which is not intuitive to interpret. Furthermore, there is not a precedent for the use of quantile regression in DID analysis. Two stage hurdle models are another approach to analysing non-parametric data[343,344]. A two-stage model asks two separate questions of the data: (i) what is like likelihood of having a non-zero outcome compared to a zero outcome? and (ii) among those who have non-zero values, what is the difference in the outcome variable? The first stage is similar to a logistic regression model, however, is performed using a linear probability model to allow the DID estimator to be interpreted as a percentage point change. The second stage is performed using a standard linear regression model; after removing the zero-values the normal distribution assumption of linear regression is no longer violated. Therefore, two stage hurdle models were chosen to analyse the non-parametric outcome data in the DID model as it enabled permitted regressions to be used in conjugation with the DID study design.

Chapter 5. Healthy Start

This chapter has since been modified and published in BMC Public Health (2021)[346].

5.1 Background

In the UK, individuals from lower socioeconomic positions are more likely to consume an unhealthy diet (Section 1.1.2), with negative consequences for their long-term health, putting them at greater risk of morbidity and mortality than higher socioeconomic groups (Section 1.1.3) The financial barrier to a healthy diet has been identified as one of the contributing factors to the socioeconomic inequalities in diets, which is being exacerbated by differential price inflation of healthy and unhealthy foods (Section 1.1.2.2).

The Healthy Start programme is one example of a food assistance programme in the UK which aims to address food insecurity through the provision of cash-value vouchers (Section 1.2.4). Qualitative evaluations have found that Healthy Start vouchers were valued by recipients and helped reduce the experience of food insecurity[199,258,262]. However, the only two existing large-scale quantitative evaluations of Healthy Start are in contradiction; with one reporting a null effect on fruit and vegetable intake[267] and the other reporting a positive effect on fruit and vegetable purchasing[264]. These two previous evaluations used Healthy Start eligibility, not participation, as the exposure variable. Not all eligible households participate in Healthy Start, with evidence showing that programme uptake has been falling in recent years[212]. It is currently unknown which household characteristics are associated with participation in Healthy Start. Moreover, there is no evidence on whether participation is associated with different spending within the eligible population. It is important for policy makers to understand if Healthy Start reaches its target population and whether it is effective at improving the nutrition of low-income families.

In this study, I aim to determine whether Healthy Start participation is associated with differences in purchasing of fruit and vegetables, infant formula and total food purchases among households who are Healthy Start participants, eligible non-participants, nearly eligible non-participants and ineligible non-participants.

5.2 Methods

5.2.1 Data source

The LCFS, a repeat cross-sectional and nationally representative survey, was used as the data source for this study and is described in greater detail in Chapter 4.

5.2.2 Study design

As discussed in Section 4.2.1 the study design options were limited as Healthy Start participation was only measured in LCFS from 2010 onwards and the sample size of Healthy Start eligible households collected in each survey year was low. Therefore, a cross-sectional study design was used, pooling years 2010-2016.

5.2.3 Study participants

The Healthy Start eligibility criteria (see Table 1.2) has both age and income specifications; the household must contain either a pregnant woman or child aged three years or below and receive income-related state benefits. Resultantly, there were two potential groups of households that could be used as a comparison group. Firstly, the income-eligible but age-ineligible groups are households who receive a qualifying income-related benefit but have a child over the age of three years old. Secondly, the income-ineligible but age-eligible group are households with a child less than three years or a pregnant woman but are over the income threshold. Although the income-eligible, age-ineligible households have been used as a comparison group in previous studies[264], it was decided that the exposure and comparison groups should have a consistent age-profile to simplify the comparisons. A higher average age of children in the household could distort the household purchases, as they buy larger amounts of possibly different types of foods. Moreover, capturing the effect of differing income was considered as a more important dynamic to study than the effect of age. Consequently, only households of all incomes that contained a pregnant woman or child aged 0-3 years were included in the analytic sample. The Healthy Start vouchers are dispensed at the household level, therefore the household was used as the unit of analysis. There was a total of 42,034 households surveyed across years 2010-2017 in the LCFS. In total, 37,147 households not containing a child 0-3 years or pregnant woman were excluded, additionally 25 households with missing data were excluded, leaving 4,869 households in the study.

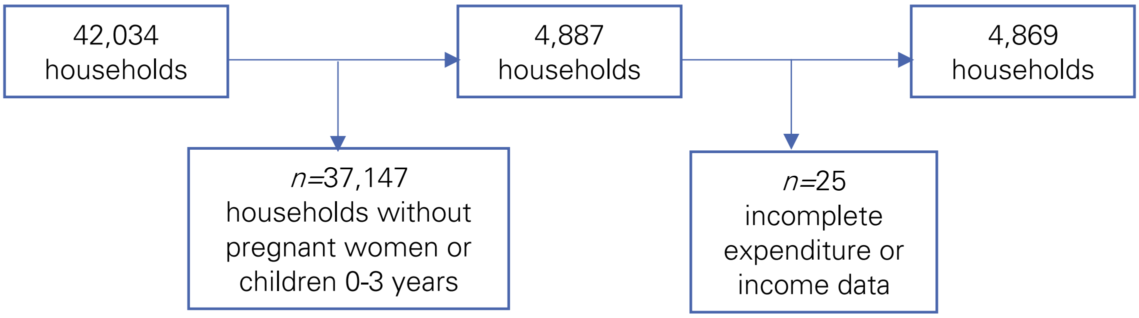

Figure 5.1 - Flow diagram of sample exclusions from the Living Costs and Food Survey

5.2.4 Exposure Variable

Data on income and welfare benefits were collected through interview and confirmed through official documentation (e.g. payslips). Income was equivalised using OECD scales to account for the effect of household size and composition on expenditure[347] Income-level was used to stratify the exposure groups. Households were categorised as eligible for Healthy Start if they received a qualifying income-related welfare benefit (Table 1.2). This group was further divided by participation in the Healthy Start scheme. The remaining households did not receive a qualifying benefit, therefore were ineligible for Healthy Start. Ineligible households were also divided into two groups, low- and high-income households. Households were defined as low-income if they had an income less than 60% of the median disposable income that year, after adjustment for inflation, congruent with government reports[106]. The low-income group represented households who just missed out on welfare schemes but were still at a high risk of experiencing food insecurity. The high-income group was included to explore and quantify differences in household expenditure across the socioeconomic gradient.

In summary, the four exposure groups derived were:

- Healthy Start Eligible Participants

  Households who received an income-related welfare benefit and reported receiving Healthy Start vouchers.

- Healthy Start Eligible Non-participants

  Households who received an income-related welfare benefit but did not report receiving Healthy Start vouchers.

- Nearly Eligible Non-participants

  Households defined as low-income but did not receive benefits. (<60% of the median disposable income)

- Ineligible Non-participants

  Households who were neither low-income nor received benefits (>60% of the median disposable income)

5.2.5 Outcome Variables

The price (£) and amount (kg) of all purchases were recorded in a two-week expenditure diary and averaged to one week. The diaries were confirmed by receipts where possible and included purchases using any form of payment, including vouchers. Both the expenditure and quantity of food purchases were used as outcomes, this was so that I could explore whether households chose different priced products within the same category. For example, low-income households are more likely to be price sensitive and therefore may choose fruit and vegetables which are lower in cost, but not volume[124]. This is important as only differences in the quantity of food purchased have important implications for health.

Healthy Start vouchers can only be redeemed against target food items, at registered Healthy Start retailers. Therefore, the outcome variables were defined following Healthy Start voucher guidelines. Any foods bought in an eating establishment were excluded.

- Fruit and vegetables:

  An aggregate variable including all plain fruit and vegetables with no added ingredients such as salt, fat or sugar. Frozen fruit and vegetables were included from 2011. See Appendix Table I.a for details of fruit and vegetable sub-categories.

- Cow's milk

  Cow's milk may be of any fat content and includes pasteurised, sterilised, long-life or ultra-heat treated (UHT) products. Excludes milk which is flavoured, condensed, or evaporated and alternative milks such as soya or oat milk.

- Infant Formula

  Powdered or liquid cow's milk based infant formula which is suitable from birth to one year. Follow-on formula for children over one year old is not permitted, however LCFS categories did not specify the formula's age-range. Therefore, this outcome variable was only analysed for households with a child less than one year old.

- Healthy Start foods

  An aggregate variable, combining fruit, vegetables, cow's milk, and infant formula.

- Total food

  Total food was defined as all food purchased by the household, excluding alcoholic beverages and food purchased in eating establishments.

To summarise, the following variables were used as outcome variables, all averaged across one week per household: (i) fruit and vegetable expenditure (£/week); (ii) Healthy Start foods expenditure (£/week); (iii) infant formula expenditure (£/week); (iv) total food expenditure (£/week); (v) fruit and vegetable quantity (kg/week) and (vi) Healthy Start foods quantity (kg/week).

Analysis using quantity variables as outcomes were restricted to years 2010-2015 as data on quantity of purchases for years 2016-17 were not released at the time of analysis.

5.2.6 Covariates

Covariates included survey year, survey quarter, household size, number of children in the household, age of HRP(years), ethnicity of HRP (White or Ethnic minorities), National Statistics Socioeconomic

Classification (NS-SEC) social class (higher professional occupations, intermediate occupations, routine and manual occupations and unemployed or students), age HRP completed full-time education (<16 years; 16-18 years and >18 years) and region (North, Midlands, East, London, South, Wales, Scotland and Northern Ireland).

5.2.7 Statistical analysis

To account for inflation, income and expenditure variables were adjusted using category specific Consumer Price Indices, using 2017 as the base year[124]. Indicators for survey year and quarter were included to control for macroeconomic differences across time. Survey weights, generated by LCFS, were used in all analyses to account for non-response bias and to produce results representative to the population. Analyses using infant formula as an outcome were performed on a subsample of households containing a child less than one-year old (*n*=1,260), as the vouchers may only be redeemed for infant formula for this age-range.

Significance tests were performed to examine the characteristics between (i) Healthy Start Eligible Participants and Eligible Non-participants; and (ii) across all four exposure groups. Depending on the variables, a student t-test, χ^2 test, Mann-Whitney, ANOVA or Kruskal-Wallis test were performed (See Table 5.1 for details).

Multivariable quantile regression was used to assess differences in each outcome between the four exposure groups, using Healthy Start Eligible Non-participants as the reference group. The outcome variables were found to be positively skewed. Linear regression models are conditional on the mean and assume normal distribution of residuals so are sensitive to skewed distributions[345]. Quantile regression estimates the median (or other percentile) of the outcome distribution instead of the mean so is therefore less sensitive to the influence of outliers. Quantile regression also allows for the effects of the covariates to differ at different points of the outcome distribution. Results are presented for the 25th, 50th and 75th percentiles of the outcome variable.

Ordinary least squares (OLS) regression was also performed and presented alongside results of the quantile regression as a comparison between the two methods and to check for robustness. Wald tests were performed to test for equality between Nearly Eligible and Ineligible coefficients at the 25th, 50th and 75th percentile. Multicollinearity was tested by calculating variation inflation factors (VIF), all values were below 10 (max VIF=1.51) indicating no evidence for multicollinearity.

Covariates were added into the regression models in a stepwise manner. Model 1 adjusted for survey year and survey quarter. Model 2 additionally included household size, number of children and age of HRP. Model 3 additionally included ethnicity of HRP, NS-SEC social class, age HRP completed full-time education and region.

For sensitivity analyses, the same descriptive analyses and quantile regressions on expenditure outcomes were performed after excluding participants without quantity of food purchases data (2015-2017). See Appendix Table I.b.

Stata V.15 (StataCorp) was used to perform all descriptive and inference tests, using a 95% confidence level for significance.

5.3 Results

Table 5.1 presents the characteristics of the analytic sample. A total of 876 households were eligible for Healthy Start, of these, 54% (*n*=475) reported participating in Healthy Start and 46% (*n*=401) households were Eligible Non-participants. Healthy Start Participants and Eligible Non-participants had similar mean income level, ethnicity, and education, but participants were more likely to be in a lower social class and have young children but were less likely to contain a pregnant woman than Eligible Non-participants. Households which were ineligible for Healthy Start were found to be older and have a higher occupation, education, and income levels than eligible households.

Table 5.1 - Sample characteristics of households containing children 0-3 years or pregnant women in the Living Costs and Food Survey (2010-2017), stratified by Healthy Start participation

		HS Participants		HS Non-participants			Nearly Eligible		Ineligible		Total		
	N (%)	475	(9.8)	401	(8.2)	*P*[a]	428	(8.8)	3565	(73.2)	4869	(100.0)	*P*[b]
Household size	Mean (SD)	3.73	(1.5)	3.5	(1.4)	0.06[c]	3.3	(1.1)	3.8	(1.1)	3.74	(1.2)	<0.01[f]
Number of children	Mean (SD)	2.22	(1.3)	1.8	(1.1)	<0.01[c]	1.6	(0.9)	1.8	(1.0)	1.79	(1.0)	<0.01[f]
Number of children 0-3 years old	Mean (SD)	1.2	(0.5)	1.0	(0.5)	<0.01[c]	1.0	(0.5)	1.1	(0.5)	1.08	(0.5)	<0.01[f]
Households with children <1-year-old	N (%)	117	(24.6)	99	(24.7)	0.97[d]	110	(25.7)	943	(26.5)	1269	(26.1)	0.74[d]
Households with pregnant women	N (%)	45	(9.6)	66	(16.6)	<0.01 [d]	85	(20.2)	473	(13.3)	669	(13.8)	<0.01[d]
Age of HRP (years)	Mean (SD)	31.1	(9.4)	32.8	(10.5)	<0.01[c]	33.3	(8.6)	35.8	(7.3)	34.84	(8.1)	<0.01[f]
Disposable household income (£/week)	Mean (SD)	153.4	(73.6)	155.6	(79.3)	0.66[c]	164.6	(57.8)	405.3	(179.7)	339.00	(192.3)	<0.01[f]
Ethnicity of HRP	N (%)					0.76 [d]							<0.01[d]
White		400	(84.0)	340	(84.8)		313	(73.1)	3047	(85.5)	4100	(84.2)	
Ethnic minority		76	(16.0)	61	(15.2)		115	(26.8)	518	(14.5)	770	(15.8)	
Social Class of HRP	N (%)					<0.01 [d]							<0.01[d]
Higher occupations		30	(6.3)	42	(10.6)		79	(18.5)	1915	(53.7)	2066	(42.4)	
Intermediate		32	(6.7)	52	(13.0)		95	(22.2)	624	(17.5)	803	(16.5)	
Routine occupations		143	(30.0)	141	(35.2)		212	(49.5)	886	(24.9)	1382	(28.4)	
Unemployed / students		271	(56.9)	166	(41.4)		42	(9.8)	140	(3.9)	619	(12.7)	
Education of HRP	N (%)					0.49 [d]							<0.01[d]
< 16 years		79	(16.6)	55	(13.7)		45	(10.5)	128	(3.6)	307	(6.3)	
16-18 years		305	(64.1)	268	(66.8)		249	(58.2)	1733	(48.6)	2555	(52.5)	
>18 years		92	(19.3)	78	(19.5)		134	(31.3)	1704	(47.8)	2008	(41.2)	
Region	N (%)					0.05 [d]							<0.01[d]
North		140	(29.4)	112	(27.9)		117	(27.3)	839	(23.5)	1208	(24.8)	
Midlands		85	(17.7)	58	(14.5)		70	(16.4)	575	(16.1)	788	(16.2)	
East		38	(8.0)	27	(6.7)		43	(10.1)	386	(10.8)	494	(10.1)	
London		49	(10.3)	58	(14.5)		47	(11.0)	396	(11.1)	550	(11.3)	
South		85	(17.9)	51	(12.7)		79	(18.5)	819	(23.0)	1034	(21.2)	
Wales		25	(5.3)	18	(4.5)		13	(3.0)	166	(4.7)	222	(4.6)	
Scotland		37	(7.8)	44	(11.0)		33	(7.7)	263	(7.4)	377	(7.4)	
N. Ireland		17	(3.6)	33	(8.3)		26	(6.1)	121	(3.4)	197	(4.1)	

		HS Participants		HS Non-participants			Nearly Eligible		Ineligible		Total		
Total Food Expenditure (£/week)	Median (IQR)	43.5	(37.1)	44.54	(44.2)	0.28 [e]	49.10	(39.0)	67.1	(43.3)	61.6	(44.8)	<0.01[g]
HS Foods expenditure (£/week)	Median (IQR)	6.7	(8.6)	7.72	(8.9)	0.06 [e]	10.29	(11.2)	13.2	(12.0)	11.8	(12.0)	<0.01[g]
HS Foods quantity (Kg/week) [h]	Median (IQR)	7.4	(7.5)	7.92	(8.4)	0.68 [e]	9.56	(8.6)	10.6	(8.8)	9.9	(8.6)	0.01[g]
FV expenditure (£/week)	Median (IQR)	3.7	(6.3)	4.47	(6.8)	0.11 [e]	5.91	(8.5)	9.1	(10.0)	7.8	(9.7)	<0.01[g]
FV quantity (Kg/week) [h]	Median (IQR)	2.5	(4.0)	2.96	(4.7)	0.26 [e]	4.03	(4.9)	5.1	(4.7)	4.5	(4.9)	0.01[g]
Milk expenditure (£/week)	Median (IQR)	1.8	(2.5)	2.00	(2.4)	0.32 [e]	1.77	(2.1)	2.2	(2.4)	2.1	(2.4)	<0.01[g]
Milk quantity (L/week) [h]	Median (IQR)	1.9	(2.5)	2.10	(2.6)	0.62 [e]	1.84	(1.9)	2.2	(2.4)	2.1	(2.4)	0.01[g]
Infant Formula expenditure (£/week) [i]	Median (IQR)	1.5	(4.3)	3.97	(7.5)	0.23 [e]	4.04	(7.3)	3.9	(8.2)	3.7	(7.9)	0.04[g]
Infant Formula quantity (Kg/week) [j]	Median (IQR)	1.8	(3.2)	3.15	(6.3)	0.04 [e]	3.15	(6.3)	3.2	(6.3)	3.2	(6.3)	0.23[g]

FV- Fruit and Vegetables; HS - Healthy Start; HRP – Household Reference Person; IQR – Interquartile Range; SD – Standard Deviation.

a) Significance test between HS participants and HS non-participants. Null hypothesis is that there is no difference between either the distribution of covariate or mean value between HS participants and HS non-participants.

b) Significance test across total sample. Null hypothesis is that there is no difference between either the distribution of covariate or mean value across HS participants, HS non-participants, Nearly Eligible Non-Participants and Ineligible Participants.

c) Student t-test; d) χ^2 test; e) Mann-Whitney test, f) ANOVA g) Kruskal-Wallis test

Results of the median quantile regression of fruit and vegetable, Healthy Start foods, infant formula, and total food expenditure across the four exposure groups are displayed in Table 5.2. In the minimally adjusted model, a significant lower purchase of fruit and vegetable and Healthy Start foods was observed in Healthy Start Participants compared to Eligible Non-participants. However, differences did not persist. In the fully adjusted models, there was no statistically significant difference between Healthy Start Participants and Eligible Non-participants in fruit and vegetable, Healthy Start food or total food expenditure. Infant formula purchases were significantly lower in Healthy Start Participants (-1.82 £/week; 95% CI -3.12, -0.51). Cow's milk was tested as an outcome but there was no difference in expenditure across all groups (Table 5.2). Nearly Eligible and Ineligible households, however, were observed with higher fruit and vegetable and Healthy Start food expenditure than Eligible Non-participants. For total food expenditure, only Ineligible households had significantly higher spending compared to Eligible Non-participants (7.30 £/week; 95% CI 3.06, 11.53).

Table 5.2 - Median regression of Healthy Start participation on food expenditure in Living Costs and Food Survey (years 2010-2017, *n*=4,870)

	Model 1		**Model 2**		**Model 3**	
	Coef.	(95% CI)	Coef.	(95% CI)	Coef.	(95% CI)
FV expenditure (£/week)						
HS Participants	-0.89*	(-1.67, -0.10)	-0.25	(-0.80,0.29)	0.37	(-0.37,1.11)
HS Non-participants	-	-	-	-	-	-
Nearly Eligible	1.56**	(0.49,2.63)	1.40**	(0.49,2.31)	1.14*	(0.18,2.09)
Ineligible	4.56***	(3.88,5.23)	3.55***	(2.91,4.18)	2.22***	(1.57,2.86)
HS food expenditure (£/week)						
HS Participants	-1.14*	(-2.27, -0.00)	-0.64	(-1.48,0.20)	-0.07	(-0.85,0.71)
HS Non-participants	-	-	-	-	-	-
Nearly Eligible	2.05**	(0.81,3.29)	1.96***	(0.84,3.09)	1.60***	(0.79,2.41)
Ineligible	5.11***	(4.26,5.97)	3.69***	(2.86,4.51)	2.56***	(1.77,3.35)
Infant formula expenditure (£/week) [a]						
HS Participants	-3.07***	(-4.80, -1.35)	-2.73**	(-4.51, -0.94)	-1.82**	(-3.12, -0.51)
HS Non-participants	-	-	-	-	-	-
Nearly Eligible	-0.53	(-1.76,0.70)	-0.61	(-1.95,0.73)	-0.54	(-1.91,0.83)
Ineligible	-0.44	(-1.49,0.61)	-0.35	(-1.52,0.82)	-0.83	(-2.04,0.38)
Total food expenditure (£/week)						
HS Participants	-0.31	(-5.99,5.37)	-4.11	(-9.46,1.25)	-1.39	(-5.72,2.95)
HS Non-participants	-	-	-	-	-	-
Nearly Eligible	4.52	(-0.02,9.06)	1.61	(-3.97,7.19)	2.65	(-2.19,7.48)
Ineligible	21.85***	(17.58,26.13)	13.43***	(8.69,18.18)	7.30***	(3.06,11.53)
Cow's milk expenditure (£/week)						
HS Participants	-0.24	(-0.53,0.04)	-0.25	(-0.53,0.02)	-0.17	(-0.43,0.09)
HS Non-participants	-	-	-	-	-	-
Nearly Eligible	-0.2	(-0.49,0.08)	-0.15	(-0.35,0.06)	-0.21	(-0.46,0.03)
Ineligible	0.14	(-0.11,0.39)	-0.02	(-0.22,0.18)	-0.18	(-0.41,0.05)

Note: **P<0.05 **P<0.01 ***P<0.001;* FV – fruit and vegetable; a) Sample of households with children <1years (*n*=1,260)
Model 1 – Adjusted for year + quarter; Model 2 – Adjusted for Model 1, household size, number of children <1 year, 0-3 years + age of HRP; Model 3 – Adjusted for Model 2, region, ethnicity, social class and education of HRP

Additionally, I assessed the differences in outcome at the 25th and 75th percentile using quantile regression across the four exposure groups. This is important as the difference in spending between Healthy Start Eligible, Nearly Eligible, and Ineligible households differed across the expenditure distribution. For example, the non-significant differences in fruit and vegetable expenditure between Healthy Start Participants and Eligible Non-participants were observed consistently at the 25th, 50th and 75th percentile (Figure 5.2). However, differences in fruit and vegetable expenditure of Nearly Eligible and Ineligible compared to Healthy Start Eligible Non-participants increased between the 25th and 75th percentile of fruit and vegetable expenditure (Figure 5.2). This implies that the more ineligible households spent on fruit and vegetables, the greater the magnitude of difference compared to Healthy Start Eligible Non-participating households. Importantly, a similar pattern was not seen for fruit and vegetable quantity (Figure 5.3). The coefficients were of consistent magnitude across all percentiles assessed. This indicates that the higher levels of expenditure observed in Figure 5.2 in the 75th percentile did not correspond to a higher quantity of fruit and vegetable purchased.

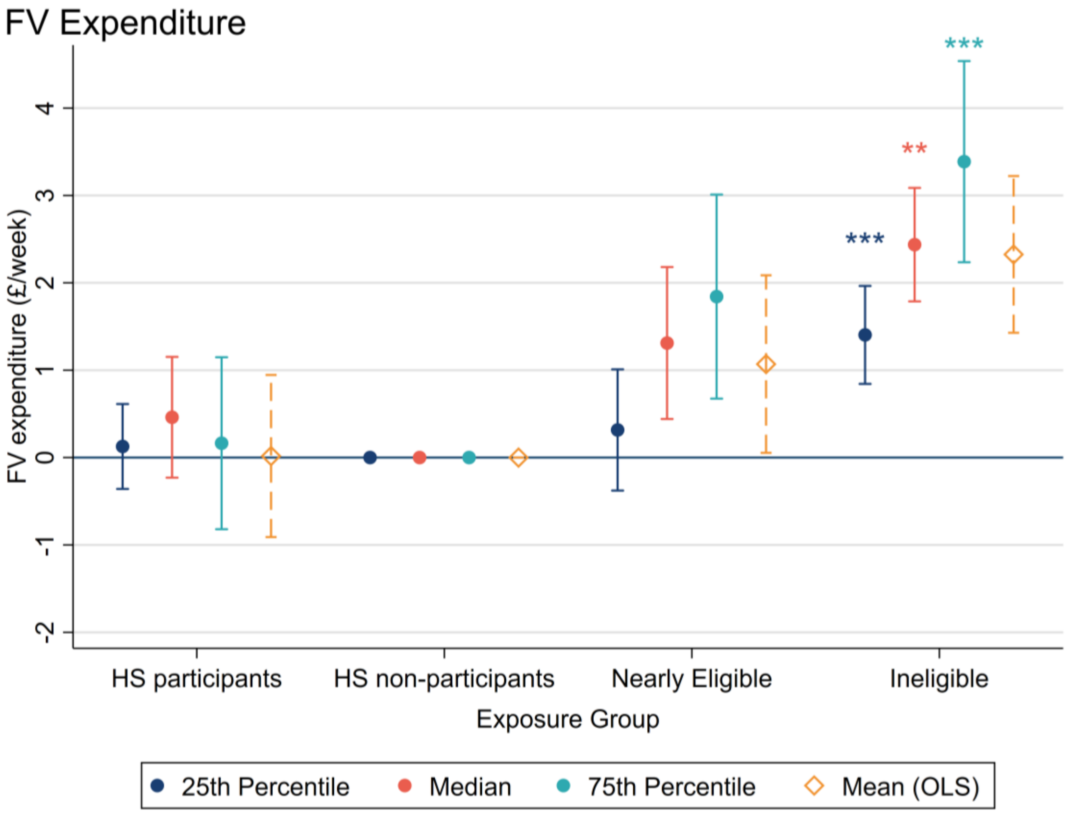

Figure 5.2 - Quantile regression of FV expenditure (£/week) by Healthy Start participation in the Living Costs and Food Survey (2010-17, *n*=4,870).

Notes: Significant difference between nearly eligible and ineligible groups using a Wald test
*P <0.05, **P <0.01 *** P <0.001.
Models were adjusted by survey year, survey quarter, household size, number of children, age of HRP, ethnicity of HRP, NS-SEC social class, age HRP completed full-time education and region.
FV- Fruit and vegetables; HS- Healthy Start; OLS- Ordinary Least Squares regression.

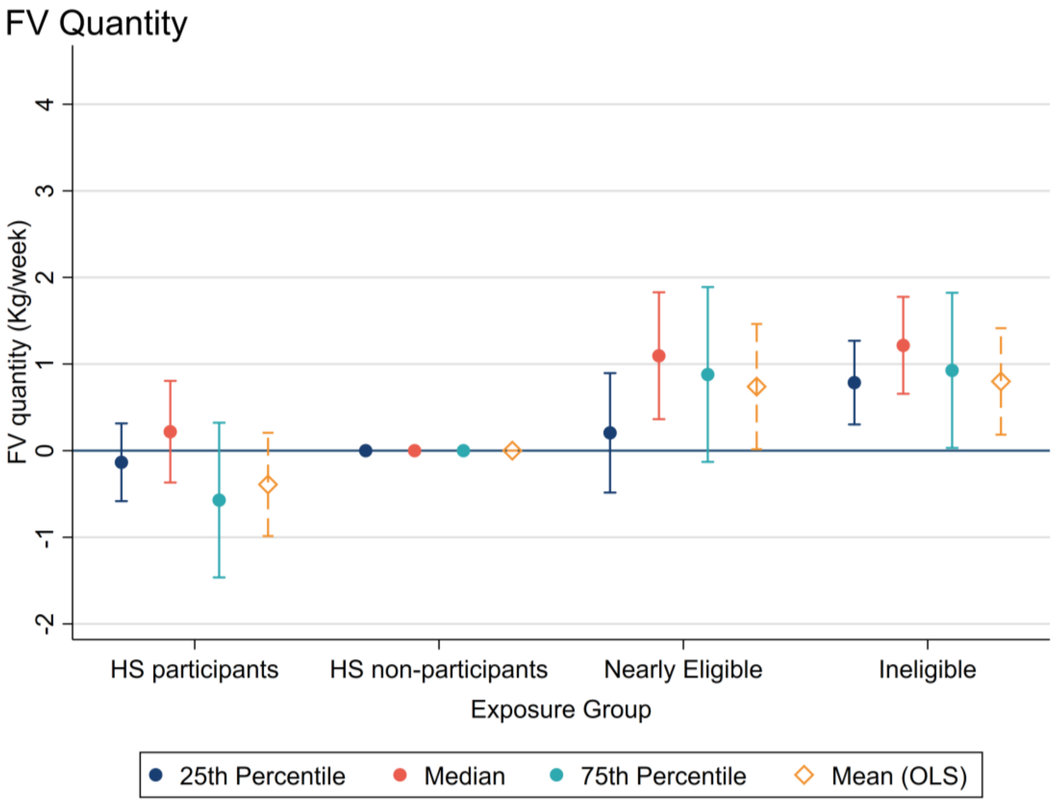

Figure 5.3 - Quantile regression of FV quantity (Kg/week) by Healthy Start participation in the Living Costs and Food Survey (2010-15, *n*=3,265).

Notes: Significant difference between nearly eligible and ineligible groups using a Wald test
*P <0.05, **P <0.01 *** P <0.001.
Models were adjusted by survey year, survey quarter, household size, number of children, age of HRP, ethnicity of HRP, NS-SEC social class, age HRP completed full-time education and region.
FV- Fruit and vegetables; HS- Healthy Start; OLS- Ordinary Least Squares regression.

Sensitivity analyses demonstrated that median regression results were robust when quantity variables were analysed (Appendix Table I.c). and when using a complete case analysis (Appendix Table I.c).

5.4 Discussion

Using nationally representative data, the present analysis did not find evidence of an association between Healthy Start participation and the purchase of fruit and vegetables, Healthy Start foods or total foods. An inequality in purchases was observed as fruit and vegetable expenditure was higher in both Nearly Eligible and Ineligible households, compared to Healthy Start Participants or Eligible Non-participants. Total food expenditure was higher only in Ineligible households.

No previous evaluation of the scheme has compared the impact of the Healthy Start programme within an eligible population. Griffith *et al*[264] used a difference-in-differences analysis of household purchase data two years before and after programme implementation. They reported a £2.43/month (£0.61/week) increase in fruit and vegetable spending in Healthy Start eligible households compared to ineligible low-income households with a child aged 4-8 years. Scantlebury *et al*[267] compared fruit and vegetable intake among adults and children aged 5 years or over from Healthy Start eligible and ineligible households in England, However, they reported no association between Healthy Start eligibility and individual fruit and vegetable intake following programme introduction. The present finding adds to the current evidence base, indicating that it is unlikely that Healthy Start vouchers had a discernible impact on the dietary behaviours of its target population, during the years 2010-2017. In lieu of an experimental design, this study has used the most appropriate control group, eligible non-participants, to evaluate the effect of the voucher.

By contrast, a similar food assistance programme in the United States, WIC (Section 1.2.4.2), has demonstrated greater success. WIC also serves low-income families with pregnant women or young children at risk of nutritional deficiencies. However, alongside distributing cash-value vouchers for fruit and vegetables, WIC additionally provides healthy food packages (Table 1.3). In general, evaluations of WIC have shown more consistent positive programme impacts on key outcome measures. National-level evaluations of the impact of WIC on dietary intake report improved intake of key food groups in WIC participating children compared to non-participating low-income children[217,218,348] Also, analyses show positive impacts of WIC on infant health outcomes[219,220]. The many differences in programme design and context make comparing between the programmes difficult. However, it is notable that WIC participants are given access to a larger amount and wider variety of food than Healthy Start participants and covers the children for a greater period of their life. These programme differences may be one reason that WIC impacts are more consistently demonstrated compared to Healthy Start.

I did not find evidence of an association between Healthy Start participation and fruit and vegetable purchases. Economic theory suggests that a voucher will only increase the spending for households which previously spent less than the voucher value on target foods[264,349]. Otherwise, the voucher will act as financial assistance, permitting money in the budget to be spent elsewhere. The data gave two indications that the Healthy Start vouchers were used as financial assistance. Firstly, as the average spending on fruit and vegetables was above the voucher value for Eligible Non-participants (£4.5/week [see Table 5.1]), the voucher value was likely below usual fruit and vegetable expenditure in low-income households. Secondly, differences in overall food expenditure were not observed between Healthy Start participating and non-participating households, indicating Healthy Start participating households did not increase their food budgets. This finding is in keeping with qualitative evidence in which some Healthy Start participants reported using the vouchers as financial assistance rather than increasing their usual fruit and vegetable expenditure[199,258]. Therefore, it is unlikely that the voucher provided enough purchasing power to encourage low-income households to increase their fruit and vegetable expenditure above usual levels[349]. This issue has been exacerbated by differential price inflation of fruit and vegetables compared to the Healthy Start voucher. Price indices show that fruit and vegetable prices have increased by 52% and 36%, respectively, between 2006-2021 (Figure 2.1). Whereas the Healthy Start Voucher, which had not changed value between 2010-2021, increased by 11%. A situation which will only worsen due to Brexit[111]. As such, it is concerning that over time the voucher decreased in value, further reducing the likelihood that it could help low-income families afford more fruit and vegetables. In response to this issue, the Scottish government raised the Healthy Start voucher value to £4.25 in August 2019, with the English government following suit in April 2021[210,350]. Increasing the benefit value is likely to counteract the effect of inflation and may better enable Healthy Start participants to make a meaningful change to their diet.

Health professionals have expressed concern that the inclusion of infant formula in the Healthy Start scheme may discourage breastfeeding[199]. In a survey of new mothers, breastfeeding initiation was 22 pp lower in Healthy Start participating mothers than the UK average[351]. However, this comparison was not made against similarly low-income individuals, therefore socioeconomic differences would likely contribute to these differences. However in this analysis, Healthy Start Participants purchased a significantly lower amount of infant formula compared to Eligible Non-participants, which could neither be explained by differences in total food expenditure nor differing prevalence of infants in the households. Although it should be noted that breastfeeding rates were unobserved thus could not be controlled for in this analysis. This is congruent with findings from a Scottish longitudinal cohort, which suggested that infant feeding practices were not significantly different between Healthy Start recipients and other nearly eligible mothers[271]. Together, these results could suggest Healthy Start does not disincentivise breast-feeding. An explanation for this finding is that the Healthy Start programme increases contact and engagement with health professionals. A consequence of this could be that Healthy Start participating mothers may be more exposed to breastfeeding promotion initiatives than non-participating households. Further investigation is needed to confirm this hypothesis.

An inequality in fruit and vegetable purchases was apparent between low-income and relatively higher-income households, reinforcing previous literature that income is associated with fruit and vegetable purchasing behaviours[352,353]. A higher quantity of fruit and vegetables purchased in Nearly Eligible households compared to Healthy Start Participants or Eligible Non-participants indicates that the programme may not mitigate even small income-inequalities. Nearly eligible households were of similar low-income levels but did not qualify for Healthy Start due to not receiving income-related benefits. Future success of the programme could be determined by its ability to reduce the socioeconomic gradient in food purchases.

This study was novel in its ability to characterise Healthy Start Participants compared to Eligible Non-participants. I found that households with pregnant women were less likely to participate in the Healthy Start scheme. This is supported by qualitative research reporting poor awareness of the scheme amongst pregnant women[199,258,260] (Section 2.1.1). A reliance on health professionals to promote the scheme has meant eligible pregnant women frequently learnt of the programme after birth, due to information overload in prenatal appointments. Additionally, qualitative research highlighted that health professionals often assumed eligibility, meaning women who lived in less-deprived areas or who appeared of higher socioeconomic class were less likely to be aware of the scheme. My research confirms these qualitative reports, demonstrating both pregnant women and households of higher socioeconomic class were less likely to participate.

5.4.1 Strengths and limitations

There are several strengths to note about this study. Firstly, this is the first quantitative evaluation of Healthy Start to use a nationally representative dataset for the UK which observed participation in the Healthy Start scheme. Additionally, using detailed income, benefit, and household composition data I was able to accurately define a range of exposure groups, this gave the analysis the unique benefit of allowing comparison against Nearly Eligible households. Finally, the results were also robust to a range of sensitivity analyses on the potential impacts of missing data.

However, there are a few limitations to note. The primary limitation is that the data were cross-sectional, therefore change in participant's purchasing behaviours as a result of the vouchers could not be determined. Additionally, pooling years limited the ability to account for macroeconomic changes over time. To counteract the impact of this, I adjusted the fiscal variables for inflation and included year and quarter indicators in analyses to reduce potential biases to variation across time. Additionally, as Healthy Start is targeted at very low-income households, the number of eligible households in the nationally representative data was low. Resultantly, the analysis was underpowered to determine significance in small differences in expenditure. Participation in the scheme was self-reported, all reported incomes revenues were confirmed with documentation, which will act to minimize any potential misclassification bias. Finally, this analysis does not reflect the range of policy changes were made to Healthy Start during 2020-2021 (Section 1.2.4). The data covering this period of change will not be released until 2022, so could not be included in the thesis.

5.5 Chapter conclusions

In this chapter, I evaluated Healthy Start and did not find evidence of different fruit and vegetable, Healthy Start foods or total food expenditure between Healthy Start participants and non-participants. However, I did find evidence that Healthy Start may have lowered the purchase of infant formula in participating households. I demonstrated there was a socioeconomic gradient in food spending which reflects the continuing inequalities in the UK. These findings implicate the changes to the Healthy Start programme were needed. Policy implications from this research will be discussed further in Chapter 11. The next research chapters will focus on evaluating school-based food assistance programmes. To determine the potential of school food to improve dietary intake in UK children, in Chapter 6 and Chapter 7 I will examine the dietary quality of school meals compared to packed lunches.

Chapter 6. Dietary quality of school meals in the United Kingdom

This section is the combined work of myself and a master's student who I helped to co-supervise during their summer project. I compiled the dataset, did the initial data preparation, advised on methods and nutritional epidemiology techniques. The student performed the initial descriptive and regression analysis. Together we prepared the results into a manuscript, which at the time of thesis submission, had not been submitted to a journal. I subsequently re-ran the analysis to make the methods consistent with the rest of the thesis. For example, I changed the reference category from school meals to packed lunches and changed the grouping of school years from key stages into primary and secondary school phases.

6.1 Background

Children in the UK are not getting the recommended dietary intake, with national estimates showing they are not meeting key recommendations for fruit and vegetables, saturated fat, sugar, or salt[1]. Moreover, there is clear evidence of a socioeconomic gradient in children's diet, with more deprived children being more likely to consume an energy dense, nutrient poor diet than those who are least deprived (Section 1.1.2).

The school environment is proposed as an equitable way to improve children's diet[184,354]. There is a body of evidence demonstrating that school meals are typically healthier than packed lunches (Section 2.2.1). However, this evidence has not answered many critical questions. For example, it is unclear whether school meals are consistently of higher quality across all school phases from primary to secondary school. Also, evidence has not included data after 2015, when food-based School Food Standards were introduced. So, it is unclear if research conducted before this date is still relevant to the present school food environment. Additionally, confirming that these associations are present in the nationally representative NDNS data is crucial to understand and quantify the potential of school-meal policies to improve dietary intake.

In this chapter I aim to quantify differences in nutritional quality between school meals and packed lunches among schoolchildren in the UK and explore if the association varies among primary and secondary schoolchildren.

6.2 Methods

6.2.1 Data Source

This study used data from the National Diet and Nutrition Survey (NDNS) rolling programme (years 2008-2017). This is a national representative dataset which collects a snapshot of the diet of the UK population, please find a detailed description in Chapter 4.

6.2.2 Study design

Although the data are repeated cross-sectional data, this study used a pooled cross-sectional study design. The annual sample size of school aged children who had recorded their lunch whilst at school was low, as discussed in Chapter 4, which precluded an analysis using multiple timepoints. All survey years were pooled to retain sample size.

6.2.3 Study participants

All NDNS participants between the ages of 4-18 years attending a primary or secondary school were included (*n*=4,800). Of this initial sample, 1,479 (31%) were excluded as they did not record a lunchtime intake whilst at school. Not recording a school lunch is likely due to the study period occurring during a school holiday. However, for older children who are permitted to leave school premises, this might indicate that they purchased and consumed lunch externally. Three participants were removed due to missing ethnicity data and 16 were removed for missing meal type data, leaving a final sample of 3,303 participants (see Figure 6.1).

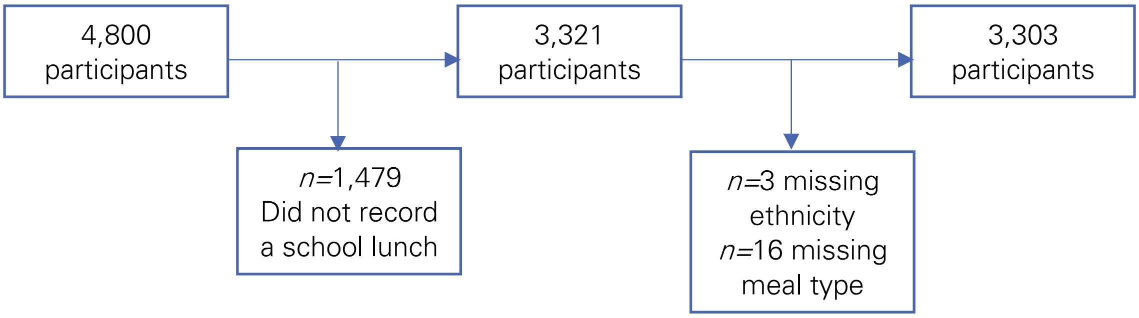

Figure 6.1 - Flow diagram of sample exclusions from the National Diet and Nutrition Survey (2008-2017)

6.2.4 Outcome variables

Information on how the NDNS collected dietary data is presented in Chapter 4. Ten food groups (fruits, vegetables, protein-rich foods [meat, fish, eggs, and beans], dairy [milk, yoghurt, and cheese], wholemeal products [wholemeal bread, brown rice], starchy products [white bread, white rice pasta, not cooked in oil], chips [inc. other starchy foods cooked in oil], crisps [inc. other savoury snacks], and sweet snacks) were chosen to reflect the 2015 English School Food Standards (Table 1.4). Detailed description of the food groups are presented in Appendix Table II.a. Intakes of food groups were assessed both as continuous variables (g/lunch) averaged across all recorded school days per participant and dichotomised variables indicating none (0g/lunch) or some (>0g/lunch) intake. Eight nutrient variables (saturated fat [g], non-milk extrinsic sugar [NMES] [g], and sodium [mg], fibre [g], vitamin C [mg], calcium [mg], and iron [mg]) reflected the nutrient guidance in the 2009 Standards[221]. Although no longer in use, the 2009 nutrient standards still provide a useful guideline for optimal lunchtime nutritional intake for children. Continuous nutrient variables were dichotomised into whether they met the age-specific minimum or maximum nutrient standards (Appendix Table II.b).

6.2.5 Exposure variables

Food items were defined as a school lunch if they occurred on a Monday-Friday between 12:00-14:00 on school premises. All items consumed as a school lunch were summed and averaged per school day by participant. The total number of school lunches recorded by participants varied from one to four days (1 day [*n*=584], 2 days [*n*=1,379],3 days [*n*=786], and 4 days[*n*=554]).

The dietary diaries indicated where an item was consumed. If the item was described as 'food from home' it was categorised as a 'packed lunch' and if it was described as 'bought at the canteen' it was categorised as a 'school meal'. If the meal type of a school lunch was not recorded for every food item (*n*=1,580), the survey question "on a school/college day, what do you/does (child's name) usually have for lunch?" was used to determine the child's meal type. For participants who had both their meal type recorded and their school meal preference recorded, there was a high level of agreement between the two measurements, with 91% of participants remaining in the same category. Participants who could not be clearly defined as bringing food from home or from school were excluded (*n*=16).

6.2.6 Covariates

Covariates included were survey year (2008-2017), sex (male/female), age (years), ethnicity (White/Ethnic minorities), equivalised household income (quintiles) and country (England, Scotland, Northern Ireland, or Wales). Participants with missing ethnicity were excluded (*n*=3). Equivalised household income was imputed for participants with missing data (*n*=137) using ten iterations of the classification and regression trees (CART) method[355] (Section 4.1.3.3).

6.2.7 Statistical analysis

Bivariate significance tests were used to assess sample characteristics across meal types (school meal vs. packed lunch), separately for each school phase (primary vs. secondary). Additionally, the food and nutritional outcomes were compared across meal types for each school phase. Survey-adjusted rank-tests were used for continuous outcomes, as they were non-normally distributed, and χ^2 tests were used for the dichotomised outcomes.

Multivariable logistic regression models were used to evaluate the association between meal type and the likelihood of students consuming each food group and meeting nutrient-based standards, using packed lunches as the reference category.

Sensitivity analyses were conducted to additionally adjust for total lunchtime energy and grams to test if systematic differences in intake could explain the findings. Further sensitivity analysis involved excluding any participants whose meal-type was based on the school meal preference survey question to test if the results were robust against potential misclassification bias.

All statistical analyses were performed using R studio (version 4.0.2). Survey weights were applied in all data analyses to account for sampling and non-response bias[1]. P-values of <0.05 were considered statistically significant for all tests.

6.3 Results

A total of 3,303 children were included in the analysis, of which 57% were in Primary school (Table 6.1). Overall, children who had a school meal were younger, from an ethnic minority household, had lower household income and from a more deprived neighbourhood than children who took a packed lunch. A higher proportion of primary schoolchildren consumed a school meal than secondary schoolchildren (49% vs 44%), although there is not strong evidence that this was a significant difference (P=0.07). In primary school, children consuming a school meal were more likely to be female and from a low-income household, which was not observed in secondary schools.

Overall, compared with packed lunches, a larger proportion of school meals contained vegetables (school meals 83% vs packed lunches 43%), protein-rich foods (86% vs 73%), starchy foods (84% vs 65%) and puddings (49% vs 24%) (Table 6.2). A smaller proportion contained fruit (52% vs 70%), wholemeal products (12% vs 35%) crisps (7% vs 42%) and sweets snacks (40% vs 66%). These findings were consistent across school phases, however in secondary schoolchildren both the proportion and median amount of fruit, vegetables protein rich foods, dairy, and puddings was lower compared to the level in primary schoolchildren, indicating a change in school meal quality. For instance, the median portion of vegetables eaten in school meals decreased from 34g/lunch in primary school to 15g/lunch in secondary school. Additionally, as children aged, a greater proportion of school meals contained sweet and savoury snacks. In primary school, 34% of school meals contained crisps, compared with 48% in secondary school.

Overall, compared to packed lunches, school meals were more likely to meet the nutrient standards for all nutrients except for iron and vitamin C (Table 6.3). These associations did not remain consistent when stratified by school phase, with a decrease in the nutritional profile of school meals in secondary schools compared to primary schools. There was only evidence of a difference between school meals and packed lunches in secondary school for sodium (school meals 71% vs packed lunches 63%) and protein (69% vs 59%). Whereas, in primary schoolchildren, school meals were more likely to meet the nutrient recommendations than packed lunches for every nutrient outcome aside from iron.

Table 6.1 - Sample characteristics of primary and secondary school children in the National Diet and Nutrition Survey (2008-2017, *n*=3,303)

	Primary (*n*=1,895, 57%)			**Secondary (*n*=1,408, 43%)**			**Total (*n*=3,303)**		
Variable	**School Meals**	**Packed Lunches**	**P**	**School Meals**	**Packed Lunches**	**P**	**School Meals**	**Packed Lunches**	**P**
n (%)	928 (49.1)	967 (50.9)		654 (44.7)	754 (55.3)		1582 (47.1)	1721 (52.9)	
Age, M (SD)	7.18 (2.01)	7.72 (2.08)	<0.001[b]	13.70 (1.93)	14.21 (1.95)	<0.001[b]	9.95 (3.78)	10.75 (3.82)	<0.001[b]
Sex, n (%)			0.03[a]			0.17[a]			0.55[a]
Male	480 (49.37)	525 (55.57)		327 (52.93)	340 (48.33)		807 (50.88)	865 (52.19)	
Female	448 (50.63)	442 (44.43)		327 (47.07)	414 (51.67)		775 (49.12)	856 (47.81)	
Ethnicity, n (%)			0.009[a]			0.02[a]			<0.001[a]
White	791 (79.58)	861 (85.57)		573 (78.92)	673 (85.52)		1364 (79.30)	1534 (85.55)	
Ethnic minorities	137 (20.42)	106 (14.43)		81 (21.08)	81 (14.48)		218 (20.70)	187 (14.45)	
Household income, n (%)			0.002[b]			0.10[b]			<0.001[a]
Low	336 (37.53)	268 (30.99)		250 (43.08)	247 (36.45)		586 (39.88)	515 (33.54)	
Mid	271 (27.00)	370 (36.58)		199 (28.06)	261 (33.93)		470 (27.45)	631 (35.34)	
High	321 (35.47)	329 (32.43)		205 (28.86)	246 (29.62)		526 (32.67)	575 (31.12)	
IMD, n (%)			0.10[a]			0.12[a]			0.01[a]
1(Least deprived)	188 (20.83)	229 (22.54)		143 (21.36)	178 (23.67)		331 (21.06)	407 (23.07)	
2	162 (15.54)	166 (19.13)		126 (20.92)	158 (21.85)		288 (17.82)	324 (20.40)	
3	199 (19.74)	207 (17.74)		127 (14.71)	156 (18.85)		326 (17.61)	363 (18.26)	
4	170 (19.79)	197 (21.86)		123 (22.10)	148 (20.81)		293 (20.77)	345 (21.37)	
5(Most deprived)	209 (24.11)	168 (18.72)		135 (20.91)	114 (14.83)		344 (22.75)	282 (16.90)	
Country, n (%)			0.64[a]			0.29[a]			0.30[a]
England	555 (82.88)	543 (82.98)		366 (84.10)	460 (87.24)		921 (83.40)	1003 (84.97)	
Scotland	135 (8.76)	166 (9.18)		87 (6.26)	96 (5.49)		222 (7.70)	262 (7.46)	
Wales	120 (5.24)	118 (4.35)		88 (5.91)	89 (4.32)		208 (5.53)	207 (4.33)	
N. Ireland	118 (3.12)	140 (3.49)		113 (3.73)	109 (2.95)		231 (3.38)	249 (3.24)	

[1]Significance test between Primary school meals and packed lunches; [2]Significance test between Secondary school meals and packed lunches; [3]Significance test between Primary school meals and packed lunches [a]Chi-square test (Adjusted for survey weights) [b]T-test (Adjusted for survey weights)

Table 6.2 - Median weight (g/lunch) and prevalence of consuming each food group by meal type in primary and secondary schoolchildren in the National Diet and Nutrition Survey (2008-2017, *n*=3,303)

	Primary		Secondary		Total	
Variable	**Median (IQR)**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	**%**
Fruit						
School meal	6.08 (0,32.74)	68*	0 (0,1.99)	30*	0.63* (0,22.33)	52*
Packed Lunch	33.87 (4.09,71.55)	85	1.21 (0,50)	52	17.79 (0,65.82)	70
Vegetables						
School meal	33.97* (16.6,54.13)	91*	14.93 *(0,36.27)	72*	26.73 *(8.5,49)	83*
Packed Lunch	0 (0,15.15)	42	0 (0,16.08)	45	0 (0,15.93)	43
Protein-rich foods						
School meal	34.25* (21.12,52)	92*	28.48 *(10.55,46.41)	78*	32.29 *(16.47,50.24)	86*
Packed Lunch	20 (4.99,34)	77	19.53 (0,37.53)	68	20 (0,35)	73
Dairy products						
School meal	7.28* (0,40)	65*	2.47 *(0,19.79)	52*	5.77 *(0,28.39)	59
Packed Lunch	27.5 (0.68,58.65)	76	0 (0,20)	45	11.8 (0,40)	61
Wholemeal products						
School meal	0* (0,0)	10*	0 *(0,0)	14*	0 *(0,0)	12*
Packed Lunch	0 (0,36)	39	0 (0,24)	29	0 (0,30.86)	35
Starchy products						
School meal	52.52* (28.79,83.67)	86*	66 *(24.22,105)	82*	58.2 *(26.91,91.8)	84*
Packed Lunch	36 (0,62.62)	66	36.78 (0,72)	63	36 (0,69.64)	65
Chips						
School meal	18.75* (0,39.58)	56*	0 *(0,0)	24*	0 *(0,35.77)	43*
Packed Lunch	0 (0,0)	7	0 (0,0)	5	0 (0,0)	6
Crisps						
School meal	0* (0,0)	5*	0 *(0,0)	10*	0 *(0,0)	7*
Packed Lunch	0 (0,12.69)	42	0 (0,15.93)	43	0 (0,14.25)	42
Sweet snacks						
School meal	0* (0,7.5)	34*	0 *(0,84.91)	48*	0* (0,17.09)	40*
Packed Lunch	17.02 (0,38.06)	68	18.27 (0,75.51)	63	17.5 (0,52.33)	66
Puddings						
School meal	24.5* (0,54.1)	66*	0 *(0,13.33)	26*	0 *(0,43.28)	49*
Packed Lunch	0 (0,13.12)	30	0 (0,0)	17	0 (0,0)	24

[1]Survey adjusted rank test; [2]Survey adjusted chi-square test

Note: IQR - Interquartile range; % - percent consuming >0g/lunch of the food group

Table 6.3 - Median nutrient consumed and prevalence of meeting nutrient recommendation by meal type in primary and secondary schoolchildren in the National Diet and Nutrition Survey (2008-2017, *n*=3,303)

	Primary		Secondary		Total	
Variable	**Median (IQR)**	**%**	**Median (IQR)**	**%**	**Median (IQR)**	**%**
Saturated fat						
School meal	5.53* (3.77,7.58)	65*	5.37 (2.99,9.08)	58	5.45* (3.55,8.15)	62*
Packed Lunch	6.32 (4.29,8.59)	51	5.32 (2.56,8.33)	62	5.86 (3.5,8.53)	56
Non-milk extrinsic sugar						
School meal	10.52* (5.36,16.65)	71*	12.81 (2.73,26.2)	63	11.55 * (4.28,19.23)	68*
Packed Lunch	16.05 (9.04,24.87)	48	11.72 (2.68,24.83)	67	14.49 (6.81,24.88)	57
Sodium						
School meal	444.1* (322.6,589.4)	59*	562.2 (359.8,763.2)	71*	490.21* (334.7,666.0)	64*
Packed Lunch	638.9 (480.6,813.4)	28	598.68 (384.9,837.9)	63	619.25 (440.8,822.1)	44
Fibre						
School meal	4.74 * (3.62,6.07)	62*	3.97 (2.7,5.38)	29	4.39* (3.29,5.77)	48*
Packed Lunch	3.97 (2.95,5.37)	46	3.72 (2.37,5.24)	26	3.85 (2.74,5.32)	37
Protein						
School meal	17.01* (13.63,20.27)	97*	16.74* (12.3,22.42)	69*	16.91* (13.08,21.04)	85*
Packed Lunch	15.48 (11.86,19.26)	93	14.6 (9.02,20.28)	59	15.22 (10.96,19.69)	77
Iron						
School meal	2.01 (1.61,2.5)	13	2.08 (1.42,2.7)	1*	2.05 (1.54,2.57)	8
Packed Lunch	2.08 (1.65,2.67)	15	2 .00 (1.31,2.71)	3	2.06 (1.52,2.7)	10
Vitamin C						
School meal	14.74* (8.89,24.63)	69*	10.35 (2.32,25.91)	42	13.31 (6.17,25.04)	57
Packed Lunch	18.32 (7.5,41.72)	66	8.32 (1.64,24.37)	39	13.25 (4,34.86)	54
Calcium						
School meal	163.38* (108.43,238.42)	38*	161.01 (99.84,261.05)	16	162.89* (104,248.55)	29*
Packed Lunch	222.97 (168.02,316.53)	65	172.29 (101.82,264.98)	13	201.06 (137.81,299.6)	41

[1]Survey adjusted rank test; [2]Survey adjusted chi-square test

Note: IQR - Interquartile range; % - percent consuming meeting nutrient recommendations

In the total sample, fully adjusted regression analyses showed that school meals were more likely to contain vegetables (AOR 6.6; 95%CI 5.3,8.4), protein-rich foods (AOR 2.2; 95%CI 1.7,2.9), starchy products (AOR 2.9; 95%CI 2.3,3.6), chips (AOR 10.6; 95%CI 8.0,14.0) and puddings (AOR 3.1; 95%CI 2.6,3.8) (Figure 6.2). However, they were less likely to contain fruit (AOR 0.4; 95%CI 0.3,0.5), wholemeal products (AOR 0.3; 95%CI 0.2,0.3), crisps (AOR 0.1; 95% CI 0.1,0.1) and sweet snacks (AOR 0.4; 95% CI

0.3,0.4). When stratified by school, effect sizes were amplified in primary schoolchildren compared to secondary schoolchildren. For example, in primary school, school meals were sixteen times more likely to contain vegetables than packed lunches but in secondary school it was only around four times (Primary AOR 16.6; 95% CI 11.8,23.5 vs Secondary AOR 3.6; 95%Co 2.6,5.0).

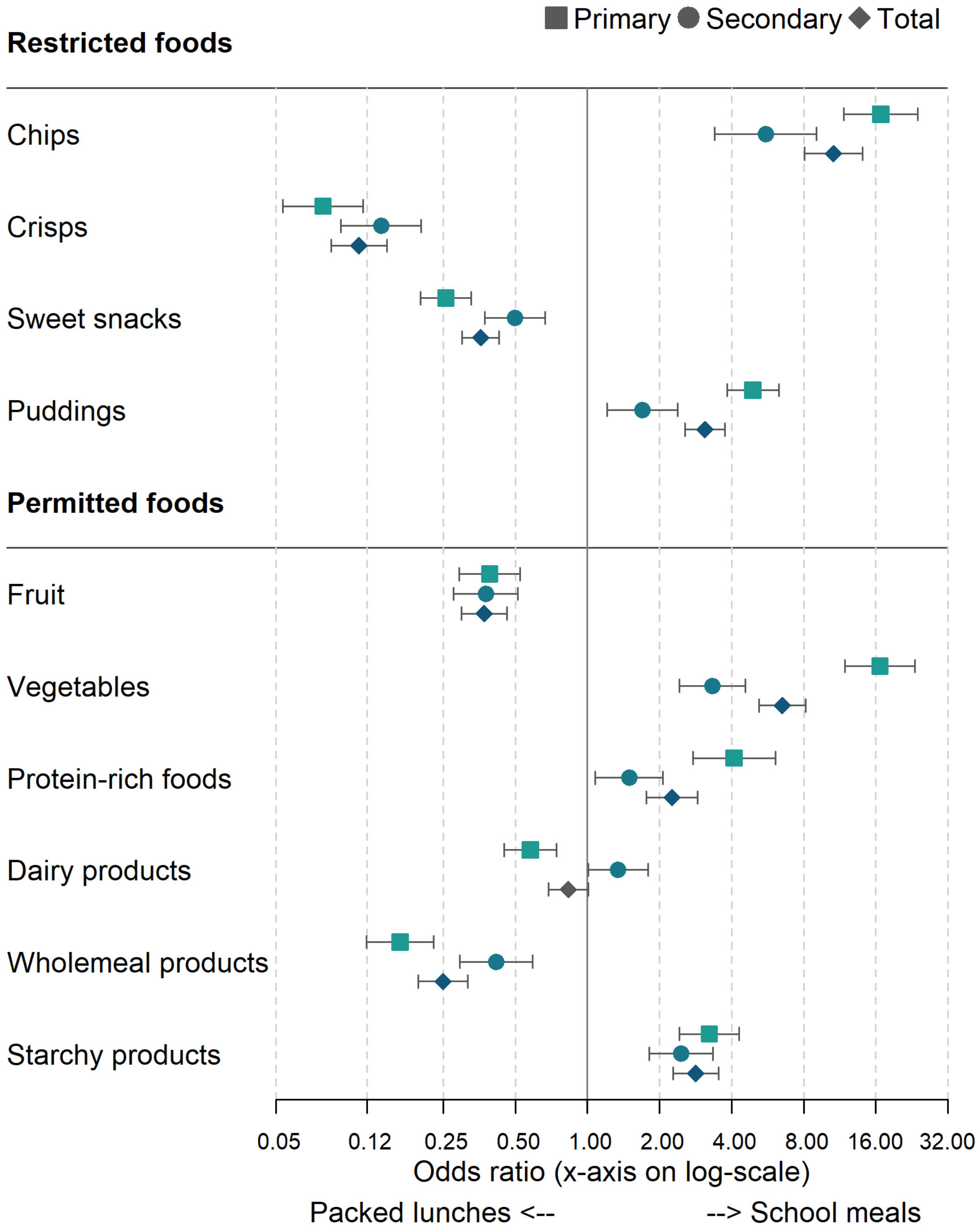

Figure 6.2 - Adjusted odds ratio (95% CI) for the likelihood of school meals in containing a food group compared to packed lunches in a sample of children from the National Diet and Nutrition Survey (2008-2017, *n*=3,303), stratified by school phase.

For the nutrient outcomes (Figure 6.3), fully adjusted regression analysis showed that school meals were more likely to meet saturated fat (AOR 1.2; 95% CI 1.0,1.5), NMES (AOR 1.6; 95% CI 1.3,2.0), sodium (AOR 2.4; 95% CI 2.0,2.9), fibre (AOR 1.5; 95% CI 1.3,1.9), and protein (AOR 1.5; 95%CI 1.1,1.9) recommendations than packed lunches in the total sample. However, they were less likely to meet calcium recommendations (AOR 0.5, 95%CI 0.4,0.6).

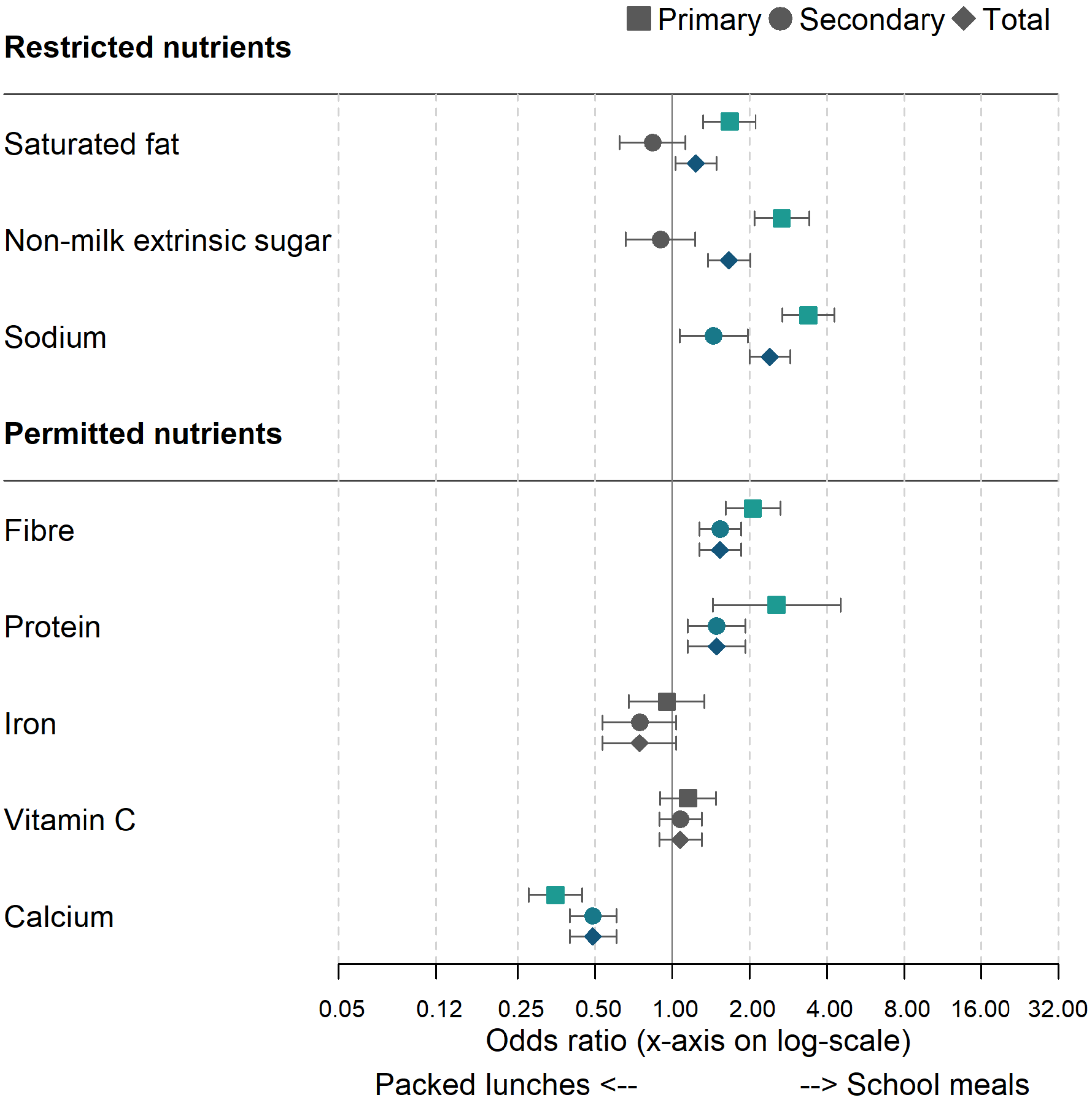

Figure 6.3 - Adjusted odds ratio (95% CI) for the likelihood of school meals meeting nutrient-based outcomes compared to packed lunches in a sample of children from the National Diet and Nutrition Survey (2008-2017, *n*=3,303), stratified by school phase.

When stratified by school phase, the associations were attenuated in secondary schoolchildren compared to primary schoolchildren, with some nutrients showing no difference. For example, primary schoolchildren's school meals were 1.6 times more likely to meet nutrient recommendations for saturated fat than packed lunches (AOR 1.6; 95% CI 1.3,2.0), but there was no evidence of a difference in secondary schoolchildren (AOR 0.9; 95% CI 0.6,1.2). All odds ratios are listed in Appendix Table II.c.

The sensitivity analysis demonstrated results were robust against any additional adjustments (Appendix Table II.d and Appendix Table II.e) or meal-type definition (Appendix Table II.f).

6.4 Discussion

In this study, I described the nutritional gap between school meals and packed lunches in relation to food and nutrient recommendations using nationally representative data that includes both primary and secondary schoolchildren in the UK. I found that children consuming school meals were more likely to meet both nutrient and food recommendations compared to those taking packed lunches. The results were most apparent for meeting vegetable recommendations and limiting the consumption of sweet and savoury snacks. However, the analysis revealed that school meals are not infallible; more than 40% of school meals still contain sweet snacks and were less likely to contain fruit and wholemeal products than packed lunches. Additionally, I demonstrated that the quality of school meals declined in secondary school children while the packed lunches remained of similar poor quality. Compared with school meals consumed by younger children, those consumed by older children were less likely to contain adequate fruit and vegetables and more likely to contain sweet and savoury snacks.

This study is the first to compare school lunches across school phases, showing that the nutritional quality of lunches in younger children was impacted by meal type. In older children, the attenuated effect size of meal type on the outcomes might be due to the declining quality of school meals with increasing age. These conclusions are congruent with previous literature reporting a consistent benefit of school meals in primary schools, with similar but smaller effect sizes seen in secondary schools[282,283,356,357]. However, only a few studies have directly explored the association by age group, so this has not been thoroughly quantified before. For instance, a study conducted before 2009 found differences in the nutrient intake of school meals and packed lunches in infant schoolchildren compared to junior schoolchildren, however the analysis did not include children over 12 years old[277].

There are multiple mechanisms which might explain why the nutritional gap between school meals and packed lunches may reduce for secondary school children. There is evidence that the School Food Standards are not applied in many secondary schools. Research has shown that the School Food Standards have improved children's diet[235–237], however the standards do not legally apply to academies formed between 2010-2014, estimated to be up to 50% of all secondary schools[232,358]. In addition, secondary schoolchildren have increased choice and autonomy over their food consumption at school, therefore individual choice may play a larger role in their diet. Qualitative research has highlighted that compared to younger children, the increased independence adolescents experience results in their food choices being influenced by preference, convenience, and social factors over nutritional quality[245,359,360]. Consequently, in instances where School Food Standard compliant options were on offer, the majority of secondary school children still chose the least healthy lunch option[245,252,361].

6.4.1 Strengths and limitations

Strengths of this study include it being the first large-scale, nationally representative, UK-wide analysis providing a comprehensive assessment of the diet and nutritional quality of school meals and packed lunches, including by school phase. In addition, the NDNS uses a high-quality, validated four-day food diary accounting for within-person day-to-day consumption variability[1]. Unlike many studies, this method records more than one lunchtime intake, so gets a better representation of school lunchtime intakes. The dietary assessment used is also highly detailed, allowing for a complete description of the food and nutrient content of the lunches.

There are several limitations which must be considered. First, the diaries of children less than 11 years were recorded by a proxy respondent, whereas students aged 12 and over completed their own food diary. This may have introduced measurement bias between older and younger children. As self-reported food diaries are often under-reported, the bias would likely underestimate the true association in secondary school children. Therefore, the true difference between the lunches of primary and secondary schoolchildren may be greater. Second, 48% of participants did not reliably record their meal type in their dietary diary. Where meal type data was unavailable, the school meal preference survey question was used to estimate meal type. For children who had both forms of measurement, it was clear there was a high similarity for the two methods. Furthermore, the findings remained consistent in sensitivity analyses which removed children whose ‘preferred’ meal type was used, suggesting that this measurement did not introduce bias into the study. Third, students who consumed lunch outside the school premises (e.g. at a shop or café) were excluded from the analysis as it could not be confirmed if this was part of a school day or a holiday. This was more likely to impact older children who are permitted to leave the school for lunch and are subsequently under-represented in the study. This will impact the standard error around the estimates in this age group and might mean that the intake of older students (over 15 years) is not well represented.

6.5 Chapter conclusions

In this chapter, I confirm using nationally representative data that on average school meals have a healthier nutritional profile than packed lunches, regarding their nutrient and food content. I also demonstrate for the first time the impact that school phase has on the nutritional quality of school meals, showing that secondary schoolchildren’s school meals are of worse dietary quality than in primary school. In the next chapter, I will explore and quantify this relationship using a previously unexplored dietary indicator, the degree of industrial food processing in the diet.

Chapter 7. Ultra-processed food content of school meals in the United Kingdom

7.1 Background

The degree of industrial food processing is a novel way of classifying dietary intake[39]. The understanding on the wide-ranging negative impacts of consuming high levels of UPF is evolving. Studies have shown that people who consume high levels of UPF have a worse dietary quality[339], are more likely to become overweight or obese[45,143,362], suffer from non-communicable diseases such as inflammatory bowel disease[363], cancer[364] and cardiovascular disease[365], and die prematurely[366]. The UK has the highest UPF intake in Europe[367], household availability of UPFs in the UK was 50.4 %, this is compared to 10.2 % in Portugal, 13.4 % in Italy and 46.2 % in Germany. Moreover, evidence indicates that children typically have higher UPF intakes than adults[368], a trend also observed in countries such as Belgium[40], US[369], Chile[370], and Canada[371]. Action to identify and reduce UPF intake in children is needed to avoid negative impacts for their long-term health and wellbeing.

As shown in Chapter 6 and the wider literature, school meals have a preferable profile of both foods and nutrients than packed lunches[277,279,281,372]. However, this relationship has not been explored in relation to industrial food-processing. Studies which have compared children's dietary intake at school compared to other settings, such as home, are unclear on whether the school setting provides a higher[373] or lower[2,374] intake of non-core or UPFs than other settings. The ultra-processed content of school lunches has not been analysed in isolation and it has not been quantified how school meal type might impact the intake of UPF. It is critical that we understand what drives intake of UPF in the school setting to better guide policy makers and parents in reducing UPF intake. Moreover, we need to quantify the quality of school meals to understand the impact of school food assistance policies.

In this study I aim to explore differences in the UPF content of school meals and packed lunches among primary and secondary schoolchildren in the UK. I also intend to explore if a child's household income impacts the amount of UPF they consume in their school lunch.

7.2 Methods

In this study, I used the same data source, study participants and exposure definition as the research in Chapter 6. In brief, this study used the NDNS data to explore the lunchtime intake of primary and secondary schoolchildren in the UK (ages 4-18 years, *n*=3,303), comparing children who have school meals against packed lunches. Please see Chapter 6 for further details.

7.2.1 Outcome Variable

The measurement and definition of lunchtime dietary intakes in the NDNS been described in Chapter 4 and Chapter 6. In brief, only the lunchtime intakes recorded at a school premises on a weekday between

12:00-14:00 were analysed in this study. Unlike Chapter 6, the degree of food processing in the lunchtime intakes is used as the exposure variable. The NOVA food classification system is used to define dietary intakes into four categories (Chapter 4):

- NOVA 1 – Unprocessed and minimally processed (MPF)
- NOVA 2 – Processed culinary ingredients
- NOVA 3 – Processed food
- NOVA 4 – Ultra-processed food (UPF)

Food consumed at school lunchtimes were categorised into these four groups. Their contribution to the diet was considered both in terms of their weight (grams) and energy content (kcal). This is due to the differing energy density of drinks and food. Drinks typically have a lower energy density than foods due to the relatively higher water content, so will make a larger contribution to the diet by their weight than their energy content. However, UPF products are also typically much more energy dense than MPF products. Certain UPF products, such as snacks, fast-food and puddings, will make a greater contribution to energy consumed than minimally processed food products such as fruit and vegetables. Therefore, it was important to use both contribution to weight and energy intake to avoid masking this difference in energy density across food and drink categories. Additionally, to account for between person variation in the amount of food consumed, the NOVA variables were made relative to total lunchtime intake, grams per total lunch grams (%g) and calories per total calories consumed (% kcal), in consistency with previous research in this field[368]. Moreover, it was observed that the intake of processed culinary ingredients and processed foods (NOVA 2 and 3) were very low and did not contribute much to the total intake, nor were they strongly associated with the intake of minimally processed (NOVA 1) or ultra-processed (NOVA 4) foods. Additionally, the minimally processed and ultra-processed food groups were found to be highly correlated, therefore it was decided presenting only the proportion of UPFs in the lunch would adequately describe the level of processing in the diet.

Additionally, the consumption of NOVA sub-categories was analysed. In the analysis I present only the NOVA 1 subgroups (unprocessed drinks, fruit and vegetables, dairy products, starchy products, minimally processed meat and fish products) and the NOVA 4 subgroups (ultra-processed drinks, ultra-processed bread, snacks, condiments, puddings, fast foods [pizza, burgers, chips], ready-to-eat dishes, yogurt and milk drinks, cheese, meat and fish, processed vegetables [baked beans]), which is the majority of dietary intake. More detail of NOVA subgroups is given in Appendix Table III.a.

7.2.2 Covariates

In consistency with Chapter 6, the covariates included were survey year (2008-2017), sex (male/female), age (years), ethnicity (White/Ethnic minorities), equivalised household income (low/middle/high) and country (England, Scotland, Northern Ireland, or Wales). In sensitivity analysis I additionally adjusted for total lunch intake, total calorie intake and BMI.

7.2.3 Statistical analysis

UPF variables were found to be non-normally distributed. Therefore, the average intake of UPF across covariates in primary and secondary students was presented using the median and the interquartile range. Survey adjusted Kruskal-Wallis tests were used to determine if differences were significant across covariate categories. To demonstrate the impact of household income on UPF intake, the median intake was presented stratified by meal type and household income. In addition, the mean intake of NOVA subgroups was presented to describe the contribution of minimally and ultra-processed food groups in children's lunchtime intake by meal type and school phase.

Median regression, or quantile regression using the 50th percentile was used to explore the difference in UPF food content between school meals and packed lunches, stratified by school phase. Median regression was used as the outcome variable was non-normally distributed and violated the assumption of normally distributed residuals required for linear regression. The benefit of using quantile regression was described in Section 4.5. Covariates were included in the model in two stages: Model 1 included age and sex and Model 2 additionally included survey year, ethnicity, region, IMD, and income. An interaction between meal type and household income was also conducted, with covariates similarly added in two steps.

Consumption of NOVA subgroups were dichotomised into consuming none (0g/lunch) or some (>0g/lunch) and logistic regression was performed to compare the intake of NOVA subgroups between meal type and stratified by school phase. Results presented were fully adjusted for all covariates but did not include an income interaction with meal type.

All statistical analyses were performed using RStudio (version 4.0.2). Survey weights were applied in all data analyses to account for sampling and non-response bias[1]. P-values of <0.05 were considered statistically for all tests.

7.3 Results

In the sample of 3,303 participants, 57% were in primary school and 47% took a school meal. The sample characteristics were described in greater detail in Chapter 6.

7.3.1 Average ultra-processed food intake in school lunches

In the total sample, UPF contributed a median of 46.8%g (Q25 26.9; Q75 77.7) to the total amount of food eaten, by weight. There were significant differences across covariates (Table 7.1). For example, children who were female, from an ethnic minority background, a higher income family and from South

England were found to consume a lower amount of UPF, by weight, in their school lunch. There was a significantly higher median intake in secondary schoolchildren (52.5%g; Q25 25.4; Q75 85.4) than primary schoolchildren (43.7%g; Q25 28.3; Q75 71.0). Broadly similar associations across the covariates were seen in both primary and secondary schoolchildren. Moreover, school meals had a lower median UPF content, by weight, in both school phases compared to packed lunches. However, whereas the UPF content of packed lunches remained consistent between primary and secondary school (59%g), the contribution of UPFs by weight in school meals rose 10 pp to 45%g in secondary schoolchildren compared to primary.

Table 7.1 - Median ultra-processed food intake (% g) at school lunchtime across study covariates and stratified by school phase in a sample of children from the National Diet and Nutrition Survey (2008-2017, *n*=3,303)

Variable	**Primary**		**Secondary**		**Total**	
	Median (Q25, Q75)	**P[1]**	**Median (Q25, Q75)**	**P[1]**	**Median (Q25, Q75)**	**P[1]**
Sex		0.07		0.03		0.01
Male	45.4 (29.4,72.4)		58.1 (27.7,87.8)		49.4 (29.3,80.4)	
Female	41.9 (26.9,70)		49.1 (23.9,81.7)		43.2 (25.4,75.4)	
Ethnicity		<0.01		0.02		<0.01
White	45.2 (29.1,73.8)		56 (25.7,87.8)		48.6 (27.7,80.6)	
Ethnic minorities	36.6 (25.2,59.1)		43.8 (22.7,70.8)		39.1 (23.9,64.6)	
Income		<0.01		0.03		<0.01
Low	47 (31.7,76.7)		58.6 (28.7,93.6)		51.7 (30.5,81.6)	
Mid	46.2 (28.5,76.1)		51.6 (25.4,82.7)		48.1 (27,79.4)	
High	37.9 (25.2,58.7)		41.7 (21.8,76.9)		39.2 (24.1,66.3)	
IMD		0.08		0.46		0.44
1 (Least deprived)	40.8 (27.2,61.7)		49.2 (25.9,74.1)		43.7 (26.3,71.5)	
2	40.4 (24.9,72.5)		52.1 (20.9,85.4)		43.5 (22.8,81.2)	
3	42.9 (29.2,67.7)		60.8 (27.9,94.1)		46.1 (28.9,78.6)	
4	49.1 (30.2,76.4)		47.9 (23.6,86)		49.2 (26.9,79.9)	
5 (Most deprived)	43 (29.2,71.9)		58.6 (27,85.4)		48.5 (29,77.3)	
Region		<0.01		0.15		<0.01
England: North	46.8 (30.2,73.9)		60.5 (27.9,85.8)		50.9 (29.7,80)	
England: Central/Midlands	51.9 (31.1,78.2)		55.6 (27.5,89.2)		53.6 (30.2,82.1)	
England: South (incl. London)	38.4 (25.2,60.2)		47.3 (23.5,82.7)		40.8 (24.9,70)	
Scotland	51 (29,80.6)		62.8 (23.4,86.8)		53 (28.3,82.7)	
Wales	52.3 (35.6,79.4)		52.9 (25.5,89.6)		52.7 (30.4,83)	
Northern Ireland	42.7 (29.2,70)		47.4 (22.2,81.3)		43.6 (25.9,73.1)	
School lunch preference		<0.01		0.01		<0.01
School meal	35.4 (23.1,48.7)		45.8 (21.9,80.3)		37.7 (22.9,60.2)	
Packed lunch	59.9 (35.6,82.5)		58.6 (29.2,91.2)		59.7 (33.2,86)	

[1] Survey adjusted Kruskal-Wallis test

When the UPF content of the diet was considered by its contribution to total energy consumed, it was found UPF content was higher by energy than by weight, with a median of 74.4%kcal (Q25 6.2; Q75 89.3) in the total sample. Similar patterns were observed between school phases and across covariates. There was a significantly higher median intake in secondary schoolchildren (77.8%; Q25 57.8; Q75 95.2) compared to primary schoolchildren (72.6%; Q25 55.1; Q75 85.7). Children who were female, of an ethnic minority, higher income household and least deprived neighbourhood consumed fewer calories as UPF in their school lunch (Table 7.2). Again, it was found that school meals had a lower proportion of energy from UPF than packed lunches, there was a 9pp difference in the UPF content of school meals between primary and secondary schoolchildren.

Table 7.2 - Median ultra-processed food intake (% kcal) at school lunchtime across study covariates and stratified by school phase in a sample of children from the National Diet and Nutrition Survey (2008-2017, *n*=3,303)

Variable	**Primary**		**Secondary**		**Total**	
	Median (Q25, Q75)	**P[1]**	**Median (Q25, Q75)**	**P[1]**	**Median (Q25, Q75)**	**P[1]**
Sex		0.2		0.03		0.01
Male	73.7 (57.5,87.1)		80.1 (61.4,97.4)		76.2 (58.9,90.4)	
Female	71.7 (51.2,84.4)		75.4 (55.5,93.7)		72.7 (53.1,88.1)	
Ethnicity		<0.01		0.39		0.01
White	73.4 (56.8,86.7)		78.6 (59.3,95.6)		75.2 (57.6,90.2)	
Ethnic minorities	66.7 (46.2,82.9)		74.4 (49.2,89.1)		70.6 (47.6,85.3)	
Income		0.05		<0.01		<0.01
Low	74.8 (57.8,86.2)		81.6 (63.5,99.6)		77.4 (60.2,92.2)	
Mid	73.3 (55.6,87.4)		78.7 (57.5,95.5)		75.5 (56.2,89.6)	
High	70.3 (51.9,82.8)		71.2 (52,88.3)		70.8 (52,85.2)	
IMD		0.03		0.07		0.02
1 (Least deprived)	71 (53.4,85.6)		72.3 (54.8,89.1)		71.4 (53.9,87.6)	
2	73.7 (54.4,84.7)		76.6 (58.9,94.9)		74.9 (56.1,88.9)	
3	71.9 (55.2,83.8)		82.5 (63.2,96.5)		74.3 (57.7,88.3)	
4	75.9 (59.4,88.5)		79.9 (59.7,95.5)		77.1 (59.7,91.3)	
5 (Most deprived)	70.5 (52.9,85.5)		78.6 (55.9,100)		72.9 (54.3,90.1)	
Region		0.22		0.91		0.91
England: North	75.4 (59.3,88.4)		77.1 (61.9,93.2)		76.2 (60,89.5)	
England: Central/Midlands	74.8 (57.3,86.7)		76.8 (59,100)		75.9 (58,92.5)	
England: South (incl. London)	70.8 (50.9,83.2)		78.8 (55.5,95)		73 (52.2,88.2)	
Scotland	71.8 (51.8,86.5)		80.1 (61.4,95.2)		73.4 (56.1,88.6)	
Wales	73 (55,86.8)		76.9 (56.7,95)		74.7 (55.9,92.1)	
Northern Ireland	73.5 (59.8,84.3)		79.1 (58.8,96.4)		76.3 (59.4,89)	
School lunch preference		<0.01		<0.01		<0.01
School meal	61 (43.7,75.3)		70.1 (47.7,88.9)		64 (45.3,80.3)	
Packed lunch	81.2 (70.5,91.3)		83.5 (64.8,99.1)		82.1 (67.9,93.9)	

[1] Survey adjusted Kruskal-Wallis test

The median levels of UPF were additionally stratified by income to explore there was an effect modifier to the association between school meals and UPF (Figure 7.1). It was found that the lowest income children were more likely to have a higher UPF intake in all meal types and school phases. The difference between income groups was greater when UPF was considered proportional to total grams. Also, the difference was greater in packed lunches which demonstrated a steeper socioeconomic gradient than school meals, this was more apparent in primary schoolchildren compared to secondary schoolchildren.

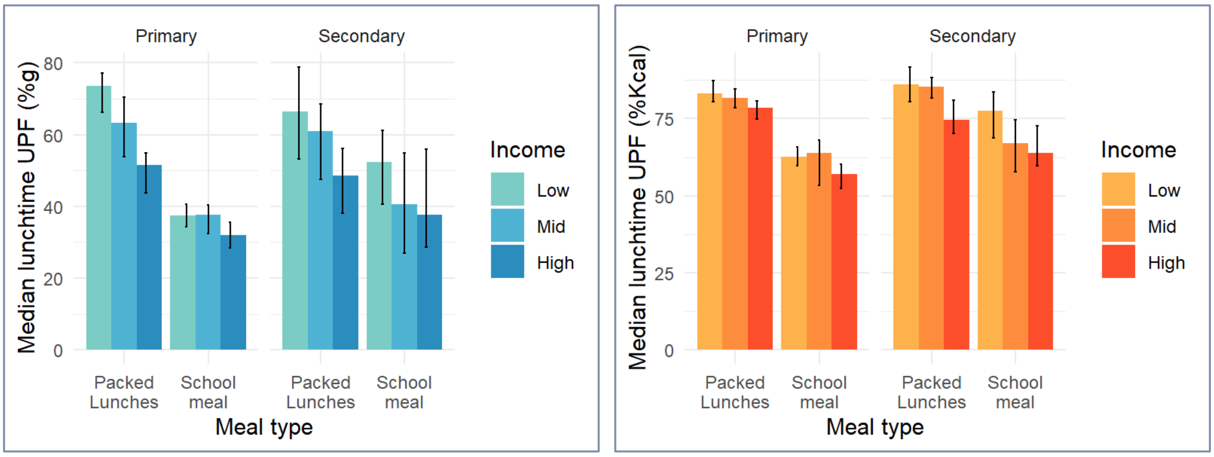

Figure 7.1 – Median intake of UPF at school lunch stratified by meal type and, income and school phase in a sample of children from the National Diet and Nutrition Survey (2008-2017, *n*=3,303)
Note: The left figure presents UPF as %g and right figure as %kcal.

7.3.2 Composition of school lunches

To explore what foods contributed to the difference between school meals and packed lunches across the school phases, the average intake of minimally and ultra-processed food groups is presented in Figure 7.2 and Figure 7.3. In primary schools, the lower intake of UPF as a proportion of grams in school meals was driven by lower intake of ultra-processed drinks, bread, and snacks but a higher intake of minimally processed meat, starchy foods and fruit and vegetables, when compared against packed lunches (Figure 7.2). In secondary schools these overall differences in food groups consumed between packed lunches and school meals remained. However, children having school meals in secondary schools consume a higher proportion of ultra-processed drinks than in primary schools, which appears to account for the higher overall level of UPF intake as a proportion of grams in secondary school compared to primary school. When the contribution of UPF to energy intake was explored (Figure 7.3), the distribution of food groups was altered compared to their contribution to grams. This is due to the differing energy densities of food and drink products. In primary school, ultra-processed bread and snacks contributed to nearly half of the energy intake of packed lunches, compared to 13% in school meals. Conversely, school meals contained a higher proportion of energy intake as fast-foods, puddings, and ready-to-eat foods and a higher proportion of energy as minimally processed fruit and vegetables than packed lunches. In secondary school, the distribution of food groups in packed lunches was similar to the distribution in primary school, with the greatest proportion of energy consumed as UPF bread and snacks. and snacks. The exception was that the school meals in secondary school had a lower intake of minimally processed fruit and vegetables and a higher intake of ultra-processed breads than the school meals in primary school.

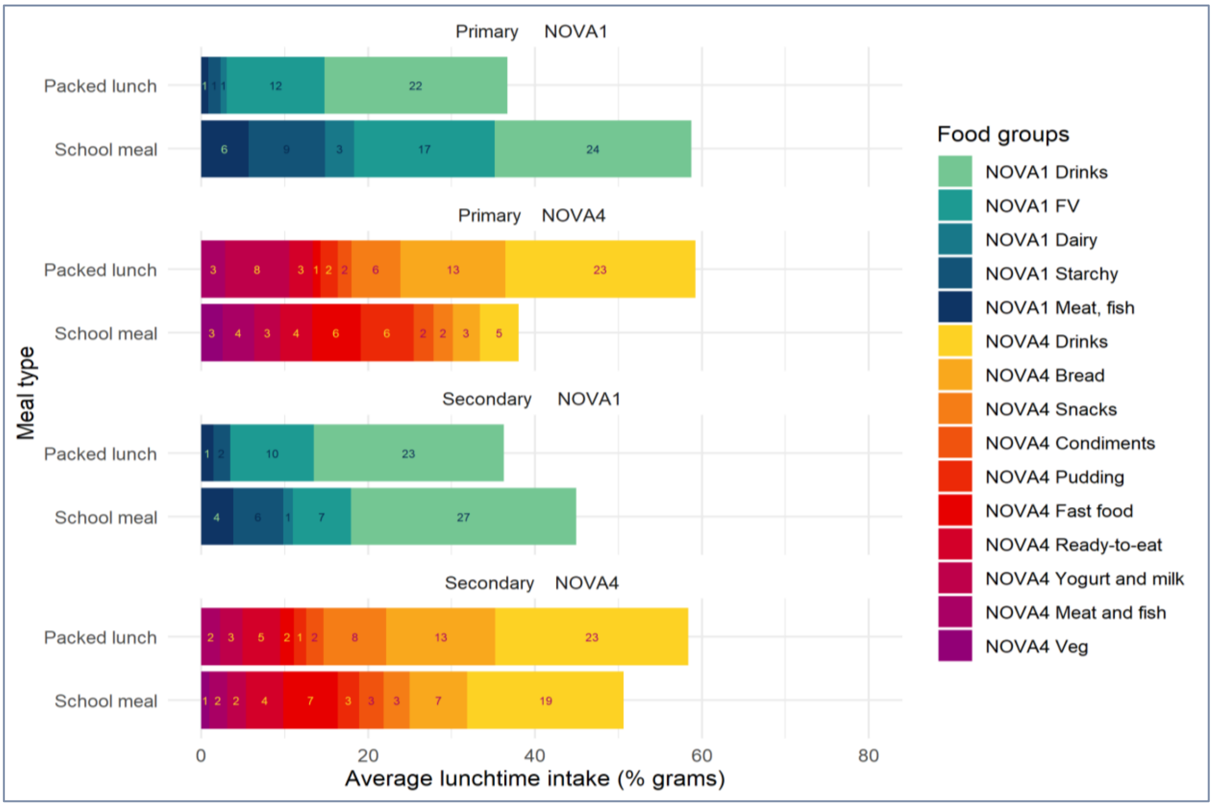

Figure 7.2 - Average contribution of minimally and ultra-processed food groups to food (%g lunch) consumed at school lunch, stratified by meal type and school phase in a sample of children from the National Diet and Nutrition Survey (2008-2017, *n*=3,303)

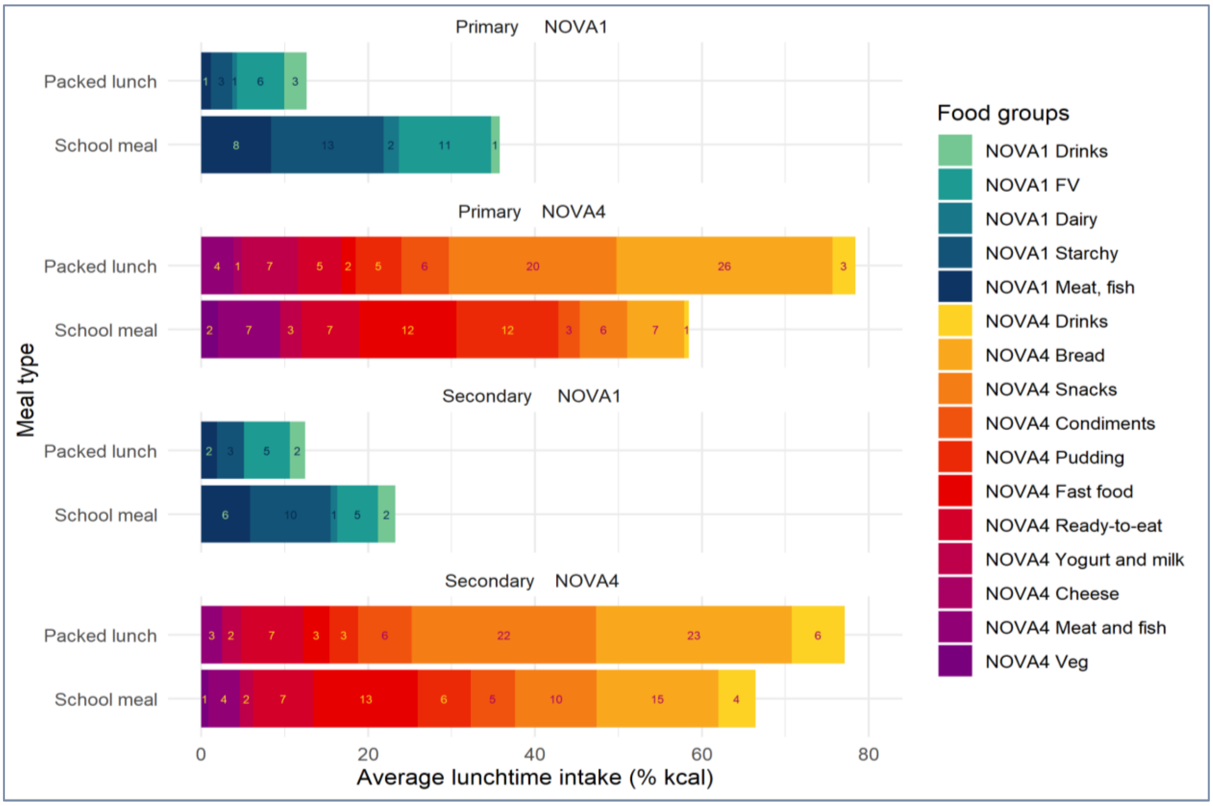

Figure 7.3 - Average contribution of minimally and ultra-processed food groups to energy intake at school lunch (% Kcal lunch), stratified by meal type and school phase in a sample of children from the National Diet and Nutrition Survey (2008-2017, *n*=3,303)

Note: NOVA1 = minimally processed; NOVA4 = ultra-processed; FV= fruit and vegetables

7.3.3 Quantile regression of meal type on ultra-processed food content

In the quantile regression analysis, the association between school meal type and UPF intake was tested. For primary schoolchildren in a minimally adjusted analysis (Model 1), having a school meal was associated with 24pp less UPF as grams and 20pp less UPF as energy at lunch (Table 7.3). After accounting for sociodemographic characteristics, these values did not greatly change. UPF as a proportion of grams per lunch was 25pp lower in school meals compared to packed lunches (95% CI -28.1, -22.3) and UPF as a proportion of calories per lunch was 20pp lower (95%CI -22.3,-17.5). The effect estimates for secondary schoolchildren were weaker compared to primary school children, but school meals still reduced the average intake of UPF. After adjustment for confounders, school meals had 12pp less UPF as a proportion of grams per lunch (95% CI -21.03,-6.51) and 11pp less UPF as a proportion of energy (95%CI -15.99,-6.96) in school meals compared to packed lunches.

Table 7.3 - Quantile regression exploring the association between meal type and ultra-processed food intake at school lunchtime in a sample of children from the National Diet and Nutrition Survey (2008-2017, *n*=3,303), stratified by school phase.

	Primary				**Secondary**			
	Model 1[1]		**Model 2[2]**		**Model 1[1]**		**Model 2[2]**	
Variable	**Coef. (95% CI)**	**P**	**Coef. (95% CI)**	**P**	**Coef. (95% CI)**	**P**	**Coef. (95% CI)**	**P**
UPF (% g)								
School meals	-24.41 (-29.43,-21.45)	<0.001	-24.78 (-28.12,-22.3)	<0.001	-15.26 (-22.49,-7.21)	<0.001	-11.64 (-21.03,-6.51)	<0.001
UPF (% kcal)								
School meals	-20.42 (-22.72,-17.68)	<0.001	-19.64 (-22.26,-17.48)	<0.001	-13.07 (-16.49,-9.63)	<0.001	-11.05 (-15.99,-6.96)	<0.001

[1]Minimally adjusted model - age and sex; [2]Fully adjusted model - age, sex, ethnicity, survey year, region, IMD, and income

When these associations were explored further, it was found there was an interaction between meal type and income. In primary school, school meals showed little difference in the UPF content by income group, either by weight or energy. However, there was evidence of a gradient in the UPF content of packed lunches. The marginal effects from the fully-adjusted regression model with the interaction are displayed in Figure 7.4. It can be seen that the lowest income group in primary school had a 20pp difference in the contribution of UPF to the weight than the high income group (low income 74%, 95% CI 68,82; high income 54% ,95% CI 47,61). The difference in consumption of UPF as a proportion of grams between low- and high-income children is likely driven by the consumption of UPF drinks, with lower income children being more likely to consume UPF beverages. The interaction term was only significant for UPF as a proportion of weight, there was no evidence of an interaction by energy in primary schoolchildren (Appendix Table III.c). This can be seen as the socioeconomic gradient for the proportion of energy consumed as UPF was similar for both packed lunches and school meals (Figure 7.4). It is notable that all groups have a high intake of UPFs as a proportion of energy. The interaction term in secondary school was not significant for either UPFs as a proportion of weight or energy; the socioeconomic gradients in UPF intake are comparable between both meal types.

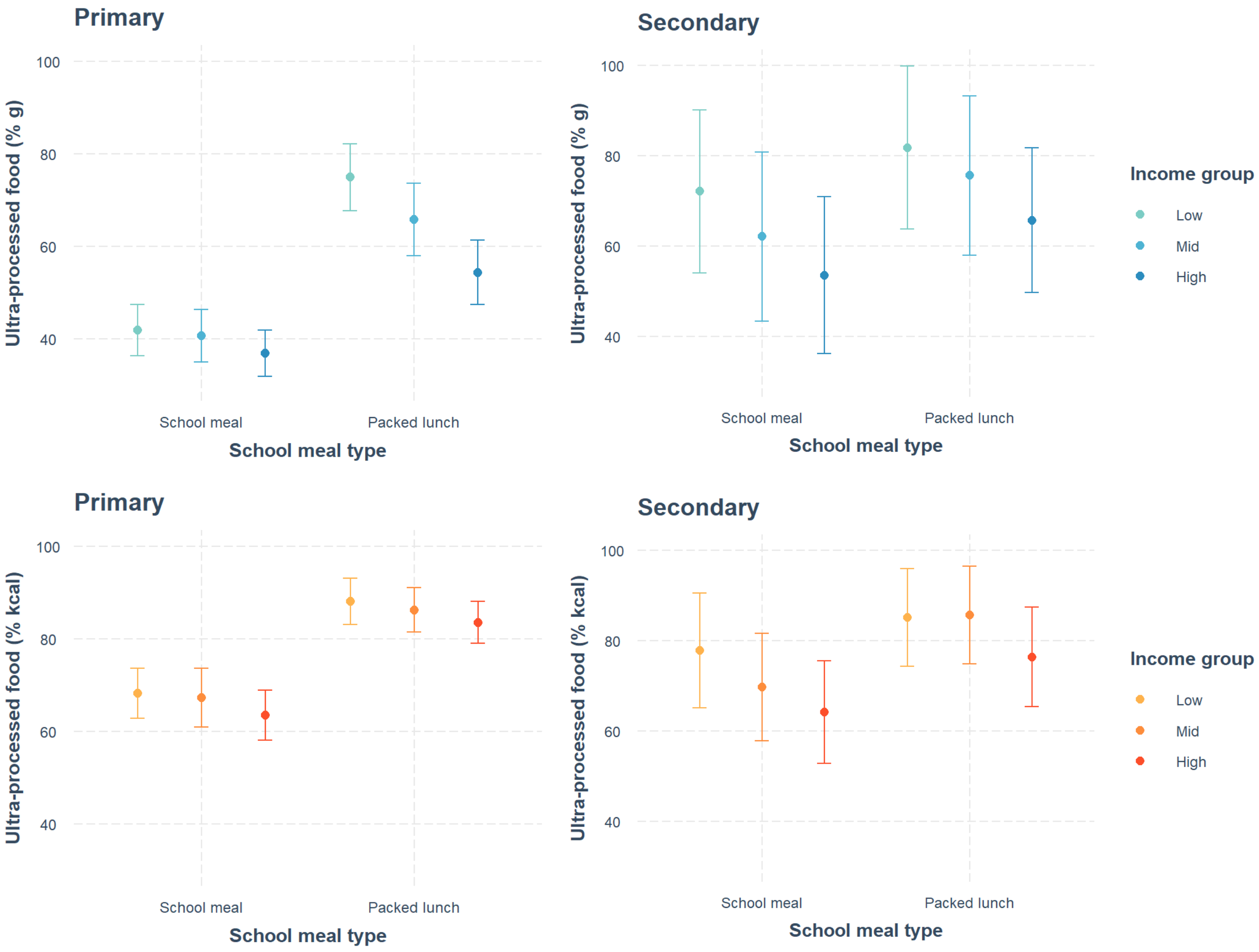

Figure 7.4 – Marginal effects from a quantile regression of ultra-processed food intake at school lunch including an interaction between meal type and income group in a sample of children from the National Diet and Nutrition Survey (2008-2017, *n*=3,303), stratified by school phase

Note: The top two panels present UPF as %g and bottom panels as %kcal. Estimates are adjusted for age, sex, survey year, ethnicity, region, IMD, and income. Full regression model is presented in Appendix Table III.c

7.3.4 Logistic regression of meal type on minimally and ultra-processed food groups

The likelihood of consuming minimally and ultra-processed food groups was explored using multivariable logistic regression (Figure 7.5). In general, there was a pattern in which the school meals of primary schoolchildren were more likely to contain minimally processed food groups and less likely to consume ultra-processed food groups than the school meals of secondary schoolchildren, when compared against packed lunches. These findings indicate that school meal quality declines in later school phases, although they are still preferable to packed lunches. For example, there was a 90% reduction in the likelihood of primary schoolchildren consuming ultra-processed drinks in their school meal compared to packed lunch (AOR 0.1; 95%CI 0.1,0.2), but there was no evidence of a difference in secondary schoolchildren (AOR 0.8; 95%CI 0.6,1.1). Equally, primary schoolchildren had a two-fold increased likelihood of consuming minimally processed fruit and vegetables in their school meal compared to a packed lunch (AOR 2.1; 95% CI 1.6,2.8), but there was no evidence in secondary school children (AOR 0.8; 95%CI 0.6,1.1). For foods such as minimally processed starchy foods, meat and fish and ultra-processed bread, the effect estimate was attenuated in secondary schoolchildren, but was still significant.

The analysis reveals that school meals did not out-perform packed lunches on every outcome. School meals were more likely to contain puddings and fast-food than packed lunches in all age groups (Pudding AOR 2.5; 95% CI 2.1,3.1, Fast food AOR 8.2; 95% CI 6.4,10.4).

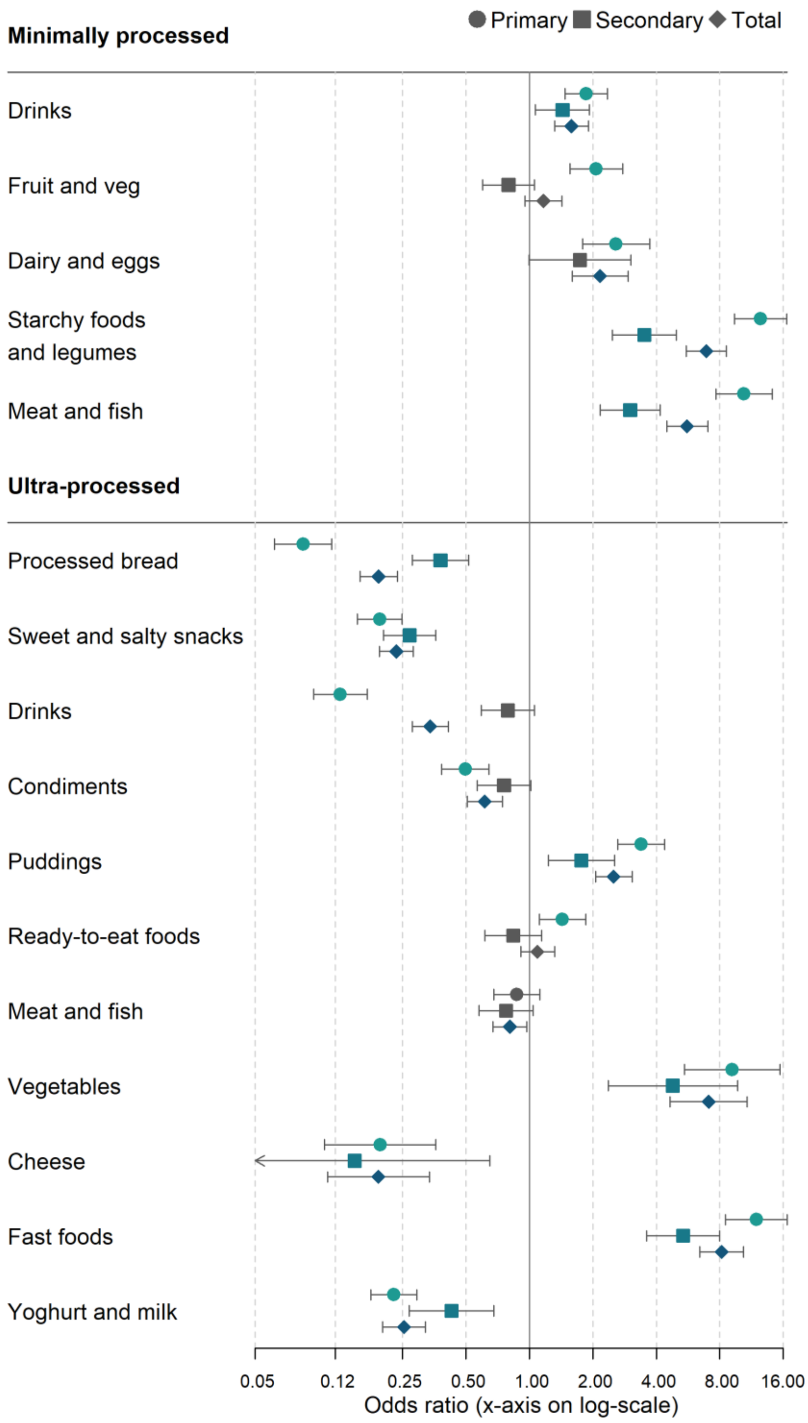

Figure 7.5 - Logistic regression of the likelihood of consuming minimally and ultra-processed food groups by meal type and school phase

Note: Packed lunches were the reference group. Fully adjusted regression model, covariates listed in Appendix Table III.b

7.4 Discussion

In this study I found that UPFs contributed to 44% of the grams consumed and 73% of the energy consumed by primary schoolchildren and 53% of the grams and 78% of the energy consumed in secondary schoolchildren. School meals had a consistently lower content of UPFs than packed lunches, however this association varied by school phase. School meals in primary schoolchildren had 25 pp (95% CI -28, -22) and 20 pp (95% CI -22, -17) fewer grams and calories as UPFs than packed lunches, respectively. The estimates were lower in secondary schoolchildren, with 11 pp (95% CI -21, -6.5) and 11 pp (95% CI -16, -7) fewer grams and energy as UPFs in school meals compared to packed lunches, respectively. Finally, the association also varied by income. In primary school, school meals removed the socioeconomic gradient which was apparent in the UPF content of packed lunches. However, in secondary school, both school meals and packed lunches displayed a socioeconomic gradient in UPF content.

The median contribution of UPF to the energy of school lunches in this study is higher than estimates of UPF across the day in children. Previous literature has determined that on average children consume between 65-69%[2,374] of their daily total calories and 45% of their daily total food intake(g)[143] as UPF. However, these studies present the mean, whereas I chose to present the median. To give a direct comparison, in this study schoolchildren consumed a mean of 70% of their energy and 54% of food weight consumed at school lunch as UPFs. This suggests that intake of UPF intake may be higher in school lunchtime than at other times in the day. One study did estimate the UPF content of lunchtime intake of children in the NDNS, the study used principal component analysis to determine the eating context of lunchtime intakes. Children who had a high factor loading to eating at school, rather than consuming at home or at cafés/shops, were estimated to consume between 66.6%-64.7% of their calories as UPF in children aged 4-10 years[374] and 67.2%-68.5% in children aged 11-18 years[2]. These estimates represent an average of all the lunches recorded in the food diary in all locations, so are diluted by lunches consumed outside of school, explaining the difference between the estimates I presented. This study is the first to estimate UPF intake in school lunchtimes exclusively and which compares the UPF content of school meals and packed lunches. As UPF intake at this age is associated with later obesity[143], it is concerning that school lunchtimes could be a source of higher UPF intake.

This study demonstrates that school meals are an effective way of lowering UPF content of school lunches. UPF contributed to 26% and 13% less of the energy content of school meals compared to packed lunches, in primary and secondary schoolchildren, respectively. This association was driven by higher intake of processed bread, snacks, and drinks in packed lunches but lower intake of minimally processed fruit, vegetables, starchy and meat products. This is expected as due to the School Food Standards school meals are more likely to be freshly prepared whereas packed lunches, by their very definition, are ready-to-eat. Packed lunches have long been recognised as being poor quality[286], with researchers highlighting their nutritional inferiority compared to school meals. These findings are consistent with the research presented in Chapter 6, but there are important distinctions between the findings. For example, in Chapter 6, I showed that school meals were more likely to contain starchy products, a food group used in the School Food Standards. However, in the present study this group was disaggregated by degree of processing, showing that packed lunches were more likely to contain processed bread, but school meals were more likely to contain minimally processed starchy foods such as rice and jacket potatoes. The School Food Standards categorisation masked this difference. Although in the same food group, processing alters the food's matrix and its health potential. Ultra-processing degrades the food structure and removes fibrous elements, making the food more digestible, less satiating, and increases the glucose potential of the food[340,341,375]. All of which are negative for digestive health and energy balance[363,376]. Additionally ultra-processed bread contains a number of acellular components such as additives, which initial animal and cellular studies indicate could impact gut microbiota[377]. Although further research in this field is required to confirm this association. These differences are true for other food groups, such as dairy products, drinks and vegetables in which school meals are more likely to contain the minimally processed version and packed lunches are more likely to contain the ultra-processed version.

School meals are posited as a way of mitigating the socioeconomic differences in the diet[184,378], as they are available to all schoolchildren. This study supports this theory but only in primary schoolchildren. Intake of UPFs is comparable in all income groups in primary schoolchildren's school meals but there are large differences in their packed lunches across income groups. In secondary school children, the socioeconomic gradient of UPF in school meals and packed lunches is similar. Demonstrating that where packed lunches remain of a consistent poor quality in all school phases, both the socioeconomic gradient and quality is worsened for school meals in secondary schools. As discussed in Chapter 6, secondary schoolchildren experience a more dynamic and variable food environment compared to primary schoolchildren. They are given more choice on what they eat for their school lunch, and where they eat it. Consequently, secondary schools aim to serve more 'on-the-go' foods[227,245]. As convenience foods are more likely to be ultra-processed, this may explain the differences seen between school phases. If unhealthy food is consistently offered alongside healthy food to children, it provides children with a choice. Unhealthy and processed food is cheap and highly marketed, especially in more deprived neighbourhoods[379], influencing children and adolescent's preference towards these products [245,289,380]. Additionally, background and home environments have been shown to influence food choice at school[381], children who eat unhealthy and processed foods outside of school are more likely to choose unhealthy foods at school, which will disproportionally include lower-income children[382].

7.4.1 Strengths and limitations

This is the first study to describe the UPF content of children's diet at school. I presented UPF as both %g and %kcal, unlike previous studies which only use one indicator, this allowed for a more thorough description of the UPF intake in school, revealing concerning level of UPF drinks consumption. The classification of food items to NOVA groups was independently performed by two researchers and corroborated with an expert in the field. The detailed dietary information provided in the NDNS dataset allowed for the NOVA categorisation to be applied to all food items, unlike other dietary recording methods, such as a FFQ. The NOVA food classification system is criticised for being too reductive and being a proxy indicator for known harmful dietary components such as high energy, fat, salt and sugar intake[383,384]. Firstly, the previous study used a variety of dietary indicators and I have demonstrated how these classic botanical food groups did not describe important differences between meal types. Additionally, using the multivariate nutrition density model proposed by Willett[334], I additionally adjusted for energy intake and total grams in sensitivity analysis to ensure there were no confounding effect from systematic differences in energy intake or in body size (Appendix Table III.d).

Furthermore, this study used a nationally representative dataset, so the results are generalisable to the UK population. The data were able to explore both the effect modification of school phase and income, which has not before been described in the school lunches of UK children. Finally, this study used the most up-to-date data, including years after the 2015 School Food Standards were introduced.

Lastly this study shares similar strengths and limitations which were discussed in Chapter 6. In brief, not all students recorded their meal type in the food diary (48%) and were assumed by answers on school lunch preference in the survey. Sensitivity analysis repeated the analysis and determined that the study's findings were robust to differences in measurement of meal type (Appendix Table III.e). Finally, as an observational study, there may be unobserved or residual confounding which may bias the estimates.

7.5 Chapter conclusions

In this chapter, I for the first time quantified the level of UPF in the UK school lunches. I found that the level of UPF intake in school lunches was higher than previous estimates in children's total diet. I also demonstrated that school meals had lower intakes of UPF than packed lunches but that this is affected by a child's age and income, in consistency with the previous chapter. Now that I have confirmed this association in the NDNS data, I will use this understanding to evaluate the UIFSM scheme in the next two chapters. I hypothesise that as school meals are of a higher nutritional quality than packed lunches, the scheme which universally provided school meals to Infant school children, will improve average dietary intakes for all children, but will have the greatest impact for low-income children.

Chapter 8. Evaluating the impact of the Universal Infant Free School Meal policy on nutrient and food content of children's lunchtime intake in the UK

8.1 Background

Evidence suggests that school meals are a preferable source of foods and nutrients compared to packed lunches (Chapter 6 and Chapter 7). However, despite this, the current uptake of school meals in the UK is low, with only 38% of infant schoolchildren taking a school meal in 2013/14[315]. Increasing the uptake of school meals has been proposed as a way of improving dietary intake in children[227]. As children consumed one third of their daily calories at school[279], this could have a measurable impact on their overall diet, health, and wellbeing.

The UIFSM policy was introduced in September 2014 in England and January 2015 in Scotland. This programme extended the previous FSM scheme, which was only available to children whose parents received welfare benefits. The UIFSM is an example of universal school-based food assistance. Since introduction, there has been studies demonstrating that the scheme is associated with improved weight in 4-5 year olds[315]. However, evaluations on the programme's impact on dietary intake since its introduction have been limited[316]. An evaluation is needed to understand the programme's impact on average lunchtime dietary intake in infant schoolchildren, how it impacts socioeconomic gradients in dietary intake and whether it could impact total dietary intake across the day.

In this study, I aim to evaluate the impact of the UIFSM policy on the dietary quality of lunchtime intake in infant schoolchildren using detailed, nationally representative dietary data. My secondary aim is to investigate whether the policy impact differed by level of household income.

8.2 Methods

In this study, I used the same data source, the NDNS, as used in Chapter 6. However, to evaluate the UIFSM policy, I used a different study design and analytic sample, which will be described in greater detail below.

8.2.1 Study design

To evaluate the impact of the UIFSM policy on dietary quality, I conducted a natural experiment evaluation using a difference-in-differences (DID) approach[324]. In this study, I estimated the impact of the UIFSM policy by comparing average changes in foods and nutrients consumed at two time points (pre-UIFSM [2010-2014] and post-UIFSM [2014-2017]) between intervention (infant schoolchildren) and control (junior schoolchildren) groups. Junior schoolchildren were used as a control group as they were closest in age and were in the same primary school environment but were not eligible for UIFSM. Therefore, the study tests the impact of school meals being universally free compared to the previous status quo of a means-tested system. I assume that the change in dietary quality in the control group would have been the same in the intervention group in absence of the UIFSM policy and that the two groups had parallel trends pre-treatment.

8.2.2 Study participants

All infant (ages 4-7 years) and junior (ages 8-11 years) schoolchildren from England or Scotland who recorded a lunchtime dietary intake on a school day were included. From the initial sample (*n*=1,127), participants were excluded if they were not at school during lunch on any of their recorded days (22%, *n*=244), their school did not provide food (2%, *n*=28) or they did not record their ethnicity (<1%, *n*=1), leaving an analytic sample of 854 participants.

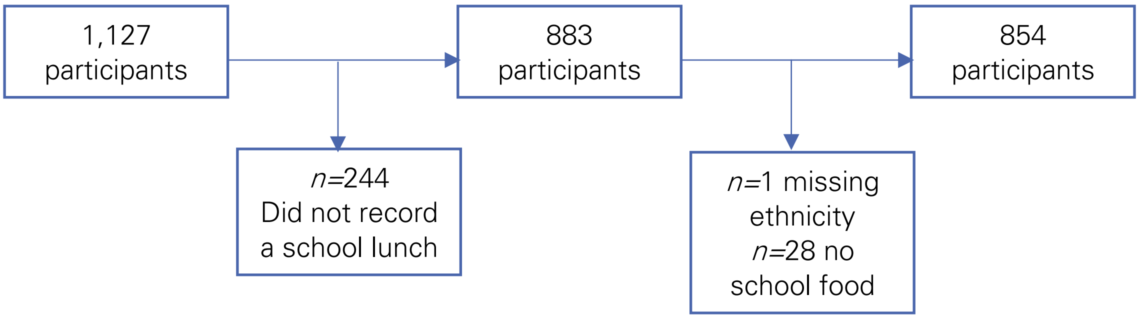

Figure 8.1 - Flow diagram of sample exclusions from school children (aged 4-11 years) in the National Diet and Nutrition Survey

8.2.3 Exposure variables

The UIFSM policy was the exposure in the analysis. Due to the relatively small samples in the intervention and control groups, the data were pooled to two timepoints. Participants were defined as being in the pre-UIFSM time-period if their dietary data were recorded before September 2014 for English participants or January 2015 for Scottish participants. The NDNS supplied a bespoke indicator of the timing of the dietary diary, as this was not available in the publicly available dataset. The post-UIFSM time-period was defined as dietary data recorded after these dates, conditional on country. Indicators of intervention time-period (0=pre-UIFSM,1=post-UIFSM) and intervention group (0=control [juniors], 1=intervention [infants]) were created.

8.2.4 Outcome Variables

This study also used school lunchtime intakes, the definition of which is described in Chapter 6. Food and nutrient intakes at lunch were averaged to one lunchtime where multiple days were recorded (1 school day [*n*=111, 13%], 2 school days [*n*=345, 40%], 3 school days [*n*=229, 27%], 4 school days [*n*=169, 20%]).

In total, 22 food group variables and 20 nutrient variables were used to evaluate changes in dietary quality. A wide range of food group variables (g/lunch) were informed by the School Food Standards and by previous literature. Food groups included wholemeal foods, starchy foods (not cooked in oil), starchy foods (cooked in oil), biscuits, crisps, puddings, sweets, sugar-sweetened beverages (SSB), dairy, fruit and vegetables and foods high in salt, fat or sugar, milk, yoghurt, cheese, high protein foods, baked beans, fruit juice, fruit, vegetables, and water. Foods were defined as being high in either salt, fat or sugar using the UK food labelling guidance[385]. See Appendix Table II.a and Appendix Table II.b for detailed descriptions of the food groups. Nutrient variables included energy (Kcal/lunch), total fat (g/lunch), saturated fat (g/lunch), carbohydrate (g/lunch), non-milk extrinsic sugar (NMES) (g/lunch), protein (g/lunch), sodium (mg/lunch), fibre (g/lunch), calcium (mg/lunch), iron (mg/lunch), zinc (mg/lunch), potassium (mg/lunch), folate (ug/lunch), vitamin C (mg/lunch), vitamin A (ug/lunch), total fat (% energy lunch), saturated fat (% energy lunch), carbohydrate (% energy lunch), NMES (% energy lunch) and protein (% energy lunch) .

Additionally, total daily nutrient intakes were calculated as the sum of all food consumed the day the child attended school, averaged to one school day if multiple school days were recorded. The same nutrient variables were used.

8.2.5 Covariates

Covariates included age (years); sex, ethnicity (White or Ethnic Minority groups); equivalized household income (£); Index of Multiple Deprivation (IMD) (quintiles); geographical region (North England, Central England, South England and Scotland) and total lunchtime intake (g/lunch). IMD is an area-based composite measure of relative deprivation in the UK[386]. All study covariates were complete except for household income which was missing for 11% of the sample (*n*=94). Missing income was imputed using the Classification and regression trees (CART) method,10 iterations were specified[355]. Income was subsequently adjusted for inflation using consumer price indices with 2017 as the base year.

8.2.6 Statistical analysis

Bivariate statistical tests compared sample characteristics between intervention and control groups, separately for pre- and post-UIFSM periods. χ^2 and t-tests were used for categorical variables and continuous variables, respectively.

A DID framework was employed to evaluate the impact of the UIFSM policy on dietary intakes. This was modelled using a regression-based approach that included intervention period, intervention group, and an interaction between them. The interaction term is the DID estimator that measures the effects of the policy by comparing average changes in the outcome between the pre- and post-UIFSM period between intervention and control groups. The control group represents the best estimate of the dietary intake in the intervention group in absence of the policy. I assumed that changes in dietary intakes over time in the intervention group would have followed a parallel trend to that of the control group in the absence of the UIFSM policy. Small annual sample sizes for the intervention and control group (min *n*=51, max *n*=91) precluded an analysis with multiple timepoints pre- and post-UIFSM.

Food-group outcomes were found to be heavily right-skewed, as not all food groups were commonly eaten by all schoolchildren. Therefore, two-part models were used to analyse the effect of UIFSM on intake of food groups. In the first stage, linear probability models were used to assess changes in the probability of consuming a food group, comparing those who had any amount of a food group to those who consumed none. In the second stage, linear regression models were used to examine changes in the average portion size of a food group, including only participants who had consumed some of the food group (intake over 0g). Nutrient outcomes were normally distributed and therefore, linear regression models were used to assess the impact of UIFSM on nutrient intake. Covariates were included in three models: Model 1 was unadjusted, Model 2 adjusted for sociodemographic covariates and Model 3 adjusted for total lunchtime intake (g).

The analyses were further stratified by income tertile (low, medium, and high) to investigate if low-income children were differentially impacted compared to higher-income children.

All models were adjusted by inverse probability weights (IPW) to ensure study covariates were well-balanced across all four groups (Pre-Infants, Pre-Juniors, Post-Infants and Post-Juniors)[387]. The IPW were computed as the inverse of the predicted probability of being in the Pre-Infants group using a multinomial regression including sex, ethnicity, region, household income, IMD, socioeconomic status, and survey weight variable. The result of the IPW is to weight participants on the likelihood of being in the intervention group conditional on observed characteristics, this reduces the possibility of selection biases due to systematic differences between the groups and aims to balance unobserved characteristics[388]. Sensitivity analyses were conducted to compare findings with and without IPW adjustment.

Further sensitivity analyses were conducted to assess potential bias due to dietary mis-reporting using the Goldberg method, adapted for children[335,336]. Unreliable energy reporters were identified by comparing a participant's estimated energy requirements to their reported energy intake. The analyses were repeated excluding participants identified as possible unreliable energy reporters (*n*=44, 5%) to assess if findings were robust to reporting bias.

All data management and analyses were conducted in R studio (version 4.0.2).

8.3 Results

In total, 854 participants were included in the study, 520 in the pre-UIFSM period and 334 in the post-UIFSM period. Take up of school meals pre-UIFSM was comparable for intervention and control groups (47.4% vs. 49.6%, respectively). After UIFSM, the proportion of the intervention group consuming a school meal was significantly higher (80.5%) than the control (48.8%). There were no significant differences in the distribution of sex or ethnicity either between groups or across time periods (Table 8.1). Additionally, there were no significant differences in income, IMD and region in the post-UIFSM period between the groups. However, in the pre-UIFSM period the intervention group was more likely to have a higher household income and come from the south of England than the control group. Application of IPW balanced all sample characteristics between intervention groups and periods (see Appendix Table IV.a).

Table 8.1 - Characteristics of schoolchildren (*n*=854) in England and Scotland in the National Diet and Nutrition Survey before and after the UIFSM policy

Variable		Pre-UIFSM (2010-2014)1			Post-UIFSM (2014-2017)		
		Intervention group (*n*=281)	**Control group** (*n*=239)	**P** [2]	**Intervention group** (*n*=172)	**Control group** (*n*=162)	**P** [3]
Age	Mean (SD)	5.6 (1.0)	9.1 (1.0)	<0.001 [b]	5.7 (1.0)	9.4 (1.0)	<0.001 [b]
Sex	n (%)			0.28 [a]			0.45 [a]
Male		144 (50.1)	132 (55.7)		84 (50.0)	90 (54.6)	
Female		137 (49.9)	107 (44.3)		88 (50.0)	72 (45.4)	
Ethnicity	n (%)			0.98 [a]			0.70 [a]
White		229 (79.8)	196 (79.9)		142 (80.0)	135 (81.9)	
Ethnic minorities		52 (20.2)	43 (20.1)		30 (20.0)	27 (18.1)	
Household income (£)	Mean (SD)	30648.3 (19539.5)	26601.9 (18800.4)	0.03[b]	31479.6 (20798.4)	28976.4 (18465.9)	0.28 [b]
IMD (quintiles)	n (%)			0.07 [a]			0.44 [a]
Least deprived		62 (19.1)	42 (19.4)		40 (20.8)	42 (27.6)	
2		49 (17.4)	41 (14.9)		29 (17.7)	29 (18.3)	
3		60 (23.2)	44 (16.5)		33 (21.0)	27 (13.5)	
4		64 (24.0)	52 (21.2)		34 (19.1)	32 (20.9)	
Most deprived		46 (16.3)	60 (28.1)		36 (21.4)	32 (19.7)	
Region	n (%)			0.03 [a]			0.16 [a]
England: North		57 (21.9)	62 (31.3)		44 (24.0)	37 (20.5)	
England: Central		44 (13.4)	42 (17.8)		28 (16.7)	25 (14.1)	
England: South		126 (55.3)	83 (40.9)		87 (51.8)	77 (49.1)	
Scotland		54 (9.5)	52 (10.0)		13 (7.6)	23 (16.3)	
School lunch type	n (%)			0.68[a]			<0.001 [a]
School meal		139 (47.4)	121 (49.6)		141 (80.5)	78 (48.8)	
Packed lunch		142 (52.6)	118 (50.4)		31 (19.5)	84 (51.2)	

[1] Threshold is September 2014 for English participants and January 2015 for Scottish participants
[2] Pre-UIFSM intervention vs Pre-UIFSM control
[3] Post-UIFSM intervention vs Post-UIFSM control
[a] Chi-square test (Adjusted for survey weights);
[b] t-test Adjusted for survey weights)
Note: UIFSM -Universal Infant Free School Meal; Intervention – Infants (4-7 years); Control – juniors (8-11 years); SD – standard deviation; IMD – Index of Multiple Variation

8.3.1 Policy impact on lunchtime food consumption patterns

The proportion of children consuming a food group was analysed in the first stage of the two-part model. Before the policy, foods which were most frequently consumed at lunchtime included white starchy foods (intervention 75.4% vs control 71.3%), fruit and vegetables (95.0% vs 91.1%) and foods high in salt (69.8% vs 70.9%), fat (87.9% vs 86.5%), and sugar (66.2% vs 71.3%)(Appendix Table IV.b). After the policy had been implemented, there was a decrease in the proportion of the intervention group who ate wholemeal (-13.9pp; 95% CI -21.6,-6.3) and crisps (-11.0pp; -18.3,-3.7) but an increase in consuming puddings (16.0pp; 5.9,26.2), with no evidence of a significant change for any food group in the control group. The DID model estimated the policy impact; the estimates remained consistent when accounting for sociodemographic covariates and total lunchtime intake (Appendix Table IV.b). The fully-adjusted results (Figure 8.2) showed that the intervention group was less likely to consume crisps after implementation of UIFSM (-18.1%; -30.5,-5.7), with weak evidence of reduction in consumption of wholemeal (-12.2%; -24.3,-0.1; P=0.05) and dairy products(-13.4%; -27.0,0.2, P=0.05). There was also some evidence that the intervention group was more likely to consume puddings after UIFSM (14.0%; -0.7,28.7; P=0.06).

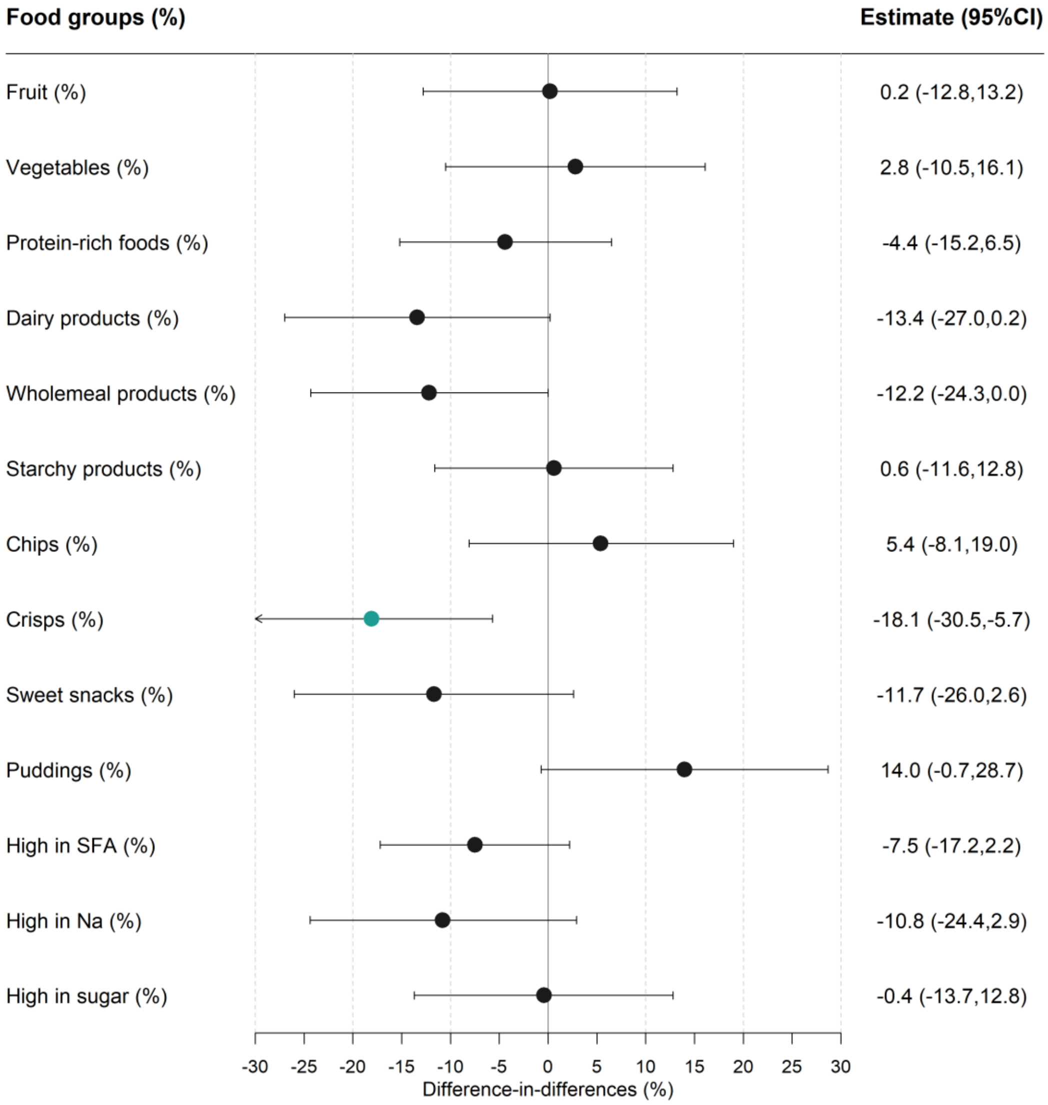

Figure 8.2 - Difference-in-differences estimates of UIFSM policy impact on the likelihood of consuming a food group in a sample of English and Scottish primary school children in the NDNS.

Note: SFA – Saturated fats, Na -– Sodium. Linear probability regression adjusted for age, sex, ethnicity, household size, region, household income, IMD and total lunchtime intake. Pre/Post prevalence of consuming food groups presented in Appendix Table IV.b

The average portion size of a food group consumed was compared among participants who ate some of that food group in the second stage of the two-part model (Figure 8.3 and Appendix Table IV.c). The average portion size for chips, sugar sweetened beverages and foods high in sodium decreased after UIFSM for the intervention but not the control group. However, there was only strong evidence for an increase in the amount of dairy consumed (20.4g; 1.7,39.0) and a reduction in the amount of foods high in sodium consumed (-9.1g; -16.6,-1.6), after adjustment for confounders in the DID model. There was no evidence that the total amount of food consumed at lunch was impacted by UIFSM.

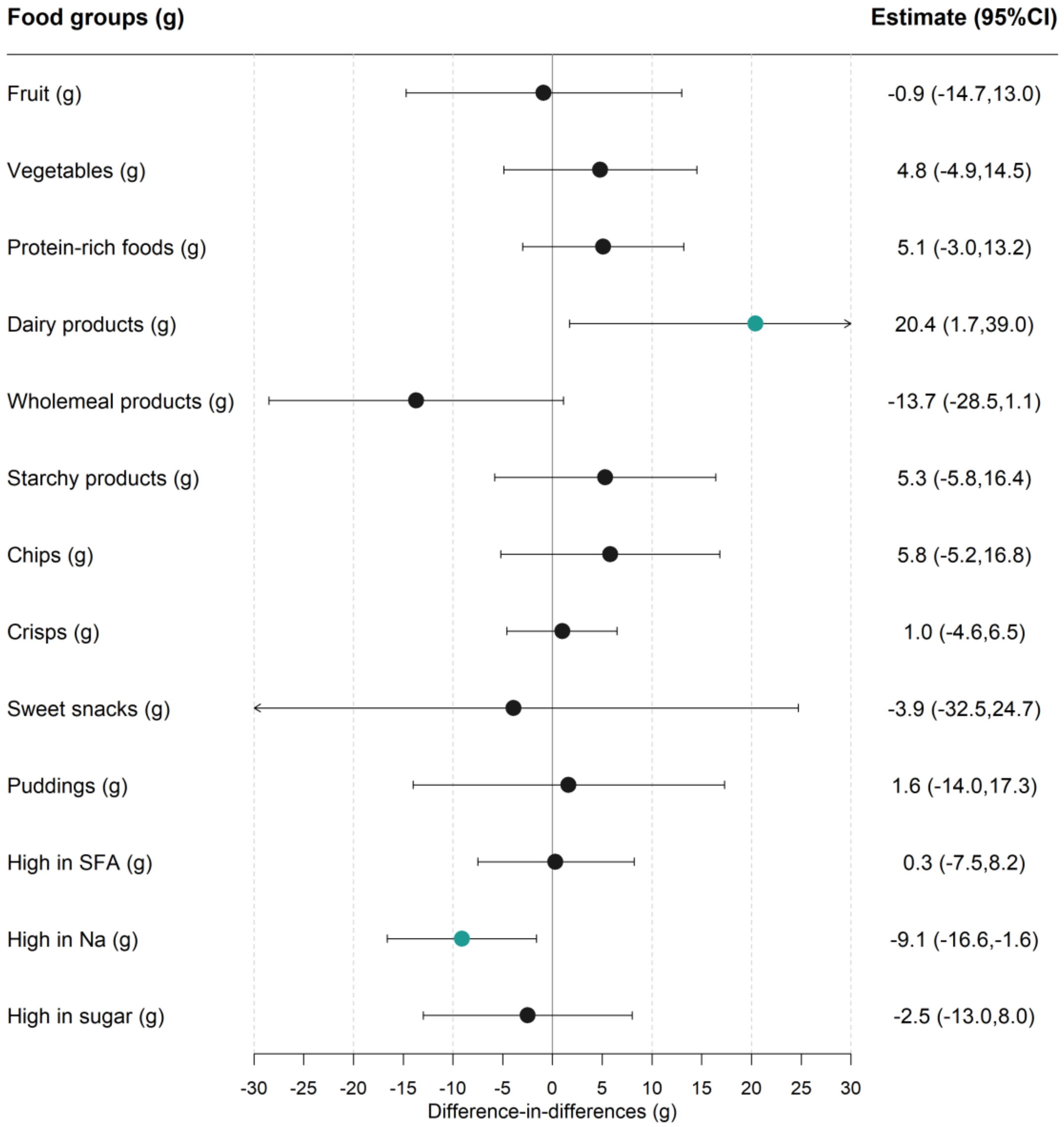

Figure 8.3 - Difference-in-differences estimates of UIFSM policy impact on the amount of food groups consumed (g) conditional on consuming the food group in a sample of English and Scottish primary school children in the NDNS

Note: SFA – Saturated fats, Na -– Sodium. Linear regression adjusted for age, sex, ethnicity, household size, region, household income, IMD and total lunchtime intake. Pre/Post amount of food group consumed presented in Appendix Table IV.c

8.3.2 Policy impact on lunchtime nutrient intakes

When the before-after nutrient intakes were analysed, it was seen that in the intervention group the post-UIFSM sodium intakes were significantly lower (pre UIFSM 515.7mg; post-UIFSM 453.0mg) and the potassium intakes were higher (pre UIFSM 592.6mg; post-UIFSM 641.7mg), with no evidence of a before-after difference in the control group (Appendix Table IV.f). Estimates of UIFSM impacts on lunchtime nutrient intake were consistent after adjusting for sociodemographic covariates and total lunchtime intake. The fully-adjusted DID model showed that UIFSM resulted in lower total fat (-2.5g; -4.5,-0.5), sodium (-103.8mg; -163.1,-44.5) and Vitamin A (-63ug ;-123.8,-4.1) intakes. There was weak evidence that UIFSM impacted energy (-31.9kcal; -66.4,2.6; *P*=0.07) and calcium intakes (-30.5mg; -66.1,5.1; *P*=0.09).

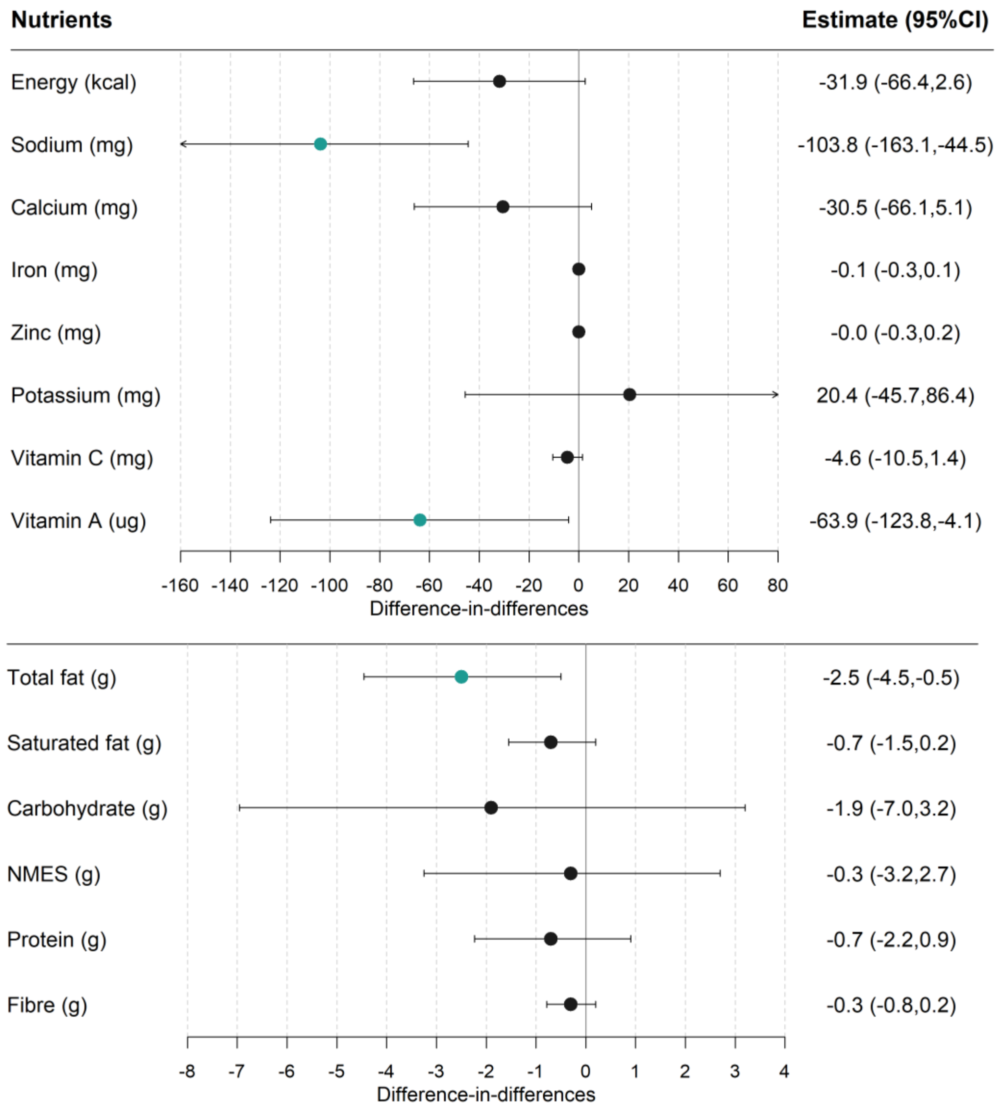

Figure 8.4 - Difference-in-differences estimates of UIFSM policy impact on lunchtime nutrient intakes in a sample of English and Scottish primary school children in the NDNS.

Note: NMES – non-milk extrinsic sugar. Linear regression adjusted for age, sex, ethnicity, household size, region, household income, IMD and total lunchtime intake. Pre/Post mean intakes of nutrients presented in Appendix Table IV.d

A comparable effect of UIFSM on fat was also observed when total fat was analysed relative to energy intake, this was explored to check if the results were robust to possible confounding influence of body size (Appendix Table IV.f).

8.4 Differences between income groups

Lunchtime intakes of food groups and nutrients were broadly similar in high-, mid- and low-income intervention groups before implementation of UIFSM (Appendix Table IV.h and Appendix Table IV.i). The exception was in wholemeal and vegetable products, which were less frequently consumed in the low- compared to the high-income intervention group. Following implementation of UIFSM, there was a significant reduction in the likelihood of consuming crisps (-32.8%; -54.9,-10.6), wholemeal products (-25.7%; -40.5,-10.8) and foods high in saturated fat (-26.5%; -42.6,-10.5) (Figure 8.5) in the low-income but not in the middle or high income groups. UIFSM was also associated with a significant increase in the proportion of the low-income group eating starchy foods cooked in oil (31.7%; 9.6,53.8), milk (18.3%; 3.7,33.0) and water (22.1%; -1.3,45.5), but not in the mid- or high-income group.

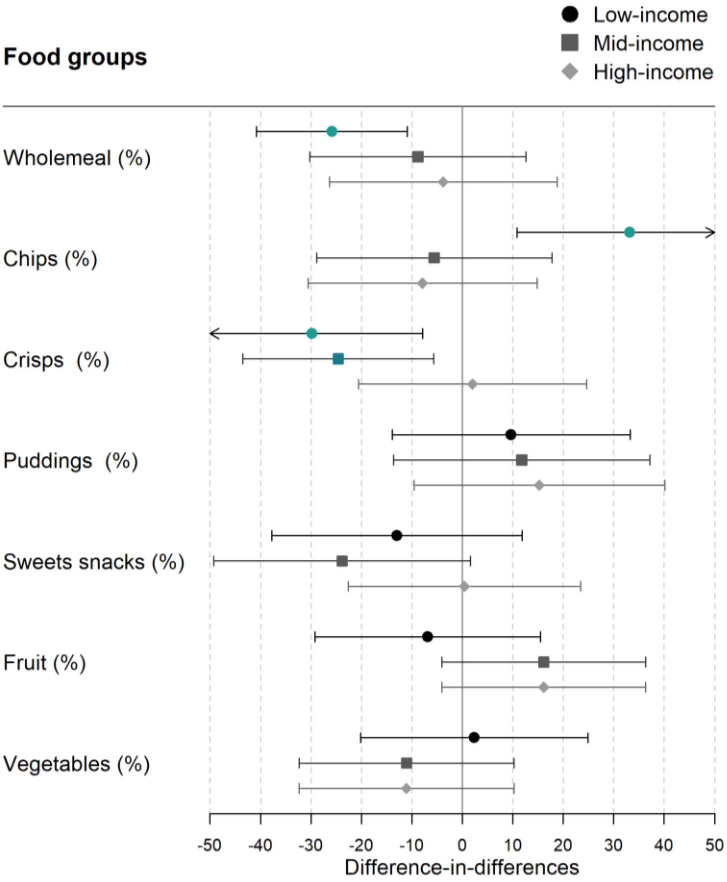

Figure 8.5 - Difference-in-differences estimates of UIFSM policy impact on food group outcomes, stratified by income-level in a sample of English and Scottish primary school children in the NDNS .

Note: Linear probability regression adjusted for sex, ethnicity, household size, region, household income, IMD and total lunchtime intake. Pre/Post intakes of food groups presented in Appendix Table IV.e

When nutrients were analysed (Figure 8.6), a decrease was observed in total fat (-7.1g; -10.7,-3.4) and sodium (-331.0mg; -434.8,-227.1) as well as energy (-122.7kcal; -181.7,-63.6), protein (-3.9g; -6.3,-1.5) iron (-0.6mg; -0.9,-0.3), zinc (-0.5mg (-0.8,-0.2), and calcium (-99.7mg; -157.2,-42.2) in the lowest income group after implementation of UIFSM. However, there was no significant change in the mid- and high-income groups.

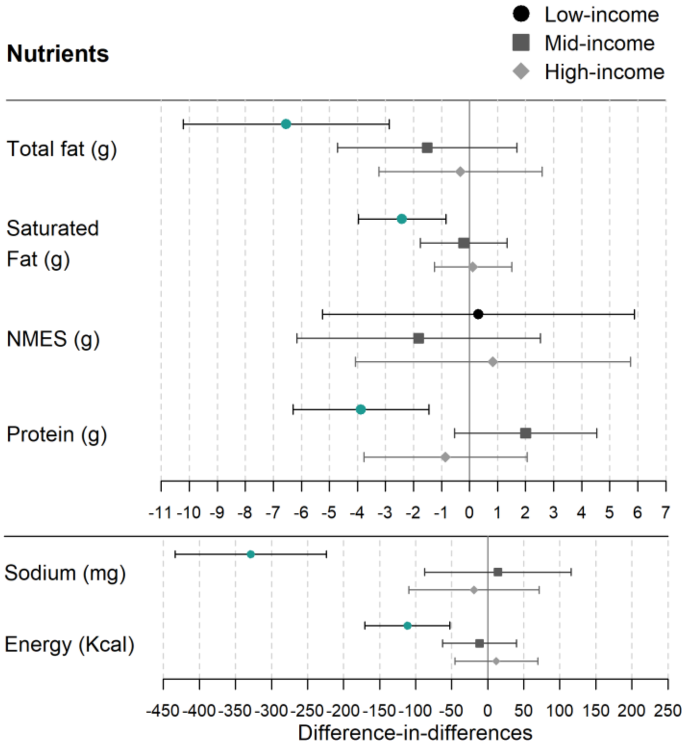

Figure 8.6 - Difference-in-differences estimates of UIFSM policy impact on nutrient outcomes, stratified by income-level in a sample of English and Scottish primary school children in the NDNS

Note: Linear regression adjusted for age, sex, ethnicity, household size, region, household income, IMD and total lunchtime intake. Pre/Post mean intakes of nutrients presented in Appendix Table IV.f

8.4.1 Policy impact on total daily nutrient intakes

The effect of UIFSM on total daily nutrient intake was analysed to assess if nutrient intakes were compensated later in the day (Appendix Table IV.g). The before-after difference in mean sodium levels were lower in the intervention group post-UIFSM. However, this effect was not observed after adjustment for confounders in the DID model (-83.1mg/day; -215.1,49.0). There was however some evidence that the UIFSM policy was associated with a reduction in fat as a proportion of total energy across the day (-1.5% fat of total energy; -3.0,-0.0), after adjustment for confounders.

8.4.2 Sensitivity analyses

Sensitivity analyses showed results were broadly similar with and without IPW adjustment (Appendix Table IV.h and Appendix Table IV.i) Additionally, the findings were not affected by removing participants identified as possible energy mis-reporters (Appendix Table IV.j and Appendix Table IV.k).

8.5 Discussion

This study evaluated the impact of UIFSM on lunchtime and total daily dietary intake in a representative sample of primary schoolchildren in England and Scotland. Implementation of UIFSM was associated with a 33-percentage-point increase in school meal uptake. I found little evidence that UIFSM affected the intake of food groups such as fruit and vegetables at lunchtime. However, there was a reduction in consumption of foods associated with packed lunches, such as crisps, wholemeal and dairy products and an increase in consuming foods associated with school meals, such as puddings. These changes were accompanied by a reduction in total fat and sodium intake; however, there was no detected change in the amount of sugar consumed. Importantly, the effect of UIFSM appeared to be greater for low-income children.

These results show a concurrent reduction in the total fat and sodium consumed at lunchtime, demonstrating that universal school-based food interventions can have a measurable impact on children's lunchtime intake. However, only a difference in total fat intake (-1.5 % energy; -3.0,-0.0) was observed in the total daily dietary intake, indicating children may compensate for the reduction in sodium elsewhere in the diet. Although this change is modest, it has potential to accumulate to a meaningful beneficial impact on child health over time and at a population-level.

I found no evidence that UIFSM affected sugar intake at lunchtime or in the total diet. The likelihood of infant schoolchildren consuming sugary foods was unchanged, with over 70% consuming foods high in sugar post-UIFSM. This may indicate that children were switching the source of their sugar intake, for example there is some indication intake that sugar-sweetened beverages (before-after difference: -6.3pp; CI -13.2,0.6; P=0.08) and yoghurts (before-after difference: -13.5pp; CI -22.9, -4.2; P<0.01) in packed lunches were replaced with puddings in school lunches (before-after difference: 16.0pp; CI 5.9,26.2; P<0.01). Although only differences in pudding intake were apparent in the DID model. The School Food Standards explicitly restrict foods high in sugar, such as sugary snacks and confectionery. Therefore, it was expected that UIFSM would lower sugar intake and it is of concern that intake of these items did not decrease post-UIFSM. Action to remove sugary items from school menus is needed to better enable children to reduce their sugar intake.

The analyses indicated that UIFSM effects were greater for children from low-income families compared to children from high income families. The low-income group in this study included children who were either eligible or ineligible for the means-tested FSM prior to introduction of UIFSM. National estimates indicate that the uptake of school meals in FSM pupils were minimally affected by UIFSM, rising only two pp to around 87%[247,315]. The rise in school meal uptake due to reduced stigma for FSM eligible pupils was lower in national estimates compared to UIFSM pilot studies[314]. Consequently, it is surprising that the middle-income group, who had a larger shift from packed lunches to school meals

(43pp increase) than the low-income group (26pp increase), did not see a similar effect in their lunchtime intake. The FSM eligibility is dependent on receiving social security benefits. As such, it is estimated 2 out of 5 children in poverty are ineligible for FSM[319]. This is partly due to a rise in in-work poverty for households with children[16]. Children who are low-income but ineligible for FSM have been shown to have less spend on their school lunches than more affluent children and are more likely to take a packed lunch (80%)[227], therefore are most at risk of taking a poor quality packed lunch. Indeed, in Chapter 7, I demonstrated that packed lunches in low-income children were more likely to contain UPFs than mid- or high-income children's packed lunches. Unfortunately, in this analysis I was unable to differentiate children who were eligible for a means-tested FSM in the low-income group from those who were not. However, it seems reasonable to hypothesise that the large differences in the low-income group were driven by the children who were not eligible for a means-tested FSM. These children likely experienced a large change in their lunchtime intake compared to FSM eligible children whose lunchtime provision remained similar. In this way, UIFSM has greater potential than the means-tested FSM to address socioeconomic inequalities in the diet, by reaching a larger proportion of low-income children.

There have only been two prior studies evaluating the impact of UIFSM on dietary intake, neither of which were nationally representative. A pilot, conducted before UIFSM was implemented, reported a shift from consuming cold foods (crisps and sandwiches) to hot foods (pasta and chips), and no significant change in an aggregated sweet foods category[313]. Similarly, in a before-and-after study, Spence *et al*[316] observed a lower intake of yoghurts, a higher consumption of cake in one school studied but overall a lower biscuit and sugar intake after UIFSM. However, this study had no control group, so could not rule out the findings being due to another confounding influence during the study period. The findings in this study demonstrate a similar pattern in dietary intake to the previous literature. I was able to extend understanding on this topic by demonstrating how the nutrient profile of lunchtime intakes were altered at a national level, for example lowering lunchtime sodium (-103.8mg; -163.1, -44.5) and total fat (-2.5g; -4.5,-0.5). Holford *et al*[315] analysed national weight data for English schoolchildren and demonstrated that children (Reception year, ages 4-5) exposed to UIFSM for longer had a small but significant increased likelihood of being a healthier weight (1.2% on average) than less exposed children. My analyses showed weak evidence for lower energy intake at lunch (-31.9kcal; -66.4,2.6; *p*=0.07), but only a reduction in fat remained in the total daily diet. It is probable that the difference in sample size between the two studies can explain the difference in results, Holford *et al* had over 154,000 first year schoolchildren, giving their analysis more statistical power to detect small changes.

8.6 Strengths and limitations

This is the first study to evaluate the national impact of the UIFSM on dietary intakes. The nationally representative dataset that I used had detailed dietary data permitting me to examine the effect on a wide range of foods and nutrients and narrow dietary intakes to a specific time and location. Additionally, I was able to assess the effect on total nutrient intake across the day, to assess whether intakes were compensated outside of school. Moreover, this is the first study to evaluate the impact between income groups, highlighting important socioeconomic differences.

There are, however, some limitations to note. Despite being universal, not all infants chose to take-up the scheme, and as such the results represent the 'intention-to-treat' effect of the policy. This implies the estimated policy impacts may thus be diluted by the 20% of infants who took a packed lunch post-UIFSM. Another potential limitation is that changes in the food environment over the study period, such as the introduction of the School Food Standards in 2015, could impact the results. However, in using junior schoolchildren as the counterfactual, I was able to control for this limitation in the DID analysis. Junior schoolchildren are in the same primary school environment, so will experience the same food environment influences as infant schoolchildren. However, a limitation is that junior schoolchildren have slightly different metabolic requirements. The DID model will also control for this difference, by cancelling out any time invariant baseline differences between groups, such as a higher average energy intake. There is a chance of an overspill effect from junior schoolchildren who were exposed to UIFSM in infant school, but as the number is small (*n*=27) this is also unlikely to impact the findings. The UIFSM policy has not been implemented in Wales and Northern Ireland, therefore infant schoolchildren in this setting would have been a more appropriate counterfactual than Junior schoolchildren in England and Scotland. However, the sample size was too small for them to be used in the analysis (pre *n*=110, post *n*= 70).

Another limitation is the potential bias due to dietary misreporting. However, sensitivity analyses which removed possible energy misreporters showed similar results, the biggest divergence being a reduction of 9.6mg in sodium (95% CI -155.0,-33.4). Additionally, there was variation in the number of days recorded between participants, from one to four days, leading to a variation in the level of measurement error in the outcome across the sample. This may lead to increased standard errors but not bias in the estimates.

The NDNS did not record whether a child attended a state or independent school. Resultantly, any independently educated children in the sample might not have been exposed to the UIFSM scheme, which is only available in state schools. National statistics estimate 0.6% of primary-school aged children attend independent schools[247], therefore the impact of bias from this source of misclassification is likely to be small. Moreover, it is unlikely that the prevalence of independent schools would vary pre- and post-UIFSM. Finally, the study is limited by small sample size; to counteract this I pooled the data across years to maximise sample size.

8.7 Chapter conclusions

In this chapter I used natural experiment methods to evaluate the impact of the UIFSM scheme on dietary intake in infant schoolchildren. I found that there was evidence of reduced intake of some food groups associated with packed lunches, and nutrients such as total fat and sodium. However, I also saw evidence of a negative impact on the pudding intake of children. Finally, I identify that there were important socioeconomic differences in the effect, whereby the lowest income children had the most to gain from the programme. These findings have important implications for policy, which will be discussed in Chapter 11. However, as I demonstrated in Chapter 7, that comparing dietary intake just using two dietary indicators limits the understanding of dietary intake and possibly masks important differences in the level of industrially processed food intake. As I demonstrated that packed lunches have a higher UPF content than school meals, I hypothesise that the UIFSM will be associated with a reduced UPF intake at a national level. In the next chapter, I go onto test this hypothesis by analysing the impact of the UIFSM on industrial processed food intake, using the same DID models.

Chapter 9. Evaluating the impact of the Universal Infant Free School Meal policy on the ultra-processed food content of children's lunchtime intake in the UK

9.1 Background

The intake of UPF is alarmingly high in British children compared to both British adults and children from other countries[39,368], with known negative consequences for child health[143]. In Chapter 7, I demonstrated packed lunches are a higher source of UPF at school lunch for children than school meals. Therefore, increasing school meals uptake could be a method of not only lowering lunchtime UPF intake in children but addressing socioeconomic differences in UPF intake. Furthermore, introducing children to healthy and minimally processed meals could help to introduce and habituate children towards healthy foods and help them form healthier dietary preferences and reduce dependency on UPFs.

In the previous chapter, I demonstrated the UIFSM had an impact on children's diet through lowering the intake of crisps, total fat, and sodium. However, I found limited impact on groups such as fruit and vegetables and an increase in the intake of puddings. It is essential that the impact of UIFSM on the intake of UPF is described. Children's food has been heavily marketed by UPF companies[380], with parents reporting being influenced by children's desire for marketed products[389]. Moreover, UPF is cheap, inherently time-saving, and convenient which suits the format of a packed lunch. School meals can be freshly prepared and are not as vulnerable to advertising influences. Therefore, I hypothesise that the universal scheme, through increasing school meal uptake, will lower the intake of UPF and increase the intake of MPF.

In this study I aim to examine if the introduction of the UIFSM policy in 2014 was associated with differences in UPF intake among infant schoolchildren (4-7 years) compared to junior schoolchildren (8-11 years).

9.2 Methods

In this study I use the same data source, study design, analytic sample, and exposure as the research in Chapter 7. In brief, in this study I used a DID study design to estimate the impact of the UIFSM policy by comparing average changes in lunchtime intakes consumed at two time points (pre-UIFSM [2010-2014] and post-UIFSM [2014-2017]) between intervention (infant schoolchildren, *n*=435) and control (junior schoolchildren, *n*=401) group, using data from the NDNS. For a more detailed description of the methodology, please see Chapter 4. In this chapter, this research will be extended by exploring the impact on a different outcome measure, the intake of UPF at lunchtime.

9.2.1 Outcome Variable

The contribution of minimally and ultra-processed food to the total food (g) or total energy (kcal) consumed at school lunchtimes was the outcome in this study. Similar to Chapter 7, this was assessed using the NOVA classification system. The main outcome measures used were the contribution of minimally processed (NOVA1) and ultra-processed (NOVA4) foods to total intake. This was considered as both relative to total grams eaten (% g) or total energy consumed (% kcal) at lunch. Additionally, the NOVA subgroups were also analysed, these include both NOVA 1 subgroups (unprocessed drinks, fruit and vegetables, dairy products, starchy products, minimally processed meat and fish products) and the NOVA 4 subgroups (ultra-processed drinks, ultra-processed bread, snacks, condiments, puddings, fast foods [pizza, burgers chips], ready-to-eat dishes, yogurt and milk drinks, cheese, meat and fish, processed vegetables [baked beans]).

For a sensitivity analysis, the contribution of MPF and UPF to the total daily energy (%kcal day and weight consumed (%g day) was calculated. This was to test if the UIFSM policy impacted total dietary intakes across the day.

9.2.2 Covariates

In consistency with Chapter 7 the following covariates included were survey year, sex (male/female), age (years), ethnicity (White/Ethnic minorities), equivalised household income (low/middle/high), country (England, Scotland, Northern Ireland, or Wales), lunch portion size (g).

9.2.3 Statistical analysis

The survey-adjusted average intake of minimally and ultra-processed food, including the contribution of NOVA subgroups, was presented for each intervention group and each time-period. Survey adjusted t-tests were used to determine if the difference in the average level of outcome before and after the policy were statistically significant.

Linear regression models were used to assess the UIFSM impact on NOVA outcomes. The models included the intervention time-period (pre-UIFSM/post-UIFSM), intervention group (control/intervention) and an interaction term between the two terms, the DID estimate. The DID estimator measures the effects of the policy by comparing average changes in the level of processed food consumed between the pre- and post-UIFSM period between intervention (infant) and control (juniors) groups. The control group represents the best estimate of the level of processed food consumed in the intervention group in absence of the policy. This assumes that changes in processed food intake over time in the intervention group would have followed a parallel trend to that of the control group in the absence of the UIFSM policy. The residuals were plotted and determined to not deviate substantially from a normal distribution and so did not violate the assumptions of linear regression. Covariates were included in three models: Model 1 was unadjusted, Model 2 adjusted for sociodemographic covariates and Model 3 adjusted for total lunchtime intake (g), see Appendix Table V.a for further details. NOVA subgroups were dichotomised into consuming none (0g/lunch) or some (>0g/lunch) and linear probability models were used to assess changes in the probability of consuming a food group. The analyses were further stratified by income tertile (low, medium, and high) to investigate if low-income children were differentially impacted compared to higher-income children. Finally, models were repeated using total daily intake of UPF and MPF as outcome variables to determine if any impact observed at lunch was also observed in the total diet.

In consistency with Chapter 7, all models were adjusted by inverse probability weights. Sensitivity analyses were performed to check the results were robust to (i) IPW specification and (ii) energy intake misreporting.

9.3 Results

In the sample of 854 participants, 453 were in the intervention group and 401 were in the control group. The sample characteristics were described in greater detail in Chapter 7.

9.3.1 Before-after differences in ultra-processed food intake in school lunches

Before UIFSM, there was a similar intake of UPF in the intervention and control groups. The intervention group consumed 50% of their lunchtime energy as UPF and 67% of their lunchtime food weight, whereas the control group consumed 48% and 70% respectively (Appendix Table V.b). In the pre-UIFSM period, the intervention and control group's intake of UPF, by weight, came from similar food sources; UPF drinks (15% intervention vs 13% control), UPF bread (8% vs 7%) and UPF yoghurts (6% vs 6%) were the biggest source of intake (Figure 9.1). However, the control group had a greater intake of minimally processed drinks (25%) compared to the intervention group (20%). Congruently, the sources of both minimally and ultra-processed food to energy intake are similar between the intervention and control group before UIFSM (Figure 9.2).

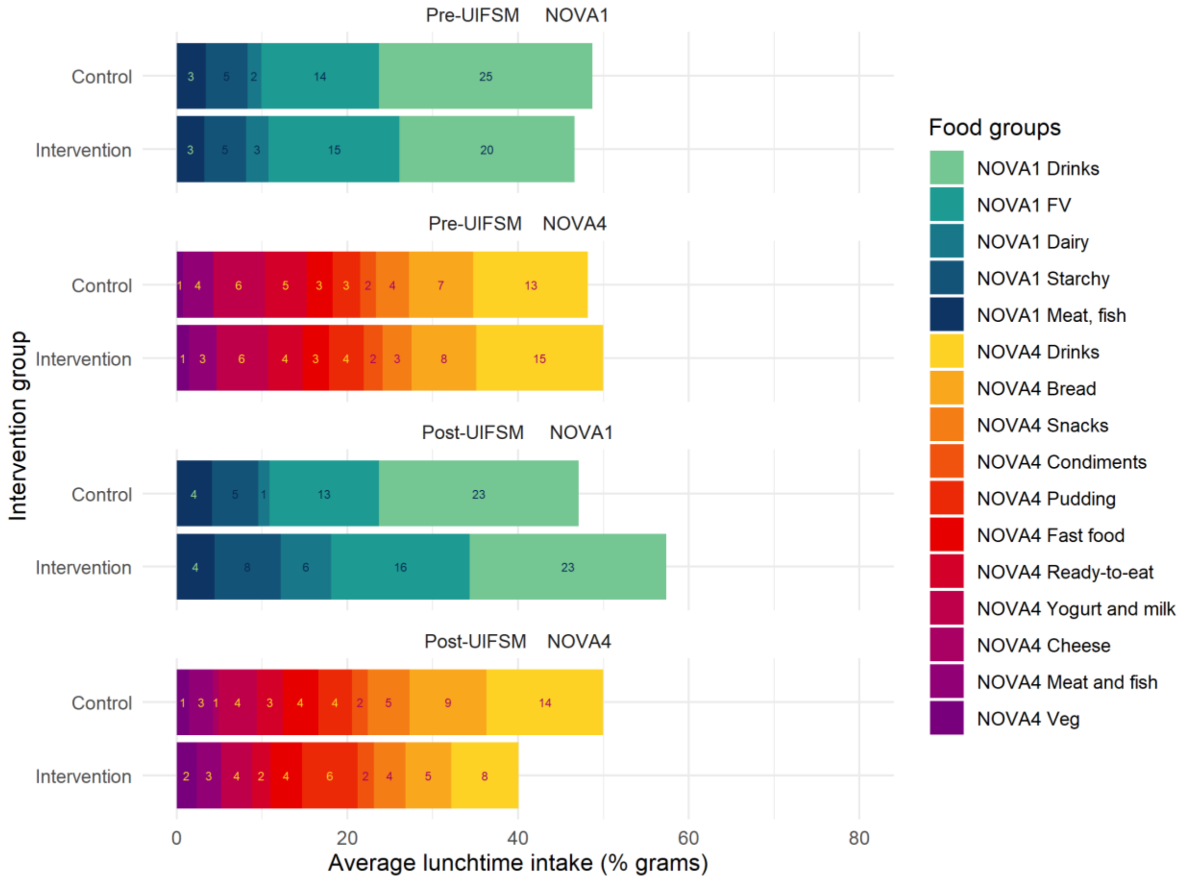

Figure 9.1 - Average contribution of minimally and ultra-processed food groups to food consumed at school lunch (% grams) in a sample of English and Scottish primary school children in the NDNS, stratified by intervention group and time-period

Note: NOVA1 = minimally processed; NOVA4 = ultra-processed; FV= fruit and vegetables; Intervention = Infants (ages 4-7 years); Control = Juniors (ages 8-11 years)

After UIFSM, the intake of UPF contributed 7 pp less to the lunchtime energy intake (post-intervention 60% kcal) and 10 pp less to the lunchtime food weight in the intervention group (post-intervention 40% kcal) (Appendix Table V.a). However, there was no evidence of a difference in the control group, with UPF intake remaining similar for both energy and weight (70%, 50%, respectively). When the contribution by food groups to lunchtime food weight was described, in Figure 9.1, the intervention group had a higher intake of minimally processed fruit and vegetables (16% intervention vs 13% control), dairy (6% vs 1%) and starchy foods (8% vs 5%) but a lower intake of processed drinks (8% vs 14%) and bread (5% vs 9%) than the control group. These patterns were similar when the contribution of food groups to energy intake was described (Figure 9.2). However, by both food weight and energy, the intake of ultra-processed puddings was higher in the intervention group than the control group post-UIFSM.

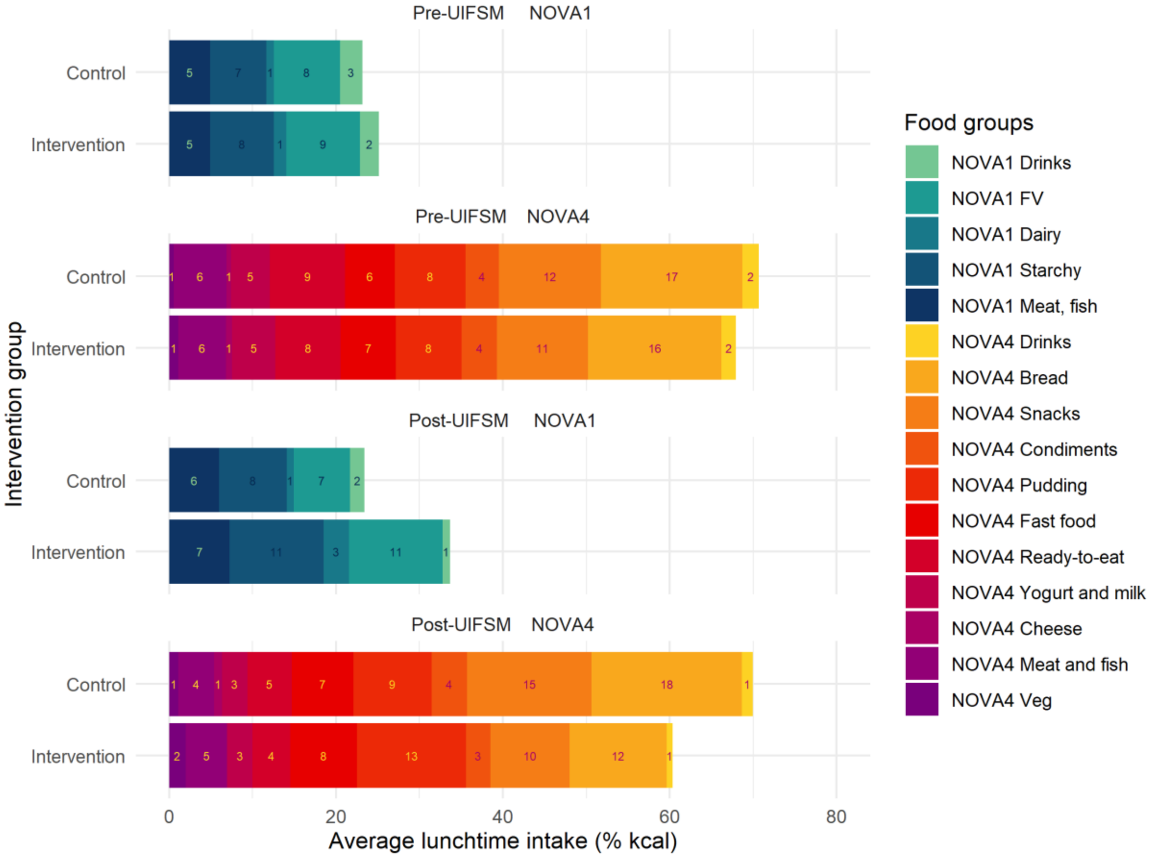

Figure 9.2 - Average contribution of minimally and ultra-processed food groups to food consumed at school lunch (% kcal) in a sample of English and Scottish primary school children in the NDNS, stratified by intervention group and time-period

Note: NOVA1 = minimally processed; NOVA4 = ultra-processed; FV= fruit and vegetables; Intervention = Infants (ages 4-7 years); Control = Juniors (ages 8-11 years)

9.3.2 UIFSM policy impact on lunchtime ultra-processed food intake.

I estimated the policy impact of UIFSM on lunchtime intake of minimally and ultra-processed food using a DID model. Addition of covariates in three steps did not considerably alter the estimates (Appendix Table V.a). After full adjustment of covariates, the UIFSM was associated with an 8.2 pp (95% CI 1.8, 14.6) increase in the amount of minimally processed food consumed by weight and a 11.8 pp (95% CI 4.1, 19.5) increase by energy, see Figure 9.3. Furthermore, there was a 6.4 pp (95% CI -12.9,0.1) decrease in UPF consumption by weight, and a 11.3 pp (95% CI -11.3, -3.5) reduction by energy. However, the evidence that UIFSM lowered the weight of UPF consumed was weaker, with the confidence intervals crossing 0 and the P value equalling 0.05. There was weak evidence that the increase in MPF was maintained throughout the day, impacting total dietary intake (Appendix Table V.e). Across the day, UIFSM was found to be associated with a 3.1 pp (95% CI-0.7,7.0, *P*=0.11) increase in food weight and a 5.1 pp (95% CI -0.4,10.5; P=0.07) of energy consumed as minimally processed food. There was also weak evidence of an effect on the contribution of UPF to energy intake across the day (-4.6pp; 95% CI -10.1,1.0; P= 0.11), but no evidence of an effect on the % grams consumed (-2.5pp; 95% CI -6.8,1.8; P=0.26).

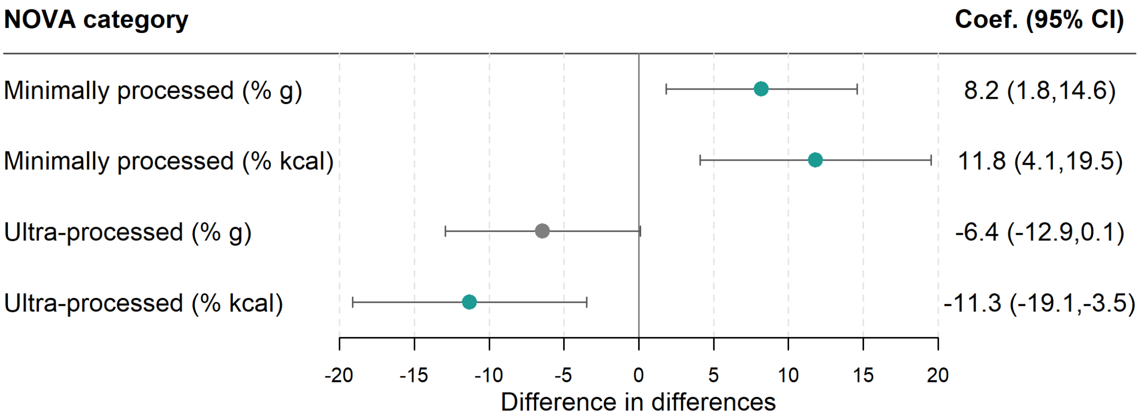

Figure 9.3 - Difference-in-differences estimates of the UIFSM policy impact on lunchtime intake of minimally processed and ultra-processed foods, as a percentage point change of both total food (g) and total energy (kcal) consumed, in a sample of English and Scottish primary school children in the NDNS.

Note: Linear regression adjusted for age, sex, ethnicity, household size, region, household income, IMD and total lunchtime intake. Pre/Post average consumption of minimally and ultra-processed foods are presented in Appendix Table V.a

When the association was disaggregated into minimally and ultra-processed food groups, the associations were less evident (Figure 9.4). There was not strong evidence of a difference in the likelihood of consuming any MPF group after UIFSM was introduced. There was evidence of a reduced likelihood of consuming UPF bread (-19.6 pp; 95% -33.5,-5.8), snacks (-17.4 pp; 95% CI -31.8,-3.1), drinks (-20.2 pp; 95% CI -33.9,-6.6) and cheese (-9.4 pp; 95% CI -16.6,-2.3). However, I also found evidence that UIFSM increased the intake of ultra-processed puddings (19.2 pp; 95% CI 4.6,33.8).

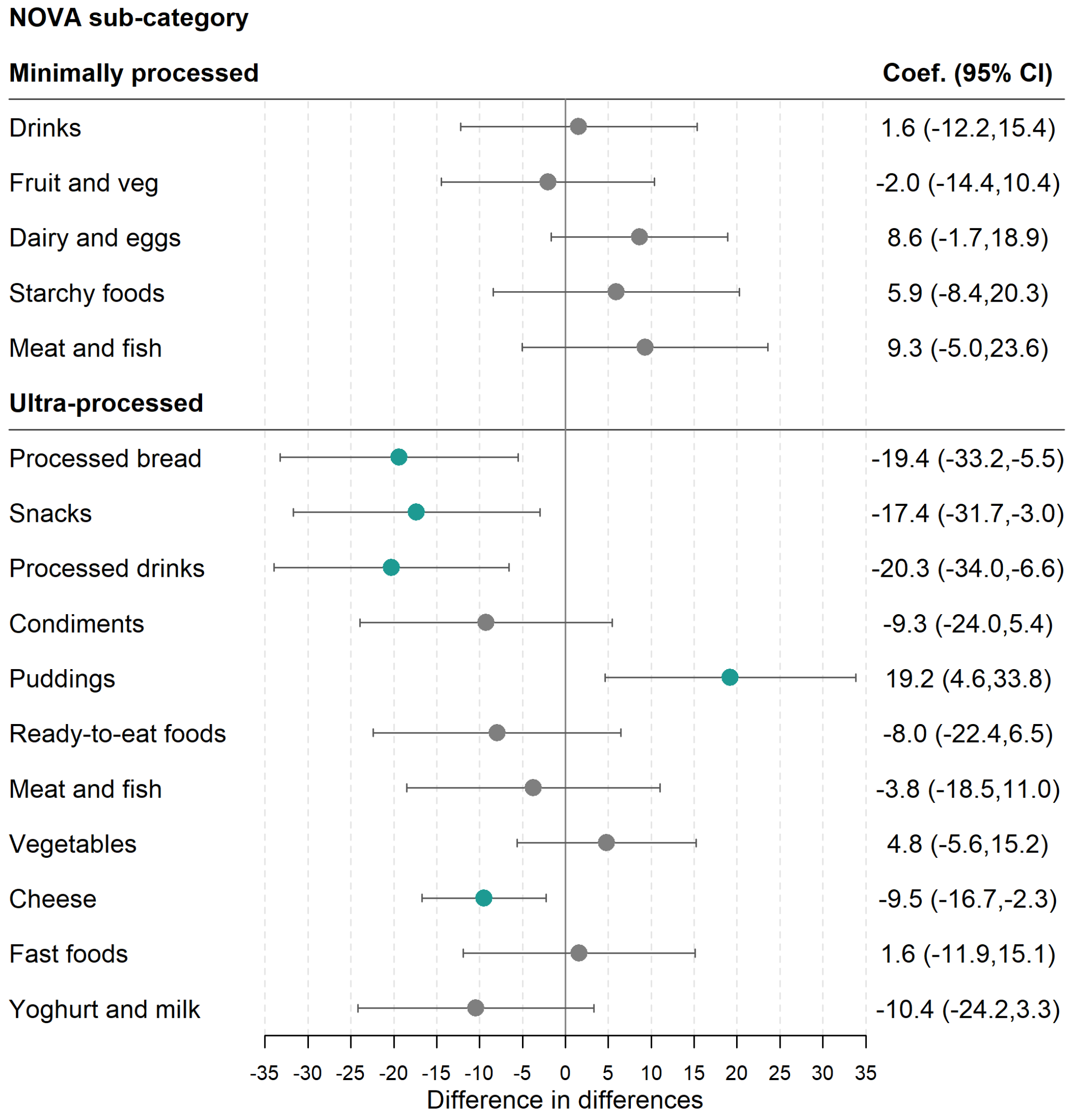

Figure 9.4 - Difference-in-differences estimates of the UIFSM policy impact on the likelihood of consuming minimally processed and ultra-processed food groups at lunchtime in a sample of English and Scottish primary school children in the NDNS

Note: Linear probability regression adjusted for age, sex, ethnicity, household size, region, household income, IMD and total lunchtime intake. Pre/Post average consumption of minimally and ultra-processed foods groups are presented in Appendix Table V.b

9.3.3 Differences of UIFSM policy impact by income group

Before UIFSM there was some evidence of a socioeconomic difference in UPF food intake (Appendix Table V.c). The highest income group had a significantly lower MPF intake than the lowest income group (54 %kcal vs 44%kcal, respectively) and higher UPF intake (43%kcal vs 53%kcal), which was evident in both the intervention and control group. However, the gradient was less apparent by % grams. The UIFSM policy was found to have a much greater impact on the processed food intake of children from low-income households than children from mid- or high-income households (Figure 9.5). For example, the minimally processed content of low-income children's lunches rose by 18-pp by weight (95% CI 6.2,28.8) and 22-pp by energy (95% CI 9.2,35.6) whereas there was no evidence of a change in mid- or high-income groups. Additionally, UPF contributed to -13% (95% CI -25.0, -1.9) of the weight and -20% (95% CI -33.6, -6.9) of the energy content of low-income children's lunches, with no evidence of a difference in mid- or high-income children. Despite there being no evidence of difference in the higher income groups, there appears to be a clear socioeconomic gradient between the income groups for all outcomes studied. Similarly, there was only weak evidence of an effect across the day for some income groups. The contribution of MPF to energy intake across the day appeared to be lower in low- (7.8pp; 95% CI -1.6,17.2; p=0.11) and mid-income groups (8.1 pp; 95% CI -1.6,17.9; p=0.10), but not high-income (-1.2pp; 95% CI -9.8,7.4; p=0.79). Likewise, there was some evidence the contribution of UPF to energy intake across the day was higher in the low-income group only (-7.8pp; 95% CI-17.5,1.8; p=0.11).

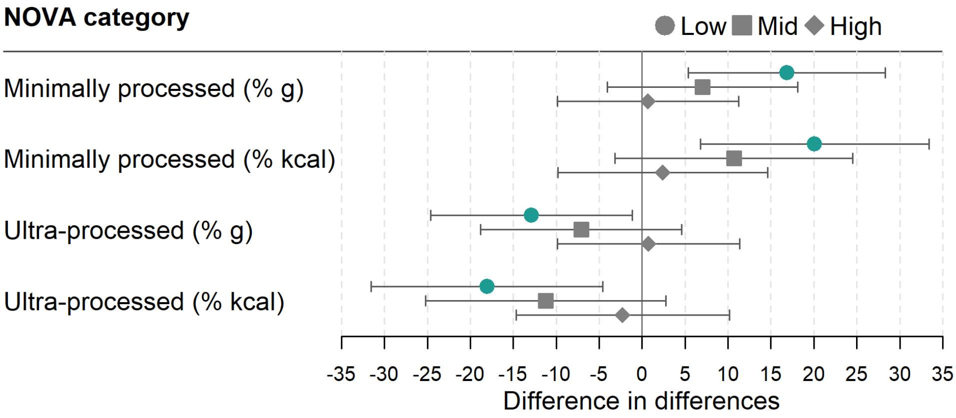

Figure 9.5 - Difference-in-differences estimates of the UIFSM policy impact on lunchtime intake of minimally processed and ultra-processed foods, as a percentage point change of both total food (g) and total energy (kcal) consumed, stratified by income in a sample of English and Scottish primary school children in the NDNS

Note: Linear regression adjusted for age, sex, ethnicity, household size, region, household income, IMD and total lunchtime intake. Average consumption of minimally and ultra-processed foods groups are presented in Appendix Table V.c

Similarly, the policy effect of UIFSM on food group consumption was only observed in the lowest-income groups. There was a lower likelihood of consuming UPF bread, snacks, drinks, and condiments in the low-income group but no other group.

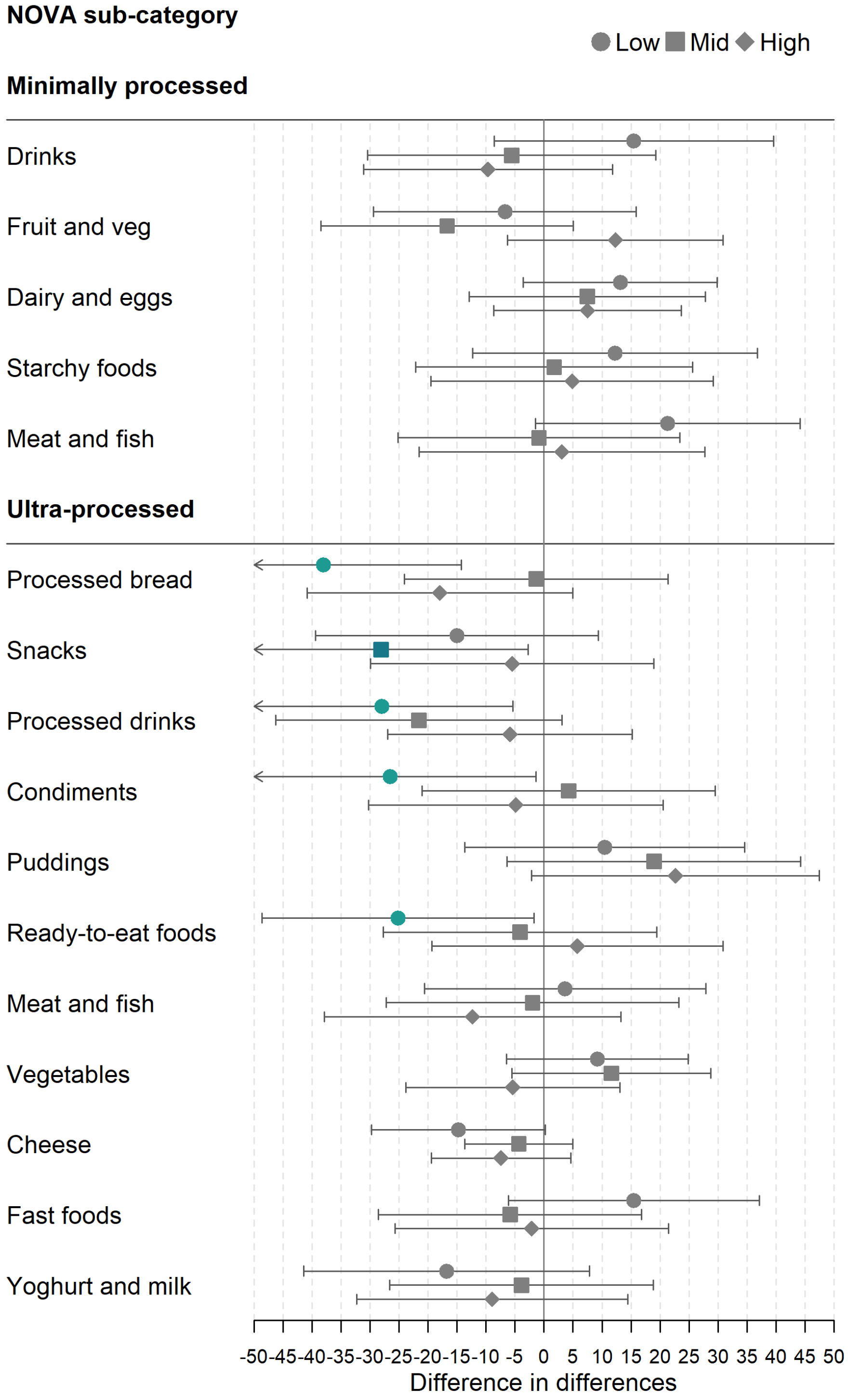

Figure 9.6 - Difference-in-differences estimates of the UIFSM policy impact on lunchtime intake of minimally processed and ultra-processed foods stratified by income groups, as a percentage point change of both total food (g) and total energy (kcal) consumed in a sample of English and Scottish primary school children in the NDNS.

Note: Linear probability regression adjusted for age, sex, ethnicity, household size, region, household income, IMD and total lunchtime intake. Average consumption of minimally and ultra-processed foods groups are presented in Appendix Table V.d

9.4 Discussion

In this natural experiment evaluating the impact of UIFSM on the degree of processing in school lunches, I demonstrated that the policy was associated with a reduction in UPF intake and an increase in MPF intake. This is the first study to evaluate the impact of the UIFSM programme on UPF intake. The effect was driven by a decrease in consuming UPFs associated with packed lunches such as processed bread, drinks, and sweet and salty snacks. However, there was also an increase in ultra-processed puddings. Additionally, I observed a socioeconomic gradient in the association, with children from low-income households more likely to reduce UPF intake at lunch than mid- or high-income children.

The reduction in intake of UPF following the UIFSM policy met the hypothesis generated from my previous research in Chapter 7 and Chapter 8. This is also backed up by research demonstrating higher intake of processed foods in packed lunches, although this has not been formally described before. In Chapter 8, I showed that a reduction in crisps led to a reduction in fat and sodium content of school lunches consumed by infant schoolchildren. I now advance this understanding by highlighting differences by level of industrial food processing. For example, I showed that there was also a reduction in ultra-processed bread and cheese intake. The School Food Standard grouping of ‘Starchy food’ and ‘Dairy’ masks the wide variety of products within this category. The previous chapter indicates there was a reduction in dairy. However, through assessing the degree of industrial food processing, I highlight that this was driven by a reduction in ultra-processed dairy products and not the preferable minimally processed sources of dairy, of which there is weak evidence of an increased intake (8.9 pp; 95% CI -1.5,19.2).

This research adds to evidence that school meals are not of an optimal quality. I found that the UIFSM policy was associated with an increase in the likelihood of consuming ultra-processed puddings. Moreover, the estimates of UIFSM policy impact on ultra-processed and minimally processed intake were substantially smaller than estimates of the difference between school meals and packed lunches in Chapter 7. This might be explained by the UIFSM policy impacts on UPF intake representing the ‘intention-to-treat’ effect. The estimates are diluted by the 20% of infants still taking a packed lunch after UIFSM was implemented. However, schools could aim to provide little or no UPF in their school meals, as unlike packed lunches there is no requirement for the food to be convenient or pre-packaged. It is therefore surprising that UPFs contribute to 40% of the weight and 60% of the energy in the post-UIFSM lunchtime intake in infant schoolchildren. This is emphasised by the consideration that the policy impacts are driven more by a reduction in UPF sub-groups associated with packed lunches and not by a big increase in MPF sub-groups. For example, the before-after difference in the contribution of minimally processed fruit and vegetables to energy intake in the intervention group only rises two pp after UIFSM to 11%kcal. As noted, UPF is higher in fat, salt and sugar and displaces MPF in the diet[39]. Increasing the amount of MPF in school lunches will increase the potential of the UIFSM programme to improve the quality of infant schoolchildren's diet by displacing UPF, restricting the source of fat, salt and sugar and increasing the fruit and vegetable content of their diet. Moreover, a minimally processed menu may increase school meal uptake by providing more appetising food and alleviating parents' concerns over the quality of school food[227].

Finally, this study demonstrated that low-income children had a greater reduction in UPF food and increase in MPF foods in their lunchtime intake than mid- or high-income children. It was seen that UPF foods contributed to a greater proportion of their energy intake than higher income children before the policy. As demonstrated in Chapter 7, the packed lunches of low-income children were more likely to have high UPF content. Therefore, it was expected that this group would experience larger differences in their lunchtime intake. However, there was not strong evidence that the differences in UPF were apparent throughout the day. It may be possible that small differences in the population were not detectable due to limited statistical power in this study.

9.4.1 Strengths and limitations

This study has many notable strengths and limitations which will be discussed in brief. As the study design was similar to Chapter 8 and the outcome variable was explored in Chapter 7, please see the relevant chapters for a more detailed discussion of the strengths and limitations relating to these aspects.

This study is the first to explore the impact of the UIFSM policy on the degree of industrial food processing in children's diet. This was strengthened by the use of nationally representative data, with detailed dietary information which enabled accurate NOVA classification of food items. The quasi-experimental DID methods controlled for sources of bias typical in observational studies. This includes accounting for underlying trends which may have affected children's lunchtimes intake, such as the introduction of the School Food Standards (Chapter 8). In the context of UPF, this is also important as there may have been an underlying trend in UPF consumption overtime, but this will have been controlled in the DID model. Finally, the use of IPW weights were used to balance observed characteristics between groups to minimise the impact of confounding.

There are limitations to note. Sample size issues precluded both the use of Infants in Wales and Northern Ireland as the control group and multiple time-points in the study (Chapter 8). The results represent the 'intention to treat' effect and are diluted by the 20% of children who took a packed lunch. Moreover, in the NDNS it was not possible to exclude children who attended an independent school

(Chapter 8). There is potential bias of dietary misreporting, which was addressed by excluding possible energy misreporters it was found that the results were not substantially altered (Appendix Table V.h).

9.4.2 Chapter conclusions

In this chapter, I advance the evaluation of the UIFSM through describing the impact on the level of ultra-processed food consumption. In congruency with my research in Chapter 7, I show that UIFSM was associated with a reduction in the UPF intake and an increase in MPF consumption. I was able to demonstrate that the differences were larger for low-income individuals. In the past four chapters I have conducted a thorough examination of both the quality of school meals compared to packed lunches and the impact of the UIFSM on dietary intake using multiple dietary indicators. Due to this, I have revealed important associations which have clear implications for policy, which will be discussed in Chapter 11. The COVID-19 pandemic led to unprecedented and major disturbances to schools in the UK in 2020. In the next chapter, I will explore how the COVID-19 lockdowns impacted access to free-school meals for UK schoolchildren.

Chapter 10. Free school meal access in the COVID-19 lockdown

This chapter is based on the short paper published in Public Health (2020)[390], within copyright.

10.1 Background

The coronavirus (COVID-19) pandemic led to a crisis in food security in the UK, deepening previously high levels of food insecurity[133,391]. This occurred on two accounts through lack of physical access to food through food shortages and lack of financial access to food (Section 1.1.2.2.3). If food insecurity caused by financial insecurity is considered alone, food insecurity in households with children rose from 5.7% pre-pandemic to 11% in April 2020[133]. Food insecurity is associated with a wide range of negative health outcomes for children, including increased hospitalisations, asthma and poor mental health[392], so the rise in food insecurity could have serious consequences for children's health and well-being.

On 20th March 2020, all UK schools closed until further notice due to COVID-19, except to vulnerable children and children of key workers. Consequently, the 1.4 million children who claim FSM in England were unable to access their entitlement unless they were eligible to attend a 'skeleton' school (were vulnerable or a child of a key worker)[247]. Vouchers worth £15 per week were introduced from 31st March 2020, to ensure FSM eligible children had continued access to lunch outside of school. Schools had the responsibility of applying for and distributing electronic voucher codes to their free school meal eligible pupils. However, each of the devolved nations took different approaches to FSM provision during lockdown including providing electronic vouchers (England); direct bank transfers (Northern Ireland, Scotland and Wales) and food parcels (Wales and England)[393]. The scheme was only made available to children on the means-tested FSM scheme, not the universal infant FSM scheme.

Upon implementation, there were reports that some beneficiaries were not able to access an FSM substitute[394]. As demonstrated in the previous research chapters, school meals can play an important role in levelling inequalities in dietary intake and have been shown to be healthier than packed lunches[244,277,286]. In a time of sudden economic change, which affected those on low-incomes the worst[395], it is essential that the government ensured continuity of the FSM scheme in the COVID-19 lockdown. Therefore, in this study I investigated access to FSM among eligible schoolchildren in the UK using the COVID-19-wave of the UKHLS. Additionally, I described factors associated with uptake and investigated whether receiving FSM was associated with measures of food insecurity.

10.2 Methods

10.2.1 Data source

UK Household Longitudinal Survey (UKHLS), alternatively called 'Understanding Society', is a nationally representative longitudinal household survey in the UK which has been running since 1991. Data is collected in waves on a range of topics including health, work, education, and income. In response to the COVID-19 pandemic, active UKHLS participants were invited to answer an online questionnaire between 17th and 30th April 2020 (COVID wave 1). The survey included a range of questions on the schooling of the children in the household, from which a child-level dataset was produced from the proxy-responses of a guardian in the household (n=4,559).

10.2.2 Study participants

The analytic sample included 635 children who had complete data and self-reported as FSM eligible. FSM eligibility was determined by the question "*Did {childname} receive free school meals at any time in January or February 2020*?". The question did not distinguish between means-tested and universal schemes and was not asked in pre-pandemic waves of the survey.

10.2.3 Outcome Variable

The primary outcome was access to free school meals during April 2020. This was determined through the survey question "*Are you now receiving vouchers or meals provided by the school?*", which the guardian answered on the child's behalf. Closed-end responses allowed the participant to indicate that either the school had provided a free meal, they had received a voucher, or they had not received anything. Free school meal access was defined as either receiving a voucher or the school providing a meal. The secondary outcome was household food insecurity. This was measured by asking the child's guardian a closed, binary question: "*Still thinking about last week, was there a time when you or others in your household were hungry but did not eat?*". Which is representative of severe food insecurity.

10.2.4 Covariates

Individual and household characteristics were included to investigate which factors explained the variation in FSM access. These characteristics included: school phase (infants [ages 4-7 years], juniors [ages 8-11 years], secondary [ages 12-18 years]); ethnicity of guardian (white/ ethnic minority), household income, country (England, Wales, Scotland and Northern Ireland) and school attendance during lockdown (Yes/No). Household income was taken from wave 9 of UKHLS (2017-19) as the variable was more complete and could be equivalised for household composition (OECD scale)[347]. Participants with missing income information were included in a fourth category.

10.2.5 Statistical analysis

Firstly, a multivariate logistic regression was used to determine the associations between the covariates and access to FSM, all covariates were included in the model. An interaction between income-level and school phase was tested to investigate whether the association between income and receiving FSM differs by school phase of the child. The interaction term was not statistically significant. Secondly, a multivariable logistic regression was used to investigate the association between access to FSM and household food insecurity measures (access to healthy food, recently going hungry). The model was adjusted for all socioeconomic covariates listed. All models accounted for survey design and sample weights to adjust for non-response and make the results representative to the UK population. Stata V.15 (StataCorp) was used to perform all descriptive and inference tests, using a 95% confidence level for significance.

10.3 Results

In the analytic sample, 635 children reported being eligible for FSM, 49% of whom did not receive any form of FSM entitlement in April 2020 (see Table 10.1). The analyses found that children who were in the lowest income category were almost five times more likely to receive their FSM entitlement than high income children (OR 4.81; 95% CI 2.10,11.03). Children who attended school during lockdown, were almost six times more likely to receive their FSM entitlement than children who could not (OR 5.87; 95% CI 1.70,20.25). Children in Wales, compared to England, were 89% less likely to access a FSM (OR 0.11; 95% CI 0.03,0.43). The analyses showed a large difference in the odds of receiving a FSM between school phase. Those in junior and secondary schools were more likely to access FSM than those in infant schools (OR 11.81 and 16.45, respectively).

A second multivariable logistic regression model which controlled for the same characteristics assessed whether access to FSM was associated with measures of food insecurity (see Table 10.2). Firstly, access to FSM was not associated with someone in the household feeling hungry but being unable to eat in the past week (OR 0.99; 95% CI 0.35,2.77). Secondly, those who accessed their FSM entitlement were found to be 14 times more likely to have recently used a foodbank (OR 13.91; 95% CI 2.18,88.81).

Table 10.1 - Characteristics associated with receiving a free school meal in lockdown among children who are eligible for a free school meal in April 2020.

	Did the child access their free school meal?					**Logistic regression ‡**	
	No (*n*=341, 49%)		**Yes (*n*=294, 51%)**		**Total (*n*=635)**		
	n	(%)	*n*	(%)	*n*	OR	95% CI
School phase							
Infants (ages 4-7)	284	(77.26)	75	(22.74)	359	*ref*	
Juniors (ages 8-11)	30	(23.69)	93	(76.31)	123	11.81***	(5.54,25.19)
Secondary (ages 12-18)	27	(16.94)	126	(83.06)	153	16.45***	(7.59,35.66)
Guardian's Ethnicity							
White	315	(49.75)	252	(50.25)	567	*ref*	
Ethnic minority	63	(43.49)	80	(56.51)	143	0.65	(0.09,4.82)
Equivalised household income †							
Low	123	(35.02)	192	(64.98)	315	4.81***	(2.10,11.03)
Middle	119	(61.84)	79	(38.16)	198	2.46	(1.00,6.10)
High	99	(81.94)	23	(18.06)	122	*ref*	
Missing	37	(46.54)	38	(53.46)	75	1.9	(0.72,5.02)
Country							
England	321	(46.73)	283	(53.27)	604	*ref*	
Wales	13	(75.75)	17	(24.25)	30	0.11**	(0.03,0.43)
Scotland	36	(65.59)	19	(34.41)	55	0.66	(0.21,2.05)
Northern Ireland	8	(53.02)	13	(46.98)	21	0.23	(0.01,4.81)
Child at school in lockdown							
Yes	16	(21.49)	32	(78.51)	48	5.87**	(1.70,20.25)
No	362	(51.23)	300	(48.77)	662	*ref*	

* *P*<0.05; **P<0.01; *** P<0.05. *ref* = reference group. OR = odds ratio. CI = confidence interval.

† Wave 9 household income (2017-18) equivalised using OECD scale and categorised into quantiles

‡ Multivariable logistic regression with school phase, Guardian's ethnicity, household income, country and school attendance included in the model.

Table 10.2 - Logistic regression of the association between food insecurity outcomes and access to free school meals in lockdown among free school meal eligible children.

	Went hungry in past week		**Used a foodbank recently**	
	OR	**95% CI**	**OR**	**95% CI**
Accessed a free school meal				
No	*ref*		*ref*	
Yes	0.99	(0.35,2.77)	13.91**	(2.18,88.81)

* *P*<0.05; **P<0.01; *** P<0.05, *ref* = reference group, OR = odds ratio, CI = confidence interval

Adjusted for: school phase, Guardian's ethnicity, household income, country and school attendance included in the model.

10.4 Discussion

These analyses demonstrate that a significant proportion of eligible children could not access free school meals during the COVID-19 lockdown. As children who attended school were more likely to receive a meal, the results indicate that the FSM vouchers did not act as a sufficient replacement for receiving a meal at school.

These data also imply that pupils at secondary schools had better access to some form of the FSM scheme than pupils at infant and junior schools. However, the assessment of FSM eligibility in the study did not distinguish between the means-tested and universal scheme. Consequently, infant school children on the universal scheme but not eligible for the means-tested scheme may be misclassified. If the results were predominantly due to misclassification, we would expect to see an effect modification by income-level. The interaction term was not significant, suggesting there is no difference in the likelihood of accessing a FSM by income-level and school-phase and indicating that misclassification does not explain this association. Moreover, the results found in this study are congruent with the literature, further indicating that the results are not an artefact of misclassification. In an online survey of over 2,000 British adults conducted in March 2020 for the *Food Foundation*, it was found that 54% of parents with children who were eligible for a FSM did not receive any form of substitute[396].

Among FSM eligible children, the lowest-income children were more likely to access FSM. Low-income households have been most greatly impacted by the COVID-19 lockdown[395], so higher uptake likely reflects a greater need in these households to limit food insecurity. This hypothesis is supported by the increased likelihood of foodbank use among children who accessed FSM. Use of food banks in this group reveals an inadequacy of government welfare schemes to protect vulnerable, low-income families in the UK from food insecurity. Although this study was not able to explore the effect on dietary quality, preliminary findings from a study which compared dietary intake at lunch before and after school closures suggested FSM eligible children had a lower dietary quality during the COVID-19 lockdown[397]. Further quantitative studies are needed to fully describe how these disruptions impacted existing inequalities in dietary intake.

The association between countries significantly differed which may reflect the variation in approach to delivering FSM during the COVID-19 lockdown across the devolved nations. FSM benefits were given as vouchers, direct bank payments and food packages. However, the sample sizes in each of the devolved nations are small and limits more thorough interrogation of this association. In the school closures occurring in January 2021, the English Government's response to FSM changed, primarily providing food packages. However, the policy was criticised for being ineffective, with widespread public disapproval of the nutritionally inadequate food packages provided to some families[398]. This issue further highlights the importance of modality of food assistance[399], although data on this period is not available in UKHLS, this could be an important future area of research.

10.4.1 Strengths and limitations

The present study made use of the nationally representative longitudinal dataset, which monitored the impact of COVID-19 on its longstanding participants. In such an unprecedented public health crisis, quick and reactive research was needed to give public health practitioners the evidence they need to protect the public, with the findings being published in August 2020.

However consequently, the study had many notable limitations. Firstly, free school meal access was measured through two categorical questions which did not distinguish between different forms of free school meals or capture reasons behind lack of access. This introduced a possible misclassification bias between the two FSM schemes. Although this was mitigated through an interaction test, this would have been more appropriately avoided if the questionnaires had been more detailed. Moreover, the lack of detail meant all forms of substitute FSM were grouped, possibly masking variation between the substitutions. Future research should build on these limitations and seek to qualitatively determine reasons behind variation in FSM access during the lockdown. Finally, the online-questionnaire format had limited detail in the food-insecurity questions, which does not directly align with validated tools for measuring food insecurity used in national surveys[6], meaning the capability of this study to comment on food insecurity outcomes was limited.

10.5 Chapter conclusions

In the first month which UK schools were closed by COVID-19, this study used nationally representative data to highlight that half of all eligible children did not receive FSM. Although the literature demonstrated that FSM access improved throughout the first lockdown, the policy developments throughout the school holidays and in the third national lockdown indicated repeated debate on the best approach to continue FSM outside of school gates. It is concerning that children from low-income families who could not attend school during lockdown continued to not have access to nutritious meals, putting their physical and mental health at risk. The present findings indicate that the FSM vouchers were not an acceptable substitute for standard FSM provision, raising a vital discussion on effective modalities of food-assistance.

Chapter 11. Discussion

11.1 Main findings

In this thesis I aimed to quantitatively evaluate two predominant food assistance policies in the United Kingdom: Healthy Start and school meal policies. I used nationally representative datasets to evaluate these policies, exploring their impact on dietary quality in children using a broad range of dietary indicators including household purchases, food and nutrient contents of food consumed and the degree of industrial food processing. My findings demonstrate a mixed impact of food assistance policies on the dietary intake of children, with both areas of success and room for improvement.

In 0, I evaluated the impact of the Healthy Start scheme on household food purchases. I demonstrated that households who received the vouchers did not have different spending on fruit, vegetables, or total food spending than eligible households who did not receive the vouchers. This finding indicated that during the study period (2010-2017) the Healthy Start programme may not have been effective at increasing fruit and vegetable spending above usual levels. The research also demonstrated there was clear socioeconomic inequalities in fruit and vegetable purchases. However, due to data availability I was not able to further evaluate Healthy Start using individual-level dietary indicators.

In Chapter 6 and Chapter 7, I compared the dietary quality of school meals and packed lunches in respect of their nutrient, food, and industrially processed-food content. This was to establish the current dietary quality of school meals and to hypothesise the impact of the UIFSM policy. I found that school meals were more likely to meet the School Food Standard's recommendations for food groups such as fruit, vegetables and protein-rich foods and nutrients such as saturated fat, sugar, and sodium. I also demonstrated that school meals had a lower content of UPF and higher content of MPF than packed lunches. Finally, I highlighted that the dietary quality of school meals varied by key characteristics such as age and income. For example, the school meals of secondary school children were of worse quality than primary schoolchildren most dietary indicators studied, and the packed lunches of low-income children contained more UPF than high-income children. The research in these chapters demonstrated the potential that increasing school meal uptake could have on the dietary intake of schoolchildren, indicating that the UIFSM policy would likely be associated with an improvement in dietary quality.

In Chapter 8 and Chapter 9, I quantitively evaluated the impact of the UIFSM scheme on dietary intake using natural experiment methods, testing the previously generated hypotheses. I showed that the introduction of the policy was associated with an increase in school meal uptake, a lower intake of foods associated with packed lunches such as crisps, and a lower intake of fat and sodium at lunchtime. I also demonstrated that the policy led to an increase in the minimally processed and a decrease in the UPF consumed at lunchtime. This research highlighted the potential of the policy to address socioeconomic differences in children's lunchtime intake, as low-income children appeared to have the largest improvement in their dietary intake, while no negative impacts were observed in higher-income children.

Finally in Chapter 10, I explored the access to FSM in the COVID-19 pandemic. I revealed that in the first month of lockdown, half of eligible children did not receive their FSM. Those who did were more likely to have been attending school, indicating that substitute FSM policies were not effective during the study period.

11.2 Strengths and limitations of the thesis

Strengths and limitations specific to each piece of research were discussed in the respective chapters, in this section I will consider the strengths and the limitations which are applicable to the thesis.

A principal strength of the thesis is that all research was conducted using nationally representative, recently collected, high quality datasets. As a result, the research is highly generalisable to the UK population. For this reason, the research has greater value for policy makers as it provides the most up-to-date information on these topics, giving a timely and useful picture of these public health policies, which is essential for decision making. This is reflected in the proactive analysis of FSM access in the COVID-19 lockdown, which was responsive to emerging issues during the pandemic.

The quality and granularity of these datasets has permitted me to answer questions which were previously unanswered. For example, I conducted the first study to evaluate Healthy Start with information on participation in the scheme. Further to this, the level of detail recorded in the NDNS dietary data enabled me to analyse the impact of the UIFSM scheme using multiple indicators which had not previously been explored. I feel it is a strength to have analysed the policy using multiple dietary indicators. The diet is highly complex, using different indicators allows for a more thorough and accurate description of the multiple dimensions involved. Furthermore, describing the level of food processing in the diet is a relatively new approach and not one which has previously been applied in school food research. However, studying the impacts of ultra-food processing is controversial, so some may feel that the inclusion of this dietary indicator is a limitation to the thesis. It has been posited that UPFs do not have an independent effect on health, aside from the known impact of consuming energy-dense, nutrient poor foods[384]. Moreover, it has been suggested that the concept is misunderstood by the public and risks labelling foods which could have a role in a balanced diet as unhealthy, such as fortified wholemeal bread[400]. However, opposing views highlight that evidence shows that UPFs drive overconsumption in an isocaloric diet[401] and have parallels with other addictive substances, making them a unique risk in the diet[402]. As the understanding on the independent impact of UPFs is growing, I feel it is a strength that this thesis includes this dietary measure. Research attention in nutritional sciences has typically followed trends, jumping from focussing from one concerning dietary indicator at a time to another, whether that is fat, sugar, dietary patterns, or degree of food-processing[22]. A lesson should be taken that all indicators have a utility and should not be staged in opposition but used to complement each other. The quality and granularity of these datasets has permitted me to answer questions which were previously unanswered. For example, I conducted the first study to evaluate Healthy Start with information on participation. Further to this, the level of detail recorded for the dietary intake in the NDNS enabled me to analyse the impact of the UIFSM scheme using multiple indicators which had not previously been described. I feel it is a strength to have analysed the policy using multiple indicators. The diet is highly complex and using different indicators allows for a more thorough and accurate description of the multiple dimensions involved. Furthermore, describing the level of food processing in the diet is a relatively new approach and not one which has previously been applied in school food research. However, studying the impacts of ultra-food processing is controversial, so some may feel that the inclusion of this dietary indicator is a limitation to the thesis. It has been posited that UPFs do not have an independent effect on health aside from the sugar, fat and salt content which is commonly high in UPF products. Academics who disagree with the indicator do not feel that the categorisation describes a new health mechanism, aside from the known impact of consuming energy-dense, nutrient poor foods[384]. Moreover, it has been suggested that the concept is misunderstood by the public and risks labelling foods which could have a role in a balanced diet as unhealthy, such as fortified wholemeal bread[400]. However, opposing views highlight that evidence shows that UPFs drive overconsumption in an isocaloric diet[401] and have parallels with other addictive substances, making them a unique risk in the diet[402]. As the understanding on the independent impact of UPFs is growing, I feel it is a strength that this thesis includes this dietary measure. Research attention in nutritional sciences has typically followed trends, jumping from focussing from one concerning dietary indicator at a time to another, whether that is fat, sugar, dietary patterns, or degree of food-processing[22]. A lesson should be taken that all indicators have value and should not be staged in opposition but used to complement each other.

There were a number of limitations that arose from conducting research using routine datasets. The population under study in this thesis, low-income children and families, represent a small segment of the general population in the UK. As such, there were issues in availability of data on my target group. Availability of data on Healthy Start participation was very limited. The LCFS was the only dataset to collect information on Healthy Start participation, however it only collects information on income and expenditure. Therefore, I was not able to extend the evaluation of Healthy Start to other outcomes such as diet, as other datasets such as the NDNS do not collect information on Healthy Start. Data availability also affected the FSM research; the NDNS and UKHLS did not reliably record whether a child was eligible or received a means-tested FSM. This is because after 2014, data collection does not distinguish between the universal and means-tested schemes, responses after this date are inaccurate and inconsistent with national estimates of FSM eligibility in the population. This further limited options within the research, such as being able to distinguish previously eligible FSM children from other low-income nearly FSM eligible children.

Furthermore, when the data were available on the target population, they were surveyed in low numbers, representing a small proportion of the dataset. This is partly due to the data being nationally representative; the numbers reflected the distribution in society. However, it is well documented that low-income populations are less likely to participate in surveys[403,404], which may have further compounded sample size issues. Population weights were used in all surveys to adjust for non-response bias to ensure the results were still representative. Yet weighting could not correct for low sample size of my target population, which was a consistent issue in this thesis and had multiple consequences. An example of such a consequence is that I could not take advantage of the multiple time-points in the repeated cross-sectional datasets I analysed. It was necessary that I pooled the data to either one or two time-points to preserve sample size. Pooled cross-sectional designs are limited as they cannot account for reverse causality and cannot account for trends which may have occurred overtime. This weakens the strength of evidence which can be concluded from this thesis. Moreover, in Chapter 7 and Chapter 9, I was unable to analyse trends over time, using such techniques as the controlled interrupted time series design. In an ideal setting, a longitudinal dataset that followed the same cohort overtime, some of whom were exposed to the policy would have provided the strongest study design to evaluate the policy impact. However in reality, such datasets are rarely available when evaluating public health policies. As such, I used the strongest possible study design with the data available using natural experiment methods to strengthen the study design and reduce bias.

11.3 Policy implications and comparison with international policies

Healthy Start

The Healthy Start evaluation indicated that the vouchers were not associated with higher fruit and vegetable purchases. The research evaluated the programme between the years 2010-2017, due to data availability at the time of analysis in 2019. Previous research conducted in 2004-2008 showed a positive impact of the vouchers[264]. To explain this discrepancy, I propose that price inflation since Healthy Start was introduced in 2006 undermined the voucher's value (see Figure 2.1). Griffith *et al*[264] studied a period when the voucher value was comparable with food costs, while I evaluated the vouchers during a period when price inflation outstripped the voucher value. For this reason, the null effect found in this thesis supports the Government's decision to increase the Healthy Start voucher value in 2021. I hypothesise that this will counteract the negative impacts of food price inflation that have occurred. However, this should also act as a warning that the voucher value should be closely monitored to, at least, be kept in line with inflation in the future. Moreover, the aims of Healthy Start should be considered carefully alongside the value of the Healthy Start voucher. In the introduction I highlight the policy's aims are poorly defined and it is not clear whether the programme's main aim is to provide a safety net or to increase fruit and vegetable intake in low-income families. If policy makers hope for the programme to increase fruit and vegetable intake to a level that will have clinically meaningful improvements to both dietary intake and health of low-income families, then the scheme will likely need a considerable increase in funding above its current level. Further research is needed to determine the price threshold required for low-income families to increase their fruit and vegetable intake to dietary recommendations.

Additionally, I showed that Healthy Start voucher uptake was low, in similarity with national estimates. For the first time, I quantitatively highlighted that certain groups of households were less likely to participate than others, such as those with pregnant women. This confirms reports in qualitative studies that pregnant women were less likely to hear about the scheme than families with young children. Policy makers should reconsider their efforts to publicise the programme, ensuring that no group are excluded. Improving universal awareness of the scheme has been suggested as a way of increasing uptake[261]. There have been no national-level campaigns to improve awareness, with local efforts targeting the eligible populations only. The scheme has recently garnered high-profile publicity through campaigning actions of footballer, Marcus Rashford, and supermarkets giving a public commitment to the scheme. Actions such as these will increase the universal awareness, raising the likelihood that previously unengaged families may become aware of their eligibility. Indeed, the National Food Strategy recommended that the government should run a large-scale Healthy Start communications campaign[12]. Moreover, the requirement for a health professional's signature was removed in April 2020 and the scheme is being digitised throughout 2021, which may help to improve future uptake of the scheme and reduce dependence on health professionals to promote the scheme. It is vital that those who are eligible are getting access to the food assistance which they are owed.

A comparative example of a food assistance policy in the US, WIC, has had a greater body of evidence demonstrating a positive policy impact than Healthy Start. For example in a study nationally representative to the US population, WIC participation was associated with increased intake of vegetables and an increase in overall dietary quality score among low-income infants (ages 2-4 years) [218,405]. Furthermore, there is evidence that the WIC programme is associated with positive health and development outcomes including an increased likelihood of recommended gestational weight gain, recommended infant birthweight[219], length-for-age z scores at 12 months and improved cognitive scores at 24 months[220]. To date, there has been no study of the impact of Healthy Start on pregnancy or infant health outcomes. In comparison to WIC, Healthy Start covers less of the low-income population, has a smaller benefit amount, and covers a greater period of the benefit's life (Section 1.2.4.2). It is important to recognise that there are many different contextual factors between the US and the UK which may explain why WIC appears to be more effective. Despite this, lessons could also be learnt from the success of the programme. As argued in Chapter 5, economic theory posits that to increase spending on a target item, a voucher value needs to be greater than a household would usually spend on that item. It is possible that WIC sees greater success as the benefit enables participating families to buy more healthy food than they would normally be able to purchase, whereas Healthy Start doesn't reach this level. There may be a threshold level for effect. This theory supports the recent increase in Healthy Start voucher value, it will be interesting to evaluate if the effect of Healthy Start changed after the value increase. However, the success of WIC may also be because WIC participants are exposed to the policy for a greater period of time, allowing for habitual dietary habits to be formed and for health benefits to appear. Although there are currently no plans to expand the age-range of Healthy Start, the National Food Strategy[12] have called for the policy to include children until their fifth birthday, in similarity with WIC.

School meal policies

The research in this thesis provides evidence that in the current school food system all schoolchildren would be better off consuming school meals over packed lunches. This demonstrates that the School Food Standards have been effective and highlights the importance of school meals as a public health tool for dietary intake. Additionally, it indicates that increasing school meal uptake would be beneficial for improving dietary intake. There was a thorough review of the school food environment published in the School Food Plan[227], which highlights the importance of increasing school meal uptake and proposes the adoption of a 'whole-school approach' . The report recommended simple changes such as teachers dining with students to improve the ethos in the dining room. However, cost is a major barrier to school meals. This is argued in the School Food Plan, showing that historically school meal uptake has mirrored the price of school food[227]. This is further demonstrated as the biggest impact on school meal uptake in recent years was the introduction of UIFSM policy. Therefore, pricing strategies, including extending universal entitlement to older children should be considered as a policy option for increasing school meal uptake in older school children. However, until this occurs it should be recognised that approximately 50% of older schoolchildren are taking packed lunches, which are not addressed by the School Food Standards. The research in this thesis confirms that these children are likely to eat a poor-quality lunch, high in ultra-processed foods. Considerations need to be made for improving packed lunches in future policies. Actions in some schools have included giving examples of healthy packed lunches to families in newsletters and running raffles which reward children who bring in School Food Standard compliant packed lunches. Some schools have taken more extreme measures of implementing packed lunch policies or banning packed lunches all together.

However, the findings in this thesis put a renewed focus on the content of school meals. Although by most indicators school meals were preferable to packed lunches, they were not optimal, indicating that significant improvements to the school food system still needs to occur. The impact of this can be seen in the evaluation of the UIFSM scheme. While there were positive impacts of UIFSM on dietary indicators, these were not observed consistently across all outcomes hypothesized to change if school meals consistently met the School Food Standards. For example, consumption of foods restricted in the School Food Standards, such as foods high in sugar, did not lower after UIFSM. Fruit and vegetables were not affected, and intake of wholemeal products lowered, likely being replaced by starchy white foods. The School Food Standards are mandatory but are not monitored in England. As such, school food quality is determined more by school leadership than central governance. The amount given to schools for UIFSM (£2.30/meal) has not changed since 2014/15. Some school leaders suggest this is insufficient and puts increased strain on already limited educational resources[250]. This issue will be further compounded by the rising costs of food. Without adequate funding, support for UIFSM by senior leadership is inconsistent[250,311]. Budget constraints in combination with lack of incentives for complying with School Food Standards are reported to contribute to non-compliance in schools[233]. As such, the capability of UIFSM to improve dietary intake is limited by a school’s resources to improve their food environment. This may explain why the UIFSM policy has not yet achieved its potential. Schools have the capability to enact small changes to their food environment, as suggested in the School Food Plan. But they will need increased fiscal resources and support to make larger changes and combat the rising cost of healthy food and serve minimally processed, freshly prepared food. Action to improve the quality of school food will maximise the benefits of UIFSM and get a greater return on investment from the policy. In addition, improving school food quality will have a secondary benefit of encouraging greater uptake, further improving children's diet. As mentioned in the literature review (Section 2.2.3.2), uptake of UIFSM is lowest in upper-class children, whose parents are concerned with school meal quality. Increasing school meal quality will likely improve uptake in this group. Additionally, the more students engage and participate in the school food environment, the more it will be seen as a positive social space to eat lunch. Investing in the school food environment will help to improve uptake. Furthermore, due to the economies of scale, increased uptake will also decrease the costs of delivering healthy food. As cost is a major barrier to school food uptake, this will in turn have a positive impact on school food uptake, an effect termed the 'virtuous cycle' in the School Food Plan[227].

Another policy implication from this thesis is the utility of universal policies at addressing socioeconomic inequalities in children's diet. I demonstrate that low-income children are more likely to consume a packed lunch high in UPFs and that the universal scheme had the greatest impact in the lowest income children. The children previously eligible for a means-tested scheme were not affected by the UIFSM, the biggest impact was in the nearly eligible children, who are hypothesised to have seen the biggest difference in their dietary intake switching from a poor-quality packed lunch to a school meal. This research highlights that the UIFSM has a greater impact on the diets of less affluent children than the means-tested scheme, indicating that many low-income children who need food assistance are excluded from the scheme.

A systematic review of the effect of universal school food programmes demonstrated a consistent impact of similar policies in other settings[254]. Examples of interventions in the US, Denmark, Norway, New Zealand, Greece, and Japan have reported improvements to school meal uptake, dietary intake, and reduced food insecurity. Of note, some studies highlighted the effect of universal programmes in reducing socioeconomic disparities in outcome measures, in congruence with the findings of this thesis[406,407]. Evidence of positive impact from similar schemes adds to the strength of evidence that universal school meal policies are an effective public health policy at improving children's dietary intake.

Extending universal free school meals to junior and secondary school children could act to reach a greater range of children who are in need. However, the substantial cost of extending universal FSM to all schoolchildren means that it is unlikely there will be the political willpower to support this policy. In consideration of cost, the National Food Strategy recommended extending free school meals to children whose families earn less than £20,000/year[12]. They estimated that this would cover 82% and 70% of households with very low and low food security, respectively. While the research on universal schemes indicate there is a benefit across the socioeconomic gradient[315], expanding the means-tested scheme to ensure the majority of food insecure children can access food assistance is a pragmatic policy option.

Food assistance in the UK

The UIFSM and Healthy Start schemes are the most prominent examples of national food assistance policy and can be used to reflect the state of food assistance policies in the UK. The introduction of the UIFSM scheme and recent improvements to the Healthy Start scheme reflect a commitment from the UK government to addressing food insecurity and dietary inequities in young children. However, both schemes are limited in their remit, which consequently limits their potential impact on reducing socioeconomic differences in dietary intake. Healthy Start, for example, only covers children during the first three years of their life and only if they are from households who claim certain benefits. Moreover, the limited voucher amount may often be shared across the household, diluting the amount available for an individual child. The UIFSM programme is available to children in the first three years of school, after which there are eleven years of school in which only children from households claiming the same selective benefits are eligible for FSM. Further to that, only term-time lunches are affected by FSM schemes, leaving holidays and evening intakes vulnerable to the external forces driving food insecurity. Consequently, if meaningful impact to dietary inequities and food insecurity are to be achieved, then a holistic review of food assistance in the UK needs to occur. Food insecure families currently experience periods of relative deprivation due to gaps between policies, from the fourth birthday until starting school, and after the age of seven. The National Food Strategy[12] recommended expanding the eligibility criteria of both Healthy Start and FSM to include all families with an income of less than £20,000 and widening the age limit of Healthy Start to include children until their fifth birthday. This expansion is needed to ensure that more vulnerable young children have continued food assistance through the critical stages in their development. In addition, social security benefits could be considered as a policy to address food insecurity. If social security benefits sufficiently covered the cost of living, there is evidence that this would be associated with lower food insecurity[127].

11.4 Further research and unanswered questions

There are several unanswered questions from this thesis which would be fascinating to explore with further research.

This thesis revealed the impact of Healthy Start on household food purchases. There is a great need for data to explore the impact of the Healthy Start programme on individual level dietary intake and health outcomes. This would answer key questions on how food is shared amongst the household and whether the intended recipient benefits from the full amount of the vouchers. It would also elucidate whether the differences observed in infant formula purchases translated to differences in infant feeding practices and therefore related health outcomes. Currently, there is not sufficient data to answer these questions. Modules on Healthy Start participation should be proposed to the steering groups of routine datasets or upcoming longitudinal birth cohorts to ensure that the data on these programmes is collected in the future.

I have mentioned the wide-ranging changes to the Healthy Start scheme which have been introduced over 2020-2021. From the research in this thesis, I hypothesise that these changes will be positive, however this needs to be quantitatively examined. In particular, there needs to be a more in-depth understanding of voucher value, inflation and household purchasing decisions to ensure the voucher value is sufficient.

Further research is needed to understand the diets of low-income children who are excluded from the means-tested FSM scheme. This is an important group which I have tried to identify in this thesis, but due to sample size and data availability issues, were hard to isolate. Policy makers need greater detail on this under-studied group to give justification for expanding FSM. Data indicate that levels of in-work poverty for households with children are rising[299], therefore it is likely that the number of at-risk but under-served children in need of food assistance will also grow. Moreover, the means-tested FSM is understudied. In the literature it is more frequently considered as a marker of deprivation than a food-assistance policy. I performed a small-scale exploratory analysis to assess the impact of COVID-19 lockdowns on FSM access, yet this could not reveal the impact on diet or food insecurity in detail. Further research using such interruptions in the FSM scheme should be explored.

Finally, there are two areas in which policy in Scotland differs with England, a comparison between the two approaches could reveal important lessons in best practice. Firstly, Scotland monitors the quality of food served in school to ensure it meets the School Food Standards set[408], unlike England which sets standards but does not monitor compliance[226]. It is evident from the research in this thesis that school meal quality does not always meet the standards. It would be valuable to identify if this policy approach in Scotland achieves increased compliance and improved school meal quality to explore if this would be a viable policy for England. As mentioned, improving school food quality has a range of benefits including increasing school meal uptake and improving the impact of UIFSM schemes. So, any action to increase school meal quality could be beneficial and cost-effective. Secondly, Scotland has chosen to take a 'cash-first' approach to food insecurity[197]. Their aim is to prevent food insecurity through increasing wages, decreasing housing costs and maximizing social security benefits. The divergence in approach between England and Scotland creates an opportunity to evaluate the differences between the effectiveness of preventative and reactionary policies for reducing food insecurity.

11.5 Conclusion

Diets in the UK are socially patterned, with the most deprived households more likely to eat unhealthily and experience food insecurity. Households with children are vulnerable to experiencing poverty and so are at high risk of food insecurity[127]. Rising food prices combined with changes to the welfare system mean that the issues around equitable access and availability to healthy food may only worsen in coming years. As diet is a cause of disease burden in the UK and inadequate diet during critical periods of growth can have long-term health consequences, addressing dietary inequities in young children is essential.

In this thesis, I evaluated food assistance policies in the UK: Healthy Start and school meal policies. I explored the impact of these policies on household food purchases and children's dietary intake using nationally representative data. I demonstrated that while there were some successes with the policies, such as lower infant formula purchases and reduced UPF intake, there are some critical changes which need to be made to improve the effectiveness of food assistance policies in the UK.

My key recommendations include:

- Review the Healthy Start policy on a regular basis, ensuring that the voucher value mirrors food price inflation
- Expand the income eligibility criteria for the Healthy Start and Free School Meal schemes to include all families whose income is less than or including £20,000/year. Long-term aim to make school meals universal.
- Expand the age range of Healthy Start to include children up until their fifth birthday
- Review school food quality and determine ways in which schools can be supported to serve more minimally processed, healthy food.

Ensuring that food assistance policies are the best use of limited government money is of great importance. Intervening at an early stage in childhood has the potential for life-long impact on the child's diet, health, and education. It is vital that we act early to prevent the consequences of socioeconomic disadvantage from accumulating across the life course.

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Appendix I. Chapter 5 supplementary tables

Appendix Table I.a - Food expenditure (£/week) and quantity (Kg/week) variables from LCFS dataset and family food database

Variable	COICOP	Description	Maffcode	Description
Fruit	1.1.6.1	Citrus fruits (fresh)	21001	Fresh oranges
			21401	Other fresh citrus fruits
	1.1.6.2	Bananas (fresh)	22801	Fresh bananas
	1.1.6.3	Apples (fresh);	21701	Fresh apples
	1.1.6.4	Pears (fresh);	21801	Fresh pears
	1.1.6.5	Stone fruits (fresh);	22101	Fresh stone fruit
	1.1.6.6	Berries (fresh)	22201	Fresh grapes
			22701	Other fresh soft fruit
	1.1.6.7	Other fresh, chilled or frozen fruits	22901	Fresh melons
			23101	Other fresh fruit
			24101	Frozen strawberries, apple slices, peach halves, oranges and other frozen fruits
Vegetables	1.1.7.1	Leaf and stem vegetables (fresh or chilled)	16701	Lettuce & leafy salads
			17101	Other fresh green vegetables
			18302	Stem vegetables
			18304	Fresh herbs
	1.1.7.2	Cabbages (fresh or chilled)	16201	Cabbages, fresh
			16301	Brussels sprouts, fresh
			13401	Cauliflower, fresh
	1.1.7.3	Vegetables grown for their fruit (fresh, chilled or frozen) *	16801	Peas, fresh
			16901	Beans, fresh
			17601	Cucumbers, fresh
			17801	Tomatoes, fresh
			18303	Marrow, courgettes, aubergine, pumpkin and other vegetables, fresh
			20301	Peas, frozen*
			20401	Beans, frozen*
	1.1.7.4	Root crops, non-starchy blubs & mushrooms (fresh or chilled)	17201	Carrots, fresh
			17301	Turnips and swede, fresh
			17401	Other root vegetables, fresh
			17501	Onions, leeks and shallots, fresh
			17701	Mushrooms, fresh
			18301	Stew-pack, stir-fry and packed mixed veg
			20801	Other frozen veg*

Variable	COICOP	Description	Maffcode	Description
	1.1.7.7	Potatoes	15501	Potatoes bought Jan-Aug, previous year's crop
			15502	Potatoes - bought Jan-Aug, this year's crop
			15503	Potatoes - bought Sep-Dec, current crop or new imported
			15504	Fresh potatoes not specified elsewhere
			15505	Fresh new potatoes
			15506	Fresh baking potatoes
Cow's milk	1.1.4.1	Whole milk	402	UHT milk
			403	Sterilised milk
			404	Pasteurised/ homogenised
	1.1.4.2	Low-fat milk	1502	Fully skimmed milk
			1503	Semi-skimmed milk
Infant Milk	1.1.4.3.	Other milk products (only for households with children <1 year)	1102	Infant or baby milks - ready to drink
			1103	Infant or baby milks - dried

COICOP = LCFS classification codes
Maffcode = Family food database classification codes
*Included from 2011 onwards

Appendix Table I.b - Sample characteristics of households containing children 0-3 years or pregnant women in the Living Costs and Food survey, UK, (years 2010-15) stratified by HS

		HS participants		HS non-participants			Nearly Eligible		Ineligible		Total		
	N (%)	344	(10.57)	281	(8.64)	P^{*}	267	(8.21)	2362	(72.59)	3254	(100)	$P^{\dagger}$
Household size	Mean (SD)	3.69	(1.55)	3.52	(1.35)	$0.14^{\ddagger}$	3.24	(1.00)	3.79	(1.09)	3.71	(1.17)	$<0.01^{\#}$
Number of children	Mean (SD)	2.19	(1.33)	1.82	(1.09)	$<0.01^{\ddagger}$	1.44	(0.86)	1.74	(1.01)	1.77	(1.06)	$<0.01^{\#}$
Number of children 0-3 years old	Mean (SD)	0.24	(0.44)	0.23	(0.43)	$<0.01^{\ddagger}$	0.26	(0.44)	0.27	(0.45)	0.26	(0.45)	$0.<0.01^{\#}$
Households with children <1 year old	N (%)	81	(23.55)	64	(22.78)	$0.82^{\S}$	70	(26.22)	623	(26.38)	838	(25.75)	$0.44^{\S}$
Households with pregnant women	N (%)	37	(10.95)	48	(17.27)	$0.02^{\S}$	53	(20.23)	330	(14.04)	468	(14.49)	$<0.01^{\S}$
Age of HRP (years)	Mean (SD)	30.16	(9.00)	32.81	(10.33)	$<0.01^{\ddagger}$	32.82	(8.61)	35.61	(7.29)	34.56	(8.11)	$<0.01^{\#}$
Equivalised gross household income (£/week)	Mean (SD)	158.69	(82.59)	163.16	(87.86)	$0.51^{\ddagger}$	176.75	(62.83)	479.38	(297.18)	393.34	(292.29)	$<0.01^{\#}$
Equivalised disposable household income (£/week)	Mean (SD)	146.74	(72.84)	151.83	(76.21)	$0.40^{\ddagger}$	160.12	(57.23)	393.98	(174.68)	327.74	(187.36)	$<0.01^{\#}$
Ethnicity of HRP	N (%)					$0.59^{\S}$							$<0.01^{\S}$
White		291	(84.59)	242	(86.12)		199	(74.53)	2033	(86.07)	2765	(84.97)	
BAME		53	(15.41)	39	(13.88)		68	(25.47)	329	(13.93)	489	(15.03)	
Social Class of HRP	N (%)					$<0.01^{\S}$							$<0.01^{\S}$
Higher managerial occupations		18	(5.23)	25	(8.90)		44	(16.48)	1239	(52.46)	1326	(40.75)	
Intermediate occupations		18	(5.23)	33	(11.74)		67	(25.09)	416	(17.61)	534	(16.41)	
Routine and manual occupations		91	(26.45)	96	(34.16)		127	(47.57)	605	(25.61)	919	(28.24)	
Unemployed or students		217	(63.08)	127	(45.20)		29	(10.86)	102	(4.32)	475	(14.60)	
Education of HRP	N (%)					$0.82^{\S}$							$<0.01^{\S}$
< 16 years		57	(16.57)	42	(14.95)		28	(10.49)	88	(3.73)	215	(6.61)	
16 – 18 years		225	(65.41)	190	(67.62)		150	(56.18)	1182	(50.04)	1747	(53.69)	
>18 years		62	(18.02)	49	(17.44)		89	(33.33)	1092	(46.23)	1292	(39.70)	
Region	N (%)					$<0.01^{\S}$							$<0.01^{\S}$
North		109	(31.69)	87	(30.96)		75	(28.09)	550	(23.29)	821	(25.23)	

		HS participants		HS non-participants			Nearly Eligible		Ineligible		Total		
Midlands		63	(18.31)	39	(13.88)		47	(17.60)	394	(16.68)	543	(16.69)	
East		31	(9.01)	13	(4.63)		21	(7.87)	245	(10.37)	310	(9.53)	
London		34	(9.88)	41	(14.59)		33	(12.36)	268	(11.35)	376	(11.56)	
South		59	(17.15)	35	(12.46)		52	(19.48)	561	(23.75)	707	(21.73)	
Wales		18	(5.23)	15	(5.34)		11	(4.12)	111	(4.70)	155	(4.76)	
Scotland		25	(7.27)	27	(9.61)		17	(6.37)	172	(7.28)	241	(7.41)	
N. Ireland		5	(1.45)	24	(8.54)		11	(4.12)	61	(2.58)	101	(3.10)	
Total Food Expenditure (£/week)	Median (IQR)	42.60	(35.41)	42.57	(41.23)	0.44¶	46.77	(39.07)	66.72	(43.13)	60.74	(44.36)	<0.01‖
Total HS Foods expenditure (£/week)	Median (IQR)	6.73	(8.21)	7.61	(8.30)	0.12¶	9.91	(11.07)	13.03	(11.60)	11.54	(11.65)	<0.01‖
Total HS Foods quantity (Kg/week)	Median (IQR)	7.41	(7.51)	7.92	(8.37)	0.68¶	9.56	(8.57)	10.56	(8.84)	9.89	(8.62)	<0.01‖
FV expenditure (£/week)	Median (IQR)	3.33	(5.92)	4.12	(6.65)	0.12¶	5.77	(7.90)	9.00	(9.60)	7.64	(9.38)	<0.01‖
FV quantity (kg/week)	Median (IQR)	2.46	(3.97)	2.96	(4.69)	0.26¶	4.03	(4.92)	5.05	(4.73)	4.51	(4.89)	<0.01‖
Cow's milk expenditure (L/week)	Median (IQR)	1.85	(2.46)	2.10	(2.57)	0.62¶	1.84	(1.92)	2.23	(2.44)	2.14	(2.43)	<0.01‖
Infant Formula expenditure (£/week) ††	Median (IQR)	1.90	(4.04)	3.82	(7.41)	0.03¶	3.83	(7.27)	3.80	(8.03)	3.72	(7.55)	0.13‖
Infant Formula expenditure (Kg/week) ††	Median (IQR)	1.75	(3.15)	3.15	(6.30)	0.04¶	3.15	(6.30)	3.15	(6.30)	3.15	(6.30)	0.23‖

Note: SD – Standard Deviation; IQR – Interquartile Range; HS - Healthy Start; HRP – Household Reference Person; BAME: Black and Minority Ethnicities; FV – Fruit and Vegetables

* Significance difference between HS participants and HS non-participants † Significance difference across total sample

‡ Student t-test; § X2 test ; ¶ Mann-Whitney test; # ANOVA; ||Kruskal-Wallis test

†† Sample of households with children <1years + survey years 2010-15 (*n*=838)

Appendix Table I.c - Quantile regression of HS participation on food expenditure and quantity in the Living Costs and Food survey, UK, years 2010-2015 (*n*=3,254)

	Model 1		**Model 2**		**Model 3**	
	Coef.	(95% CI)	Coef.	(95% CI)	Coef.	(95% CI)
FV expenditure (£/week)						
HS participants	-1.10*	(-1.96,-0.23)	0.14	(-0.59,0.87)	0.44	(-0.26,1.14)
HS non-participants	-	-	-	-	-	-
Nearly Eligible	1.84**	(0.61,3.07)	2.07***	(0.91,3.22)	1.64**	(0.57,2.71)
Ineligible	4.50***	(3.79,5.21)	3.84***	(3.10,4.58)	2.36***	(1.65,3.08)
FV quantity (Kg/week)						
HS participants	-0.35	(-1.09,0.39)	0.1	(-0.47,0.67)	0.23	(-0.32,0.79)
HS non-participants	-	-	-	-	-	-
Nearly Eligible	1.31***	(0.55,2.07)	1.29***	(0.67,1.91)	1.05**	(0.27,1.83)
Ineligible	2.24***	(1.57,2.91)	1.61***	(1.15,2.06)	1.06***	(0.52,1.60)
HS food expenditure (£/week)						
HS participants	-1.14	(-2.35,0.07)	-0.47	(-1.60,0.66)	0.09	(-0.67,0.85)
HS non-participants	-	-	-	-	-	-
Nearly Eligible	2.14**	(0.78,3.50)	2.38***	(0.98,3.78)	2.42***	(1.35,3.50)
Ineligible	4.96***	(4.01,5.90)	3.83***	(2.80,4.87)	2.72***	(1.86,3.59)
HS food quantity (Kg/week)						
HS participants	-0.63	(-1.66,0.40)	-0.24	(-1.28,0.80)	-0.51	(-1.56,0.53)
HS non-participants	-	-	-	-	-	-
Nearly Eligible	1.18	(-0.17,2.54)	1.65**	(0.55,2.74)	1.30*	(0.13,2.47)
Ineligible	2.37***	(1.42,3.32)	1.40**	(0.43,2.37)	0.92	(-0.15,2.00)
Infant formula expenditure (£/week) †						
HS participants	-2.73**	(-4.50,-0.96)	-2.87**	(-4.59,-1.16)	-2.45***	(-3.67,-1.23)
HS non-participants	-	-	-	-	-	-
Nearly Eligible	-0.72	(-2.55,1.11)	-0.9	(-2.63,0.84)	-1.03	(-2.67,0.62)
Ineligible	-0.58	(-1.96,0.79)	-0.74	(-2.10,0.62)	-1.73*	(-3.20,-0.26)
Infant formula quantity (Kg/week) †						
HS participants	-1.4	(-2.93,0.13)	-1.38	(-3.01,0.24)	-1.58*	(-3.10,-0.06)
HS non-participants	-	-	-	-	-	-
Nearly Eligible	0	(-1.25,1.25)	-0.06	(-1.47,1.35)	-1.14	(-2.96,0.67)
Ineligible	0	(-0.63,0.63)	-0.08	(-0.73,0.58)	-0.85	(-1.87,0.16)

*P<0.05 **P<0.01 ***P<0.001

† Sample of households with children <1years (*n*=838)

Model 1 – Adjusted for year + quarter

Model 2 – Adjusted for Model 1, household size, number of children <1 year, 0-3 years + age of HRP

Model 3 – Adjusted for Model 2, region, ethnicity, social class and education of HRP

Appendix II. Chapter 6 supplementary tables

Appendix Table II.a - Operational definitions of food and nutrient outcome variables.

Outcome	Units	Operational Definition
Food Groups		
Fruit	g	Fruit, including from composite dishes. Includes canned but does not include dried fruit
Vegetables	g	Any vegetable, including from composite dishes
Protein-rich foods	g	Any meat, fish, egg, or beans, including from composite dishes
Wholemeal products	g	Any wholemeal starch product. Including brown bread, brown rice and brown pasta
Starchy products	g	Any white starchy product, not cooked in oil. Including white bread, white rice and white pasta
Chips		Any white starchy product, cooked in oil. Including chips and potato wedges
Dairy (milk, yoghurt, cheese)	g	Any dairy milk, yogurt, or cheese including from composite dishes.
Crisps and savoury snacks	g	Any crisps or savoury snacks (Includes all potato and cereal based snacks, popcorn (not sweet), twiglets, pretzels, pork scratchings)
Sweet snacks		Any manufactured/retail or homemade biscuit, any sugar or chocolate confectionery, buns, cakes, pastries, fruit pies,
Puddings	g	Any cereal-based milk puddings, sponge puddings, and other cereal based puddings (manufactured/homemade)
Nutrients		
Fibre	g	AOAC method of measuring fibre
Vitamin C	mg	Any vitamin C
Calcium	mg	Any calcium
Iron	mg	Sum of all haem iron and non-haem iron
Non-milk extrinsic sugar	g	‘Free-sugar’ which is not attached to a cell. Sum of all sugars in fruit juices, table sugar, honey, sucrose and glucose syrups added to foods. Does not include sugars from fruit.
Saturated fatty acids	g	Any saturated fatty acids
Sodium	mg	Any sodium

Appendix Table II.b - Nutrient Recommendations for primary and secondary students.

	Recommendation	
Nutrient type (units)	**Primary**	**Secondary**
Nutrients with minimum recommendation*		
Fibre (g)	4.2	5.2
Vitamin C (mg)	10.5	14.0
Calcium (mg)	193.0	350.0
Iron (mg)	3.0	5.2
Nutrients with maximum recommendation†		
NMES (g)	15.5	18.9
SFA (g)	6.5	7.9
Salt (g)	1.2	1.8

*Minimum recommendation refers to nutrients that must be at a minimum intake to meet the 2008/09 English nutrient-based standards[221].

†Maximum recommendation refers to nutrients that must remain below a certain level to meet the 2008/09 English nutrient-based standards[221].

*Minimum recommendation refers to nutrients that must be at a minimum intake to meet the 2008/09 English nutrient-based standards[221].

†Maximum recommendation refers to nutrients that must remain below a certain level to meet the 2008/09 English nutrient-based standards[221].

Appendix Table II.c - Fully adjusted logistic regression of the likelihood of consuming food groups and meeting nutrient recommendations in school meals compared to packed lunches stratified by school phase

	Primary1		Secondary1		Total1	
Variable	**AOR (95% CI)**	**P**	**AOR (95% CI)**	**P**	**AOR (95% CI)**	**P**
Food groups						
Fruit	0.4 (0.3,0.5)	<0.01	0.4 (0.3,0.5)	<0.01	0.4 (0.3,0.5)	<0.01
Vegetables	16.6 (11.8,23.5)	<0.01	3.6 (2.6,5.0)	<0.01	6.6 (5.3,8.4)	<0.01
Protein-rich foods	4.1 (2.7,6.2)	<0.01	1.6 (1.1,2.2)	0.01	2.2 (1.7,2.9)	<0.01
Dairy products	0.6 (0.4,0.7)	<0.01	1.3 (1.0,1.8)	0.05	0.8 (0.7,1.0)	0.07
Wholemeal products	0.2 (0.1,0.2)	<0.01	0.4 (0.3,0.6)	<0.01	0.3 (0.2,0.3)	<0.01
Starchy products	3.1 (2.4,4.2)	<0.01	2.5 (1.9,3.5)	<0.01	2.9 (2.3,3.6)	<0.01
Chips	17.4 (12.1,25.0)	<0.01	5.8 (3.5,9.4)	<0.01	10.6 (8.0,14.0)	<0.01
Crisps	0.1 (0.1,0.1)	<0.01	0.1 (0.1,0.2)	<0.01	0.1 (0.1,0.1)	<0.01
Sweet snacks	0.2 (0.2,0.3)	<0.01	0.5 (0.4,0.6)	<0.01	0.4 (0.3,0.4)	<0.01
Puddings	5.0 (3.9,6.5)	<0.01	1.7 (1.2,2.5)	<0.01	3.1 (2.6,3.8)	<0.01
Nutrients						
Saturated fat	1.6 (1.3,2.0)	<0.01	0.9 (0.6,1.2)	0.31	1.2 (1.0,1.5)	0.03
Non-milk extrinsic sugar	2.6 (2.1,3.4)	<0.01	0.9 (0.7,1.3)	0.67	1.6 (1.3,2.0)	<0.01
Sodium	3.3 (2.6,4.2)	<0.01	1.5 (1.1,2.0)	0.01	2.4 (2.0,2.9)	<0.01
Fibre	2.1 (1.7,2.7)	<0.01	1.2 (0.9,1.7)	0.23	1.5 (1.3,1.9)	<0.01
Protein	2.5 (1.4,4.6)	<0.01	1.5 (1.1,2.0)	0.01	1.5 (1.1,1.9)	<0.01
Iron	1.0 (0.7,1.4)	0.97	0.3 (0.1,0.8)	0.01	0.8 (0.5,1.1)	0.10
Vitamin C	1.2 (0.9,1.5)	0.20	1.1 (0.8,1.5)	0.51	1.1 (0.9,1.3)	0.42
Calcium	0.3 (0.3,0.4)	<0.01	1.3 (0.9,1.9)	0.15	0.5 (0.4,0.6)	<0.01

[1] Adjusted for age, sex,survey year, ethnicity, region, household income and IMD

AOR - Adjusted odds ratio; CI - confidence interval

Appendix Table II.d - Logistic regression of the likelihood of consuming food groups in school meals compared to packed lunches stratified by school phase, additionally adjusted by energy and lunch portion.

	Primary						Secondary					
	Model 1[1]		Model 2[2]		Model 3[3]		Model 1[1]		Model 2[2]		Model 3[3]	
Variable	AOR (95% CI)	P	AOR (95% CI)	P	AOR (95% CI)	P	AOR (95% CI)	P	AOR (95% CI)	P	AOR (95% CI)	P
Fruit	0.4 (0.3,0.5)	<0.01	0.4 (0.3,0.6)	<0.01	0.4 (0.3,0.5)	<0.01	0.4 (0.3,0.5)	<0.01	0.3 (0.3,0.5)	<0.01	0.3 (0.2,0.5)	<0.01
Vegetables	16.6 (11.8,23.5)	<0.01	16.8 (11.9,23.8)	<0.01	18.0 (12.7,25.7)	<0.01	3.6 (2.6,5.0)	<0.01	3.7 (2.6,5.1)	<0.01	3.5 (2.5,4.9)	<0.01
Protein-rich foods	4.1 (2.7,6.2)	<0.01	4.3 (2.8,6.5)	<0.01	4.2 (2.8,6.4)	<0.01	1.6 (1.1,2.2)	0.01	1.5 (1.1,2.2)	0.01	1.4 (1.0,2.0)	0.04
Dairy products	0.6 (0.4,0.7)	<0.01	0.6 (0.5,0.8)	<0.01	0.6 (0.4,0.7)	<0.01	1.3 (1.0,1.8)	0.05	1.3 (1.0,1.8)	0.07	1.3 (1.0,1.7)	0.11
Wholemeal products	0.2 (0.1,0.2)	<0.01	0.2 (0.1,0.2)	<0.01	0.2 (0.1,0.2)	<0.01	0.4 (0.3,0.6)	<0.01	0.4 (0.3,0.6)	<0.01	0.4 (0.3,0.6)	<0.01
Starchy products	3.1 (2.4,4.2)	<0.01	3.3 (2.5,4.4)	<0.01	3.2 (2.4,4.2)	<0.01	2.5 (1.9,3.5)	<0.01	2.7 (2.0,3.7)	<0.01	2.4 (1.8,3.3)	<0.01
Chips	17.4 (12.1,25.0)	<0.01	18.1 (12.5,26.2)	<0.01	17.5 (12.2,25.3)	<0.01	5.8 (3.5,9.4)	<0.01	5.8 (3.6,9.5)	<0.01	5.6 (3.4,9.1)	<0.01
Crisps	0.1 (0.1,0.1)	<0.01	0.1 (0.1,0.1)	<0.01	0.1 (0.1,0.1)	<0.01	0.1 (0.1,0.2)	<0.01	0.1 (0.1,0.2)	<0.01	0.1 (0.1,0.2)	<0.01
Sweet snacks	0.2 (0.2,0.3)	<0.01	0.3 (0.2,0.3)	<0.01	0.2 (0.2,0.3)	<0.01	0.5 (0.4,0.6)	<0.01	0.4 (0.3,0.6)	<0.01	0.4 (0.3,0.6)	<0.01
Puddings	5.0 (3.9,6.5)	<0.01	6.1 (4.6,8.1)	<0.01	5.2 (4.0,6.8)	<0.01	1.7 (1.2,2.5)	<0.01	1.8 (1.3,2.5)	<0.01	1.7 (1.2,2.3)	<0.01

[1] Main analysis - adjusted for age, sex,survey year, ethnicity, region, household income and IMD; [2] Model 1 aditionally adjusted for energy (kcal/lunch); [3] Model 1 aditionally adjusted for grams (grams/lunch)

AOR - Adjusted odds ratio; CI - confidence interval

Appendix Table II.e - Logistic regression of the likelihood of meeting nutrient recommendations in school meals compared to packed lunches stratified by school phase, additionally adjusted by energy and lunch portion.

	Primary						**Secondary**					
	Model 1[1]		**Model 2[2]**		**Model 3[3]**		**Model 1[1]**		**Model 2[2]**		**Model 3[3]**	
Variable	**AOR (95% CI)**	**P**	**AOR (95% CI)**	**P**	**AOR (95% CI)**	**P**	**AOR (95% CI)**	**P**	**AOR (95% CI)**	**P**	**AOR (95% CI)**	**P**
Saturated fat	1.6 (1.3,2.0)	<0.01	1.3 (1.0,1.7)	0.06	1.6 (1.3,2.0)	<0.01	0.9 (0.6,1.2)	0.31	0.8 (0.6,1.2)	0.33	0.9 (0.7,1.2)	0.60
Non-milk extrinsic sugar	2.6 (2.1,3.4)	<0.01	2.5 (1.9,3.2)	<0.01	2.7 (2.1,3.4)	<0.01	0.9 (0.7,1.3)	0.67	0.9 (0.7,1.3)	0.76	1.0 (0.7,1.4)	0.90
Sodium	3.3 (2.6,4.2)	<0.01	3.5 (2.6,4.8)	<0.01	3.5 (2.8,4.5)	<0.01	1.5 (1.1,2.0)	0.01	2.0 (1.4,2.9)	<0.01	1.7 (1.2,2.3)	<0.01
Fibre	2.1 (1.7,2.7)	<0.01	3.0 (2.3,4.0)	<0.01	2.4 (1.9,3.1)	<0.01	1.2 (0.9,1.7)	0.23	1.2 (0.9,1.7)	0.25	1.1 (0.8,1.5)	0.61
Protein	2.5 (1.4,4.6)	<0.01	6.5 (2.9,14.2)	<0.01	2.9 (1.6,5.2)	<0.01	1.5 (1.1,2.0)	0.01	1.8 (1.2,2.7)	<0.01	1.3 (1.0,1.8)	0.09
Iron	1.0 (0.7,1.4)	0.97	1.3 (0.9,2.0)	0.16	1.0 (0.7,1.5)	0.92	0.3 (0.1,0.8)	0.01	0.2 (0.1,0.8)	0.03	0.2 (0.1,0.8)	0.02
Vitamin C	1.2 (0.9,1.5)	0.20	1.3 (1.0,1.7)	0.06	1.2 (0.9,1.6)	0.13	1.1 (0.8,1.5)	0.51	1.1 (0.8,1.5)	0.61	1.0 (0.7,1.3)	0.98
Calcium	0.3 (0.3,0.4)	<0.01	0.3 (0.3,0.5)	<0.01	0.3 (0.3,0.4)	<0.01	1.3 (0.9,1.9)	0.15	1.5 (0.9,2.2)	0.09	1.3 (0.9,1.8)	0.22

[1]Main analysis - adjusted for age, sex,survey year, ethnicity, region, household income and IMD; [2]Model 1 aditionally adjusted for energy (kcal/lunch); [3]Model 1 aditionally adjusted for grams (grams/lunch)
AOR - Adjusted odds ratio; CI - confidence interval

Appendix Table II.f - Fully adjusted logistic regression of the likelihood of consuming food groups and meeting nutrient recommendations in school meals compared to packed lunches stratified by school phase and repeated on a smaller sample where mealtype was taken from the dietary diary only.

	Primary				Secondary			
Variable	**Model 1[1] AOR (95% CI)**	**P**	**Model 2[2] AOR (95% CI)**	**P**	**Model 1[1] AOR (95% CI)**	**P**	**Model 2[2] AOR (95% CI)**	**P**
Food groups								
Fruit	0.4 (0.3,0.5)	<0.01	0.4 (0.3,0.5)	<0.01	0.4 (0.3,0.5)	<0.01	0.2 (0.2,0.4)	<0.01
Vegetables	16.6 (11.8,23.5)	<0.01	35.2 (21.5,57.4)	<0.01	3.6 (2.6,5.0)	<0.01	3.9 (2.3,6.4)	<0.01
Protein-rich foods	4.1 (2.7,6.2)	<0.01	4.4 (2.7,7.3)	<0.01	1.6 (1.1,2.2)	0.01	1.5 (0.8,2.6)	0.17
Dairy products	0.6 (0.4,0.7)	<0.01	0.5 (0.4,0.7)	<0.01	1.3 (1.0,1.8)	0.05	1.7 (1.1,2.7)	0.02
Wholemeal products	0.2 (0.1,0.2)	<0.01	0.1 (0.0,0.1)	<0.01	0.4 (0.3,0.6)	<0.01	0.2 (0.1,0.3)	<0.01
Starchy products	3.1 (2.4,4.2)	<0.01	4.3 (3.0,6.3)	<0.01	2.5 (1.9,3.5)	<0.01	2.8 (1.6,4.8)	<0.01
Chips	17.4 (12.1,25.0)	<0.01	67.6 (33.4,136.7)	<0.01	5.8 (3.5,9.4)	<0.01	-	-
Crisps	0.1 (0.1,0.1)	<0.01	0.0 (0.0,0.0)	<0.01	0.1 (0.1,0.2)	<0.01	0.0 (0.0,0.1)	<0.01
Sweet snacks	0.2 (0.2,0.3)	<0.01	0.2 (0.1,0.3)	<0.01	0.5 (0.4,0.6)	<0.01	0.3 (0.2,0.5)	<0.01
Puddings	5.0 (3.9,6.5)	<0.01	6.1 (4.4,8.6)	<0.01	1.7 (1.2,2.5)	<0.01	2.9 (1.6,5.3)	<0.01
Nutrients								
Saturated fat	1.6 (1.3,2.0)	<0.01	2.1 (1.5,2.9)	<0.01	0.9 (0.6,1.2)	0.31	0.7 (0.4,1.2)	0.22
Non-milk extrinsic sugar	2.6 (2.1,3.4)	<0.01	2.8 (2.0,3.8)	<0.01	0.9 (0.7,1.3)	0.67	0.8 (0.5,1.3)	0.46
Sodium	3.3 (2.6,4.2)	<0.01	4.2 (3.1,5.8)	<0.01	1.5 (1.1,2.0)	0.01	1.6 (1.0,2.5)	0.07
Fibre	2.1 (1.7,2.7)	<0.01	2.5 (1.8,3.4)	<0.01	1.2 (0.9,1.7)	0.23	1.1 (0.6,1.8)	0.77
Protein	2.5 (1.4,4.6)	<0.01	3.1 (1.4,6.9)	0.01	1.5 (1.1,2.0)	0.01	1.4 (0.9,2.3)	0.17
Iron	1.0 (0.7,1.4)	0.97	0.9 (0.6,1.3)	0.59	0.3 (0.1,0.8)	0.01	0.2 (0.0,0.7)	0.02
Vitamin C	1.2 (0.9,1.5)	0.20	1.4 (1.0,1.9)	0.07	1.1 (0.8,1.5)	0.51	1.3 (0.8,2.1)	0.29
Calcium	0.3 (0.3,0.4)	<0.01	0.3 (0.2,0.4)	<0.01	1.3 (0.9,1.9)	0.15	1.4 (0.7,2.7)	0.38

[1] Main analysis - adjusted for age, sex, survey year, ethnicity, region, household income and IMD;
[2] Model 1 only including participants with meal type recorded in dietary diary.
AOR - Adjusted odds ratio; CI - confidence interval

Appendix III. Chapter 7 supplementary tables

Appendix Table III.a - Operational definitions of NOVA subgroup variables.

Variable	Definition
Minimally processed (NOVA1)	
Drinks	Water; coffee, tea; fresh fruit juices and smoothies;
Fruit and veg	Fruit, vegetables, fungi, nuts and seed
Dairy and eggs	Milk, plain yoghurt, eggs
Starchy foods and legumes	Grains, legumes , pasta, homemade pies and pastries
Meat and fish	Fish, poultry, red meat, pies and pastries with meat or fish, seafood
Ultra-processed (NOVA4)	
Processed bread	Industrially manufactured bread
Sweet and salty snacks	Industrially manufactured cakes, pies, biscuits, sweet snacks, salty snacks (crisps)
Drinks	Soft drinks (high and low calorie), and fruit drinks
Condiments	Sauces, dressings, gravy, spread, margarine
Puddings	Ice cream, ice pops, desserts, sweet spreads and icing, artificial sugars and sweetners
Ready-to-eat foods	Pasta and rice dishes (ready-to-eat/heat); Egg and cheese dishes (ready-to-eat/heat); Bacon/sausages dishes (ready-to-eat/heat); Meat dishes (ready-to-eat/heat) Chicken/turkey dishes (ready-to-eat/heat); Fish dishes (ready-to-eat/heat); Vegetables dishes (ready-to-eat/heat); Meat alternatives Potato dishes (ready-to-eat/heat); Instant and canned soups; Industrially manufactured meat pies and pastries
Meat and fish	Processed meat and fish (bacon, ham,
Vegetables	Processed vegetables (baked beans)
Cheese	Processed cheese and cheese prodcuts
Fast foods	Pizza; French fries and other potato products; Sandwiches and hamburguers
Yoghurt and milk	Industrially manufactured yoghurts and milk drinks

Appendix Table III.b - Logistic regression of the likelihood of consuming minimally and ultra-processed food groups by meal type and school phase

	Primary		Secondary		Total	
Variable	**AOR (95% CI)**	**P**	**AOR (95% CI)**	**P**	**AOR (95% CI)**	**P**
Minimally processed (NOVA1)						
Drinks	1.9 (1.5,2.3)	<0.01	1.4 (1.1,1.9)	0.02	1.6 (1.3,1.9)	<0.01
Fruit and veg	2.1 (1.6,2.8)	<0.01	0.8 (0.6,1.1)	0.11	1.2 (1.0,1.4)	0.13
Dairy and eggs	2.6 (1.8,3.7)	<0.01	1.7 (1.0,3.0)	0.05	2.2 (1.6,2.9)	<0.01
Starchy foods and legumes	12.5 (9.4,16.7)	<0.01	3.5 (2.5,5.0)	<0.01	6.9 (5.5,8.6)	<0.01
Meat and fish	10.4 (7.7,14.2)	<0.01	3.0 (2.2,4.2)	<0.01	5.6 (4.5,7.0)	<0.01
Ultra-processed (NOVA4)						
Processed bread	0.1 (0.1,0.1)	<0.01	0.4 (0.3,0.5)	<0.01	0.2 (0.2,0.2)	<0.01
Sweet and salty snacks	0.2 (0.2,0.2)	<0.01	0.3 (0.2,0.4)	<0.01	0.2 (0.2,0.3)	<0.01
Drinks	0.1 (0.1,0.2)	<0.01	0.8 (0.6,1.1)	0.11	0.3 (0.3,0.4)	<0.01
Condiments	0.5 (0.4,0.6)	<0.01	0.8 (0.6,1.0)	0.06	0.6 (0.5,0.7)	<0.01
Puddings	3.4 (2.6,4.4)	<0.01	1.8 (1.2,2.5)	<0.01	2.5 (2.1,3.1)	<0.01
Ready-to-eat foods	1.4 (1.1,1.9)	0.01	0.8 (0.6,1.1)	0.26	1.1 (0.9,1.3)	0.34
Meat and fish	0.9 (0.7,1.1)	0.28	0.8 (0.6,1.0)	0.09	0.8 (0.7,1.0)	0.02
Vegetables	9.2 (5.4,15.4)	<0.01	4.8 (2.4,9.7)	<0.01	7.1 (4.6,10.8)	<0.01
Cheese	0.2 (0.1,0.4)	<0.01	0.1 (0.0,0.6)	0.01	0.2 (0.1,0.3)	<0.01
Fast foods	11.9 (8.5,16.7)	<0.01	5.4 (3.6,8.0)	<0.01	8.2 (6.4,10.4)	<0.01
Yoghurt and milk	0.2 (0.2,0.3)	<0.01	0.4 (0.3,0.7)	<0.01	0.3 (0.2,0.3)	<0.01

Note: Models adjusted for age, sex, survey year, ethnicity, region, household income and IMD; Packed lunches were reference group

AOR - Adjusted odds ratio; CI - confidence interval

Appendix Table III.c - Quantile regression on ultra-processed food with an interaction between meal type and income group, stratified by school phase

	Primary				**Secondary**			
	Model 1[1]		**Model 2[2]**		**Model 1[1]**		**Model 2[2]**	
Variable	**Coef (95% CI)**	**P-value**	**Coef (95% CI)**	**P-value**	**Coef (95% CI)**	**P-value**	**Coef (95% CI)**	**P-value**
UPF (% g)								
Intercept	74.79 (61.55,81.57)	<0.01	69.11 (58.65,83.11)	<0.01	90.38 (57.25,112.44)	<0.01	84.15 (55.95,106.53)	<0.01
Meal type								
School meals	-36.82 (-41.35,-30.26)	<0.01	-33.05 (-38.53,-26.89)	<0.01	-12.88 (-29.54,0.66)	0.12	-9.68 (-25.17,-2.25)	0.1
Income								
Mid income	-11.24 (-18.25,-1.19)	0.02	-9.19 (-16.61,-3.4)	0.02	-6.82 (-19.63,6.48)	0.39	-6.14 (-18.86,3.94)	0.33
High income	-22.5 (-29.68,-16.05)	<0.01	-20.63 (-26.85,-14.5)	<0.01	-17.98 (-31.8,-3.36)	0.02	-16.08 (-26,-2.96)	<0.01
Interaction								
Mid income * School Meal	11.68 (2.06,24.22)	0.03	7.98 (-0.94,17.6)	0.08	-4.96 (-22.49,11.72)	0.65	-3.84 (-23.04,13.24)	0.68
High income * School Meal	17.01 (10.72,24.22)	<0.01	15.6 (9.26,24.7)	<0.01	1.18 (-18.94,17.07)	0.91	-2.47 (-15.65,9.17)	0.77
UPF (% kcal)								
Intercept	79.98 (75.08,84.49)	<0.01	80.72 (73.09,86.31)	<0.01	84.25 (70.8,102.55)	<0.01	81.36 (64.94,100.41)	<0.01
Meal type								
School meals	-21.12 (-24.81,-17.66)	<0.01	-19.92 (-23.73,-15.76)	<0.01	-7.78 (-15.63,-2.38)	0.04	-7.31 (-12.92,2.15)	0.08
Income								
Mid income	-1.66 (-5.8,1.25)	0.51	-1.91 (-5.14,0.87)	0.22	-0.2 (-4.57,3.94)	0.95	0.62 (-5.46,6.15)	0.79
High income	-5.72 (-9.65,-2.84)	0.02	-4.56 (-7.64,-2.16)	<0.01	-9.94 (-15.73,-3.24)	<0.01	-8.71 (-13.13,-2.27)	<0.01
Interaction								
Mid income * School Meal	3.06 (-2.19,8.09)	0.48	0.99 (-5.87,6.89)	0.76	-3.62 (-7.52,-0.24)	0.09	-8.71 (-21,-0.14)	0.12
High income * School Meal	0.8 (-3.86,6.29)	0.81	-0.12 (-6.73,4.74)	0.96	-8.63 (-18.5,-1.37)	0.11	-4.83 (-13.41,4.78)	0.39

[1]Interaction model with minimal adjustments - age and sex; [2]Interaction model with full adjustments - age, sex, survey year, ethnicity, region, IMD, and income;

Appendix Table III.d - Sensitivity analysis (1) Additional adjustments for energy, lunch portion and BMI to the quantile regression on ultra-processed food and meal type.

	Primary								Secondary							
	Main analysis[1]		**+ Energy (Lunch)[2]**		**+ Grams (lunch)[3]**		**+ BMI[4]**		**Main analysis1**		**+ Energy (Lunch)[2]**		**+ Grams (lunch)[3]**		**+ BMI[4]**	
Variable	**Coef (95% CI)**	**P**	**Coef (95% CI)**	**P**	**Coef (95% CI)**	**P**	**Coef (95% CI)**	**P**	**Coef (95% CI)**	**P**	**Coef (95% CI)**	**P**	**Coef (95% CI)**	**P**	**Coef (95% CI)**	**P**
UPF (% g)																
School meals	-24.78 (-28.12,-22.3)	<0.001	-24.32 (-27.64,-21.03)	<0.001	-24.55 (-28.12,-20.09)	<0.001	-24.92 (-28.26,-22.14)	<0.001	-11.64 (-21.03,-6.51)	<0.001	-12.64 (-19.86,-4.82)	<0.001	-9.45 (-15.48,-5.64)	<0.001	-11.06 (-21.94,-5.62)	<0.00
UPF (% kcal)																
School meals	-19.64 (-22.26,-17.48)	<0.001	-19.56 (-22.21,-17.28)	<0.001	-19.43 (-22.15,-17.25)	<0.001	-20.04 (-22.47,-17.83)	<0.001	-11.05 (-15.99,-6.96)	<0.001	-10.71 (-14.89,-7.54)	<0.001	-10.47 (-14.58,-6.24)	<0.001	-11.3 (-15.86,-7.3)	<0.00

[1]Main analysis - adjusted for age, sex, ethnicity, survey year, region, IMD, and income; [2]Additionally adjusted for lunchtime energy intake (kcal); [3]Additionally adjusted for lunchtim amount (grams); [4]Additionally adjusted for BMI

Appendix Table III.e - Sensitivity analysis (2) Quantile regression on ultra-processed food and meal type with exclusion of sample who meal type was not recorded in the dietary diary

	Primary				**Secondary**			
	Model 1[1]		**Model 2[2]**		**Model 1[1]**		**Model 2[2]**	
Variable	**Coef (95% CI)**	**P-value**	**Coef (95% CI)**	**P-value**	**Coef (95% CI)**	**P-value**	**Coef (95% CI)**	**P-value**
UPF (% g)								
School meals	-25.55 (-28.41,-21.04)	<0.001	-29.51 (-33.66,-26.98)	<0.001	-12.83 (-20.82,-6.64)	<0.001	-9.72 (-24.99,-4.03)	<0.001
UPF (% kcal)								
School meals	-19.89 (-22.41,-17.57)	<0.001	-23.04 (-25.82,-20.54)	<0.001	-12.38 (-16,-8.92)	<0.001	-17.85 (-24.44,-11.08)	<0.001

[1]Fully adjusted model - age, sex, ethnicity, survey year, region, IMD, and income; [2] Analysis run on reduced sample who recorded meal type in the dietary dietary (N=2,355)

Appendix IV. Chapter 8 supplementary tables

Appendix Table IV.a - Characteristics of schoolchildren (*n*=854) in England and Scotland before and after implementation of the UIFSM policy, after weighting with IPW.

		Pre-UIFSM (2010-2014)[1]			**Post-UIFSM (2014-2017)**		
Variable		Intervention group: Infants (N=281)	Control group: Juniors (N=239)	P value[2]	Intervention group: Infants (N=172)	Control group: Juniors (N=162)	P value[3]
Age	Mean (SD)	5.6 (1.0)	9.1 (1.0)	<0.001[b]	5.7 (1.0)	9.4 (1.0)	<0.001[b]
Sex	n (%)			0.28[a]			0.45[a]
Female		137 (49.9)	107 (44.3)		88 (50.0)	72 (45.4)	
Ethnicity	n (%)			0.98[a]			0.70[a]
Ethnic minorities		52 (20.2)	43 (20.1)		30 (20.0)	27 (18.1)	
Household income (£)	Mean (SD)	30648.3 (19539.5)	26601.9 (18800.4)	0.03[b]	31479.6 (20798.4)	28976.4 (18465.9)	0.28[a]
Index of multiple deprivation (quintiles)	n (%)			0.07[a]			0.44[a]
Least deprived		62 (19.1)	42 (19.4)		40 (20.8)	42 (27.6)	
2		49 (17.4)	41 (14.9)		29 (17.7)	29 (18.3)	
3		60 (23.2)	44 (16.5)		33 (21.0)	27 (13.5)	
4		64 (24.0)	52 (21.2)		34 (19.1)	32 (20.9)	
Most deprived		46 (16.3)	60 (28.1)		36 (21.4)	32 (19.7)	
Region	n (%)			0.03[a]			0.16[a]
England: North		57 (21.9)	62 (31.3)		44 (24.0)	37 (20.5)	
England: Central		44 (13.4)	42 (17.8)		28 (16.7)	25 (14.1)	
England: South		126 (55.3)	83 (40.9)		87 (51.8)	77 (49.1)	
Scotland		54 (9.5)	52 (10.0)		13 (7.6)	23 (16.3)	
School lunch type	n (%)			0.68[a]			<0.001[a]
School meal		139 (47.4)	121 (49.6)		141 (80.5)	78 (48.8)	
Packed lunch		142 (52.6)	118 (50.4)		31 (19.5)	84 (51.2)	

[1] Threshold is September 2014 for English participants and January 2015 for Scottish participants

[2] Pre-UIFSM intervention vs Pre-UIFSM control

[3] Post-UIFSM intervention vs Post-UIFSM control

[a] Chi-square test (Adjusted for survey weights);

[b] t-test (Adjusted for survey weights)

Note: UIFSM -Universal Infant Free School Meal; SD – standard deviation

Appendix Table IV.b - Prevalence of food-group consumption in schoolchildren pre- and post-UIFSM and estimates of UIFSM policy impact.

Variable	Pre-UIFSM	Post-UIFSM	Difference	P[1]	Model 1[2]	P	Model 2[3]	P	Model 3[4]	P
	% taking	% taking	Diff. (95% CI)		Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Fruit										
Intervention	77.2	72.1	5.1 (-4.2,14.5)	0.28	0.9 (-12.6,14.4)	0.89	1.2 (-12.0,14.5)	0.86	0.2 (-12.8,13.2)	0.98
Control	76.0	69.9	6.0 (-3.7,15.8)	0.22						
Vegetables										
Intervention	71.2	78.9	-7.7 (-17.0,1.6)	0.10	2.5 (-11.3,16.4)	0.72	3.1 (-10.2,16.3)	0.65	2.8 (-10.5,16.1)	0.68
Control	64.8	70.0	-5.2 (-15.5,5.1)	0.33						
Protein-rich foods										
Intervention	83.3	82.1	1.1 (-7.3,9.6)	0.79	-4.4 (-15.6,6.7)	0.44	-4.1 (-15.0,6.8)	0.46	-4.4 (-15.2,6.5)	0.43
Control	85.6	88.8	-3.3 (-10.6,4.0)	0.38						
Dairy										
Intervention	70.5	66.1	4.4 (-5.3,14.0)	0.38	-12.8 (-26.7,1.1)	0.07	-12.8 (-26.4,0.8)	0.07	-13.4 (-27.0,0.2)	0.05
Control	65.8	74.3	-8.4 (-18.4,1.5)	0.10						
Wholemeal										
Intervention	27.0	13.1	13.9 (6.3,21.6)	<0.01	-11.8 (-24.3,0.7)	0.06	-11.8 (-24.0,0.4)	0.06	-12.2 (-24.3,0.0)	0.05
Control	27.3	25.1	2.1 (-7.7,12.0)	0.67						
Starchy foods (no oil)										
Intervention	75.4	84.9	-9.5 (-17.4,-1.6)	0.02	0.4 (-11.8,12.7)	0.94	0.5 (-11.6,12.7)	0.93	0.6 (-11.6,12.8)	0.92
Control	71.3	80.4	-9.0 (-18.4,0.3)	0.06						
Chips										
Intervention	31.7	36.9	-5.2 (-14.7,4.3)	0.28	4.7 (-9.3,18.6)	0.51	5.0 (-8.6,18.6)	0.47	5.4 (-8.1,19.0)	0.43
Control	31.7	32.3	-0.5 (-10.9,9.8)	0.92						
Crisps										
Intervention	22.1	11.1	11.0 (3.7,18.3)	<0.01	-17.8 (-30.3,-5.3)	0.01	-17.6 (-30.0,-5.2)	0.01	-18.1 (-30.5,-5.7)	<0.01
Control	24.4	31.2	-6.8 (-17.0,3.3)	0.19						
Sweet snacks										
Intervention	47.3	40.2	7.2 (-3.0,17.3)	0.17	-11.8 (-26.7,3.2)	0.12	-11.6 (-25.9,2.7)	0.11	-11.7 (-26.0,2.6)	0.11
Control	51.3	55.9	-4.6 (-15.6,6.4)	0.41						
Puddings										
Intervention	44.5	60.5	-16.0 (-26.2,-5.9)	<0.01	14.1 (-0.9,29.0)	0.07	14.5 (-0.2,29.2)	0.05	14.0 (-0.7,28.7)	0.06
Control	45.7	47.6	-1.9 (-12.9,9.0)	0.73						
High in saturated fat										
Intervention	87.9	83.0	4.9 (-2.2,12.1)	0.18	-7.0 (-17.2,3.2)	0.18	-6.9 (-16.7,2.9)	0.17	-7.5 (-17.2,2.2)	0.13
Control	86.5	88.6	-2.1 (-9.4,5.2)	0.57						
High in sodium										
Intervention	69.8	61.5	8.3 (-1.7,18.2)	0.10	-10.4 (-24.5,3.8)	0.15	-10.1 (-23.9,3.6)	0.15	-10.8 (-24.4,2.9)	0.12
Control	70.9	73.0	-2.1 (-12.1,7.9)	0.68						

Variable	**Pre-UIFSM**	**Post-UIFSM**	**Difference**	**P[1]**	**Model 1[2]**	**P**	**Model 2[3]**	**P**	**Model 3[4]**	**P**
	% taking	**% taking**	**Diff. (95% CI)**		**Coef. (95% CI)**		**Coef. (95% CI)**		**Coef. (95% CI)**	
High in sugar										
Intervention	66.2	71.2	-5.0 (-14.5,4.5)	0.30	-0.4 (-14.0,13.3)	0.96	-0.1 (-13.3,13.1)	0.99	-0.4 (-13.7,12.8)	0.95
Control	71.3	76.7	-5.4 (-15.2,4.4)	0.28						
Milk										
Intervention	8.2	18.5	-10.3 (-18.0,-2.6)	0.01	9.5 (0.4,18.6)	0.04	9.3 (0.5,18.2)	0.04	9.2 (0.3,18.0)	0.04
Control	5.2	6.0	-0.8 (-5.6,4.0)	0.74						
Yoghurt										
Intervention	39.9	26.3	13.5 (4.2,22.9)	<0.01	-11.2 (-25.1,2.6)	0.11	-11.0 (-24.7,2.6)	0.11	-11.6 (-25.3,2.0)	0.10
Control	34.0	31.7	2.3 (-7.9,12.5)	0.66						
Cheese										
Intervention	50.5	50.3	0.3 (-10.1,10.6)	0.96	-12.3 (-27.4,2.7)	0.11	-12.4 (-27.3,2.4)	0.10	-12.6 (-27.5,2.2)	0.10
Control	46.1	58.1	-12.1 (-22.9,-1.2)	0.03						
Meat, fish and eggs										
Intervention	80.8	80.6	0.2 (-8.5,8.9)	0.96	-1.0 (-12.8,10.8)	0.86	-0.8 (-12.4,10.8)	0.89	-1.1 (-12.7,10.4)	0.85
Control	84.1	84.9	-0.8 (-8.9,7.2)	0.84						
Baked beans										
Intervention	14.2	23.4	-9.2 (-17.6,-0.9)	0.03	4.8 (-6.0,15.5)	0.38	4.8 (-5.6,15.3)	0.36	4.8 (-5.7,15.2)	0.37
Control	8.8	13.2	-4.4 (-11.2,2.4)	0.20						
Fruit juice										
Intervention	65.8	51.8	14.0 (3.8,24.2)	0.01	-10.9 (-25.5,3.7)	0.14	-11.1 (-25.5,3.2)	0.13	-12.0 (-26.2,2.2)	0.10
Control	66.9	63.8	3.1 (-7.4,13.6)	0.56						
Water										
Intervention	53.4	62.8	-9.4 (-19.8,1.0)	0.08	5.8 (-9.3,20.9)	0.45	6.1 (-8.4,20.7)	0.41	4.7 (-9.5,18.8)	0.52
Control	53.1	56.7	-3.6 (-14.6,7.3)	0.51						
Sugar-sweetened beverages										
Intervention	14.2	8.0	6.3 (-0.6,13.2)	0.08	-2.2 (-11.9,7.6)	0.66	-2.3 (-12.0,7.3)	0.64	-2.6 (-12.3,7.1)	0.60
Control	14.5	10.3	4.1 (-2.8,11.0)	0.25						

[1]Survey adjusted t-test; [2]Model 1 - Unadjusted linear probability regression; [3]Model 2 - Linear probability regression adjusted for sex, ethnicity, household size, region, household income and IMD; [4]Model 3 - Linear probability regression additionally adjusted for total lunchtime intake (grams)
SD - standard deviation; CI - confidence interval

Appendix Table IV.c - Amount food-group consumed in schoolchildren pre- and post-UIFSM, conditional on consumption, and estimates of UIFSM policy impact.

Variable	N	Pre-UIFSM	Post-UIFSM	Difference	P[1]	Model 1[2]	P	Model 2[3]	P	Model 3[4]	P
	Pre / Post	Mean (SD)	Mean (SD)			Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Total lunchtime intake											
Intervention	281/172	387.7 (120.3)	408.7 (147.7)	21.0 (-6.5,48.6)	0.14	19.3 (-28.4,67.1)	0.43	20.1 (-27.2,67.5)	0.40	-0.0 (-0.0,0.0)	0.38
Control	239/162	428.6 (156.3)	430.3 (180.4)	1.7 (-37.4,40.7)	0.93						
Fruit											
Intervention	217/126	41.9 (37.4)	37.1 (38.0)	-4.7 (-13.8,4.3)	0.31	-1.5 (-15.7,12.6)	0.83	-1.5 (-15.6,12.5)	0.83	-0.9 (-14.7,13.0)	0.90
Control	173/117	45.8 (46.0)	42.6 (38.9)	-3.2 (-14.0,7.7)	0.56						
Vegetables											
Intervention	200/139	37.1 (28.6)	41.1 (27.8)	4.1 (-2.7,10.9)	0.24	5.9 (-4.3,16.2)	0.26	6.0 (-4.0,16.0)	0.24	4.8 (-4.9,14.5)	0.33
Control	155/115	36.8 (27.7)	35.0 (28.5)	-1.9 (-9.5,5.8)	0.64						
Protein-rich foods											
Intervention	234/146	36.7 (24.8)	42.0 (27.5)	5.3 (-0.6,11.2)	0.08	5.4 (-3.0,13.9)	0.21	5.6 (-2.8,13.9)	0.19	5.1 (-3.0,13.2)	0.22
Control	201/145	36.7 (24.7)	36.6 (26.6)	-0.1 (-6.2,6.0)	0.97						
Dairy											
Intervention	198/113	50.8 (48.0)	62.5 (63.7)	11.7 (-4.8,28.2)	0.17	23.1 (3.0,43.2)	0.02	21.6 (2.9,40.3)	0.02	20.4 (1.7,39.0)	0.03
Control	160/121	48.4 (52.7)	37.1 (36.1)	-11.4 (-22.9,0.1)	0.05						
Wholemeal											
Intervention	76/23	39.1 (21.7)	30.8 (18.2)	-8.2 (-17.6,1.2)	0.09	-13.5 (-29.5,2.6)	0.10	-14.0 (-29.4,1.4)	0.08	-13.7 (-28.5,1.1)	0.07
Control	58/40	41.1 (26.4)	46.3 (30.8)	5.3 (-7.8,18.3)	0.43						
Starchy foods (no oil)											
Intervention	212/146	54.2 (28.4)	62.9 (35.2)	8.7 (1.7,15.7)	0.02	6.1 (-5.3,17.4)	0.30	6.1 (-5.2,17.4)	0.29	5.3 (-5.8,16.4)	0.35
Control	175/130	61.3 (33.6)	63.9 (37.3)	2.6 (-6.3,11.5)	0.56						
Chips											
Intervention	89/74	39.7 (22.2)	39.0 (21.4)	-0.7 (-7.4,6.1)	0.84	6.2 (-4.7,17.1)	0.27	5.8 (-5.2,16.8)	0.30	5.8 (-5.2,16.8)	0.30
Control	75/50	42.5 (23.4)	35.6 (20.3)	-6.9 (-15.4,1.7)	0.12						
Crisps											
Intervention	62/18	14.4 (8.0)	17.6 (8.4)	3.1 (-1.5,7.8)	0.19	0.5 (-5.2,6.2)	0.86	1.0 (-4.6,6.5)	0.73	1.0 (-4.6,6.5)	0.73
Control	52/50	14.4 (6.9)	17.0 (8.8)	2.6 (-0.6,5.9)	0.11						
Sweet snacks											
Intervention	133/71	65.3 (85.5)	37.5 (50.6)	-27.8 (-46.8,-8.8)	<0.01	-4.6 (-35.8,26.6)	0.77	-2.4 (-31.3,26.4)	0.87	-3.9 (-32.5,24.7)	0.79
Control	124/93	71.2 (99.3)	48.0 (72.7)	-23.2 (-48.1,1.6)	0.07						
Puddings											
Intervention	125/103	45.4 (30.2)	59.3 (53.6)	13.9 (-3.2,31.0)	0.11	3.5 (-16.4,23.3)	0.73	2.0 (-14.0,18.0)	0.81	1.6 (-14.0,17.3)	0.84
Control	108/77	37.3 (28.9)	47.7 (34.1)	10.4 (0.3,20.5)	0.04						
High in saturated fat											
Intervention	247/142	38.9 (26.7)	38.2 (24.3)	-0.7 (-6.4,5.0)	0.81	0.5 (-7.6,8.7)	0.90	0.5 (-7.4,8.4)	0.90	0.3 (-7.5,8.2)	0.94

Variable	N	Pre-UIFSM	Post-UIFSM	Difference	P[1]	Model 1[2]	P	Model 2[3]	P	Model 3[4]	P
	Pre / Post	Mean (SD)	Mean (SD)			Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Control	208/142	41.3 (27.0)	40.1 (24.1)	-1.2 (-7.0,4.6)	0.68						
High in sodium											
Intervention	196/108	36.6 (27.4)	26.2 (18.2)	-10.4 (-15.9,-4.9)	<0.01	-8.3 (-16.2,-0.4)	0.04	-9.1 (-16.7,-1.5)	0.02	-9.1 (-16.6,-1.6)	0.02
Control	165/124	34.5 (25.7)	32.4 (22.0)	-2.1 (-7.8,3.6)	0.48						
High in sugar											
Intervention	186/123	35.0 (36.9)	32.2 (22.5)	-2.8 (-9.8,4.1)	0.42	-1.6 (-12.2,9.1)	0.77	-1.9 (-12.5,8.7)	0.73	-2.5 (-13.0,8.0)	0.64
Control	175/123	35.6 (36.7)	34.3 (33.7)	-1.3 (-9.3,6.7)	0.75						
Milk											
Intervention	23/28	106.5 (51.2)	120.6 (59.7)	14.2 (-18.7,47.0)	0.40	74.1 (8.9,139.3)	0.03	57.6 (-5.5,120.6)	0.08	37.4 (-23.4,98.3)	0.23
Control	15/11	135.8 (75.1)	75.9 (50.6)	-60.0 (-116.3,-3.6)	0.05						
Yoghurt											
Intervention	112/47	52.1 (32.5)	47.6 (24.0)	-4.5 (-14.6,5.5)	0.38	5.3 (-11.1,21.7)	0.53	5.1 (-11.6,21.8)	0.55	3.4 (-13.0,19.9)	0.68
Control	82/55	58.4 (40.2)	48.6 (32.6)	-9.8 (-22.8,3.2)	0.14						
Cheese											
Intervention	142/87	12.5 (10.0)	12.9 (10.9)	0.3 (-3.1,3.8)	0.85	-1.8 (-6.3,2.6)	0.42	-2.2 (-6.3,1.9)	0.29	-2.4 (-6.4,1.7)	0.26
Control	109/90	10.8 (10.3)	13.0 (9.2)	2.2 (-0.6,4.9)	0.12						
Meat, fish and eggs											
Intervention	227/143	31.7 (21.6)	31.4 (16.7)	-0.3 (-4.4,3.8)	0.88	2.3 (-3.8,8.5)	0.46	2.7 (-3.3,8.7)	0.38	2.4 (-3.5,8.3)	0.43
Control	196/140	33.7 (21.9)	31.1 (18.4)	-2.7 (-7.3,1.9)	0.26						
Baked beans											
Intervention	40/40	34.8 (20.4)	39.4 (25.1)	4.6 (-5.4,14.5)	0.37	-7.2 (-32.3,17.9)	0.57	-6.9 (-29.5,15.8)	0.55	-6.3 (-28.4,15.8)	0.58
Control	24/21	35.0 (25.2)	46.8 (40.4)	11.8 (-11.2,34.8)	0.32						
Fruit juice											
Intervention	185/85	44.4 (61.3)	28.0 (52.5)	-16.3 (-31.6,-1.1)	0.04	-7.8 (-31.6,16.1)	0.52	-9.0 (-33.5,15.4)	0.47	-10.7 (-35.3,13.8)	0.39
Control	161/106	51.8 (68.5)	43.2 (63.6)	-8.6 (-26.9,9.7)	0.36						
Water											
Intervention	150/118	125.2 (87.2)	149.5 (113.5)	24.3 (-1.1,49.7)	0.06	16.4 (-36.8,69.7)	0.55	18.7 (-28.8,66.3)	0.44	12.1 (-18.7,43.0)	0.44
Control	121/88	167.1 (114.6)	174.9 (166.0)	7.9 (-39.0,54.7)	0.74						
Sugar-sweetened beverages											
Intervention	40/10	167.4 (78.6)	110.2 (72.2)	-57.2 (-108.4,-6.0)	0.03	-29.7 (-106.9,47.5)	0.45	-34.2 (-112.0,43.7)	0.39	-47.7 (-116.3,20.8)	0.18
Control	38/16	190.8 (97.9)	163.2 (90.4)	-27.6 (-85.4,30.3)	0.35						

[1]Survey adjusted t-test; [2]Model 1 - Unadjusted linear regression; [3]Model 2 - Linear regression adjusted for sex, ethnicity, household size, region, household income and IMD; [4]Model 3 - Linear regression additionally adjusted for total lunchtime intake (grams)

SD - standard deviation; CI - confidence interval

Appendix Table IV.d - Lunchtime nutrient intake in schoolchildren pre- and post-UIFSM and estimates of UIFSM policy impact.

Variable	Pre-UIFSM	Post-UIFSM	Difference	P[1]	Model 1[2]	P	Model 2[3]	P	Model 3[4]	P
	Mean (SD)	Mean (SD)	Diff. (95% CI)		Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Energy (Kcal)										
Intervention	410.9 (131.0)	411.0 (133.5)	-0.1 (-28.8,28.7)	1.00	-24.7 (-63.8,14.5)	0.22	-24.6 (-62.7,13.6)	0.21	-31.9 (-66.4,2.6)	0.07
Control	447.4 (140.6)	472.2 (118.8)	-24.7 (-51.3,1.8)	0.07						
Total fat (g)										
Intervention	15.7 (7.5)	15.2 (6.9)	0.5 (-1.0,2.0)	0.52	-2.2 (-4.3,-0.1)	0.04	-2.2 (-4.3,-0.2)	0.03	-2.5 (-4.5,-0.5)	0.01
Control	16.5 (7.3)	18.2 (7.1)	-1.7 (-3.2,-0.3)	0.02						
Saturated fat (g)										
Intervention	5.9 (3.2)	5.7 (3.3)	0.2 (-0.5,0.9)	0.59	-0.6 (-1.5,0.4)	0.23	-0.6 (-1.5,0.3)	0.21	-0.7 (-1.5,0.2)	0.14
Control	6.0 (3.3)	6.4 (2.8)	-0.4 (-1.0,0.2)	0.22						
Carbohydrate (g)										
Intervention	55.2 (18.3)	56.0 (18.6)	-0.7 (-4.7,3.2)	0.71	-0.8 (-6.5,4.8)	0.77	-0.8 (-6.3,4.7)	0.77	-1.9 (-7.0,3.2)	0.46
Control	62.2 (21.1)	63.8 (17.8)	-1.6 (-5.7,2.5)	0.44						
NMES (g)										
Intervention	13.7 (10.0)	12.7 (10.2)	1.0 (-1.2,3.2)	0.36	0.1 (-3.1,3.2)	0.97	0.0 (-3.0,3.1)	0.98	-0.3 (-3.2,2.7)	0.84
Control	15.7 (11.2)	14.6 (10.1)	1.1 (-1.2,3.3)	0.35						
Protein (g)										
Intervention	15.7 (5.5)	16.1 (6.0)	-0.5 (-1.7,0.8)	0.46	-0.4 (-2.1,1.4)	0.67	-0.4 (-2.1,1.3)	0.67	-0.7 (-2.2,0.9)	0.42
Control	16.4 (6.5)	17.3 (5.1)	-0.9 (-2.1,0.4)	0.17						
Sodium (mg)										
Intervention	515.7 (241.9)	453.0 (207.1)	62.7 (18.2,107.1)	0.01	-94.7 (-159.1,-30.3)	<0.01	-94.4 (-157.2,-31.5)	<0.01	-103.8 (-163.1,-44.5)	<0.01
Control	534.6 (233.4)	566.6 (212.9)	-32.0 (-78.7,14.7)	0.18						
Fibre (g)										
Intervention	4.3 (1.9)	4.4 (1.6)	-0.1 (-0.5,0.2)	0.52	-0.2 (-0.8,0.3)	0.44	-0.2 (-0.7,0.3)	0.46	-0.3 (-0.8,0.2)	0.26
Control	4.4 (1.9)	4.8 (2.0)	-0.3 (-0.8,0.1)	0.13						
Calcium (mg)										
Intervention	209.8 (133.0)	206.5 (131.3)	3.3 (-25.8,32.5)	0.82	-25.0 (-63.2,13.2)	0.20	-26.2 (-62.7,10.2)	0.16	-30.5 (-66.1,5.1)	0.09
Control	200.9 (119.6)	222.5 (108.1)	-21.7 (-46.4,3.1)	0.09						
Iron (mg)										
Intervention	2.0 (0.7)	1.9 (0.7)	0.0 (-0.1,0.2)	0.68	-0.1 (-0.3,0.1)	0.50	-0.1 (-0.3,0.1)	0.52	-0.1 (-0.3,0.1)	0.33
Control	2.2 (0.8)	2.2 (0.7)	-0.0 (-0.2,0.1)	0.59						
Zinc (mg)										
Intervention	1.7 (0.7)	1.8 (0.9)	-0.1 (-0.3,0.1)	0.24	-0.0 (-0.3,0.3)	0.99	-0.0 (-0.3,0.2)	0.97	-0.0 (-0.3,0.2)	0.72
Control	1.8 (0.8)	1.9 (0.7)	-0.1 (-0.3,0.0)	0.14						
Potassium (mg)										
Intervention	592.6 (228.5)	641.7 (257.3)	-49.1 (-99.1,0.9)	0.05	32.3 (-41.0,105.6)	0.39	33.1 (-39.4,105.5)	0.37	20.4 (-45.7,86.4)	0.55
Control	611.7 (262.5)	628.6 (227.7)	-16.8 (-70.5,36.9)	0.54						

Variable	Pre-UIFSM	Post-UIFSM	Difference	P[1]	Model 1[2]	P	Model 2[3]	P	Model 3[4]	P
	Mean (SD)	Mean (SD)	Diff. (95% CI)		Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Folate (ug)										
Intervention	45.5 (22.6)	41.7 (20.4)	3.8 (-0.4,8.1)	0.08	-2.9 (-9.7,4.0)	0.41	-2.8 (-9.5,3.9)	0.41	-3.8 (-10.1,2.4)	0.23
Control	46.0 (27.2)	45.0 (21.9)	1.0 (-4.4,6.3)	0.73						
Vitamin C (mg)										
Intervention	23.4 (20.7)	19.4 (18.8)	4.0 (-0.2,8.2)	0.06	-3.7 (-9.9,2.5)	0.24	-3.9 (-10.0,2.3)	0.22	-4.6 (-10.5,1.4)	0.13
Control	24.3 (21.5)	24.0 (20.2)	0.3 (-4.3,4.9)	0.90						
Vitamin A (ug)										
Intervention	225.1 (274.4)	193.7 (207.1)	31.4 (-16.2,79.0)	0.20	-61.4 (-122.6,-0.2)	0.05	-59.7 (-120.0,0.7)	0.05	-63.9 (-123.8,-4.1)	0.04
Control	147.0 (171.6)	177.0 (197.9)	-30.0 (-68.6,8.6)	0.13						
Fat (% of Energy)										
Intervention	33.2 (8.7)	32.3 (8.5)	0.8 (-0.9,2.6)	0.35	-2.5 (-4.9,0.0)	0.05	-2.4 (-4.9,-0.0)	0.05	-2.4 (-4.9,0.0)	0.05
Control	32.7 (8.4)	34.3 (7.3)	-1.6 (-3.3,0.1)	0.06						
Saturated Fat (% of Energy)										
Intervention	12.4 (4.8)	11.9 (4.8)	0.5 (-0.5,1.5)	0.32	-0.8 (-2.2,0.5)	0.21	-0.8 (-2.1,0.5)	0.20	-0.9 (-2.2,0.4)	0.20
Control	11.7 (4.7)	12.0 (3.7)	-0.3 (-1.2,0.5)	0.46						
Carbohydrate (% of Energy)										
Intervention	53.8 (10.5)	55.1 (9.2)	-1.3 (-3.3,0.7)	0.21	2.8 (-0.1,5.6)	0.06	2.8 (-0.0,5.6)	0.05	2.7 (-0.1,5.5)	0.06
Control	55.6 (10.2)	54.2 (8.2)	1.5 (-0.5,3.4)	0.15						
NMES (% of Energy)										
Intervention	12.9 (8.7)	11.4 (7.7)	1.5 (-0.2,3.1)	0.09	0.2 (-2.3,2.6)	0.90	0.2 (-2.2,2.5)	0.90	0.0 (-2.3,2.4)	0.97
Control	13.6 (8.8)	11.9 (7.4)	1.6 (-0.1,3.4)	0.07						
Protein (% of Energy)										
Intervention	15.7 (6.0)	16.1 (5.1)	-0.4 (-1.4,0.7)	0.50	0.1 (-1.3,1.5)	0.85	0.1 (-1.2,1.5)	0.84	0.1 (-1.2,1.5)	0.83
Control	14.8 (4.5)	15.0 (4.2)	-0.2 (-1.1,0.7)	0.62						

[1]Survey adjusted t-test; [2]Model 1 - Unadjusted linear regression; [3]Model 2 - Linear regression adjusted for sex, ethnicity, household size, region, household income and IMD; [4]Model 3 - Linear regression additionally adjusted for total lunchtime intake (grams)

SD - standard deviation; CI - confidence interval; NMES – non-milk extrinsic sugars

Appendix Table IV.e - Prevalence of food-group consumption in schoolchildren and estimates of UIFSM policy impact stratified by income

Variable	Low-income Pre-UIFSM	Difference	Mid-income Pre-UIFSM	Difference	High-income Pre-UIFSM[2]	Difference	Low-income DiD[2]	P	Mid-income DiD	P	High-Income DiD	P
	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)	Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Fruit												
Intervention	80.5 (39.9)	-2.5 (-16.5,11.5)	79.4 (40.7)	-23.1* (-41.4,-4.9)	72.5 (44.8)	11.2 (-2.5,24.8)	-8.6 (-30.8,13.6)	0.45	-17.7 (-41.5,6.0)	0.14	23.2 (3.4,43.0)	0.02
Control	67.3 (47.1)	4.7 (-13.2,22.5)	72.3 (45.1)	-3.0 (-19.5,13.6)	86.0 (35.0)	-17.0* (-33.2,-0.7)						
Vegetables												
Intervention	69.5 (46.3)	11.6 (-3.2,26.4)	58.8 (49.5)	11.7 (-7.4,30.7)	84.3b (36.5)	1.6 (-9.4,12.7)	8.3 (-14.3,30.8)	0.47	4.3 (-20.2,28.8)	0.73	-7.1 (-27.3,13.1)	0.49
Control	62.4 (48.7)	2.7 (-15.6,21.0)	57.1 (49.8)	7.6 (-10.1,25.3)	72.4 (45.0)	7.0 (-10.5,24.5)						
Protein-rich foods												
Intervention	84.1 (36.7)	-1.8 (-16.1,12.6)	81.4 (39.1)	0.3 (-16.0,16.5)	84.3 (36.5)	-1.9 (-14.7,10.8)	0.1 (-19.0,19.3)	0.99	-4.0 (-24.4,16.3)	0.70	-10.9 (-26.5,4.7)	0.17
Control	84.0 (36.8)	-2.9 (-19.0,13.2)	82.4 (38.4)	4.8 (-8.4,18.1)	89.2b (31.3)	7.6 (-0.8,16.0)						
Dairy												
Intervention	70.7 (45.8)	-4.7 (-21.6,12.2)	72.2 (45.1)	-11.5 (-29.6,6.6)	68.6 (46.6)	3.4 (-11.5,18.2)	-21.6 (-44.1,0.8)	0.06	-12.2 (-35.8,11.3)	0.31	-4.1 (-26.2,18.0)	0.71
Control	66.9 (47.3)	15.2 (0.1,30.2)	62.4 (48.8)	3.9 (-13.9,21.6)	67.5 (47.2)	9.2 (-8.3,26.6)						
Wholemeal												
Intervention	23.2 (42.5)	-21.3* (-0.3,-11.4)	27.8a (45.1)	-10.0 (-24.8,4.9)	29.4b (45.8)	-11.3 (-24.4,1.9)	-25.7 (-40.5,-10.8)	<0.01	-11.9 (-33.8,10.1)	0.29	2.0 (-20.7,24.6)	0.87
Control	9.3 (29.2)	4.0 (-7.7,15.6)	29.4a (45.9)	4.2 (-12.9,21.3)	40.6b (49.5)	-15.1 (-34.0,3.7)						
Starchy foods (no oil)												
Intervention	72.0 (45.2)	16.3* (0.0,29.4)	73.2 (44.5)	9.5 (-5.2,24.2)	80.4 (39.9)	4.0 (-8.8,16.8)	-1.6 (-19.9,16.6)	0.86	11.4 (-10.9,33.7)	0.32	-6.2 (-28.6,16.3)	0.59
Control	69.6 (46.2)	18.3* (4.3,32.3)	75.6 (43.2)	-1.4 (-17.6,14.9)	69.6 (46.3)	11.2 (-5.7,28.2)						
Chips												
Intervention	28.0 (45.2)	10.5 (-6.4,27.3)	30.9 (46.5)	6.8 (-10.2,23.7)	35.3 (48.0)	-0.8 (-16.0,14.5)	31.7 (9.6,53.8)	0.01	0.9 (-22.1,23.9)	0.94	-14.7 (-37.6,8.3)	0.21

Variable	Low-income Pre-UIFSM	Difference	Mid-income Pre-UIFSM	Difference	High-income Pre-UIFSM[2]	Difference	Low-income DiD[2]	P	Mid-income DiD	P	High-Income DiD	P
	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)	Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Control	37.1 (48.5)	-19.8* (-35.1,-4.6)	26.8 (44.6)	7.0 (-10.1,24.1)	30.9 (46.5)	11.8 (-7.5,31.0)						
Crisps												
Intervention	24.4 (43.2)	-10.3 (-24.1,3.5)	26.8 (44.5)	-13.5 (-27.6,0.6)	15.7 (36.5)	-9.7* (-18.9,-0.5)	-32.8 (-54.9,-10.6)	<0.01	-17.0 (-38.0,3.9)	0.11	-4.1 (-23.8,15.6)	0.68
Control	17.6 (38.3)	22.4* (5.4,39.5)	28.1 (45.3)	4.9 (-11.8,21.6)	27.3 (44.9)	-5.1 (-23.4,13.2)						
Sweet snacks												
Intervention	50.0 (50.3)	-9.4 (-26.9,8.1)	52.6 (50.2)	-12.4 (-31.2,6.5)	40.2 (49.3)	-0.5 (-16.7,15.7)	-18.1 (-42.8,6.6)	0.15	-24.4 (-49.0,0.2)	0.05	10.0 (-13.6,33.7)	0.41
Control	49.1 (50.3)	9.0 (-9.1,27.2)	52.9 (50.3)	15.4 (-2.4,33.2)	52.1 (50.3)	-11.1 (-30.9,8.6)						
Puddings												
Intervention	46.3 (50.2)	10.9 (-7.1,28.9)	40.2 (49.3)	23.7* (5.6,41.7)	47.1 (50.2)	12.8 (-3.7,29.3)	10.1 (-13.1,33.3)	0.39	25.1 (0.3,49.8)	0.05	5.6 (-19.5,30.7)	0.66
Control	44.4 (49.9)	5.4 (-13.1,24.0)	39.9 (49.3)	0.7 (-17.2,18.5)	51.0 (50.4)	2.4 (-17.7,22.5)						
High in saturated fat												
Intervention	92.7 (26.2)	-11.3 (-24.4,1.8)	82.5 (38.2)	5.3 (-5.8,16.5)	89.2 (31.2)	-10.0 (-22.6,2.6)	-26.5 (-42.6,-10.5)	<0.01	6.6 (-8.2,21.3)	0.38	-2.4 (-19.7,14.9)	0.79
Control	76.0 (42.9)	16.4* (4.4,28.3)	91.8 (27.6)	-0.4 (-12.2,11.3)	91.3 (28.3)	-8.7 (-22.2,4.8)						
High in sodium												
Intervention	70.7 (45.8)	-10.7 (-28.0,6.7)	72.2 (45.1)	-8.4 (-26.3,9.5)	66.7 (47.4)	-6.3 (-22.5,9.8)	-24.7 (-48.1,-1.3)	0.04	-2.3 (-23.3,18.7)	0.83	-0.4 (-24.3,23.4)	0.97
Control	55.3 (50.0)	14.3 (-4.2,32.8)	83.9a (37.0)	-1.4 (-16.0,13.3)	74.3 (44.0)	-8.8 (-26.9,9.3)						
High in sugar												
Intervention	74.4 (43.9)	-7.6 (-24.5,9.3)	69.1 (46.5)	1.1 (-15.9,18.2)	56.9 (49.8)	19.4* (4.5,34.3)	-14.4 (-35.5,6.8)	0.18	-0.3 (-22.1,21.5)	0.98	10.8 (-10.7,32.3)	0.33
Control	70.6 (45.8)	9.3 (-5.7,24.3)	74.4 (44.0)	2.1 (-13.5,17.7)	69.6 (46.3)	4.8 (-14.2,23.9)						
Milk												
Intervention	3.7 (18.9)	17.4* (0.0,30.0)	6.2 (24.2)	5.1 (-7.3,17.4)	13.7 (34.6)	10.2 (-4.2,24.6)	18.3 (3.7,33.0)	0.01	-2.6 (-17.6,12.4)	0.73	12.9 (-2.2,27.9)	0.09

Variable	Low-income Pre-UIFSM	Difference	Mid-income Pre-UIFSM	Difference	High-income Pre-UIFSM[2]	Difference	Low-income DiD[2]	P	Mid-income DiD	P	High-Income DiD	P
	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)	Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Control	8.9 (28.6)	-3.7 (-12.3,4.8)	2.5 (15.8)	7.6 (-1.1,16.3)	4.1 (20.0)	-1.8 (-8.5,4.8)						
Yoghurt												
Intervention	37.8 (48.8)	-1.9 (-18.8,14.9)	45.4 (50.0)	-21.4* (-39.1,-3.6)	36.3 (48.3)	-16.1* (-29.7,-2.4)	-15.7 (-39.7,8.4)	0.20	-10.1 (-32.5,12.4)	0.38	-5.3 (-27.8,17.2)	0.64
Control	34.1 (47.6)	12.5 (-5.7,30.7)	35.7 (48.3)	-7.6 (-24.3,9.1)	32.7 (47.3)	-9.0 (-26.8,8.8)						
Cheese												
Intervention	57.3 (49.8)	-4.6 (-22.5,13.2)	45.4 (50.0)	-4.2 (-23.1,14.6)	50.0 (50.2)	7.9 (-8.4,24.1)	-16.2 (-41.5,9.0)	0.21	-11.5 (-37.0,14.0)	0.38	-8.0 (-33.0,17.1)	0.53
Control	45.1 (50.0)	12.4 (-5.8,30.5)	41.5 (49.6)	9.6 (-8.6,27.8)	50.2 (50.4)	16.0 (-3.2,35.3)						
Meat, fish and eggs												
Intervention	81.7 (38.9)	-2.6 (-17.5,12.4)	81.4 (39.1)	0.3 (-16.0,16.5)	79.4 (40.6)	1.3 (-12.2,14.7)	-3.4 (-23.5,16.6)	0.74	-0.4 (-21.3,20.5)	0.97	-2.6 (-20.4,15.2)	0.78
Control	81.7 (38.9)	-0.6 (-16.9,15.6)	81.9 (38.7)	1.1 (-13.0,15.2)	87.7 (33.1)	2.4 (-9.5,14.2)						
Baked beans												
Intervention	12.2 (32.9)	4.0 (-8.3,16.4)	12.4 (33.1)	19.4* (2.8,36.0)	17.6 (38.3)	3.4 (-9.3,16.1)	10.0 (-5.6,25.6)	0.21	14.2 (-3.2,31.5)	0.11	-9.7 (-27.1,7.7)	0.28
Control	12.6 (33.4)	-5.5 (-15.1,4.1)	8.3 (27.7)	3.3 (-7.6,14.2)	5.9 (23.8)	13.9* (0.3,27.4)						
Fruit juice												
Intervention	61.0 (49.1)	-5.7 (-23.6,12.1)	73.2 (44.5)	-18.1 (-36.2,0.0)	62.7 (48.6)	-17.6* (-33.8,-1.3)	-21.4 (-45.2,2.4)	0.08	-16.0 (-40.2,8.2)	0.20	2.4 (-21.7,26.6)	0.84
Control	61.7 (48.9)	13.6 (-2.9,30.1)	69.8 (46.2)	-3.0 (-20.2,14.2)	69.0 (46.6)	-17.8 (-37.3,1.7)						
Water												
Intervention	53.7 (50.2)	11.2 (-6.2,28.6)	46.4 (50.1)	8.1 (-11.3,27.4)	59.8 (49.3)	10.1 (-6.1,26.2)	22.1 (-1.3,45.5)	0.06	-10.9 (-35.8,13.9)	0.39	-0.9 (-24.2,22.3)	0.94
Control	51.3 (50.2)	-17.7* (-35.2,-0.2)	39.0 (49.1)	19.5* (1.8,37.3)	65.0b (48.1)	8.4 (-10.2,26.9)						
Sugar-sweetened beverages												
Intervention	13.4 (34.3)	-6.1 (-16.3,4.2)	20.6 (40.7)	-5.7 (-21.4,10.1)	8.8 (28.5)	-7.8* (-13.7,-1.9)	-6.4 (-22.3,9.5)	0.43	1.5 (-16.6,19.6)	0.87	0.8 (-11.4,12.9)	0.90

Variable	Low-income Pre-UIFSM	Difference	Mid-income Pre-UIFSM	Difference	High-income Pre-UIFSM[2]	Difference	Low-income DiD[2]	P	Mid-income DiD	P	High-Income DiD	P
	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)	Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Control	13.9 (34.8)	0.3 (-12.7,13.4)	16.6 (37.5)	-5.3 (-17.6,6.9)	13.3 (34.2)	-7.1 (-18.3,4.1)						

[1] Survey adjusted t-test; [2] Linear regression adjusted for sex, ethnicity, household size, region, household income, IMD and total lunchtime intake (g)
* P<0.05; SD - standard deviation; CI - confidence interval

Appendix Table IV.f - Mean lunchtime nutrient intakes in schoolchildren and estimates of UIFSM policy impact stratified by income

Variable	Low-income Pre-UIFSM	Difference	Mid-income Pre-UIFSM	Difference	High-income Pre-UIFSM	Difference	Low-income DiD[2]	P	Mid-income DiD[2]	P	High-Income DiD[2]	P
	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)	Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Energy (Kcal)												
Intervention	429.7 (152.9)	-19.4 (-69.2,30.5)	412.2 (130.1)	4.0 (-50.1,58.1)	394.7 (110.4)	11.4 (-32.7,55.5)	-122.7 (-181.7,-63.6)	<0.01	12.5 (-39.1,64.2)	0.63	-0.1 (-58.1,57.8)	1.00
Control	407.1 (140.1)	85.1* (36.1,134.0)	460.8 (132.7)	-8.7 (-50.2,32.8)	471.1 (140.8)	6.5 (-39.6,52.6)						
Total fat (g)												
Intervention	17.4 (9.1)	-2.4 (-5.2,0.3)	15.1 (6.7)	0.5 (-2.3,3.3)	14.9 (6.7)	0.1 (-2.3,2.4)	-7.1 (-10.7,-3.4)	<0.01	-0.1 (-3.3,3.1)	0.96	-0.8 (-3.8,2.2)	0.60
Control	15.2 (6.4)	4.3* (1.3,7.3)	17.0 (7.5)	0.6 (-1.9,3.0)	17.2 (7.7)	0.7 (-1.6,3.0)						
Saturated fat (g)												
Intervention	6.5 (3.9)	-0.8 (-2.0,0.4)	5.6 (2.9)	0.1 (-1.1,1.4)	5.7 (2.9)	-0.0 (-1.2,1.2)	-2.7 (-4.2,-1.1)	<0.01	0.3 (-1.2,1.8)	0.71	0.2 (-1.3,1.7)	0.78
Control	5.3 (3.1)	1.6* (0.5,2.8)	6.5 (3.6)	-0.1 (-1.2,1.0)	6.3 (3.4)	-0.3 (-1.3,0.7)						
Carbohydrate (g)												
Intervention	55.9 (19.8)	1.0 (-6.0,8.1)	57.3 (19.0)	-0.5 (-7.7,6.7)	52.7 (16.2)	1.5 (-4.5,7.4)	-11.7 (-20.2,-3.1)	0.01	2.4 (-5.0,9.8)	0.53	1.8 (-7.3,10.8)	0.70
Control	56.4 (22.4)	9.9* (3.1,16.7)	64.1 (19.1)	-3.0 (-9.1,3.1)	65.8 (20.5)	-0.9 (-8.5,6.7)						
NMES (g)												
Intervention	13.4 (9.7)	0.4 (-3.9,4.7)	15.5 (10.6)	-2.2 (-6.2,1.7)	12.2 (9.5)	-1.2 (-4.0,1.7)	-0.6 (-6.1,5.0)	0.84	0.2 (-4.1,4.5)	0.93	-0.3 (-5.1,4.5)	0.90

Variable	Low-income Pre-UIFSM	Difference	Mid-income Pre-UIFSM	Difference	High-income Pre-UIFSM	Difference	Low-income DiD[2]	P	Mid-income DiD[2]	P	High-Income DiD[2]	P
	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)	Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Control	15.2 (12.7)	0.6 (-3.5,4.8)	16.8 (11.0)	-2.8 (-6.1,0.5)	15.3 (10.0)	-0.9 (-5.2,3.3)						
Protein (g)												
Intervention	15.9 (6.1)	-0.3 (-2.3,1.7)	15.3 (5.2)	0.3 (-1.7,2.4)	15.8 (5.1)	1.4 (-1.1,3.8)	-3.9 (-6.3,-1.5)	<0.01	1.1 (-1.4,3.6)	0.39	0.1 (-3.0,3.2)	0.96
Control	14.8 (6.2)	2.5* (0.5,4.5)	16.9 (6.2)	-0.7 (-2.7,1.3)	17.4b (6.7)	1.0 (-1.1,3.1)						
Sodium (mg)												
Intervention	567.6 (302.5)	-141.1* (-229.4,-52.8)	509.2 (234.4)	-38.1 (-120.2,43.9)	480.2 (181.9)	-22.4 (-78.9,34.0)	-331.0 (-434.8,-227.1)	<0.01	17.0 (-86.4,120.5)	0.75	-7.4 (-97.6,82.8)	0.87
Control	442.2 (226.0)	161.0* (85.1,237.0)	603.0a (230.3)	-47.0 (-126.4,32.3)	561.0 (219.6)	-12.3 (-93.5,68.9)						
Fibre (g)												
Intervention	4.2 (2.0)	-0.0 (-0.6,0.6)	4.2 (1.9)	0.3 (-0.4,0.9)	4.5 (1.7)	0.1 (-0.4,0.6)	-0.6 (-1.4,0.2)	0.13	-0.1 (-1.1,0.8)	0.75	-0.3 (-1.1,0.5)	0.47
Control	3.6 (1.5)	0.3 (-0.2,0.8)	4.5a (2.2)	0.4 (-0.5,1.2)	5.0b (1.7)	0.2 (-0.4,0.9)						
Calcium (mg)												
Intervention	215.7 (148.1)	-6.7 (-53.4,40.1)	201.8 (129.9)	0.1 (-55.7,56.0)	212.7 (123.8)	-3.7 (-51.3,44.0)	-99.7 (-157.2,-42.2)	<0.01	23.9 (-38.3,86.1)	0.45	-15.3 (-75.9,45.3)	0.62
Control	178.4 (120.8)	72.5* (32.7,112.2)	219.9 (128.9)	-21.7 (-61.5,18.1)	205.5 (109.4)	20.4 (-25.3,66.1)						
Iron (mg)												
Intervention	1.9 (0.7)	-0.2 (-0.4,0.1)	1.9 (0.7)	0.0 (-0.2,0.3)	2.1b (0.7)	0.0 (-0.2,0.3)	-0.6 (-0.9,-0.3)	<0.01	0.2 (-0.1,0.5)	0.31	0.0 (-0.4,0.4)	0.92
Control	1.9 (0.7)	0.4* (0.1,0.6)	2.2 (0.8)	-0.1 (-0.4,0.2)	2.4b (0.9)	-0.0 (-0.3,0.3)						
Zinc (mg)												
Intervention	1.8 (0.7)	-0.1 (-0.3,0.2)	1.6 (0.7)	0.2 (-0.2,0.5)	1.8 (0.7)	0.3 (-0.1,0.7)	-0.5 (-0.8,-0.2)	<0.01	0.2 (-0.2,0.6)	0.34	0.1 (-0.3,0.6)	0.58
Control	1.5 (0.7)	0.3* (0.1,0.5)	1.9a (0.7)	-0.0 (-0.3,0.2)	1.9b (0.9)	0.1 (-0.2,0.4)						
Potassium (mg)												
Intervention	584.1 (236.3)	78.6 (-7.3,164.5)	597.2 (214.0)	39.6 (-48.3,127.6)	595.1 (237.5)	32.8 (-51.9,117.5)	37.5 (-66.4,141.5)	0.48	37.3 (-79.2,153.8)	0.53	-43.4 (-153.8,67.0)	0.44

Variable	Low-income Pre-UIFSM	Difference	Mid-income Pre-UIFSM	Difference	High-income Pre-UIFSM	Difference	Low-income DiD[2]	P	Mid-income DiD[2]	P	High-Income DiD[2]	P
	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)	Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Control	576.9 (259.1)	-8.3 (-83.7,67.2)	621.3 (276.2)	-5.5 (-105.8,94.8)	633.7b (254.8)	56.7 (-34.3,147.6)						
Folate (ug)												
Intervention	45.0 (22.4)	-5.3 (-13.0,2.5)	42.9 (21.2)	-0.1 (-7.7,7.6)	48.5 (23.9)	-6.2 (-12.9,0.5)	-10.8 (-20.5,-1.1)	0.03	8.1 (-2.6,18.8)	0.14	-10.6 (-21.3,0.1)	0.05
Control	38.5 (23.9)	2.1 (-5.3,9.4)	50.3a (32.2)	-8.5 (-17.7,0.7)	49.0b (24.6)	3.0 (-7.0,13.0)						
Vitamin C (mg)												
Intervention	20.4 (20.9)	1.0 (-6.9,8.9)	26.1 (20.6)	-6.5 (-14.2,1.2)	23.2 (20.6)	-5.9 (-11.9,0.1)	-4.1 (-14.6,6.3)	0.44	-3.1 (-13.4,7.3)	0.56	-5.1 (-14.6,4.3)	0.28
Control	21.3 (20.1)	4.0 (-3.7,11.8)	26.9 (23.5)	-3.8 (-11.9,4.3)	25.0 (21.1)	-0.9 (-9.0,7.2)						
Vitamin A (ug)												
Intervention	214.7 (252.1)	-47.1 (-122.5,28.3)	223.1 (324.6)	-67.7 (-147.5,12.1)	235.4 (239.7)	22.9 (-64.1,109.9)	-79.4 (-166.5,7.7)	0.07	-116.9 (-225.0,-8.8)	0.03	-14.3 (-133.4,104.9)	0.81
Control	126.7 (186.1)	15.0 (-28.5,58.5)	140.8 (154.8)	45.6 (-26.8,117.9)	168.5b (170.3)	26.7 (-44.8,98.1)						
Fat (% of Energy)												
Intervention	34.8 (9.6)	-2.8 (-5.8,0.2)	31.9 (8.0)	0.2 (-2.9,3.3)	33.0 (8.6)	-0.2 (-3.3,2.9)	-3.0 (-7.0,1.0)	0.14	-1.8 (-6.1,2.4)	0.39	-1.9 (-6.2,2.4)	0.38
Control	33.4 (8.3)	0.8 (-2.3,3.8)	32.6 (9.0)	2.1 (-1.0,5.2)	32.0 (8.2)	1.8 (-1.1,4.7)						
Saturated Fat (% of Energy)												
Intervention	12.9 (4.8)	-0.8 (-2.4,0.8)	11.6 (4.5)	0.0 (-1.9,1.9)	12.8 (5.0)	-0.8 (-2.5,0.9)	-1.7 (-4.0,0.5)	0.13	-0.3 (-2.7,2.2)	0.84	-0.4 (-2.5,1.7)	0.73
Control	11.4 (5.1)	1.0 (-0.6,2.6)	12.1 (4.6)	0.4 (-1.2,2.0)	11.7 (4.6)	-0.4 (-1.8,0.9)						
Carbohydrate (% of Energy)												
Intervention	52.3 (10.6)	3.5* (0.5,6.5)	55.3 (10.5)	0.6 (-3.2,4.4)	53.5 (10.3)	0.0 (-3.4,3.5)	3.8 (-0.3,7.9)	0.07	2.5 (-2.7,7.6)	0.34	1.7 (-3.3,6.8)	0.51
Control	55.3 (9.2)	-0.6 (-3.7,2.4)	56.1 (10.3)	-1.9 (-5.5,1.6)	55.5 (10.9)	-1.8 (-5.4,1.9)						
NMES (% of Energy)												

Variable	Low-income Pre-UIFSM	Difference	Mid-income Pre-UIFSM	Difference	High-income Pre-UIFSM	Difference	Low-income DiD[2]	P	Mid-income DiD[2]	P	High-Income DiD[2]	P
	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)	Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Intervention	12.1 (7.7)	0.3 (-3.0,3.6)	14.5 (9.3)	-2.8 (-5.7,0.2)	11.9 (8.7)	-1.8 (-4.1,0.6)	2.0 (-2.3,6.3)	0.36	-0.8 (-4.8,3.1)	0.69	-0.3 (-4.0,3.3)	0.85
Control	14.0 (9.3)	-1.3 (-4.4,1.8)	14.5 (9.3)	-2.3 (-5.2,0.6)	12.5 (7.8)	-1.4 (-4.4,1.6)						
Protein (% of Energy)												
Intervention	15.0 (4.4)	0.8 (-1.0,2.6)	15.2 (4.8)	0.2 (-1.3,1.8)	16.9b (7.7)	0.2 (-1.8,2.2)	0.4 (-1.9,2.8)	0.71	0.7 (-1.4,2.7)	0.53	-1.0 (-3.6,1.5)	0.44
Control	14.8 (4.3)	-0.1 (-1.7,1.5)	14.8 (4.5)	-0.3 (-1.7,1.1)	14.8 (4.6)	1.1 (-0.6,2.7)						

[1]Survey adjusted t-test; [2]Linear regression adjusted for sex, ethnicity, household size, region, household income, IMD and total grams

* P<0.05; SD - standard deviation; CI - confidence interval

Appendix Table IV.g - Mean daily nutrient intakes in schoolchildren, on a school day, and estimates of UIFSM policy impact.

Variable	**Pre-UIFSM**	**Post-UIFSM**	**Difference**	**P**[1]	**Crude DiD**[2]	**P**	**Adjusted DiD**[3]	**P**
	Mean (SD)	**Mean (SD)**	**Diff. (95% CI)**		**Coef. (95% CI)**		**Coef. (95% CI)**	
Energy (Kcal)								
Intervention	1407.5 (325.9)	1408.4 (351.6)	0.9 (-80.3,82.1)	0.98	7.4 (-102.3,117.0)	0.90	2.1 (-101.2,105.5)	0.97
Control	1580.8 (361.5)	1574.3 (332.1)	-6.5 (-80.3,67.3)	0.86				
Total fat (g)								
Intervention	51.7 (16.6)	51.3 (17.6)	-0.4 (-4.4,3.7)	0.86	-1.9 (-7.3,3.5)	0.48	-2.2 (-7.3,3.0)	0.41
Control	56.7 (18.0)	58.3 (15.6)	1.6 (-2.0,5.1)	0.39				
Saturated fat (g)								
Intervention	21.0 (7.8)	20.7 (8.4)	-0.3 (-2.2,1.5)	0.73	-0.5 (-2.9,2.0)	0.71	-0.5 (-2.9,1.8)	0.65
Control	22.1 (8.2)	22.2 (7.5)	0.1 (-1.5,1.8)	0.86				
Carbohydrate (g)								
Intervention	194.8 (46.3)	196.6 (48.8)	1.7 (-8.9,12.4)	0.75	6.1 (-9.3,21.5)	0.44	5.5 (-9.2,20.1)	0.46
Control	223.0 (51.6)	218.7 (51.3)	-4.4 (-15.5,6.8)	0.44				
NMES (g)								
Intervention	49.8 (26.6)	47.1 (23.4)	-2.7 (-7.6,2.2)	0.28	2.3 (-5.5,10.0)	0.57	2.2 (-5.4,9.7)	0.57
Control	60.8 (29.6)	55.8 (25.9)	-4.9 (-11.0,1.1)	0.11				
Protein (g)								
Intervention	52.8 (13.9)	52.4 (15.4)	-0.5 (-4.1,3.2)	0.81	0.4 (-4.4,5.2)	0.86	0.3 (-4.3,4.8)	0.91
Control	58.6 (15.1)	57.7 (13.6)	-0.9 (-4.0,2.3)	0.58				
Sodium (mg)								
Intervention	1532.3 (467.0)	1414.0 (431.6)	-118.3 (-209.6,-27.0)	0.01	-76.3 (-214.0,61.4)	0.28	-83.1 (-215.1,49.0)	0.22
Control	1720.9 (527.0)	1678.8 (454.1)	-42.1 (-145.3,61.1)	0.42				
Fibre (g)								
Intervention	14.2 (4.2)	15.0 (5.4)	0.8 (-0.4,2.0)	0.18	0.6 (-1.0,2.2)	0.49	0.5 (-1.0,2.1)	0.48
Control	15.3 (4.8)	15.6 (5.0)	0.2 (-0.8,1.3)	0.66				
Calcium (mg)								
Intervention	810.5 (317.2)	795.2 (325.4)	-15.2 (-83.6,53.1)	0.66	-21.4 (-115.4,72.6)	0.66	-25.5 (-115.0,63.9)	0.58
Control	796.9 (310.5)	803.1 (278.3)	6.2 (-58.4,70.7)	0.85				
Iron (mg)								
Intervention	7.9 (2.4)	7.9 (2.5)	0.0 (-0.5,0.6)	0.91	0.5 (-0.3,1.4)	0.22	0.5 (-0.3,1.3)	0.21
Control	9.5 (3.1)	9.0 (2.8)	-0.5 (-1.1,0.1)	0.13				
Zinc (mg)								
Intervention	6.1 (2.0)	6.1 (2.2)	-0.0 (-0.6,0.5)	0.98	-0.1 (-0.8,0.6)	0.84	-0.1 (-0.8,0.5)	0.76
Control	6.5 (2.0)	6.6 (2.0)	0.1 (-0.4,0.5)	0.77				
Potassium (mg)								
Intervention	2133.2 (540.5)	2153.6 (610.8)	20.4 (-124.2,165.0)	0.78	84.6 (-111.2,280.3)	0.40	77.9 (-107.5,263.3)	0.41
Control	2259.1 (625.0)	2194.9 (584.9)	-64.2 (-196.3,67.9)	0.34				

Variable	Pre-UIFSM	Post-UIFSM	Difference	P[1]	Crude DiD[2]	P	Adjusted DiD[3]	P
	Mean (SD)	Mean (SD)	Diff. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Folate (ug)								
Intervention	180.8 (61.8)	173.3 (54.1)	-7.5 (-19.2,4.2)	0.21	5.7 (-14.4,25.7)	0.58	5.2 (-14.0,24.4)	0.60
Control	205.5 (83.0)	192.3 (68.2)	-13.2 (-29.5,3.1)	0.11				
Vitamin C (mg)								
Intervention	84.0 (46.9)	77.9 (40.6)	-6.1 (-14.9,2.7)	0.18	-5.1 (-18.6,8.4)	0.46	-5.2 (-18.5,8.2)	0.45
Control	85.5 (48.7)	84.4 (47.7)	-1.0 (-11.2,9.2)	0.84				
Vitamin A (ug)								
Intervention	663.7 (434.6)	576.3 (403.1)	-87.4 (-169.8,-5.0)	0.04	-94.8 (-215.7,26.2)	0.12	-90.8 (-209.2,27.5)	0.13
Control	551.3 (438.1)	558.7 (419.9)	7.4 (-81.3,96.0)	0.87				
Fat (% of Energy)								
Intervention	32.7 (5.3)	32.4 (5.3)	-0.3 (-1.4,0.8)	0.60	-1.5 (-3.0,0.0)	0.05	-1.5 (-3.0,-0.0)	0.05
Control	32.0 (5.0)	33.2 (4.7)	1.2 (0.2,2.3)	0.03				
Saturated Fat (% of Energy)								
Intervention	13.2 (3.0)	12.9 (3.0)	-0.3 (-0.9,0.3)	0.29	-0.5 (-1.3,0.4)	0.26	-0.5 (-1.3,0.4)	0.26
Control	12.4 (2.9)	12.6 (2.8)	0.2 (-0.4,0.8)	0.58				
Carbohydrate (% of Energy)								
Intervention	55.6 (6.1)	56.2 (6.6)	0.6 (-0.8,1.9)	0.42	1.6 (-0.2,3.5)	0.08	1.6 (-0.2,3.4)	0.08
Control	56.6 (5.1)	55.6 (5.7)	-1.1 (-2.3,0.2)	0.09				
NMES (% of Energy)								
Intervention	13.9 (6.1)	13.2 (5.8)	-0.7 (-1.9,0.6)	0.29	0.4 (-1.3,2.1)	0.66	0.4 (-1.3,2.1)	0.63
Control	15.0 (5.6)	14.0 (5.4)	-1.1 (-2.3,0.1)	0.09				
Protein (% of Energy)								
Intervention	15.2 (2.7)	14.9 (3.0)	-0.2 (-0.8,0.4)	0.50	-0.0 (-0.9,0.8)	0.95	-0.0 (-0.9,0.8)	0.96
Control	15.0 (2.8)	14.8 (2.5)	-0.2 (-0.8,0.4)	0.57				

[1]Survey adjusted t-test; [2]Unadjusted linear regression; [3]Linear regression adjusted for sex, ethnicity, household size, region, household income and IMD
SD - standard deviation; CI - confidence interval

Appendix Table IV.h - Difference-in-differences estimates for food-group outcomes using different specifications of IPW and level of adjustment

Variable	no IPW Unadjusted	P	no IPW Adjusted	P	IPW Unadjusted	P	IPW Adjusted	P
Wholemeal	-0.15(-0.28,-0.03)	0.02	-0.13(-0.25,-0.00)	0.04	-0.12(-0.24,0.01)	0.06	-0.12(-0.24,0.00)	0.06
Starchy foods (no oil)	0.11(-0.02,0.23)	0.09	0.09(-0.03,0.22)	0.14	0.00(-0.12,0.13)	0.94	0.01(-0.12,0.13)	0.93
Crisps	-0.19(-0.32,-0.07)	<0.01	-0.20(-0.33,-0.07)	<0.01	-0.18(-0.30,-0.05)	0.01	-0.18(-0.30,-0.05)	0.01
Puddings	0.23(0.07,0.38)	<0.01	0.21(0.06,0.36)	0.01	0.14(-0.01,0.29)	0.07	0.15(-0.00,0.29)	0.05
Dairy	-0.15(-0.29,-0.01)	0.04	-0.15(-0.30,-0.01)	0.03	-0.13(-0.27,0.01)	0.07	-0.13(-0.26,0.01)	0.07
Fruit and vegetables	0.03(-0.05,0.10)	0.52	0.02(-0.06,0.10)	0.59	0.01(-0.07,0.10)	0.77	0.02(-0.06,0.10)	0.70
High in saturated fat	-0.04(-0.15,0.07)	0.48	-0.05(-0.15,0.06)	0.41	-0.07(-0.17,0.03)	0.18	-0.07(-0.17,0.03)	0.17
High in sodium	-0.17(-0.31,-0.03)	0.02	-0.15(-0.29,-0.02)	0.03	-0.10(-0.24,0.04)	0.15	-0.10(-0.24,0.04)	0.15
High in sugar	0.07(-0.06,0.21)	0.29	0.06(-0.07,0.20)	0.36	-0.00(-0.14,0.13)	0.96	-0.00(-0.13,0.13)	0.99

Note:
- “no IPW” – Models accounted for survey weighting, does not include an IPW weight
- “IPW” - IPW weight produced using multinomial regression with survey weights included as a predictor. Pre-infants as focal. This weight was used in the main analyses.
- “Unadjusted” - not adjusted for covariates
- “Adjusted” - adjusted for covariates

Appendix Table IV.i - Difference in difference estimates for the nutrients outcomes using different specifications of IPW and level of adjustment

Variable	no IPW Unadjusted	P	no IPW Adjusted	P	IPW Unadjusted	P	IPW Adjusted	P
Energy (Kcal)	-19.8 (-62.3,22.7)	0.36	-20.7 (-62.4,21.0)	0.33	-24.7 (-63.8,14.5)	0.22	-24.6 (-62.7,13.6)	0.21
Total fat (g)	-2.9 (-5.2,-0.5)	0.02	-2.9 (-5.3,-0.6)	0.01	-2.2(-4.3,-0.1)	0.04	-2.2 (-4.3,-0.2)	0.03
Carbohydrate (g)	2.4 (-3.9,8.7)	0.45	2.4 (-3.8,8.5)	0.45	-0.8(-6.5,4.8)	0.77	-0.8 (-6.3,4.7)	0.77
NMES (g)	3.0 (-0.2,6.2)	0.07	3.2 (0.0,6.3)	0.05	0.1(-3.1,3.2)	0.97	0.0 (-3.0,3.1)	0.98
Protein (g)	-0.8 (-2.5,1.0)	0.39	-0.8 (-2.6,0.9)	0.36	-0.4(-2.1,1.4)	0.67	-0.4 (-2.1,1.3)	0.67
Sodium (mg)	-126.7 (-193.7,-59.8)	<0.01	-119.7 (-184.2,-55.2)	<0.01	-94.7(-159.1,-30.3)	<0.01	-94.4 (-157.2,-31.5)	<0.01
Potassium (mg)	47.3 (-26.7,121.4)	0.21	40.4 (-33.2,114.0)	0.28	32.3(-41.0,105.6)	0.39	33.1 (-39.4,105.5)	0.37

Note:
- “no IPW” – Models accounted for survey weighting, does not include an IPW weight
- “IPW” - IPW weight produced using multinomial regression with survey weights included as a predictor. Pre-infants as focal. This weight was used in the main analyses.
- “Unadjusted” - not adjusted for covariates
- “Adjusted” - adjusted for covariates

Appendix Table IV.j - Difference-in-differences estimates for nutrient outcomes excluding unreliable energy reporters

Variable	Main analysis Unadjusted	P	Main analysis Unadjusted	P	Reliable reporters Unadjusted	P	Reliable reporters Adjusted	P
Energy (Kcal)	-24.7 (-63.8,14.5)	0.22	-31.9 (-66.4,2.6)	0.07	-26.3 (-65.8,13.2)	0.19	-32.5 (-67.5,2.5)	0.07
Total fat (g)	-2.2 (-4.3,-0.1)	0.04	-2.5 (-4.5,-0.5)	0.01	-2.1 (-4.3,0.0)	0.05	-2.3 (-4.3,-0.3)	0.03
Carbohydrate (g)	-0.8 (-6.5,4.8)	0.77	-1.9 (-7.0,3.2)	0.46	-1.5 (-7.2,4.2)	0.62	-2.4 (-7.6,2.7)	0.35
NMES (g)	0.1 (-3.1,3.2)	0.97	-0.3 (-3.2,2.7)	0.84	-0.0 (-3.3,3.2)	0.98	-0.4 (-3.4,2.7)	0.81
Protein (g)	-0.4 (-2.1,1.4)	0.67	-0.7 (-2.2,0.9)	0.42	-0.4 (-2.2,1.4)	0.63	-0.7 (-2.3,1.0)	0.43
Sodium (mg)	-94.7 (-159.1,-30.3)	<0.01	-103.8 (-163.1,-44.5)	<0.01	-87.8 (-153.7,-21.9)	0.01	-94.2 (-155.0,-33.4)	<0.01
Potassium (mg)	32.3 (-41.0,105.6)	0.39	20.4 (-45.7,86.4)	0.55	24.3 (-50.4,98.9)	0.52	14.2 (-53.5,81.8)	0.68

Note: Reliable reporter = participants whose reported energy was under (*n*=42) and over(*n*=2) their estimated energy requirement.
Unadjusted - Linear regression not adjusted for covariates;
Adjusted - Linear regression not adjusted for sex, ethnicity, household size, region, household income, IMD and total lunch (g)

Appendix Table IV.k - Difference-in-differences estimates for food-group outcomes excluding unreliable energy reporters

Variable	Main analysis Unadjusted	P	Main analysis Unadjusted	P	Reliable reporters Unadjusted	P	Reliable reporters Adjusted	P
Wholemeal	-0.12 (-0.24,0.01)	0.06	-0.12 (-0.24,0.00)	0.05	-0.12 (-0.25,0.01)	0.06	-0.12 (-0.25,0.00)	0.06
Chips	0.00 (-0.12,0.13)	0.94	0.01 (-0.12,0.13)	0.92	0.01 (-0.11,0.14)	0.83	0.02 (-0.11,0.14)	0.83
Crisps	-0.18 (-0.30,-0.05)	0.01	-0.18 (-0.30,-0.06)	<0.01	-0.17 (-0.30,-0.04)	0.01	-0.17 (-0.30,-0.04)	0.01
Puddings	0.14 (-0.01,0.29)	0.07	0.14 (-0.01,0.29)	0.06	0.12 (-0.04,0.27)	0.13	0.12 (-0.03,0.27)	0.13
Dairy	-0.13 (-0.27,0.01)	0.07	-0.13 (-0.27,0.00)	0.05	-0.15 (-0.30,-0.01)	0.04	-0.16 (-0.30,-0.02)	0.04
Fruit and vegetables	0.01 (-0.07,0.10)	0.77	0.01 (-0.07,0.09)	0.81	0.01 (-0.08,0.09)	0.84	0.01 (-0.07,0.09)	0.84
High in saturated fat	-0.07 (-0.17,0.03)	0.18	-0.08 (-0.17,0.02)	0.13	-0.05 (-0.15,0.05)	0.30	-0.05 (-0.15,0.04)	0.30
High in sodium	-0.10 (-0.24,0.04)	0.15	-0.11 (-0.24,0.03)	0.12	-0.09 (-0.24,0.05)	0.20	-0.09 (-0.23,0.05)	0.20
High in sugar	-0.00 (-0.14,0.13)	0.96	-0.00 (-0.14,0.13)	0.95	-0.02 (-0.16,0.12)	0.83	-0.01 (-0.15,0.12)	0.83

Note: Reliable reporter = participants whose reported energy was under (*n*=42) and over(*n*=2) their estimated energy requirement.
Unadjusted - Linear regression not adjusted for covariates;
Adjusted - Linear regression not adjusted for sex, ethnicity, household size, region, household income, IMD and total lunch (g)

Appendix V. Chapter 9 supplementary tables

Appendix Table V.a - Mean consumption of minimally and ultra-processed foods at lunchtime in schoolchildren before-and-after the UIFSM policy and estimates of UIFSM policy impact.

Variable	Pre-UIFSM	Post-UIFSM	Difference	P[1]	Model 1[2]	P	Model 2[3]	P	Model 3[4]	P
	Mean (SD)	**Mean (SD)**	**Diff. (95% CI)**		**Coef. (95% CI)**		**Coef. (95% CI)**		**Coef. (95% CI)**	
Minimally processed (% kcal)										
Infants	25.0 (21.8)	33.7 (25.4)	8.7 (3.6,13.8)	<0.01	8.3 (1.5,15.1)	0.02	8.4 (1.9,14.8)	0.01	8.2 (1.8,14.6)	0.01
Juniors	23.0 (20.4)	23.4 (20.4)	0.4 (-4.1,4.8)	0.87						
Minimally processed (% g)										
Infants	47.0 (26.5)	57.3 (25.1)	10.3 (4.9,15.8)	<0.01	12.2 (4.2,20.3)	<0.01	12.3 (4.5,20.1)	<0.01	11.8 (4.1,19.5)	<0.01
Juniors	49.0 (26.7)	47.1 (26.8)	-1.9 (-7.8,4.0)	0.53						
UPF (% kcal)										
Infants	67.4 (22.9)	60.4 (24.9)	-7.0 (-12.0,-2.0)	0.01	-6.6 (-13.4,0.2)	0.06	-6.6 (-13.1,-0.1)	0.05	-6.4 (-12.9,0.1)	0.05
Juniors	70.4 (21.7)	69.9 (20.8)	-0.4 (-5.1,4.2)	0.86						
UPF (% g)										
Infants	50.0 (26.7)	40.1 (25.1)	-9.9 (-15.4,-4.4)	<0.01	-11.7 (-19.9,-3.5)	0.01	-11.7 (-19.7,-3.8)	<0.01	-11.3 (-19.1,-3.5)	<0.01
Juniors	48.2 (27.2)	50.0 (26.9)	1.8 (-4.2,7.8)	0.56						

[1] Survey adjusted t-test between pre and post-UIFSM period; [2] Model 1 - Unadjusted linear regression; [3] Model 2 - Linear regression adjusted for sex, ethnicity, household size, region, household income and IMD; [4] Model 3 - Linear regression additionally adjusted for total lunchtime intake (grams)

SD - standard deviation; CI - confidence interval

Appendix Table V.b - Prevalence of consuming minimally and ultra-processed food groups at lunchtime in schoolchildren before-and-after the UIFSM policy and estimates of UIFSM policy impact.

Variable	Pre-UIFSM	Post-UIFSM	Difference	P[1]	Model 1[2]	P	Model 2[3]	P	Model 3[4]	P
	% taking	% taking	Diff. (95% CI)		Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Minimally processed (NOVA1)										
Drinks										
Intervention	64.1	67.3	3.3 (-6.9,13.4)	0.53	2.8 (-11.7,17.4)	0.71	3.0 (-11.1,17.1)	0.68	1.8 (-12.1,15.6)	0.80
Control	65.2	65.6	0.5 (-10.0,10.9)	0.93						
Fruit and veg										
Intervention	82.2	79.7	-2.5 (-11.2,6.2)	0.57	-1.7 (-14.8,11.4)	0.80	-1.1 (-13.7,11.5)	0.86	-1.9 (-14.3,10.5)	0.76
Control	72.6	71.8	-0.8 (-10.6,9.0)	0.87						
Dairy and eggs										
Intervention	12.5	22.6	10.1 (1.7,18.6)	0.02	9.2 (-1.3,19.8)	0.09	9.1 (-1.2,19.5)	0.08	8.9 (-1.5,19.2)	0.09
Control	9.8	10.7	0.9 (-5.5,7.3)	0.78						
Starchy foods and legumes										
Intervention	42.3	57.9	15.6 (5.2,26.0)	<0.01	5.4 (-9.6,20.4)	0.48	5.9 (-8.5,20.2)	0.42	5.8 (-8.5,20.2)	0.43
Control	38.2	48.4	10.2 (-0.7,21.0)	0.07						
Meat and fish										
Intervention	32.0	43.6	11.5 (1.5,21.6)	0.02	9.2 (-5.4,23.8)	0.22	9.4 (-4.9,23.8)	0.20	9.2 (-5.1,23.5)	0.21
Control	35.7	38.0	2.3 (-8.3,13.0)	0.66						
Ultra-processed (NOVA4)										
Processed bread										
Intervention	64.1	52.7	-11.4 (-21.5,-1.2)	0.03	-19.2 (-33.3,-5.0)	0.01	-19.2 (-33.1,-5.3)	0.01	-19.6 (-33.5,-5.8)	0.01
Control	66.2	74.0	7.8 (-2.1,17.7)	0.12						
Sweet and salty snacks										
Intervention	53.7	45.1	-8.6 (-18.9,1.7)	0.10	-17.2 (-32.0,-2.4)	0.02	-17.0 (-31.3,-2.7)	0.02	-17.4 (-31.8,-3.1)	0.02
Control	56.6	65.2	8.6 (-2.0,19.2)	0.11						
Drinks										
Intervention	38.4	21.9	-16.5 (-26.0,-7.1)	<0.01	-19.2 (-33.2,-5.1)	0.01	-19.4 (-33.0,-5.7)	0.01	-20.2 (-33.9,-6.6)	<0.01
Control	32.5	35.1	2.6 (-7.7,13.0)	0.62						
Condiments										
Intervention	58.0	53.2	-4.8 (-15.1,5.5)	0.36	-8.7 (-23.7,6.3)	0.25	-8.6 (-23.4,6.2)	0.26	-9.3 (-24.0,5.4)	0.21
Control	53.9	57.9	3.9 (-7.0,14.8)	0.48						
Puddings										
Intervention	42.7	59.5	16.8 (6.6,26.9)	<0.01	19.4 (4.6,34.3)	0.01	19.7 (5.1,34.3)	0.01	19.2 (4.6,33.8)	0.01
Control	44.5	41.8	-2.7 (-13.5,8.2)	0.63						
Ready-to-eat foods										
Intervention	43.4	30.0	-13.4 (-23.4,-3.5)	0.01	-8.1 (-22.7,6.5)	0.28	-7.9 (-22.4,6.5)	0.28	-8.0 (-22.4,6.4)	0.28

Variable	Pre-UIFSM	Post-UIFSM	Difference	P[1]	Model 1[2]	P	Model 2[3]	P	Model 3[4]	P
	% taking	% taking	Diff. (95% CI)		Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Control	42.5	37.2	-5.4 (-16.0,5.3)	0.33						
Meat and fish										
Intervention	48.4	42.7	-5.7 (-15.9,4.6)	0.28	-3.5 (-18.5,11.5)	0.65	-3.4 (-18.2,11.4)	0.65	-3.9 (-18.6,10.9)	0.61
Control	49.9	47.7	-2.1 (-13.2,8.9)	0.70						
Vegetables										
Intervention	14.2	23.4	9.2 (0.9,17.6)	0.03	4.8 (-6.0,15.5)	0.38	4.8 (-5.6,15.3)	0.36	4.8 (-5.7,15.2)	0.37
Control	8.8	13.2	4.4 (-2.4,11.2)	0.20						
Cheese										
Intervention	8.2	1.8	-6.3 (-10.0,-2.7)	<0.01	-9.4 (-16.7,-2.1)	0.01	-9.5 (-16.7,-2.2)	0.01	-9.4 (-16.6,-2.3)	0.01
Control	5.9	8.9	3.0 (-3.3,9.4)	0.35						
Fast foods										
Intervention	29.5	37.4	7.8 (-1.7,17.4)	0.11	1.2 (-12.6,15.1)	0.86	1.2 (-12.4,14.7)	0.87	1.6 (-11.9,15.1)	0.81
Control	26.4	33.0	6.6 (-3.5,16.7)	0.20						
Yoghurt and milk										
Intervention	42.0	29.0	-13.0 (-22.5,-3.4)	0.01	-10.3 (-24.3,3.8)	0.15	-10.0 (-23.8,3.8)	0.15	-10.7 (-24.6,3.1)	0.13
Control	36.4	33.7	-2.7 (-13.0,7.6)	0.61						

[1]Survey adjusted t-test; [2]Model 1 - Unadjusted linear probability regression; [3]Model 2 - Linear probability regression adjusted for sex, ethnicity, household size, region, household income and IMD; [4]Model 3 - Linear probability regression additionally adjusted for total lunchtime intake (grams)

SD - standard deviation; CI - confidence interval

Appendix Table V.c - Mean consumption of minimally and ultra-processed foods at lunchtime in schoolchildren before the UIFSM policy by income group and estimates of UIFSM policy impact stratified by income group

Variable	**Low-income Pre-UIFSM**	**Difference**	**Mid-income Pre-UIFSM**	**Difference**	**High-income Pre-UIFSM**	**Difference**	**Low-income DiD**[2]	**P**	**Mid-income DiD**[2]	**P**	**High-Income DiD**[2]	**P**
	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)1	Mean (SD)	Diff. (95% CI)	Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Minimally processed (% g)												
Infants	22.9 (20.4)	11.0* (1.4,20.5)	22.4 (21.1)	6.0 (-2.7,14.8)	29.1 (23.1)	10.0* (2.7,17.2)	17.5 (6.2,28.8)	<0.01	5.6 (-4.9,16.1)	0.30	1.0 (-9.3,11.3)	0.85
Juniors	25.2 (24.9)	-8.7* (-16.5,-0.9)	19.9 (18.1)	0.4 (-6.1,6.9)	23.6 **b** (17.5)	8.8* (0.8,16.8)						
Minimally processed (% kcal)												
Infants	44.4 (26.2)	11.9* (2.0,21.8)	41.9 (28.0)	9.1 (-0.7,18.9)	54.0 **b** (23.9)	11.1* (4.0,18.2)	22.4 (9.2,35.6)	<0.01	8.0 (-5.8,21.8)	0.26	4.8 (-6.2,15.8)	0.39
Juniors	48.8 (30.4)	-12.6* (-22.9,-2.2)	44.0 (27.8)	1.2 (-8.9,11.3)	52.8 **b** (21.7)	5.0 (-4.6,14.6)						
UPF (% g)												
Infants	69.2 (23.1)	-9.1 (-18.5,0.3)	70.0 (22.7)	-4.1 (-12.9,4.7)	63.5 (22.6)	-8.7* (-15.7,-1.7)	-13.4 (-25.0,-1.9)	0.02	-3.8 (-14.7,7.1)	0.50	-2.6 (-13.0,7.7)	0.62
Juniors	70.4 (24.5)	6.3 (-1.8,14.4)	72.6 (20.8)	-0.7 (-7.8,6.4)	68.7 **b** (19.9)	-6.3 (-14.5,1.9)						
UPF (% kcal)												
Infants	52.5 (26.7)	-11.3* (-21.1,-1.4)	55.4 (28.3)	-8.5 (-18.5,1.4)	42.7 **b** (23.6)	-11.0* (-18.1,-3.9)	-20.2 (-33.6,-6.9)	<0.01	-8.1 (-22.1,5.8)	0.25	-5.7 (-16.9,5.5)	0.32
Juniors	49.4 (30.2)	10.7* (0.1,21.4)	52.6 (28.6)	-0.8 (-11.1,9.4)	44.0 **b** (22.9)	-4.0 (-13.7,5.8)						

[1] Survey adjusted t-test between pre- and post-UIFSM periods, post-UIFSM averages are not displayed; [2] Linear regression adjusted for age, sex, ethnicity, household size, region, household income, IMD and total grams

* P<0.05; SD - standard deviation; CI - confidence interval

Appendix Table V.d - Prevalence of consuming minimally and ultra-processed food groups at lunchtime in schoolchildren before-and-after the UIFSM policy by income group and estimates of UIFSM policy impact stratified by income group

Variable	Low-income Pre-UIFSM	Difference	Mid-income Pre-UIFSM	Difference	High-income Pre-UIFSM[2]	Difference	Low-income DiD[2]	P	Mid-income DiD	P	High-Income DiD	P
	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)	Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Minimally processed (NOVA1)												
Drinks												
Intervention	56.1	11.4 (-5.6,28.4)	63.9	-2.0 (-21.2,17.2)	70.6	2.5 (-13.1,18.1)	18.5 (-5.1,42.2)	0.12	-7.1 (-31.3,17.1)	0.57	-8.2 (-29.8,13.4)	0.46
Control	59.2	-11.5 (-29.9,6.8)	59.5	3.5 (-14.1,21.2)	74.4 **b**	8.6 (-8.4,25.5)						
Fruit and veg												
Intervention	79.3	-3.3 (-17.7,11.2)	80.4	-8.3 (-26.4,9.7)	86.3 **b**	5.0 (-4.7,14.6)	-4.7 (-27.3,17.9)	0.68	-18.4 (-40.2,3.4)	0.10	15.3 (-2.0,32.7)	0.08
Control	64.4	-1.1 (-19.6,17.4)	63.5	12.5 (-4.0,29.0)	86.3 **b**	-12.1 (-28.0,3.9)						
Dairy and eggs												
Intervention	9.8	17.4* (0.0,32.5)	8.2	7.9 (-5.5,21.3)	18.6	6.7 (-8.2,21.6)	16.4 (-0.4,33.3)	0.06	2.4 (-16.0,20.9)	0.80	12.0 (-5.0,29.1)	0.17
Control	10.3	-2.7 (-12.6,7.2)	12.2	6.8 (-6.1,19.6)	7.7	-3.3 (-12.4,5.7)						
Starchy foods and legumes												
Intervention	45.1	13.3 (-4.4,30.9)	36.1	10.2 (-8.6,29.0)	46.1	23.8* (7.6,40.0)	13.4 (-11.4,38.2)	0.29	1.4 (-22.1,24.8)	0.91	2.2 (-22.6,26.9)	0.86
Control	38.4	2.4 (-15.7,20.5)	29.4	10.7 (-6.5,27.8)	44.7 **b**	18.9 (-0.4,38.2)						
Meat and fish												
Intervention	29.3	12.4 (-5.0,29.7)	33.0	6.9 (-11.5,25.2)	33.3	16.0 (-0.2,32.2)	20.9 (-1.9,43.7)	0.07	2.5 (-21.4,26.5)	0.84	-3.4 (-28.4,21.7)	0.79
Control	37.5	-13.2 (-29.2,2.9)	32.4	3.1 (-14.2,20.3)	36.5	15.2 (-4.7,35.0)						
Ultra-processed (NOVA4)												
Processed bread												
Intervention	63.4	-8.5 (-26.2,9.2)	63.9	-8.2 (-26.8,10.5)	64.7	-17.3* (-33.6,-1.0)	-37.3 (-60.5,-14.0)	<0.01	-2.1 (-25.0,20.8)	0.86	-14.4 (-37.4,8.7)	0.22

Variable	Low-income Pre-UIFSM	Difference	Mid-income Pre-UIFSM	Difference	High-income Pre-UIFSM^2	Difference	Low-income DiD^2	P	Mid-income DiD	P	High-Income DiD	P
	Mean (SD)	Diff. (95% CI)^1	Mean (SD)	Diff. (95% CI)^1	Mean (SD)	Diff. (95% CI)	Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Control	50.6	29.5* (13.7,45.4)	76.7	-3.7 (-19.7,12.2)	71.4	-1.2 (-19.2,16.7)						
Sweet and salty snacks												
Intervention	51.2	-6.2 (-24.1,11.6)	64.9	-18.7 (-37.6,0.3)	45.1	-1.0 (-17.4,15.4)	-20.7 (-45.1,3.7)	0.10	-28.9 (-53.4,-4.3)	0.02	-1.0 (-25.2,23.3)	0.94
Control	51.6	13.9 (-3.8,31.7)	58.0	11.9 (-5.7,29.5)	59.7	0.1 (-19.4,19.6)						
Drinks												
Intervention	39.0	-18.0* (-0.3,-2.7)	46.4	-12.7 (-31.7,6.3)	30.4	-20.3* (-31.9,-8.6)	-29.2 (-51.7,-6.8)	0.01	-24.9 (-49.4,-0.5)	0.05	-4.7 (-24.5,15.1)	0.65
Control	35.3	8.0 (-10.3,26.3)	32.4	13.6 (-3.9,31.1)	30.2 **b**	-13.3 (-30.5,3.8)						
Condiments												
Intervention	62.2	-5.6 (-23.4,12.1)	57.7	-1.8 (-20.7,17.2)	54.9	-7.7 (-24.1,8.6)	-28.3 (-53.2,-3.3)	0.03	5.3 (-19.6,30.3)	0.67	-5.1 (-30.3,20.2)	0.70
Control	42.3	22.8* (5.5,40.2)	64.4	-5.0 (-22.9,12.8)	55.9	-5.5 (-25.5,14.6)						
Puddings												
Intervention	39.0	20.4* (0.0,37.9)	40.2	23.5* (5.4,41.5)	48.0	6.9 (-9.6,23.5)	12.9 (-11.2,37.1)	0.30	30.3 (5.4,55.2)	0.02	12.0 (-13.3,37.2)	0.35
Control	35.4	9.5 (-8.4,27.5)	43.9	-6.5 (-24.4,11.3)	52.6	-8.4 (-28.4,11.6)						
Ready-to-eat foods												
Intervention	47.6	-25.4* (-0.4,-9.9)	36.1	-5.1 (-24.2,14.1)	47.1	-11.1 (-27.0,4.8)	-27.0 (-50.2,-3.8)	0.02	0.4 (-23.7,24.5)	0.97	0.8 (-24.1,25.7)	0.95
Control	40.4	1.4 (-16.8,19.6)	41.2	-4.5 (-22.0,13.0)	45.3	-11.3 (-30.8,8.1)						
Meat and fish												
Intervention	42.7	-6.0 (-23.6,11.5)	52.6	-1.1 (-20.3,18.1)	49.0	-10.1 (-26.0,5.7)	8.5 (-15.6,32.6)	0.49	-1.9 (-27.6,23.7)	0.88	-15.8 (-40.5,8.8)	0.21
Control	48.7	-14.6 (-32.2,3.0)	49.0	1.4 (-16.9,19.7)	51.5	4.3 (-15.5,24.2)						
Vegetables												
Intervention	12.2	4.0 (-8.3,16.4)	12.4	19.4* (2.8,36.0)	17.6	3.4 (-9.3,16.1)	10.0 (-5.6,25.6)	0.21	14.2 (-3.2,31.5)	0.11	-9.7 (-27.1,7.7)	0.28

Variable	Low-income Pre-UIFSM	Difference	Mid-income Pre-UIFSM	Difference	High-income Pre-UIFSM^2	Difference	Low-income DiD^2	P	Mid-income DiD	P	High-Income DiD	P
	Mean (SD)	Diff. (95% CI)^1	Mean (SD)	Diff. (95% CI)^1	Mean (SD)	Diff. (95% CI)	Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Control	12.6	-5.5 (-15.1,4.1)	8.3	3.3 (-7.6,14.2)	5.9	13.9* (0.3,27.4)						
Cheese												
Intervention	13.4	-8.6 (-17.7,0.6)	8.2	-7.2* (-13.1,-1.4)	3.9 **b**	-3.9* (-7.7,-0.1)	-14.7 (-29.4,0.0)	0.05	-7.3 (-17.9,3.2)	0.17	-5.5 (-16.9,6.0)	0.35
Control	4.3	6.1 (-7.1,19.3)	6.4	1.3 (-7.2,9.8)	6.8	2.2 (-9.2,13.6)						
Fast foods												
Intervention	32.9	-0.3 (-16.6,16.0)	25.8	9.8 (-6.8,26.5)	30.4	13.2 (-2.7,29.2)	15.1 (-6.3,36.5)	0.17	-2.8 (-25.0,19.5)	0.81	-3.5 (-27.3,20.3)	0.77
Control	31.5	-12.8 (-28.0,2.3)	20.9	13.8 (-2.9,30.4)	26.1	16.5 (-2.3,35.2)						
Yoghurt and milk												
Intervention	40.2	-0.2 (-17.5,17.0)	48.5	-21.9* (-39.7,-4.0)	37.3	-15.5* (-29.5,-1.6)	-18.7 (-43.1,5.7)	0.13	-6.8 (-29.4,15.8)	0.56	-3.7 (-26.3,19.0)	0.75
Control	36.3	16.8 (-1.5,35.2)	38.9	-10.8 (-27.6,6.0)	34.6 **b**	-10.5 (-28.4,7.4)						

[1] Survey adjusted t-test; [2] Linear regression adjusted for age, sex, ethnicity, household size, region, household income, IMD and total lunchtime intake (g)

* P<0.05; SD - standard deviation; CI - confidence interval

Appendix Table V.e - Mean consumption of minimally and ultra-processed foods across the school day in schoolchildren before-and-after the UIFSM policy and estimates of UIFSM policy impact.

Variable	Pre-UIFSM	Post-UIFSM	Difference	P[1]	Model 1[2]	P	Model 2[3]	P	Model 3[4]	P
	Mean (SD)	**Mean (SD)**	**Diff. (95% CI)**		**Coef. (95% CI)**		**Coef. (95% CI)**		**Coef. (95% CI)**	
Minimally processed (% kcal day)										
Infants	31.0 (12.3)	30.6 (14.5)	-0.4 (-3.2,2.5)	0.80	3.3 (-0.8,7.5)	0.11	3.3 (-0.6,7.2)	0.09	3.1 (-0.7,7.0)	0.11
Juniors	28.8 (14.1)	25.1 (12.7)	-3.7 (-6.8,-0.7)	0.02						
Minimally processed (% g day)										
Infants	56.6 (17.2)	58.7 (18.5)	2.1 (-1.7,5.9)	0.28	5.2 (-0.7,11.0)	0.09	5.3 (-0.2,10.8)	0.06	5.1 (-0.4,10.5)	0.07
Juniors	56.1 (18.1)	53.1 (20.4)	-3.0 (-7.5,1.4)	0.18						
UPF (% kcal day)										
Infants	62.2 (13.8)	63.0 (15.9)	0.8 (-2.4,4.0)	0.63	-2.8 (-7.4,1.9)	0.24	-2.7 (-7.0,1.7)	0.23	-2.5 (-6.8,1.8)	0.26
Juniors	65.5 (14.9)	69.0 (14.5)	3.5 (0.2,6.9)	0.04						
UPF (% g day)										
Infants	41.3 (17.4)	39.4 (18.7)	-1.9 (-5.8,2.0)	0.34	-4.7 (-10.6,1.3)	0.12	-4.8 (-10.3,0.8)	0.09	-4.6 (-10.1,1.0)	0.11
Juniors	42.2 (18.2)	45.0 (20.6)	2.8 (-1.7,7.3)	0.23						

[1]Survey adjusted t-test between pre and post-UIFSM period; [2]Model 1 - Unadjusted linear regression; [3]Model 2 - Linear regression adjusted for sex, ethnicity, household size, region, household income and IMD; [4]Model 3 - Linear regression additionally adjusted for total lunchtime intake (grams)

SD - standard deviation; CI - confidence interval

Appendix Table V.f - Mean consumption of minimally and ultra-processed foods across the school day in schoolchildren before the UIFSM policy by income group and estimates of UIFSM policy impact stratified by income group

Variable	**Low-income Pre-UIFSM**	**Difference**	**Mid-income Pre-UIFSM**	**Difference**	**High-income Pre-UIFSM**	**Difference**	**Low-income DiD**[2]	**P**	**Mid-income DiD**[2]	**P**	**High-Income DiD**[2]	**P**
	Mean (SD)	Diff. (95% CI)[1]	Mean (SD)	Diff. (95% CI)1	Mean (SD)	Diff. (95% CI)	Coef. (95% CI)		Coef. (95% CI)		Coef. (95% CI)	
Minimally processed (% kcal day)												
Infants	30.1 (12.1)	-1.8 (-6.9,3.3)	29.6 (12.9)	-0.9 (-6.1,4.3)	33.0 **b** (11.5)	1.8 (-2.2,5.7)	5.9 (-1.0,12.8)	0.09	5.0 (-1.2,11.2)	0.12	0.1 (-6.0,6.3)	0.97
Juniors	28.8 (16.5)	-7.7* (-12.9,-2.4)	28.1 (12.8)	-5.4* (-9.8,-0.9)	29.4 **b** (13.0)	1.5 (-4.1,7.1)						
Minimally processed (% g day)												
Infants	54.3 (17.5)	1.0 (-6.3,8.2)	54.1 (18.5)	0.4 (-6.7,7.5)	60.9 **b** (14.9)	5.5* (0.9,10.1)	9.5 (-0.2,19.1)	0.06	6.1 (-2.8,14.9)	0.18	0.2 (-8.2,8.5)	0.96
Juniors	56.3 (19.0)	-7.6 (-16.1,0.9)	53.7 (18.9)	-5.7 (-12.5,1.0)	57.8 **b** (16.7)	4.3 (-3.2,11.9)						
UPF (% kcal day)												
Infants	64.1 (13.7)	0.8 (-5.1,6.7)	63.3 (14.9)	1.9 (-4.1,7.9)	59.6 **b** (12.4)	-0.8 (-5.0,3.5)	-6.3 (-14.0,1.3)	0.10	-3.1 (-10.3,4.1)	0.40	0.5 (-6.3,7.2)	0.89
Juniors	66.1 (16.2)	7.4* (1.6,13.1)	66.4 (14.2)	4.3 (-0.7,9.4)	64.4 **b** (14.2)	-0.7 (-6.8,5.4)						
UPF (% g day)												
Infants	43.9 (17.8)	-1.2 (-8.5,6.2)	43.7 (18.7)	0.1 (-7.1,7.3)	36.8 **b** (14.8)	-5.2* (-9.8,-0.6)	-9.4 (-19.3,0.4)	0.06	-4.9 (-13.9,4.2)	0.29	0.0 (-8.4,8.4)	1.00
Juniors	42.2 (18.9)	7.3 (-1.4,16.0)	44.7 (19.0)	5.0 (-1.9,11.9)	40.3 **b** (16.8)	-4.1 (-11.7,3.5)						

[1] Survey adjusted t-test between pre- and post-UIFSM periods, post-UIFSM averages are not displayed; [2] Linear regression adjusted for age, sex, ethnicity, household size, region, household income, IMD and total grams

* P<0.05; SD - standard deviation; CI - confidence interval

Appendix Table V.g - Difference-in-differences estimates for NOVA outcomes using different specifications of IPW and covariate adjustment.

Variable	Survey weighted no IPW Unadjusted	P	Survey weighted no IPW Unadjusted	P	IPW Unadjusted	P	IPW Adjusted	P
Minimally processed (% g)	10.2 (3.5,16.9)	<0.01	9.5 (3.1,16.0)	<0.01	8.3 (1.5,15.1)	0.02	8.2 (1.8,14.6)	0.01
Minimally processed (% kcal)	10.6 (2.8,18.5)	0.01	9.7 (2.2,17.2)	0.01	12.2 (4.2,20.3)	<0.01	11.8 (4.1,19.5)	<0.01
UPF (% g)	-6.8 (-13.8,0.1)	0.06	-6.3 (-13.2,0.5)	0.07	-6.6 (-13.4,0.2)	0.06	-6.4 (-12.9,0.1)	0.05
UPF (% kcal)	-9.9 (-17.9,-1.9)	0.02	-9.0 (-16.8,-1.3)	0.02	-11.7 (-19.9,-3.5)	0.01	-11.3 (-19.1,-3.5)	<0.01

Note:
Survey adjusted - estimate accounts for survey weighting, does not include an IPW weight.
IPW - IPW weight produced using multinomial regression with survey weights included as a predictor. Pre-infants as focal. This weight was used in the main analyses.
Unadjusted - Linear regression not adjusted for covariates
Adjusted - Linear regression not adjusted for sex, ethnicity, household size, region, household income, IMD and total lunch (g)

Appendix Table V.h - Difference-in-differences estimates for NOVA outcomes after removing unreliable energy reporters from the analytic sample

Variable	Main analysis Unadjusted	P	Main analysis Unadjusted	P	Reliable reporters Unadjusted	P	Reliable reporters Adjusted	P
Minimally processed (% g)	8.3 (1.5,15.1)	0.02	8.2 (1.8,14.6)	0.01	7.2 (0.4,14.1)	0.04	7.0 (0.5,13.4)	0.03
Minimally processed (% kcal)	12.2 (4.2,20.3)	<0.01	11.8 (4.1,19.5)	<0.01	11.5 (3.3,19.8)	0.01	11.1 (3.2,19.0)	0.01
UPF (% g)	-6.6 (-13.4,0.2)	0.06	-6.4 (-12.9,0.1)	0.05	-5.3 (-12.3,1.6)	0.13	-5.1 (-11.7,1.6)	0.13
UPF (% kcal)	-11.7 (-19.9,-3.5)	0.01	-11.3 (-19.1,-3.5)	<0.01	-11.1 (-19.5,-2.7)	0.01	-10.7 (-18.7,-2.7)	0.01

Note:
Reliable reporter = participants whose reported energy was under (*n*=42) and over(*n*=2) their estimated energy requirement.
Unadjusted - Linear regression not adjusted for covariates
Adjusted - Linear regression not adjusted for age, sex, ethnicity, household size, region, household income, IMD and total lunch (g)

Appendix VII. Research training plan

Name of student Jennie Parnham	**Supervisor 1** Dr Eszter Vamos	**Supervisor 2** Prof Christopher Millett	**Department** Primary Care and Public Health	**Date of registration** 3rd October 2018
Project title: Evaluating the impact of the Healthy Start Programme on purchasing and nutrition outcomes				**Date:**
Skills required	**Source**	**Timetable**	**Progress/completion**	**Evidence of achievement**
Research student induction	School of Public Health	October 2018	2nd October 2018	Attendance
Developing a proposal	School of Public Health	October 2018	9th October 2018	Attendance
Library session: Advanced literature search/Ovid databases	School of Public Health	October 2018	12th October 2018	Attendance
NIHR SPHR Induction	NIHR SPHR	November 2018	9th November 2018	Attendance
Publication and Research Paper Writing	School of Public Health	November 2018	4th November 2018	Attendance
How to write a PhD	School of Public Health	November 2018	28th November 2018	Attendance
Introduction to teaching and learning	Graduate School Course	January 2019	14th January 2019	Attendance
Understanding and developing assertiveness	Graduate School Course	March 2019	5th March 2019	Attendance
Introduction to assessment and feedback	Graduate School Course	May 2019	20th May 2019	Attendance

Perfecting presentations: Poster top tips webinar	Graduate School Course	1st May 2019	1st May 2019	Attendance (online)
Introduction to R	Imperial College	22nd August 2020	22nd August 2020	Attendance
Policy evaluation methods	Institute for Fiscal Studies, UCL	January 2020	14th-17th January 2020	Attendance
Progression for Your PhD: Negotiation for Your Doctorate and Beyond	Graduate School Course	January 2020	30th January 2020	Attendance
Perfecting Presentations: Present your Poster!	Graduate School Course	March 2020	20th March 2020	Attendance (online)
Preparing for Viva	School of Public Health	Autumn 2020		
Applying for Post-Doc Research Funding	School of Public Health	Autumn 2020		

Appendix VIII. Publication and presentations

11.6 Publications

Title	Journal	Date
Half of children entitled to free school meals do not have access to the scheme during COVID-19 lockdown in the UK[390]	Public Health	Accepted August 2020
Healthy Start scheme associated with increased food expenditure in low-income families with young children in the United Kingdom?[346]	BMC Public Health	Accepted November 2021
Dietary quality of school meals and packed lunches: a national study of primary and secondary school children in the UK	Public Health Nutrition	Submitted November 2021
'The impact of the Universal Infant Free School Meal policy on dietary quality in English and Scottish primary school children: evaluation of a natural experiment	International Journal Behavioral Nutrition and Physical Activity	Submitted November 2021

11.7 Presentations

Free School Meals research	
PHE Science and research conference - Oral presentation	2021
UKSBM ASM 2021 - Oral presentation	2021
Healthy Start research	
PHE Science and research conference - Oral presentation	2021
World Conference on Public Health 2020 - Poster presentation	2020
NIHR School of Public Health Research executive meeting – Oral Presentation	2020
NIHR School of Public Health Research ASM - Poster Presentation	2020

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