The effects of takeaway (fast) food consumption on UK adolescent’s diet quality and BMI

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The work in **Chapter 4** of the thesis has appeared in publication as follows: *The cross-sectional relationships between consumption of takeaway food, eating meals outside the home and diet quality in British adolescents, 16 November 2018, Ayyoub K Taher, Nina Evans and Charlotte EL Evans. I was responsible for designed the research question and methods of the study, carried out statistical and data analysis, wrote the first draft of the manuscript and revised subsequent drafts.* The contribution of the other authors was: N.E. *carried out statistical and data analysis and revised drafts of the manuscript. C.E.L.E. designed the research question, assisted with statistical analysis methods and revised all versions of the manuscript.*

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Ayyoub Taher, Charlotte Evans and Graham Clarke: P3-37-04 - Evaluating the UK takeaway food environment around secondary schools: comparison of different methods. 13th European Nutrition Conference, FENS 2019| Malnutrition in an Obese World: European Perspectives Sep 16 ,2019.

Ayyoub K Taher, Charlotte EL Evans and Graham P Clarke. UKCO 2019 Leeds University. Best Poster Abstract award: Takeaway food outlets around secondary schools in the UK: using different methods for evaluating the takeaway food environment. Ayyoub Taher, University of Leeds. UK Congress on Obesity. Obesity Abstracts September 2019 Volume 1ISSN 2632-9808 (online) DOI: 10.1530/obabs.1.OC3.3. 2019

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Abstract

Many existing NCDs have emerged not only due to the increasing rates of obesity and overweight among children, but also because of children’s unhealthy diets. Adolescence may be one of the best times to tackle health problems and alert young people to the need to improve their dietary behaviour. Dietary habits are reportedly shaped during adolescence, and the habits formed in this period can potentially last into adulthood. Examining the intakes of individual nutrients or food items is not enough to assess overall diet quality, as both the quality and variety of the whole diet must be considered. The surrounding food environment, particularly takeaway food outlets, is also believed to affect an individual’s diet quality and obesity risk. However, few researchers have explored the associations between takeaway consumption, types of school lunch and overall diet quality among adolescents. Moreover, worldwide, there are no standardised measures used to calculate the density and proximity of food outlets around homes, schools, work or any other facilities. In addition, few studies have explored the longitudinal associations between the takeaway food environment and secondary school adolescents’ BMI and body fatness.

This thesis first investigated the associations between takeaways and meals-out consumption (at and outside the home) and overall diet quality in UK adolescents from the National Diet and Nutrition Survey (NDNS) years’ 1–6 data. Frequent consumption of takeaway meals and meals out have been found to be negatively associated with the diet quality of British adolescents aged 11–18 years. Subsequently, I explored the associations between the types of lunch consumed on a school day and UK adolescents’ overall diet quality, also using also the NDNS years’ 1–8 data. Students purchasing food from shops or cafes were found to have statistically lower overall diet quality scores compared with other sources of lunches, including hot and cold school meals and packed lunches brought from home.

Next, I investigated the differences in using different methods for evaluating the school food environment using Avon Longitudinal Study of Parents and Children (ALSPAC) data. I located both schools and hot food takeaways (HFTs) using ArcGIS software. Statistical distinctions were observed between straight-line and

road network density and the proximity of HFTs. Moreover, Lin's concordance correlation coefficient test showed that both methods were in a poor-to-moderate strength of agreement. I also used the Hansen Index, whereby both the number and proximity of the outlets were considered.

Finally, I investigated the longitudinal associations between availability, proximity and accessibility of HFTs and Body Mass Index (BMI), as well as the body fatness of school adolescents. The participants were included from the ALSPAC study and visited the clinic five times during the study period at age 11, 12, 13, 15 and 17 years. Consistent with the previous findings, the overall results regarding the associations between availability, proximity or accessibility of HFTs and BMI and body fat percentage of school adolescents showed null/negative associations.

This thesis highlights the importance of being a takeaway consumer on overall diet quality, especially during childhood. These findings are likely to be useful for informing future governmental policies to improve the dietary behaviour and health status of young people in the UK. This work also helped in highlighting the importance of consistent methods to be used to measure the food environment, especially around schools which, therefore, may lead to more effective policies. Finally, the findings also show that focusing solely on HFTs may not support the hypothesis that limiting the number of food outlets around schools would reduce the risk of being obese or having a higher body fat percentage. In this age group, more comprehensive measures may be needed to improve the food environment near schools.

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List of Abbreviations

Abbreviation	Description
ADPH	Association of Directors of Public Health
ALSPAC	Avon Longitudinal Study of Parents and Children
ANOVA	Analysis of Variance
BCTs	Behaviour change techniques
BDA	British Dietetic Association
BMI	Body Mass Index
BMSDS	BMI standard deviation score
BNF	British Nutrition Foundation
CAPI	Computerised Assisted Personal Interviews
Cardio Vascular Disease	Cardio Vascular Disease
CCC	Concordance Correlation Coefficient
CPM	Counts per minute
CRIACC	Centre for Research in Primary and Community Care
DAG	Directed Acyclic Graph
DAx	Diet Adequacy sub-component
DDc	Dietary Diversity component
DEc	Dietary Equilibrium component
DEx	Diet Excess sub-component
DEXA	Dual-Energy X-ray Absorptiometry
DINO	Diet In Nutrients Out

DOH	Department of Health
DQI	Diet quality index
DQc	Dietary quality component
DQI-A	Diet quality index for adolescent
FBDG	Food Based Dietary Guidelines
Food-EPI	Food Environment Policy Index
FSA	Food Standards Agency
GIS	Geographical Information System
HBSC	Health Behaviour in School-Aged Children
HEI	Healthy eating index
HFTs	hot food takeaways
HSE	Health Survey England
IMD	Index of Multiple Deprivation
INFORMAS	International Network for Food and Obesity / non-communicable Diseases Research, Monitoring and Action Support
LDL	Low-density lipoproteins
LGA	Local Government Association
LSOAs	Lower-Layer Super Output Areas
m	metre
NPPF	National Planning Policy Framework
NCDs	non-communicable diseases
NCMP	National Child Measurement Programme
NDNS	National Diet and Nutrition Survey

NHS	National Health Service
NMES	Non-Milk Extrinsic Sugars
NSLP	National School Lunch Programme
NSPs	Non-Starch Polysaccharides
OECD	Organisation for Economic Cooperation and Development
OS	Ordnance survey
PHE	Public Health England
POIs	Points of Interest
PRUs	Pupil referral units
PUFA	polyunsaturated fatty acid
RCTs	Randomised control trails
RSPH	Royal Society for Public Health
SENs	Special education needs
SPDs	supplementary planning documents
UK	United Kingdom
UKAMF	UK Access Management Federation
WHO	World Health Organisation
WSO	Whole System Obesity

Chapter 1 : Introduction

The significant global rise in diet-related non-communicable diseases (NCDs) indicates that there are serious nutrition-related issues in both developed and developing countries (Food Standards Agency [1]). Overweight and obesity are major causes of illness and premature death, and they are linked with several diseases, such as type 2 diabetes, stroke, heart disease and some cancers (World Health Organisation [2]). In 2015, the World Health Organisation (WHO) announced that cardiovascular diseases, especially strokes and heart disease, are responsible for most deaths [3]. Two years earlier, the WHO declared that many existing NCDs have not only emerged due to the increasing rates of obesity and overweight among children, but also because of children's unhealthy diets [2]. Furthermore, being obese during childhood is not only linked with the likelihood of being obese in adulthood, but also increases the risk of developing and suffering from breathing difficulties, fractures, hypertension and premature death. For children and adolescents aged between 5 and 19 years, overweight is defined as BMI-for-age greater than 1 standard deviation above the WHO growth reference median. In contrast, obesity is defined as BMI-for-age greater than 2 standard deviations above the WHO growth reference median (BMI; Body Mass Index) [4].

Obesity is a complex issue and results from multiple causes and contributors such as individual behaviours (including dietary patterns, physical activity, inactivity and use of medication) and genetics (individual response to, for example, high calorie intake which varies from one person to another and highlights the fact that genes may also play a role in the development of obesity). Moreover, other factors such as food and physical activity environments, education and skills, food marketing and food promotions are also considered as contributing factors to obesity. Energy balance between calories consumed from food and drinks and calories used by the human body helps in preventing weight gain (which may result in overweight and obesity) [5]. Nevertheless, the imbalance between energy intake and energy expenditure is known to be one of the causes of overweight and obesity issues [4]. In general, fast food meals are typically known to be high in saturated fat, salt and calories. The consumption of excess calories from fast food meals (up to 500 calories per day) is believed to be one of the possible causes contributing to childhood obesity and overweight [6].

In addition to the effects environmental and individual factors exert on people's diet quality, a direct relationship has been established between the number of fast food outlets in the neighbourhood where people live and people's diet quality and obesity rates. Attention is now being drawn to the influence of the school neighbourhood on food choices. Public Health England (PHE) is currently working on reducing sugar intake and categorising foods based on their nutrient content. Out-of-home meals from restaurants, café shops, takeaway and fast food restaurants and sandwich shops in particular sell food and meals that are considered high in saturated fat, sugar and total energy [7]. One of the concerns over children eating healthily is the proximity of fast food outlets to schools. The period after school is known to be the most popular time for students to purchase food from surrounding shops; and many students are also allowed to leave schools during the lunch break. Limiting the establishment of new food outlets, especially around schools, is considered to be one of the primary concerns of health organisations, such as the Chartered Institute for Environmental Health and Department of Health (DOH) [8]. However there is little research in this area.

1.1 Fast and/or takeaway food

In the United Kingdom (UK), fast food and takeaway outlets made nearly £9 billion in 2005, with an estimated 5% annual increase [9]. In 2014, a growth rate of 3.5% in the market of fast and takeaway food was observed compared with the previous year. A similar growth rate in the number of fast food outlets in the UK (except Northern Ireland) was also documented in 2018 compared with 2017 [10]. This supports the prediction that the growth rate of fast and takeaway food markets will reach 9.2% by 2019 [11]. By the end of March 2015, about 15% of meals were eaten outside the home, exhibiting a 5% increase compared with 2014. Moreover, the percentage of people who consumed meals outside the home increased by 7% from 2010 to 2014 (68% to 75%, respectively) [7]. In the United States in 2011–2012, 16.9% and 8.7% of the mean energy (calories) intakes were obtained from fast food among adolescents aged 12–19 years and younger children aged 2–11 years, respectively [12]. The consumption of foods from fast food outlets increased by 300% in the United States between 1977 and 1996 [13]. Revenue in fast food outlets increased by 73% in the UK between 1995 and 2005 [14]. In the UK, the density of fast food outlet varies by geographical location of the city; Figure 1-1 illustrates the variation in the density of the fast food outlets per 100,000 population by local authority in the UK.

Although a systematic review has shown that eating out is positively associated with the BMI status of adults, the comparison between study results is difficult [15]. This stems from the fact that different studies adopt variations of the definition of ‘out of home eating’ [15]. The same is true for takeaway (fast) food; thus, different people have different definitions of fast food. However, PHE has recently defined fast food as any food that is available quickly; thus, the definition is not restricted to the traditional definition of burgers, kebabs and sandwiches. However, several research studies have adopted different perspectives in their methodologies. For example, they have argued that fast food can be obtained from either fast food outlets or other places such as supermarkets, restaurants and convenience stores [16]. Therefore, a clear definition of fast food needs to be outlined during the study design. Generally, fast food may be defined as ‘food purchased in self-service or carry-out eating places without waitress service’, including foods that are high in saturated fat and low in micronutrient contents [17].

The Food and You Survey provided an essential background concerning eating behaviour and food safety of the UK population aged 16 years and over (without an upper age limit) [18]. This survey advocates a broad definition of “eating out”, arguing that this term may be considered to mean consuming foods from a variety of stores and establishments, such as restaurants, cafes and coffee shops, sandwich bars and fast food outlets. The prevalence of buying takeaway food and eating out was relatively high in all three waves of the survey (2010, 2012 and 2014). In fact, there was an increase in the percentage of people who reported eating out in the previous 7 days in waves 2 and 3 (75%) compared to wave 1 (69%). Eating at restaurants and eating fast food were also common among all participants regardless of age. Around 29% of all participants from all waves ate at restaurants and 20% consumed fast food. Moreover, younger adults (16–35 years) exhibited a higher percentage (85%) of eating out behaviour compared with other age groups (35 – 54 years, 77%; 55 – 74 years, 68%). Similarly, concerning the frequency of eating out, younger adults were observed to eat out more frequently than did older counterparts. This may indicate the importance of focussing on the nutritional knowledge and eating behaviour manifested in younger populations [18].

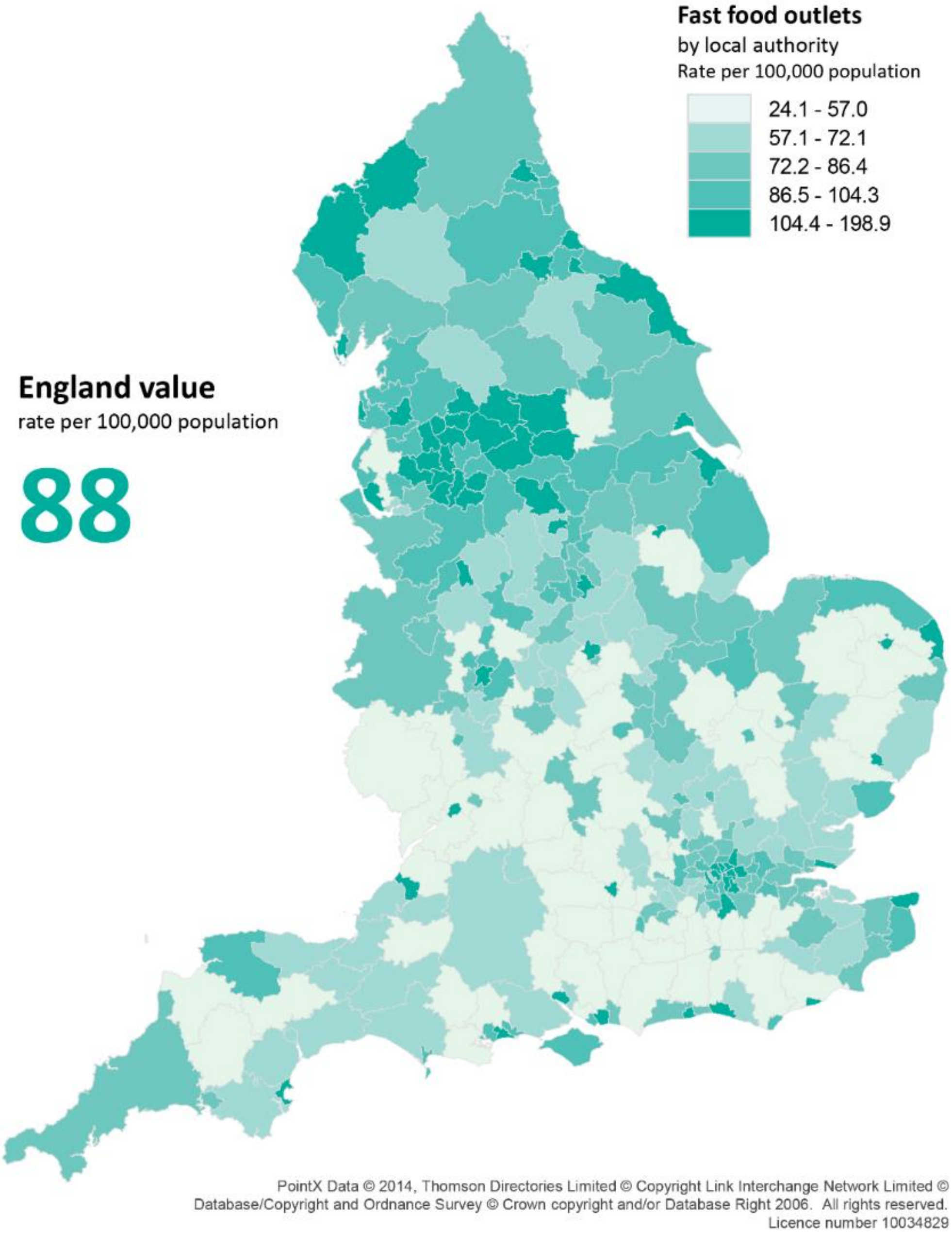


Figure 1-1 Density of fast food outlets in the UK by local authority [19]

1.2 Adolescence period

The UK is one of the first countries that have developed guidelines on weighing school students. In the UK, the government believes that screening of BMI is essential and helps conduct local interventions, tackling the obesity problem and policy planning. Therefore, during primary school, students are weighed in reception year (4 – 5 years) and again in year 6 (10 – 11 years) before leaving for secondary school [20]. A recent plan of a novel school-based intervention study, which focused on children aged 9 – 11 years, showed that obesity exists in school [21]. However, few cohort studies consider adolescents. Moreover, due to the global rise in the obesity rate among children and adolescents, in 2005 WHO discussed the importance of weight screening among both primary and secondary school students [20]. The WHO has identified childhood obesity as one of the most challenging public health issues of the 21st century [22]. More than £5 billion were spent by the National Health Service (NHS) England on overweight/obesity-related illnesses in 2014/2015 [23]. By 2050, an extra £4.5 billion per year may be added to the cost of treating obesity-related diseases, mainly because 50–60% of males and females are predicted to be clinically obese by 2050 [24]. To address this issue, the WHO's 'European Food and Nutrition Action Plan 2015–2020' clarified that restricting the marketing of unhealthy food is a key priority for tackling obesity among the younger generations [2].

In this study, adolescents are represented by all young people aged between 11 and 18 years. WHO defines adolescence as the period between childhood and adulthood with adolescent age being 11 – 19 years [25]. In the UK, adolescents aged 10 – 19 years represented 11% of the total UK population in 2015 [26]. Adolescents need specific attention due to the changes that take place during this period of their life, which are believed to impact the reformation of health policies and programmes [26]. Adolescence may be the best time to tackle health problems and alert young people about the need to improve their dietary behaviour [27]. Dietary habits are reported to be shaped during adolescence, and the habits formed in this period can potentially last into adulthood [27, 28]. Worryingly, the life expectancy of today's children is predicted to be shorter than that of previous generations due to obesity-associated diseases (for the first time in many generations). UK city councils have focused on limiting the number of takeaway outlets but there have been few other environmental interventions aimed at preventing obesity. Therefore, urgent action needs to be taken with an evaluation of the effectiveness of these actions, to improve health of young people. Focusing on a range of environmental factors, such as improving healthy food in places where young people congregate and not solely limiting the clustering of takeaway outlets, will have an impact on young children’s dietary intake and exercise behaviours and improve the quality of family-life [29, 30]. In addition, adolescents are the parents of the future, and according to the Health Behaviour in School-aged Children (HBSC) national report, adolescence is a vital transition period in which wellbeing and emotional health can be constructed. This has important consequences for future life chances [31]. Furthermore, during adolescence, physical changes occur, and increased levels of nutrients are needed to support these changes, including growth and maintaining a healthy weight [32].

PHE has published its strategy to encourage healthy eating out of the home (Figure 1-2). This strategy is focussed on influencing the food environment and making healthier options available for people. The strategy also focuses on targeting the obesity epidemic by encouraging collaborative work between local authorities and identifying local needs. This may involve, for instance, the act of locating fast food outlets, and mapping levels of obesity and deprivation. It also highlights the vital role that schools can play to improve students’ eating behaviour inside and outside the school premises. For example, focus group discussions may be used to help researchers explore the reasons behind people's behaviours and to understand people's opinions of a programme such as the school food standards [33]. This may also help schools to improve their canteen and the meal choices offered at schools during lunch break. This is critical for the purpose of encouraging students to consume lunches provided by their school’s canteen. Moreover, PHE stated that city councils should use their licensing power to control outlets and sites under council control [34].

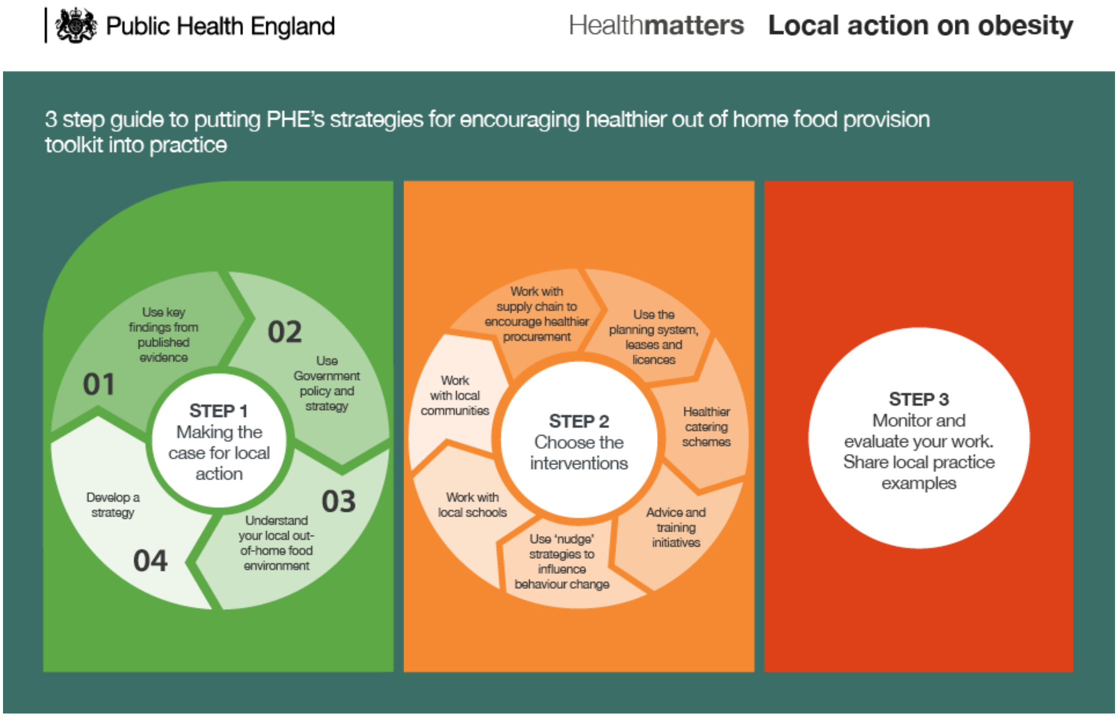


Figure 1-2 PHE strategy to tackle obesity in the UK [34]

It is well established that poor diet is one of the major threats to health and wellbeing, especially when associated with the intake of foods high in sugar and fat [35] and several studies have examined the impact of takeaway food consumption on the intake of individual foods and nutrients, such as soft drinks, sodium, total fat and vegetables. Examining the intakes of individual nutrients or food groups is not enough to assess diet quality, as both the quality and variety of the whole diet must be considered; thus, it is important to explore the relationship between individuals' whole dietary intake and their health status [36]. The need for a new tool to assess the overall diet quality particularly among adolescent age groups is crucial. Healthy eating indices (HEIs) and diet quality indices (DQIs) were both developed to assess the overall quality of people's dietary intake and focus on concerns surrounding the major diet-related diseases [37, 38].

1.3 Diet Quality Indices (DQIs)

In 1990, a diet quality index (DQI) was developed with the objectives of reflecting the population's level of adherence to the WHO's dietary guidelines and determining other important factors linked with a healthy diet [39]. Many of the developed DQIs, especially those targeting adults, have been used for monitoring nutrition and to assess the risks of mortality and chronic diseases, such as cardiovascular diseases, cancers and obesity [40, 41]. Healthy eating indices (HEIs) and DQIs were developed to assess the quality of people's dietary intake and focus on concerns surrounding the major diet-related diseases [37, 38]. Both types of indices are based on a variety of food groups and nutrients and they are considered good tools to evaluate the quality of an individuals' overall diet [42]. Although DQIs are mainly developed to be used in specific populations, many studies have used them (with or without modifications) for different populations and locations. However, many of the recent available tools have been developed from an existing index (i.e. an HEI or DQI). For example, the DQI-International, Mediterranean DQI, DQI for pre-schoolers and DQI for Adolescents (DQI-A) are adapted or updated tools from an original version of the DQI.

1.3.1 The Diet Quality Index for Adolescents (DQI-A)

The need for a simple, easy-to-interpret tool to indicate the quality of a diet without requiring intensive conversion analysis of foods to nutrients resulted in the development of the DQI-A [36, 38]. The DQI-A is based on the intake of food groups without including the intake of nutrients, and it was adapted from a validated index called the Diet Quality Index for Preschool Children. The validated DQI for pre-schoolers was derived from the original DQI. The DQI-A was mainly developed to assess the degree of adherence of an adolescent diet to the Food-based Dietary Guidelines (FBDGs) [43]. The FBDGs, also known as dietary guidelines, are used to provide information for different government sectors to implement interventions toward healthy eating and lifestyles. Such interventions may focus on food and nutrition, polices regarding health and agriculture, as well as educational programmes. Therefore, the primary role of FBDGs is to provide advice to the general public, thereby enabling individuals to meet their daily dietary requirements of both nutrients and food groups. This has the potential to prevent chronic diseases and promote healthy lifestyles [44].

1.4 Thesis aims

The overall aim of this thesis is to explore the association between takeaway (fast) food consumption and availability/accessibility and UK adolescents' diet quality and BMI. Variables including frequency of consuming takeaway food and density, proximity or accessibility of takeaway shops were evaluated and related to adolescents' overall diet quality (DQI-A) and health outcomes (BMI and Body fat percentage). In general, the objectives of the results chapters (4, 5, 6 &7) are based on the analysis of two high-quality UK data sets.

It is important to explore the relationship between individuals' whole dietary intake and their health status; as examining the intakes of individual nutrients or food groups may not be sufficient to assess diet quality where both the quality and variety of the whole diet must be considered [36]. Few studies in Europe and the US have used an overall diet quality index such as the Mediterranean diet score or the healthy eating index to assess the impact of fast food consumption or home and school lunches on overall diet quality [45, 46]. The consumption frequency of takeaway meals at home increased significantly with age among children from 18.4% for 5 to 9 years to 27.7% for 15 to 18 years [47]. Moreover, the number of older adolescents who consume school meals decreases as some adolescents leave the school premises during lunchtime [48]. Therefore, in Chapter 4 and Chapter 5 the NDNS data were used to explore the relationships between the higher consumption of takeaway (fast) food at home (29.8%), outside the home (24.3%) and during school time (17.5%) and lower diet quality among adolescents using the DQI-A as an assessment tool for the diet quality.

In addition, different studies used different methods to measure the food environment around different facilities such as schools, home and work place. Researchers need to choose the appropriate method to conduct a study, as their selection could have an impact on the overall results of that study. Therefore, to raise the awareness, in Chapter 6 I compared the results from using different methodologies to measure the food environment for our case study area of Avon in the UK. Finally, planning policies to discourage unhealthy fast food by limiting the number of fast food outlets around schools exists in the UK. However, long-term effectiveness and their impact on health should be studied and explored [49, 50]. Therefore, in Chapter 7 I aimed to investigate the longitudinal relationships between the density, proximity and accessibility of hot food takeaways (HFTs) and adolescent's health outcomes including BMI z–score and body fat percentage).

1.4.1 Study objectives by chapters

Chapter 2: Literature review

- To review obesity status of UK adolescents with more detail for the Avon region
- To review adolescents' diet quality
- To review the latest actions undertaken by UK city councils and local authorities toward fast food environments
- To review the food environments with more details on previous studies conducted in relation to schools

Chapter 3: Methodology

- To review the data sets to be used in this study
- To describe the statistical test to be used

Chapter 4: The cross-sectional relationships between consumption of takeaway food, eating meals outside the home and diet quality in British adolescents

- To evaluate the association of frequency of consuming takeaway meals with diet quality of UK adolescents.
- To evaluate the association of frequency of consuming meals out of the house with diet quality of UK adolescents.

Chapter 5: Cross-sectional associations between lunch type consumed on a school day and British adolescents' overall diet quality

- To investigate the association between the types of lunch consumed in a school day and diet quality of UK adolescents.

Chapter 6: Cross-sectional evaluation of the food environment around secondary schools in the UK; comparison of different methods

- To examine the differences in using different methods to evaluate the food environment particularly around secondary schools in the Avon region in the UK including:
  1. To investigate the differences of using the road network against circular buffers to measure density.
  2. To investigate the differences of using road network against straight line methods to measure proximity.
  3. To evaluate the use of the Hansen Accessibility index to create a food outlet accessibility score for the Avon region.

Chapter 7: clustering of takeaway food shops and health outcomes of secondary school adolescents.

- To investigate the longitudinal associations between availability of takeaway outlets near schools and BMI of UK adolescents at school.
- To investigate the longitudinal association between availability of takeaway outlets near schools and body fat percentage of UK adolescents at school.

1.5 Thesis framework

Figure 1-3 illustrates the thesis structure, by chapter. It contains eight chapters in total, starting with the introduction and then more detailed reviews of the literature and latest statistical facts. The methodology chapter (chapter 3) discusses in detail the use of different data sets and how the calculations/classifications were performed during the data analysis sections. Then, the remaining 4 chapters can be divided into two phases: namely exploring, 1) the National Diet and Nutrition Survey (NDNS) and 2) the Avon Longitudinal Study for Parent and Children (ALSPAC).

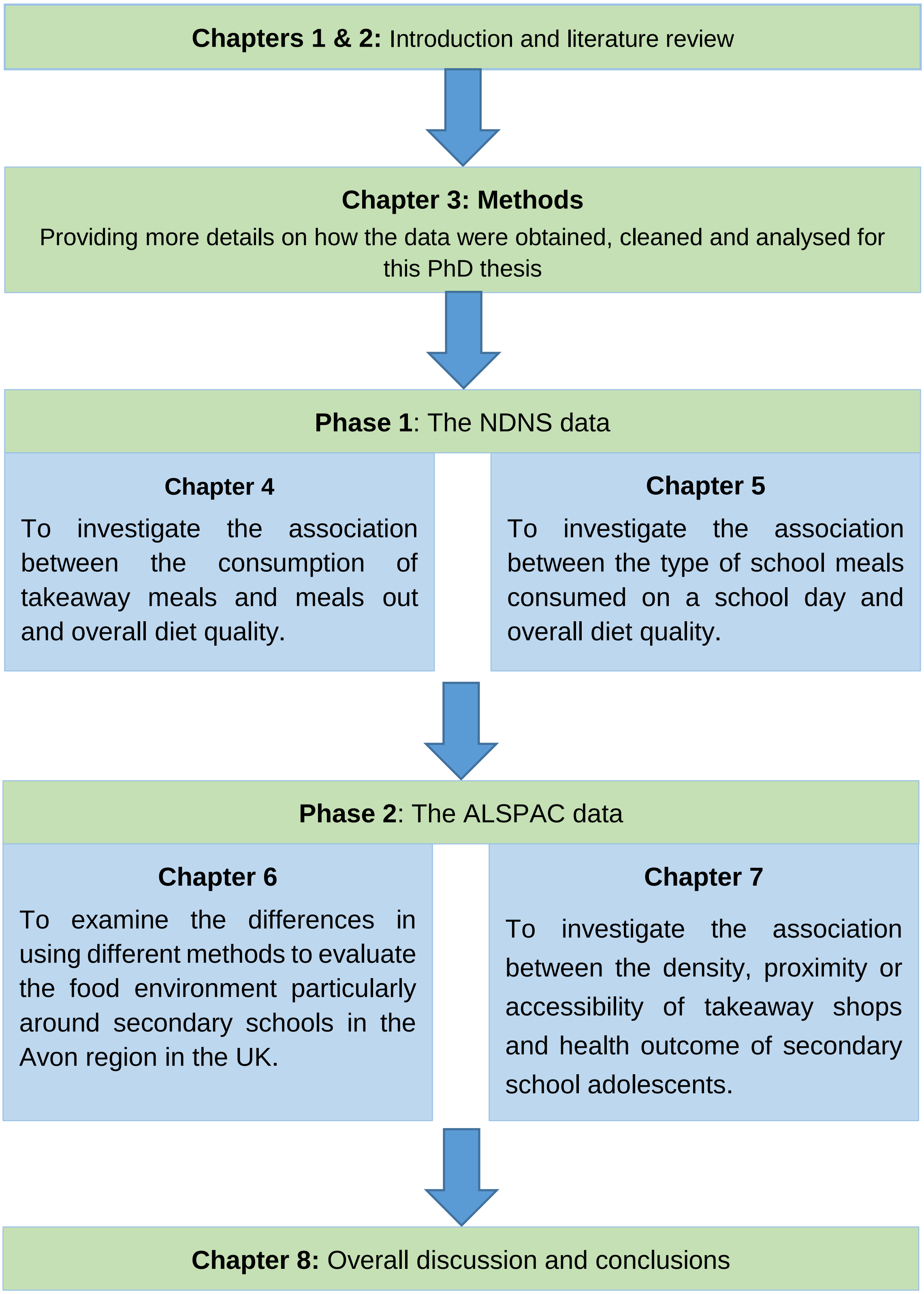


Figure 1-3 Overall thesis structure

1.6 Conclusion

This chapter provides a brief introduction that discusses the importance of takeaway (fast) food consumption, particularly among the adolescent age group and provides the rationale for the thesis. It introduces the need for the DQI-A tool, and highlights the overall aim and objectives of the thesis using a flow diagram. Moreover, this thesis is in agreement with the three main steps mentioned by the PHE, and focuses on improving understanding of people’s relationship with the food environment, including the local school environment, and describing the impact of the availability of hot food takeaways on health status of UK adolescents at school. The next chapter provides an in-depth review of the literature focusing on obesity, diet quality and the surrounding environment. In addition, policies to limit the number of fast food outlets are reviewed at national and international levels in the next chapter.

Chapter 2 Literature review

2.1 Obesity background

A. Worldwide

Between 1975 and 2016, obesity almost tripled worldwide. In 2016, the global rates of obesity and overweight in adults were reported to be 13% and 39%, respectively. In the same year, 41 million children aged under 5 years were found to be obese or overweight. Also, the prevalence of obesity and overweight has increased dramatically amongst children and adolescents aged 5–19 years. In 1975, less than 1% and 4% of children and adolescents were obese and overweight, respectively. Worldwide, over 340 million children and adolescents (ages 5–19 years) were obese (14%) or overweight (37%) in 2016 [4]. The Organisation for Economic Cooperation and Development (OECD) stated that the prevalence of obesity in adults increased dramatically since the 1990s in many countries, including the United States of America, England, Mexico and France (Figure 2-1). Furthermore, despite the use of self-reported measurements, between 2001 and 2014 the rates of adolescents reported to be overweight or obese at age 15 years increased among the majority of OECD countries (Figure 2-2). In addition, it is expected that the rates of obesity will show a steady increase until 2030. Furthermore, it has been projected that approximately 47%, 39% and 35% of the population in the United States, Mexico and England, respectively, are expected to be obese by 2030 (Figure 2-3) [51].

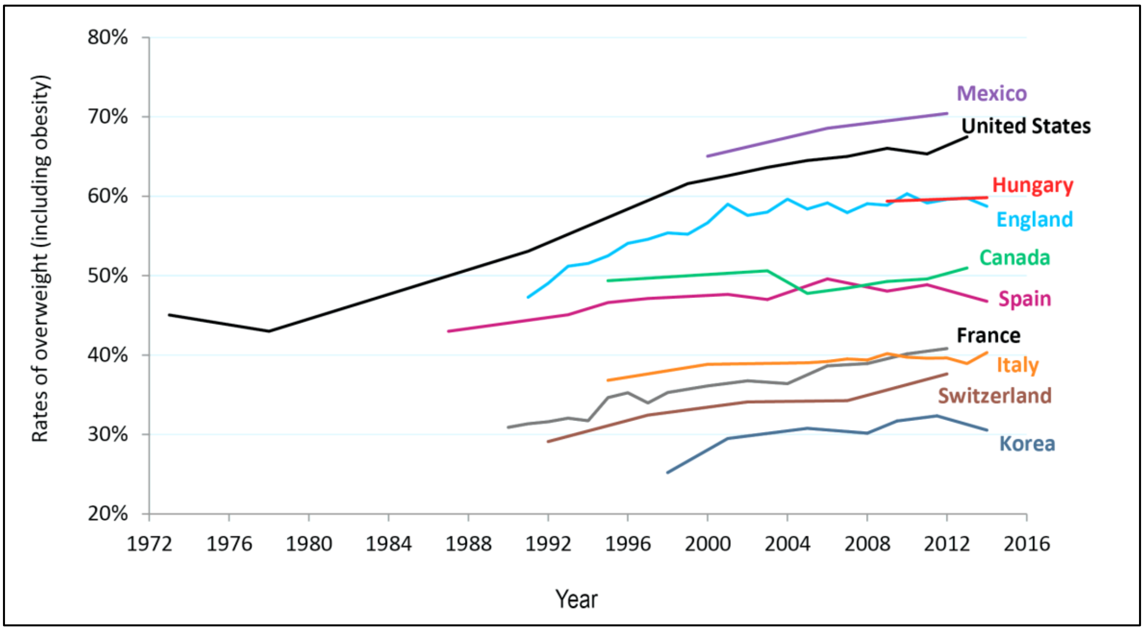


Figure 2-1 Overweight and obesity rates in OECD countries between 1972 and 2016 among adults aged 15–74 years [51].

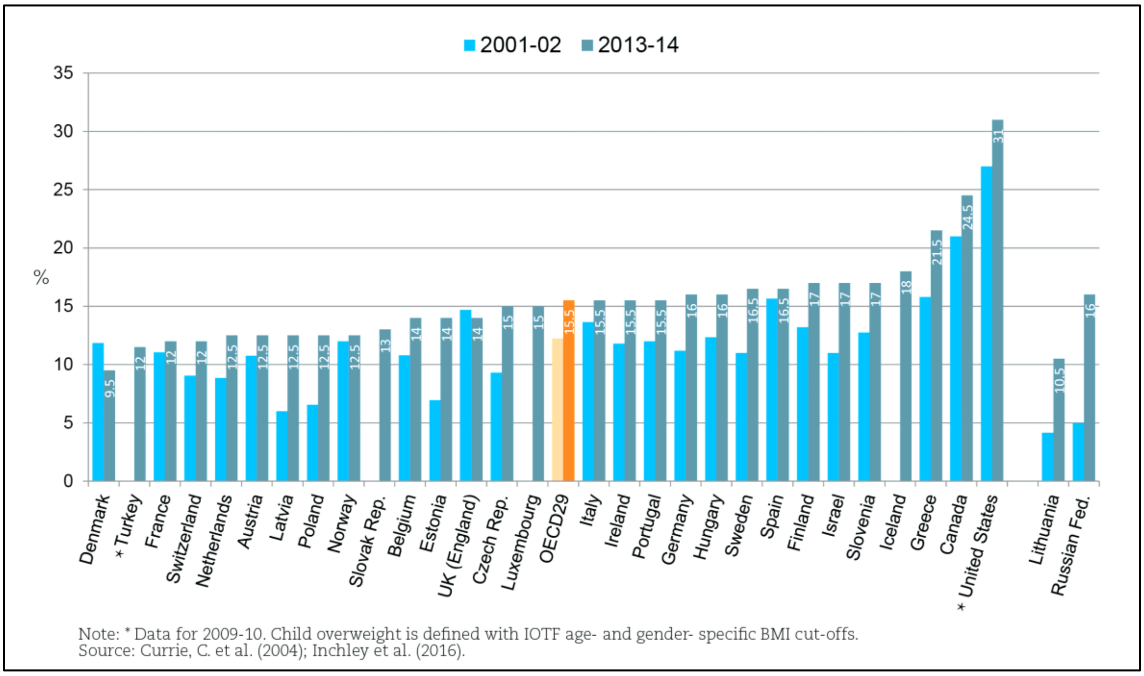


Figure 2-2 The percentage of adolescents who reported to be overweight or obese at the age of 15 years among OECD countries in 2001-2002 and 2013-2014 [51].

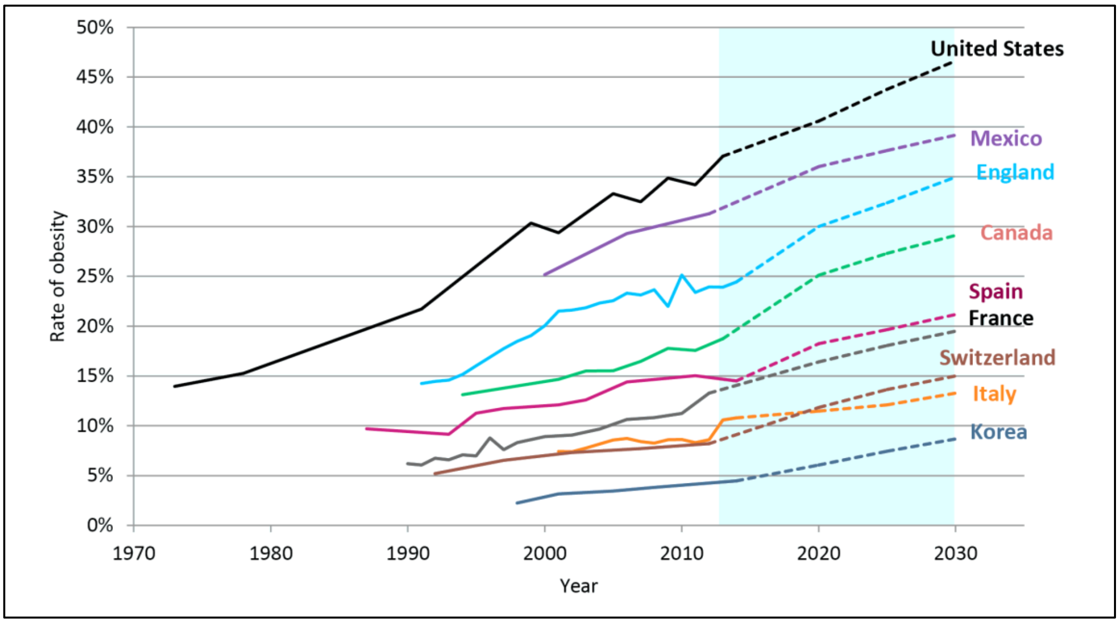


Figure 2-3 Projected levels of obesity among selected OECD countries until 2030 [51].

B. UK

According to PHE, the prevalence of obesity has also tripled in the United Kingdom over the past 20 years, [52]. Statistical analyses gathered in 2017 by PHE demonstrated that around 67% of males and 61% of females were overweight or obese, respectively [52]. In England, the latest survey conducted by the National Child Measurement Programme (NCMP), which was carried out in 2017–2018, reported that 14.2% and 20.1% of children aged 10–11 years were obese and overweight, respectively (Figure 2-4). Results from the Health Survey for England (HSE) showed that approximately 29% of children aged 2–15 years were obese or overweight in 2017 [22]. In 2014, 34.6% and 36.2% of boys and girls aged 11–15 years were obese and overweight, respectively [53]. The trend in the prevalence of overweight and obese girls and boys increased from 2015 to 2017 (Figure 2-5).

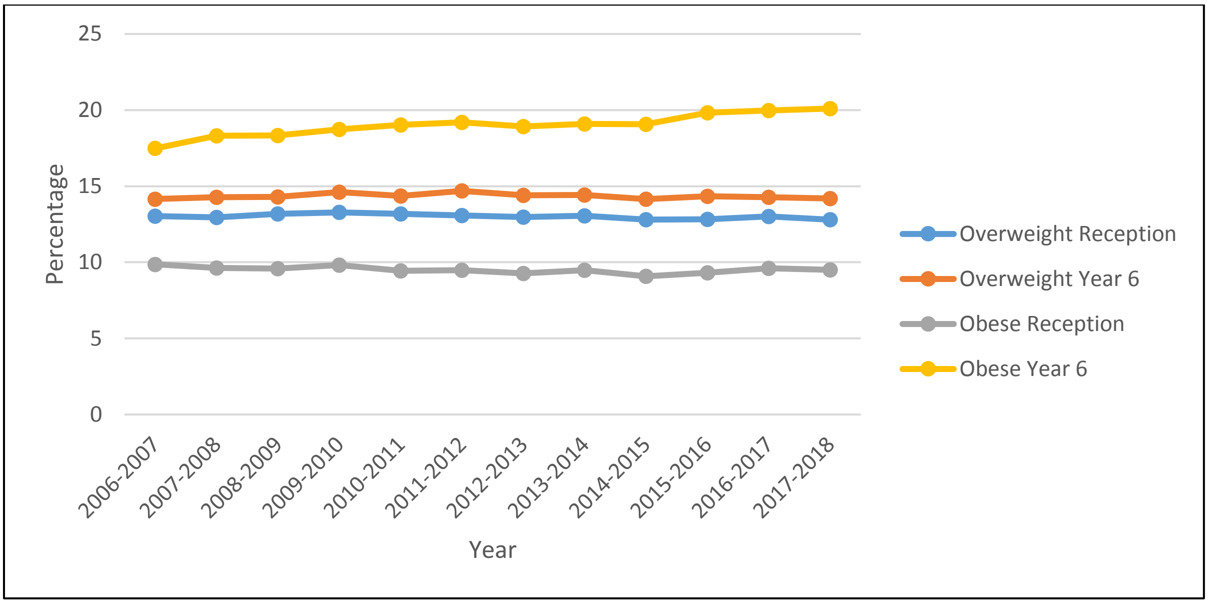


Figure 2-4 The prevalence of overweight and obesity among children, by year and age, from 2006 to 2018 in England [54].

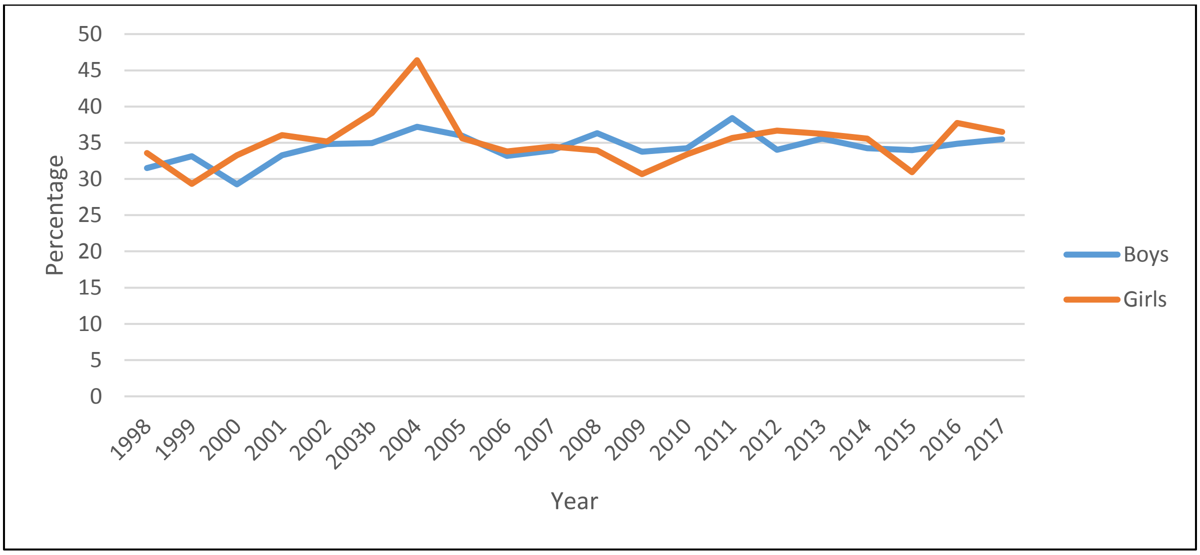


Figure 2-5 Prevalence trends of overweight and obese boys and girls aged 11–15 years participating in Health Survey England (HSE) from 1998 to 2017 [55].

C. Avon region

The Avon region in the UK where the ALSPAC (Avon Longitudinal Study of Parent and Children; years 2005-2011) study data were collected was used in this thesis in chapters 6 and 7. The Avon region is an area in the South West of England where the ALSPAC (Avon Longitudinal Study of Parent and Children; years 2005-2011) study data used in chapters 6 and 7 were collected. A brief background of the study area and its obesity characteristics is useful here. The Avon region largely mirrors the population structure of England overall. [56-58]. In England in 2017–2018, an average of 22.4% and 34.3% of reception year and Year 6 school children, respectively, were found to be overweight or obese [59]. According to the National Child Measurement Programme (NCMP) of 2016, 9% and 20% of UK children were found to be obese in reception year and Year 6, respectively (Figure 2-4) [60]. Results from NCMP in the Avon region (2016) also showed a similar percentage of obesity among children in reception year living in the Avon region with an average rate of 8.7%. However, Year 6 children living in the Avon region showed a lower obesity prevalence (15.5%). Concordant with national UK statistics, the prevalence of overweight and obesity among children living in the Avon region did not show a constant trend (increase or decrease) over the years (Figure 2-6) [54]. More so, in the UK, the prevalence of overweight and obesity in older adolescents aged 11–15 years was estimated to be 37% and 36% in 2003 and 2016, respectively [61]. Nevertheless, obesity prevalence varied by region, wherein the South West region had a higher prevalence of obesity amongst adults aged 16 years and over (equating to around 22% in 2015 [60]) compared with the prevalence amongst children in the Avon region (Figure 2-6). Overall, about a third of children in England leaving primary school are overweight or obese.

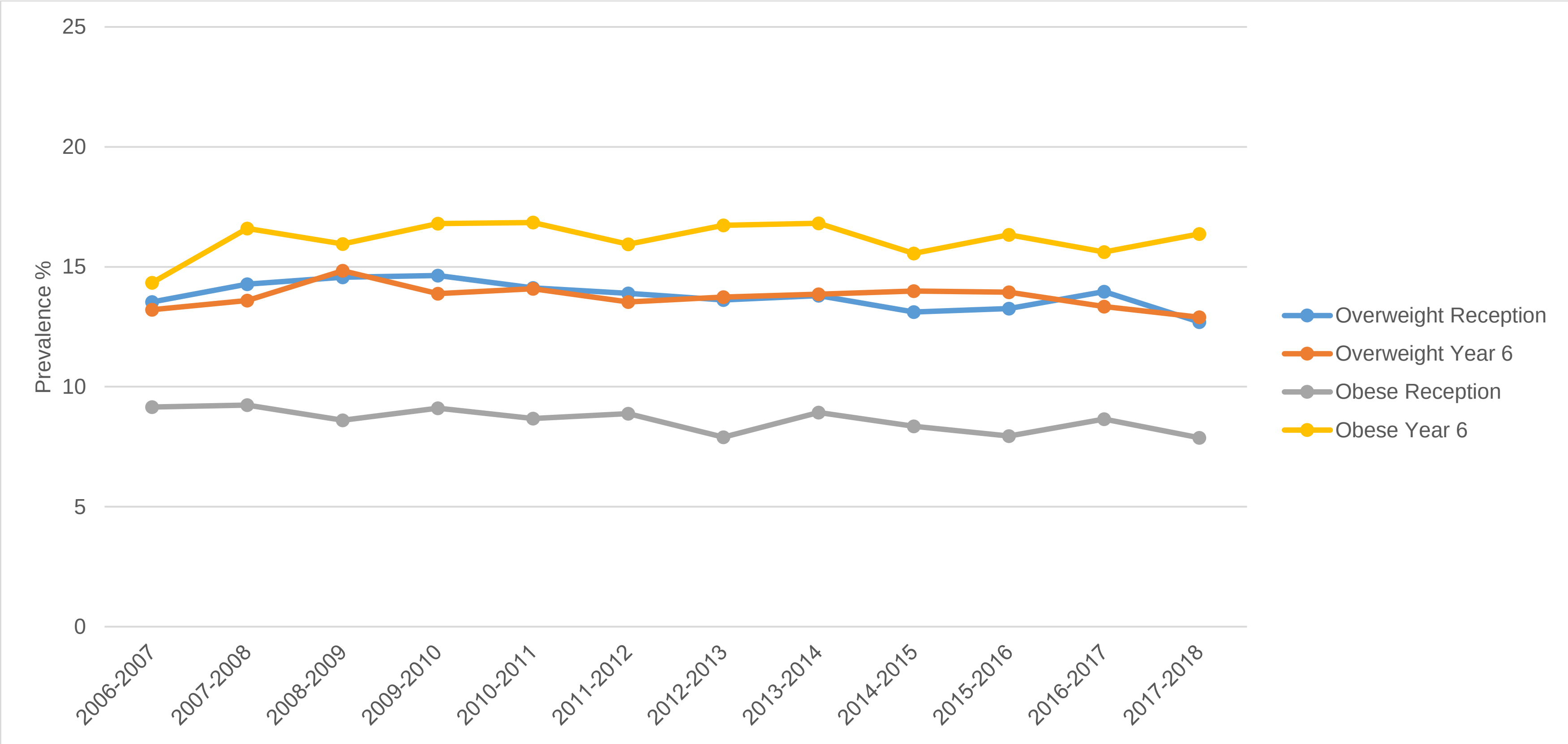


Figure 2-6 Overweight and obesity prevalence among children, by year and age from 2006 to 2018, Avon region [54]**.**

2.2 Determinants of health

Health quality is not simply based on individual's behaviours, genetics and medical care. Other factors such as social, economic and environmental factors can also contribute in shaping people's lives and therefore make a difference in health outcomes. The Dahlgren and Whitehead model (Figure 2-7) illustrates the wider determinants of health outside individual factors such as age, sex and constitutional factors that are largely fixed. Interactions between individuals with their peers, social and community networks could also influence their health. Moreover, living and working conditions, food supply, access to essential goods and availability of services influence individual's ability to maintain their health. All of these factors interact and are related to the wider socioeconomic and cultural environment [62].

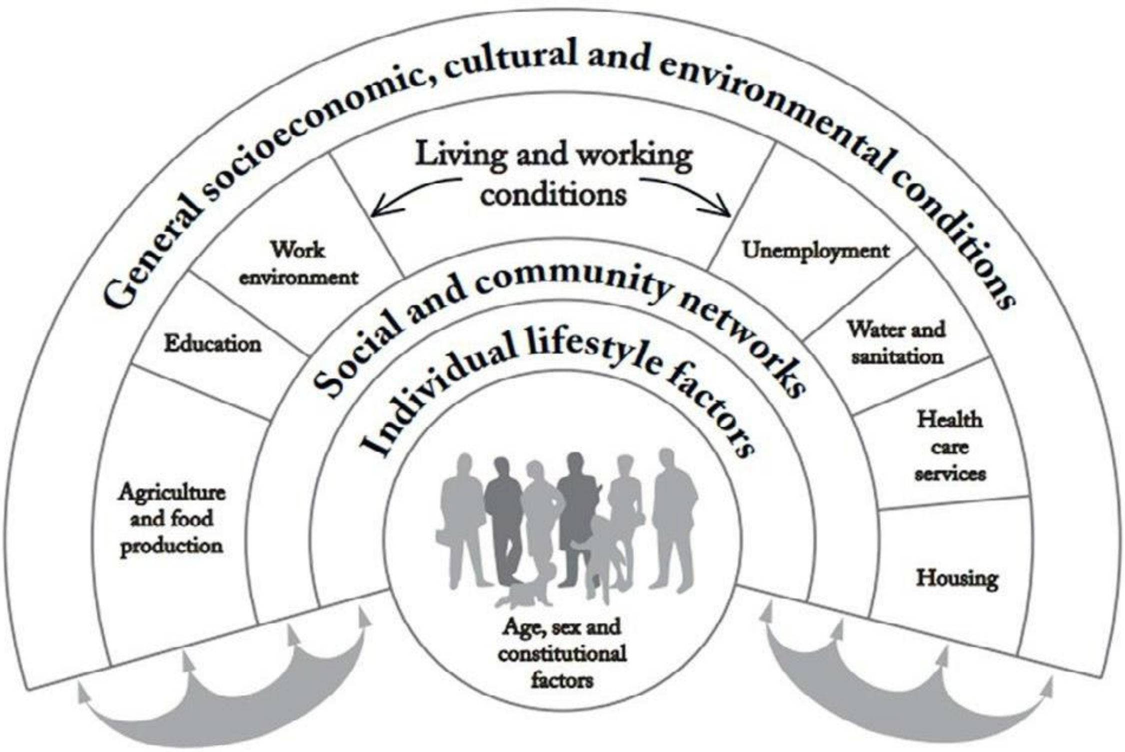


Figure 2-7 The Dahlgren and Whitehead model of the main determinants of health

Another example of complexity of health determinants can be obtained from the Foresight report "Obesity System Map" (Link to access the map - "https://assets.publishing.service.gov.uk/government/uploads/system/uploads/at tachment_data/file/296290/obesity-map-full-hi-res.pdf”). The map shows the relationships between energy balance (energy intake vs energy expenditure) and the outlying set of 108 variables. Some of these variables are directly and others indirectly influencing energy balance. Nevertheless, there are seven key subsystems constructing the obesity system map including; 1- Physiology cluster (*e.g.* level of satiety and resting metabolic rate); 2- Individual activity cluster (*e.g.* occupational and transport activity, parental model activity and learned activity patterns); 3- Physical activity environment cluster *(e.g.* cost of physical cost and walkability of the living environment); 4- Food consumption cluster (*e.g*. portion size, energy dense of food and availability and variety of food); 5- Food production cluster (*e.g.* market price of food and wider social and economic situations); 6- Individual psychology cluster (*e.g*. level of food literacy and parental control) and 7- Social psychology cluster (*e.g.* education, Tv watching and social accessibility of fatness). The food environment is not specifically mentioned as a domain. It is important to consider the variation between individuals where some of the obesity contributors are more important for some than the others. For example, some people may be more likely to be affected by genetic predisposition while others can be influenced by social and environmental circumstances [63]. For this reason, all the subsystems need to be addressed in order to improve dietary behaviour and health outcomes.

It is crucial to also understand that there are various causes of childhood and adulthood obesity within the classification of socioeconomic inequalities, such as deprivation, education levels and ethnic variation [64]. Researchers have observed that groups with lower socioeconomic status consume less oily fish, fruit and vegetables, and more red and processed meat and foods high in sugar compared with higher socioeconomic groups [65], and this is discussed further in sections 2.3 to 2.33.

2.3 Inequalities in obesity and healthy eating

The rate of obesity is high in England amongst both adults and children. Inequalities in child obesity, especially amongst those living in the most deprived areas, have been observed over the years and the situation is deteriorating even further. Multiple causes and contributors play a role in the development of overweight and obesity issues. Individual behaviours such as dietary patterns, physical activity and inactivity and use of medication are contributing factors to obesity. For example, consuming a healthy dietary patterns and following the dietary guidelines by eating whole grains, fruit and vegetables, lean protein and drinking water could help in preventing excess weight from consuming extra calories from energy-dense foods. Moreover, following physical activity guidelines could also help to maintain body weight (individual health).

Other factors such as the food and physical activity environments, education and skills, food marketing and promotions are also considered as contributing factors to obesity [5]. These environments vary by level of deprivation, which contribute to inequalities in diet and health in the UK. According to the Marmot review [66] (Health Equity in England), inequalities in obesity can be as a result of several factors such as lack of diversity in retail offerings, lack of green infrastructure, littler and area degradation and crime and fear of crime. Although, none of these were directly linked with increasing risk of obesity, lack of good quality green spaces, and poorer local environments overall in more deprived areas could lower levels of physical exercise and therefore increase risk of obesity. Similarly, a lack of diversity in retail offerings leads to a high density of fast food outlets, where in the most deprived areas the number of fast food outlets is five times higher than the most affluent areas.

2.3.1 Obesity, deprivation, and the density of fast food outlets

In England, the NCMP has shown that the prevalence of obesity is strongly associated with deprivation rates among children attending schools in year 6 (10–11 years; [67]). Figure 2-9 portrays a positive correlation between overweight percentage amongst children aged 10–11 and 4–5 years and an increased deprivation score. This was also true for both genders (boys and girls) aged 2–15 years, where the highest percentage of overweight including obese (yellow bars) was observed among those living in the most deprived areas (Figure 2-10; A & B).

A cross-sectional study found that the largest contribution to fast food exposure variable was deprivation which could be due to people living in more deprived areas eating more fast food due to the relative cheapness of this type of food [68]. Studies stated that children who consume fast food have higher intakes of energy and fat and lower intakes of milk and vegetables compared with children who did not consume fast food. Consequently, those who consume fast food could possibly be more likely to be in positive energy balance which leads to weight gain [68]. In Norfolk, for example, the number of takeaway outlets increased by 45% from 1990 to 2008. It was found that the density of those takeaway food outlets was higher in the most deprived areas [69]. Figure 2-8 illustrates the latest statistics concerning the number of fast food outlets and the relationship to deprivation in the United Kingdom.

In 2011, PHE stated that the high price of healthy foods is one of the greatest barriers affecting low-income household food choices. Results from HSE 2007 showed that 20% of the participants reported that cost is one of the major barriers to healthy eating. Moreover, for people with lower household incomes who completed the Low Income Diet and Nutrition Survey, 2005 [70], the most frequently reported barrier to healthy eating was the price of healthy foods. Furthermore, a greater increase was reported in the price of healthy foods compared with that of less healthy alternatives between 2002 and 2012. Fruits and vegetables showed the highest price increase, followed by milk and dairy products. Only the price of starchy food items, such as bread, rice, potato and pasta, remained constant in that duration, with a slight increase in 2008 [71]. Meals offered by quick service restaurants are found to be cheaper than those of other restaurants, hotels and pubs. In addition, healthy meal options offered by McDonald's are more than double the price of their cheapest available meal [35].

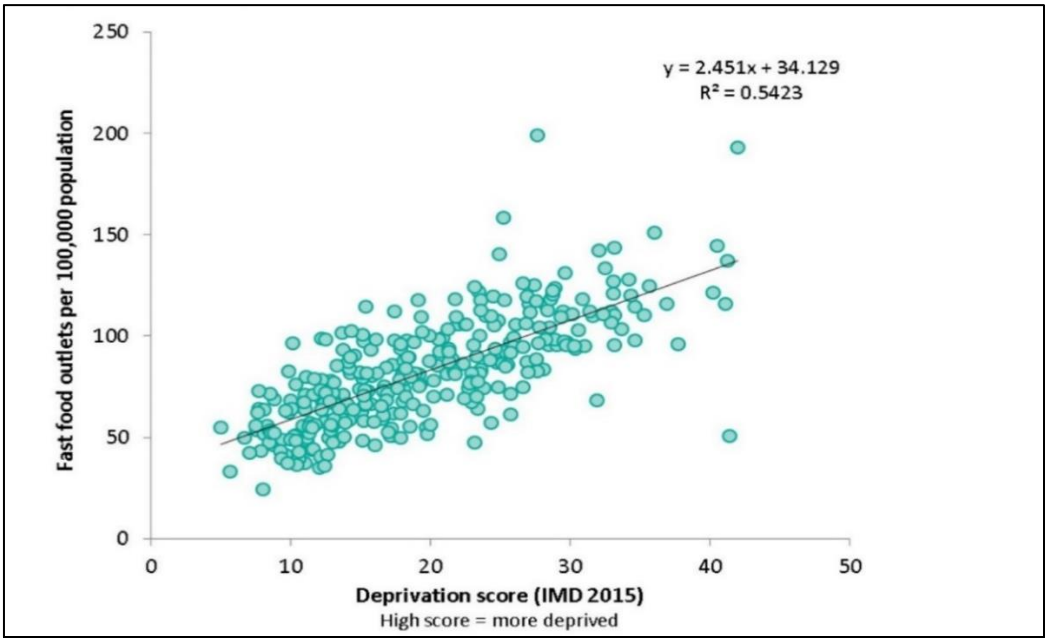


Figure 2-8: Relationship between the density of fast food outlets and local authority's deprivation scores [48].

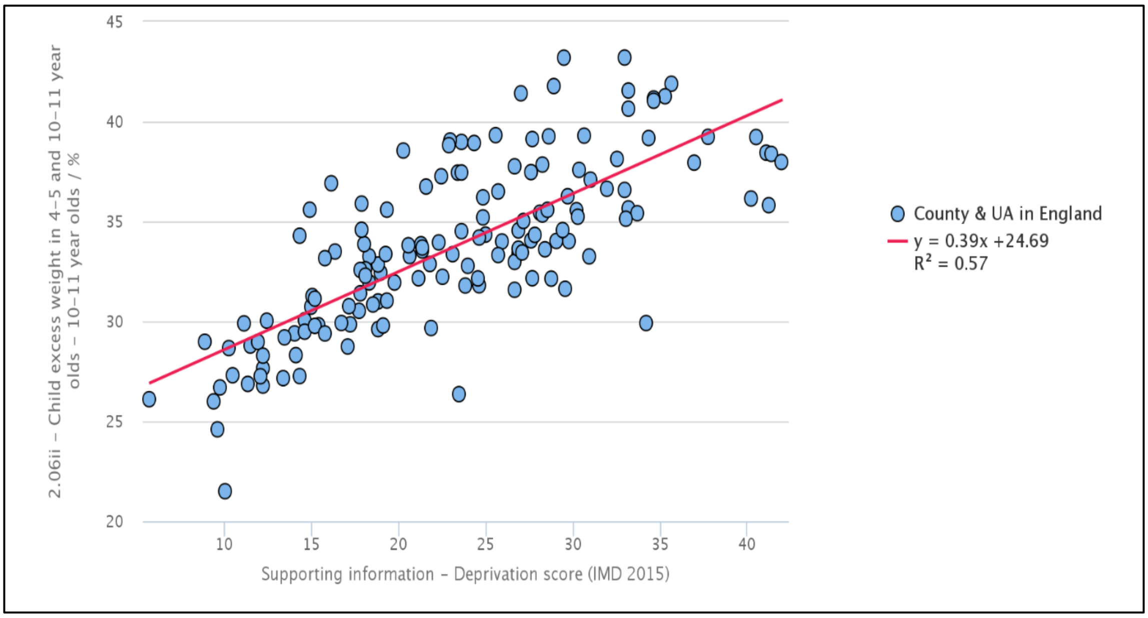


Figure 2-9 Relationship between obesity among children aged 4–5 and 10–11 years and local authority's deprivation scores [48, 59].

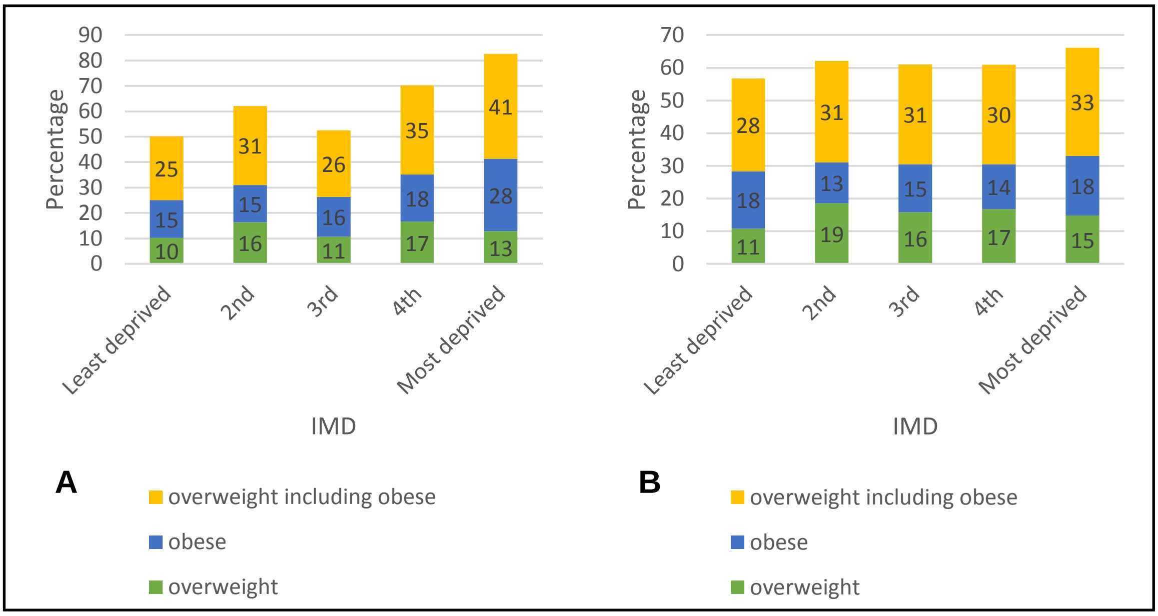


Figure 2-10 Prevalence of overweight and obesity in boys (A) and girls (B) aged 2–15 years by Index of Multiple Deprivation levels [55].

2.3.2 Household income

In HSE report the household income was categorised into five different quintiles based on income levels by the office for National Statistics. This allows for comparison between each of the equalised groups and it may help clarify the possible effect of inequalities on diet quality and the prevalence of obesity [72].

Statistics have indicated that obesity is higher among children, especially those aged 2–15 years, living in low-income families (

Figure **2-11**). Similar results have been observed in the United States in children aged 2–4 years; in the UK, the prevalence of obesity increased from 11.8% in the highest quantile to 14.3% in the lowest quantile [72].

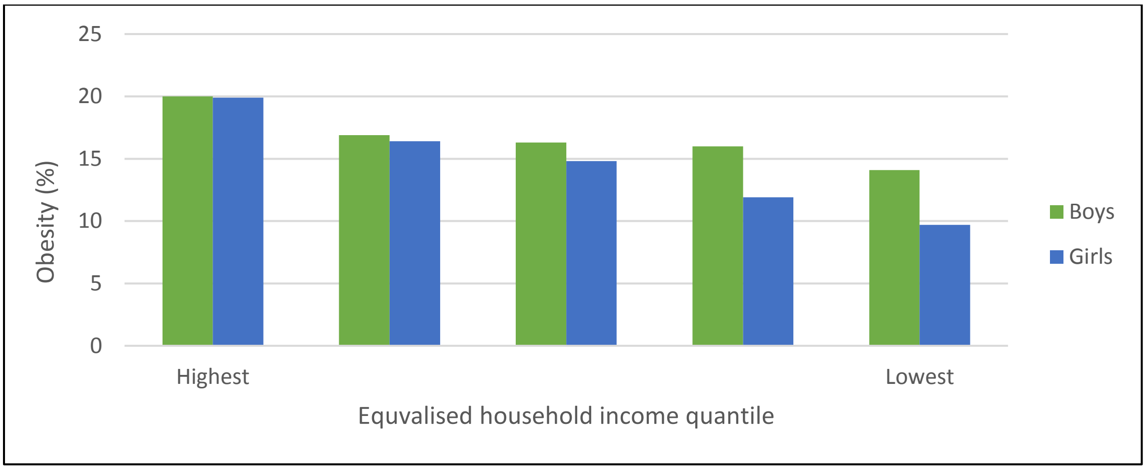


Figure 2-11 Prevalence of obesity among boys and girls aged 2–15 years by equivalised household income, 2006–2010, from HSE; [55].

The NDNS analysed the mean intake of different food items, including total energy and percentage of five-a-day achievement, among young people aged 11–18 years living in families of different levels of household income. Boys living in the highest household income quintile demonstrated the highest average intake of food energy, percentage of five-a-day achievement, and most other selected food items, such as total fruit, total vegetables and total non-starch polysaccharides (NSPs). However, this was seen among girls in the same age group, which may indicate that girls are more cautious about their daily dietary intake. However, the mean intakes of healthy food items, such as fruit, vegetables and fruit juice (not to exceed 150 g/day) were higher for both boys and girls in the fourth and fifth quintiles than those in the first and second household income quintiles. Nevertheless, in all household quintiles, the mean intake of Non-milk extrinsic sugars (NMES) and saturated fat percentage exceeded the recommended intake of 11% for both genders [73].

2.3.3 Age and eating behaviour

Data from the NDNS programme concerning children in years 1–4 informed the conductance of a cross-sectional study, which showed that the consumption measured using the frequency of out-of-home meals was higher among older adolescents (15–18 years) than it was in younger ones (10–14 years). Nonetheless, no significant differences were observed between adolescents with different socioeconomic statuses. In contrast, the consumption frequency of takeaway meals at home increased significantly with age among children from 18.4% for 5– to 9–years to 27.7% for 15– to 18–years. Furthermore, children of lower socioeconomic status ate significantly more takeaway food at home compared with children living in higher-class households. The consumption frequency of takeaway meals increased significantly from 17% for children living in the most affluent households to 26% for children living in the least affluent households [47].

2.4 Diet quality

The HBSC survey, an international effort, reported that daily consumption of breakfast and fruit decreased with age among children aged 11–15 years in most participating countries and regions [31]. Increases in trends of daily soft drink consumption were also observed. Thirty nine countries and regions were included in the HBSC study, amongst which were England, Armenia, Austria, Belgium, Canada, France, Germany, Greece, Ireland, Italy and Spain. Although several campaigns and efforts (standard school meals menu, five-a-day fruit and vegetables, regulation of food promotion and television advertisements) have been implemented to increase people's intake of fruit and vegetables, especially in the UK, it is estimated that only 8% of young people aged 11–18 years meet the five-a-day recommendation [74].

In one prospective cohort study, the risk of weight gain was shown to be reduced by increasing the intake of fruit and vegetable by 100 g per day [75]. In addition, the results obtained from the NDNS (years 1 and 2 combined) showed a higher mean intake of protein and NSPs and a lower consumption of trans-fatty acids and saturated fat compared with the results obtained from the NDNS rolling programme in 1997 [76]. However, the results from a more recent NDNS report for years 1 to 4 confirmed that the mean consumption of saturated fats, salts and non-milk extrinsic sugars were higher than the recommended dietary levels. Moreover, the mean consumptions of fruit and vegetables, oily fish and NSPs were lower than the recommended levels among all age groups [73].

Poor diet is one of the major threats to health and wellbeing, especially when associated with the intake of foods high in sugar and fat [35]. The food environment plays a crucial role in individual behaviours and food choices. Aspects of the food environment include the type and quality of food available at home and surrounding food stores, as well as food prices [53, 64]. However, one of the major causes of overweight and obesity issues lies in the imbalance between energy intake and energy expenditure. This imbalance means that people consume more food and drinks (calories) than needed, resulting in storage of excess calories as fat which over time this can lead to weight gain. Moreover, one of the primary means of consuming excess calories is the overconsumption of energy-dense foods –high in fat and sugars – coupled with people's increasingly sedentary lifestyle [4]. Although obesity is complex and caused by many factors including social, economic and biological factors, the obesogenic environment is also an important determinant of the overall energy intake and expenditure [77]. Overconsumption of energy-dense foods derived from fast and convenience food outlets has been identified as a major contributor to the increased risk of obesity and diabetes among young generations [78, 79]. Two longitudinal prospective studies including young adults aged 18–30 years, followed for 15 and 3 years respectively, found that an increased frequency of fast food restaurant visits [80] and consumption of fast food [81] can lead to increased body weight (baseline compared with follow up).

Higher fat consumption and total energy intakes are linked with eating takeaway and fast food, which offer a variety of ready-to-eat meals and energy-dense foods [82]. Consumption of fast food remains positively and significantly associated with total energy intake (caloric intake) and total intake of fat, saturated fat, carbohydrates, sugar, and sugar-sweetened beverages [83]. Consumption of takeaway meals and food purchased outside home as opposed to those prepared at home was negatively associated with diet quality [84]. In addition, several US cohort studies have reported that the consumption of fast food is negatively associated with diet quality [85, 86]. A study conducted on 6212 children in the United States revealed that the consumption of fast food was common among both genders, all ethnic groups, all household income levels and all regions [85]. The children involved in the study were 4–19 years, and two types of comparison (within and between subjects) was carried out. The analysis resulting from both comparisons showed that the consumption of fast food was positively associated with energy intake, total fat and added sugar, and negatively associated with the intake of fruit and non-starchy vegetables. Therefore, it is evident that fast food consumption impacted negatively on the children's diet quality. Moreover, fast food intake was higher in older children aged 9–13 and 14–19 years compared with the younger group, aged 4–8 years. This may highlight the fact that older children are at greater liberty to spend their own money on food items than are younger ones [87]. Therefore, the factors driving children/adolescents towards consuming more takeaway foods need critical consideration [68, 88].

Several studies have examined the impact of fast food consumption on the intake of individual foods and nutrients, such as soft drinks, sodium, total fat and vegetables. Other studies have cross-matched the quality of home or school lunches against the National School Lunch Programme (NSLP) guidelines using either individual food items or nutrients and diet quality indices as the diet quality indicator [46, 89]. Nevertheless, few studies in Europe or the US have used an overall diet quality index to assess the impact of fast food consumption or home and school lunches on overall diet quality [45, 46, 90], see Table 2-1. In addition, only one Canadian cross-sectional study examined the associations between school lunch-time food sources and diet quality using healthy eating index scores [91]. Examining the intakes of individual nutrients or food groups is insufficient to assess overall diet quality, as both the quality and variety of the whole diet need to be considered; in order to explore the relationship between individuals' whole dietary intake and their health status [36].

Table 2-1 Few studies that have investigated the associations of takeaway food consumption with overall diet quality.

Research study	Country/reference	Outcome
The frequency of consumption of takeaway or fast food among young Australian adults.	Australia/ [45]	Young adults aged 26-36 years who consumed takeaway or fast food twice per week or more had a poorer diet quality.
The frequency of consumption of fast food among Spanish men and women aged 25–74 years.	Spain/ [90]	The consumption of fast food more than once per week was negatively associated with overall diet quality.
Consumption of home and school breakfast and lunch among children aged 5–11 years.	US/ [46]	No differences in HEI score among home and school breakfast consumers. School lunch consumers have a higher HEI compared to home lunch consumers.
Food source for school lunch of Canadian children and adolescents aged 6–17 years.	Canada/ [91]	Home-packed lunches have a better nutritional quality compared with school and off-campus lunches.

2.5 The food environment

Data published in 2019 indicates that in England, the total number of secondary school students was 4.7 million in 3448 state-funded schools. Students spend nearly 190 days (6 months) of the whole year in school [92]. Legislation has been enacted across the United Kingdom regarding improving the school food environment by cutting down sales of foods that are high in fat, salt and sugars, as well as providing better food choices for meals within schools [92]. Evidence has shown that the dietary quality of children consuming school meals tends to be better than that of children consuming packed lunches (food brought from outside the school). However, the number of children who consume school meals has shown a decrease, especially for those moving from the primary to secondary stage, as the latter are often allowed to leave school during lunchtime [48]. In the UK, secondary schools adopt independent policies pertinent to allowing students to have lunch offsite during break time. However, in May 2016, a group of secondary school students submitted a petition asking the UK Government and Parliament to allow them to leave school during lunchtime; the petition was drafted because students complained about the taste of food provided in schools (‘It’s not nice food’). The petition was rejected because the UK Government and Parliament (2016) stated that schools’ governing bodies have the power to act in individual cases. Yet, secondary school students are allowed to leave the school site during lunch break in many areas of the UK [93].

In general, the obesogenic environment may be improved by promoting physical activity and implementing policies that restrict easy access to high-density foods. A study showed that around 23% of the recommended energy intake of secondary school students was obtained from foods purchased from takeaway outlets. The nutritional quality of the purchased food items comprised 38% saturated fat, 22% sugar and 15% NMES [94]. A cross-sectional study conducted in five urban regions in New Zealand suggested that the high density of fast and convenience food stores around different types of schools tended to encourage students to eat unhealthy foods [95]. However, the findings from this study are not directly applicable to other areas with different deprivation levels or social classes. Moreover, in Scotland, an observational study including pupils from five secondary schools showed that the number of food outlets located within a 10 minute-walk varies from one school to another. However, the results also stated that most students purchased unhealthy convenience foods during lunch break, and these were largely from local shops, such as fish and chips shops, cafes, pizzerias, kebab shops and supermarkets.

The availability of fast food restaurants (outlets) around homes and schools can promote the consumption of energy-dense foods and decrease the consumption of healthy foods [96]. Moreover, a cross-sectional US study including approximately 3 million adolescents in grade 9 found that fast food restaurants within 160 metres (m) of schools resulted in a significant increase of 5.2% in the rate of obesity in school students [97]. In the UK, a cross-sectional study including adults aged 29–62 years reported that higher exposure to fast food outlets at home and work was positively associated with higher fast food consumption and BMI [98]. These data highlight the potential benefits of implementing regulatory controls such as taxation of unhealthy foods, restrictions on the number of outlets offering unhealthy food outside the school and promotion of healthy foods inside the school premises [99]. In 2013, one of the most important pieces of advice from the Academy of Medical Royal Colleges was that PHE should audit policies concerning licensing and catering arrangements by local authorities. Although reducing rates of obesity is complex, local authorities have started the planning systems to regulate the growth in the number of takeaway or fast food restaurants around schools [100]. The proposed policy would focus on reducing the density of fast food outlets around schools, colleges and other leisure places where children are more likely to gather [48].

2.6 National (UK) policy and food environment

In England, obesity and related health diseases cost the NHS in 2015-2016 more the £6 billion per year. Furthermore, local authorities had to spend £352 million per year to increase social care budgets related to obesity. Alarmingly, childhood obesity is one of the top ten priority issues that city councils are concerned about [101]. Therefore, PHE, in collaboration with the Local Government Association (LGA) and the Association of Directors of Public Health (ADPH), have designed the Whole System Obesity (WSO) programme. The programme aims to assist local authorities in their attempts to tackle obesity using the most appropriate methods. The programme is still under construction and the final route map was originally estimated to be launched in spring, 2019. This programme's key priority is to identify all possible means of collaboration between local authorities to generate more practical results and recommendations for the ultimate aim of tackling obesity. More so, the summary report advised that, in addition to creating a more healthy environment, limiting the number of unhealthy food outlets could result in less litter [102].

Tackling childhood obesity, mainly by limiting the proliferation of unhealthy food outlets in local area and changing individual dietary behaviour, can be achieved through government legislation. Recently, the UK Parliament stated that many local authorities have considered hot food takeaways in their plans [50]. In the UK, one of the available tools used to address the over-proliferation of hot food takeaways is the 'takeaways toolkit'. This tool focusses on three approaches to tackling obesity in city centres and around schools: 1) increasing healthier food choices in takeaway and food shops, 2) reducing the consumption of fast food inside schools by working with the government and 3) implementing policy and regulation measures to solve the clustering of hot food takeaways (HFTs) shops

[48]. In 2019, the RSPH (Royal Society for Public Health) also made calls to use the licensing and planning tools to prevent fast food outlets from opening within a 5-minute walk of school gates to reduce the harm of offering easily accessible junk food. Besides this, Sustain published a new report ('Hot Food Takeaways: Planning a route to healthier communities'**)** which highlighted a series of recommendations on planning and licensing to tackle childhood obesity and improve quality of food options. For example, recommendations on increasing the adoption of planning restrictions and upholding existing policies by reviewing the available evidence collected from the fast food chain [103]. Some local authorities in the UK have also adopted supplementary planning documents (SPDs). Local authorities in these documents have highlighted the importance of reducing the harm of overweight and obesity. However, controlling the concentration or adopting the exclusion zones policy can only limit the number of HFTs outlets. There is currently a lack of evidence demonstrating that limiting the number of takeaway outlets or banning the establishment of a new outlet impacts the health status of school students [48]. Similarly, limiting the hours of operation of HFTs shops can only control the purchasing at certain times. Addressing obesity at the local level is complex and no single intervention can completely solve the problem, leaving public health authorities to consider multiple solutions.

2.6.1 Types of food outlet

Local authorities have designed or drafted their SPDs to limit the effect of hot takeaway food shops. The planned strategies include 'hot food takeaways' (class A5) in their restriction policy; businesses are labelled as class A5 when their primary concern is to sell hot food for consumption from their shops. Most of the participating authorities are known to have high deprivation levels among their populations [104]. Fifteen authorities have prepared SPDs and used methodologies aimed at achieving the best results. Ten local authorities focussed only on hot food takeaways, while four expanded their coverage to include hot food takeaways in retail outlets and shopping centres. The final document focused on exclusion zones, where no hot takeaway food shops are allowed within 400-m of primary and secondary schools, youth facilities, children's playing fields or parks and leisure centres. Some councils have adopted a different methodology that uses an 800-m exclusion zone instead of a 400-m exclusion zone. They argue that this seems more reasonable, especially during lunchtime.

Moreover, policies on limiting the number of HFTs in high streets and shopping centres have also been implemented [104]. It is also important to note that many of the SPDs drafted or adopted by local authorities may be out of date and lack in information regarding their planning system [49]. Nevertheless, some local authorities are still evaluating the arguments concerning the effectiveness of limiting the number of takeaway or fast food shops in tackling obesity. Some city councils are aware of the risks associated with being overweight or obese, and this problem has been linked to the number of hot food takeaways and fast food shops clustered around schools. It has also been claimed that healthier food choices at food outlets would help address the issue. However, a crucial point that needs to be considered is that the SPDs only cover HFTs (class A5). Different types of shops, such as restaurants, cafés and sandwich shops are not included because they are classified as class A1, A2, A3 and A4 shops, respectively (Table **2-2**). For example, sandwich bars and internet cafes are classified as A1 shops, financial and professional services are classified as A2 buildings, restaurants and cafés are classified A3 shops, drinking establishments such as public houses and wine bars are classified as A4 shops; where hot food takeaways – (offering hot food for consumption off the premises) are classified as A5 shops.

In England, The National Planning Policy Framework (NPPF) sets and describes the application of the government’s planning policies [105]. The aim of the planning system is to achieve sustainable development mainly through building a strong economy (innovation and improved productivity), healthy communities (availability of accessible services and open spaces) and protect our environment (effective use of land, minimising waste and pollution). Planning policies and decisions should promote healthy and safe communities for example by promoting social interaction, providing safe places, enable and support healthy lifestyles. Moreover, local planning authorities should apply their planning powers to ensure current and next generations have safe and accessible green infrastructure, sports facilities, local shops and access to healthier food. Considering all types of businesses and using the legislative power of the local authorities are essential steps in addressing the proliferation of these outlets which could help in tackling childhood obesity [50].

Table 2-2 Examples of class A5 shops based on Supplementary Planning Documents (SPDs) designed by different city councils [106-108].

Examples of class A5 shop types	Examples of shop types NOT categorised as class A5
Chicken shops	Restaurants/cafés/bistros
Fish and chips shops	Public houses (Pubs)
Pizza shops	Wine, shisha bars
Chinese, Indian or other takeaway shops	Sandwich, coffee and cake shops
Kebab and burger shops	Ice cream parlours

2.6.2 Local authorities' variations in policy

Several sources of information obtained by reviewing selected city councils reports have shown that the surrounding environment is a key factor in shaping a population's dietary habits and preferences. However, in 2010, permission was granted for one fast food shop to be established close to a school in Medway. The main reason for this was a lack of evidence demonstrating that opening a single takeaway shop would have a direct relationship with the obesity status of school students [48]. Also, despite the fact that in the UK more than 20 local authorities have considered restrictions on HFTs [109], in April 2015, Denbighshire county councillors voted not to ban hot food takeaway outlets within 400 m of school premises and to remove the banning paragraph from their SPDs [110]. Once again, this was due to the absence of conclusive proof that opening a single takeaway shop would have a direct relationship with the health status of school students [48]. Wilkins and his team highlighted the absence of best-practice methods to measure density, proximity and accessibility of the food environment around homes, schools and workplaces [111]. In this light, it is essential to develop an evidence base to prove the effectiveness of the SPDs plan. This may be achievable through conducting a thorough review of the available published study cases and datasets. An annual monitoring report must be published by all local authorities to provide up-to-date information about the effects of suggested policies and regulations. Nevertheless, the relationship between the density of fast food outlets (HFTs) and secondary school students' BMI has not been examined, particularly longitudinally.

Nevertheless, some cities (such as Brighton and Hove) take a different point of view. In 2009, the City Council considered a possible relationship between the location of fast food outlets around schools and childhood obesity. A year later, a councillor stated that the council must consider the health and wellbeing of school students, as the number of fast food restaurants, coffee shops and other food shops was high, especially in Patcham. Councillors were asked to refuse future applications and take action to prevent restaurants from being located close to schools. It was argued that the presence of such restaurants could result in easy access to unhealthy foods for pupils, particularly during the lunch break [112].

Another example is Birmingham, where, again, the City Council announced that the widespread presence of takeaway and fast food restaurants is a contributor to the obesogenic environment. Some of the schools in Birmingham have as many as 19 fast food shops within approximately 400 m. The City Council decided that this growth must be stopped; in 2012, it announced that the number of hot food takeaways must be limited to 10% on high streets and in any shopping areas. Since the inauguration of the limitation plan in 2014, 15 out of 36 applications to start HFTs have been refused. In 2015, the total number of refused applications reached 26 out of 42 [113, 114].

In Peterborough, 65% of adults, 30% of 10–to 11-years and 25% of 4–to 5-years are obese or overweight. These percentages are near the average obesity and overweight status in England. Peterborough City Council's annual report for 2015 mentioned that improving access to healthy foods and reducing concentration of fast food outlets are important solutions. Therefore, actions should be taken concerning the number of fast food stores near schools, workplaces and colleges to tackle obesity [115]. Furthermore, in Sandwell (2012), incorporation of school sectors with public health organisations has demonstrated an effective impact on the surrounding environment of schools, especially by implementing SPDs [48].

Similarly, in Liverpool, one of the plans to tackle obesity entails limiting the establishment of hot food takeaway outlets. The city council set the policy of limiting the number/concentration of takeaway hot food shops as a key priority. The proposed plan was expected to be submitted by the end of 2017, and would discuss regulation of the location of hot takeaway shops, such as preventing these shops from operating within 400 m of a secondary school boundary, and restrictions on opening times to limit the consumption of takeaway foods [116]. In 2018, the city council published their plan in line with the previous SPDs [117]. In Newcastle, an SPD was adopted in October 2016, wherein one of the policies focussed on the actual walking distance between secondary schools and surrounding HFTs rather than using a radius estimation tool (Figure 2-12).

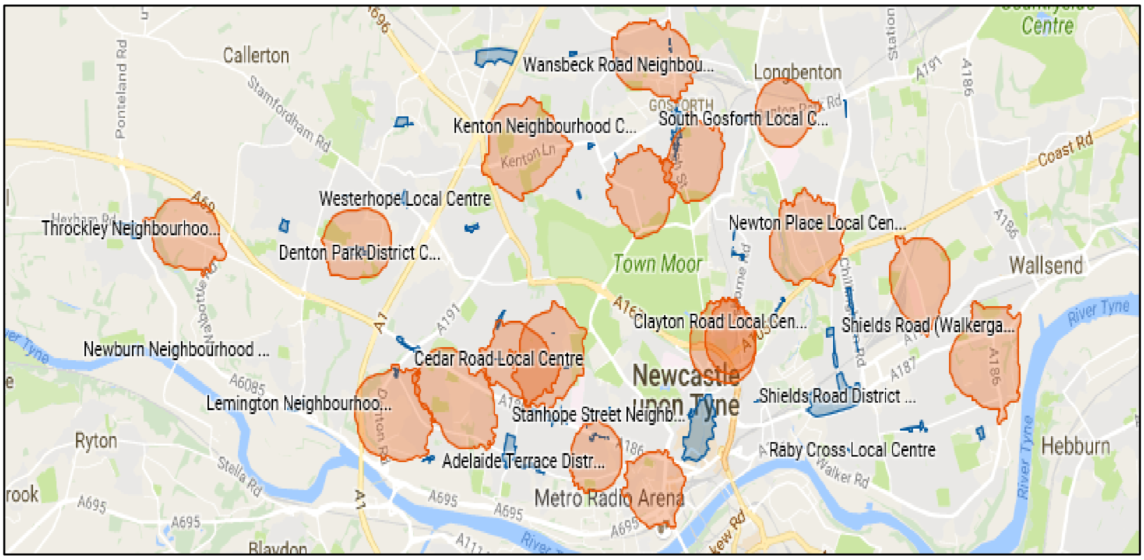


Figure 2-12 Map of secondary schools' restriction zones (orange areas) and hot food takeaways (blue areas) in Newcastle-upon-Tyne [108].

In addition, the Avon region including Bristol, South Gloucestershire, Bath and North East Somerset has proposed policies regarding the clustering of the HFTs (Table **2-3**; No 12-14). A Bristol-based study showed that parents are concerned about the clustering of takeaways outlets around schools and their homes ("When takeaways are everywhere, the children are going to buy it whenever they have the money," one mother said) [109]. In Bath and North East Somerset, the density of fast food outlets increased from 63 outlets per 100,000 population in 2010 to 70.3 outlets per 100,000 population in 2015 [118].

The proposed policies aim to create a healthier food zone and help young people maintain a healthy weight. This is primarily through imposing strict limitations on the number and opening hours of fast food outlets near schools and youth facilities and during school hours. Many other local authorities have designed or drafted their SPDs to limit the effect of hot takeaway food shops [108]. Table **2-3** shows examples of the latest action from city and local authority councils around the UK to improve food environments, particularly around primary and secondary schools. Some of the actions have not been updated since the first draft, while others have been updated by the councils following recommendations and suggestions published by organisations, such as PHE and DOH. In general, the finalised SPDs adopted by many authorities have focused on exclusion zones, where no hot takeaway food shops are allowed within 400-m to 800-m of primary and secondary schools, youth facilities, children’s playing fields or parks and leisure centres [104].

Table 2-3 Examples of city/local authority councils and their latest actions toward fast food (HFTs), particularly around schools.

No.	City/Local authority (Year)	SPDs adopt/draft date	Action proposed or taken	My comment	Since first draft
1	**Manchester City Council (2019) [119]**	March 2017	HFTs can be proposed within 400-m of a primary or secondary school if the hot food takeaway follows the time restriction. This time restriction differs between primary and secondary schools. Nevertheless, among secondary schools, HFTs must not open to public before 5:30 pm on weekdays. Manchester has used the 400-m buffer mainly because it equates to a 1-5 minute walk, which is considered a reasonable distance from schools to the food outlets.	Adolescents are willing to travel for a longer distance	Updated
2	**Warrington Borough City Council (2014) [107]**	April 2014	Same as Manchester City Council SPDs, and HFTs are not open to public before 5:00 pm on weekdays.	Not updated to reflect the follow-up of the policies. .Adolescents are willing to travel for a longer distance	Updated
3	**Halton Borough Council (2012) [120]**	March 2012	400-m exclusion zone for both primary and secondary schools	No restrictions mentioned on opening time	No update
4	**Gateshead Council (2015) [121]**	2015	No permission granted within 400-m radius of entry points of secondary schools, youth centres, leisure centres and parks	No restrictions mentioned on opening time	Updated

5	**Bradford Council (2014) [106]**	November 2014	No HFTs fall within 400-m of the boundary of an existing primary or secondary school or youth centred facility	No restrictions mentioned on opening time	No updated
6	**Liverpool City Council (2018) [117]**	January 2018	400-m exclusion buffer of the boundary of a secondary school or sixth form college and restriction of opening time to 5:00 pm on weekdays	NA	Updated
7	**Newcastle City Conuncil (2016) [108]**	October 2016	Exploring the traveling route to school within a proxy of HFTs as well as a 400-m radius buffer	NA	Updated
8	**Leeds City Council (2018) [122]**	November 2018	Restrictions for new A5 outlets within 400-m of a secondary school main school building.	NA	Updated
9	**Salford City Council (2014) [123]**	January 2014	400-m road network exclusion buffer of a secondary school and restriction of opening time to 5:00 pm on weekdays	400-m was set as distance that pupils are unlikely to access food outlets beyond this distance	No update
10	**Barking and Dagenham Council (2010) [124]**	July 2010	400-m exclusion buffer of a secondary school boundary	NA	No update
11	**Medway Council (2014) [125]**	July 2014	400-m circular buffer exclusion zone and restrictions of time only of newly established HFTs	NA	No update

12	**Bristol City Council (2017) [126]**	March 2017	Bristol City Council is evaluating the impact of increasing the prohibition radius of takeaway outlets around schools and youth facilities to 800-m instead of 400-m.	No information of implementation of the recommended suggestions	Updated
13	**South Gloucestershire Council (2018) [127]**	March 2018	Plan to restrict the proximity of HFTs within 400-m of schools and youth facilities and plan to restrict operating hours	No information of implementation of the recommended suggestions	updated
14	**Bath and North East Somerset Council (2018) [118]**	Winter 2018	Proposed policy to not permit the establishment of HFTs within the recommended distance (400-m) and to apply restrictions on operation hours	No information of implementation of the recommended suggestions	updated
15	**Nottingham City Council (2015) [128]**	November 2015	400-m from the nearest pedestrian entrance of a school to the main entrance of HFTs	No consideration of 800-m	Updated
16	**Wakefield Council (2016) [129]**	March 2016	Exclusion area of 400-m buffer around schools	No consideration of 800-m	Updated
17	**London Assembly (2019) [130]**	London Boroughs (New London Plan)	No permission within 400-m walking distance from an existing or proposed primary and secondary school If permission required, the operator has to operate in compliance with “the Healthier Catering Commitment standard”	No consideration of 800-m London is a special case where in-depth investigation is needed	Updated

2.7 The Food Environment Policy Index (Food-EPI)

The Food Foundation is a registered charity working in partnership with researchers, campaigners, community bodies, industry, government and citizens mainly to change food policy and business practice and making access to a healthy diet affordable by everyone [131]. This charity also works in collaboration with academic professionals researching into food policy, food consumption, obesity and population health. The Food Foundation has stated that several factors, such as food advertising, takeaway shop proliferation and promotion of unhealthy products, can lead consumers to eat unhealthy food choices. A tool called the Food Environment Policy Index (Food-EPI) was designed and implemented in England by the Food Foundation and being used by other organisations, such as the World Obesity Federation, Food Research Collaboration and International Network for Food and Obesity / non-communicable Diseases Research, Monitoring and Action Support (INFORMAS). This tool was developed to encourage, influence and fill the critical gaps in government polices to help create a healthy environment. The Food-EPI only focusses on food environment factors that have a direct relationship with consumer choice. The index consists of two main components: governmental polices and infrastructure support. Both components are further categorised into 13 domains representing the governmental polices and their infrastructure support. Government policies need to be effective to address, for example, the problem of the obesogenic environment. This can be achieved either by comparing the implementation of the policies in one country with those of other countries or by comparing those policies with a good practice statement, serving as a 'gold standard', which is usually set out by the government under each domain. Good practice statements refer to all of the statements that illustrate the measure such as policies and infrastructure support that the governments put in in place to create a healthier food environment.

First, the initial steps in order to develop the Food-EPI are to identify the critical gaps and to prioritise actions to review and compile all available evidence. Then, independent experts would be expected to produce reports for governments and stockholders after reviewing the available evidence and identifying critical gaps in the policies. In the Food-EPI, rating scores in the range of 1 – 5 points (1 = poor implementation and 5 = good implementation) were given by non-government members from an expert panel to government policies in comparison with both international examples and good practice statements [131]. First, experts had to rate the policies against international examples of best practice to illustrate how well England is doing compared to other countries. Second, experts had to rate policies against gold standard (as set out in the good practice statement) to illustrate is England doing as good as it should be). A list of International and good practice statements of examples where governments have taken action and leadership to improve food environments which therefore could be used as potential standards for other countries have been compiled by the INFORMAS group. Focusing on zoning laws and policies, the international examples includes both South Korea (the sale of foods considered unhealthy by the Food and Drug Administration of Korea are prohibited within 200 metres of schools) and Detroit in the US (the building of fast food restaurants within 500 feet are prohibited near of all elementary, junior and senior high schools). Nevertheless, 15 UK local authorities that have developed SPDs for considering the existence hot food takeaways were used as examples for developing the good practice statements. Results from the expert panel show that planning policies to limit takeaways scored less than 2.5 and 1.5 points against international examples and good practice statements, respectively. Experts have stated that the UK has a poor policy implementation record regarding food outlets, and nationally, no clear guidance has been provided on zoning regulations to encourage healthy food consumption.

2.8 International variations in methodology

Like the variations in policy at the national level, internationally different methods have been used in different countries to measure the food environment or evaluate its impact on health, particularly around schools. To make effective policies, the most appropriate tools to measure the food environment need to be evaluated. This could help determine the number of fast food outlets available within walking distances [132]. Worldwide, there are no standardised measures used to calculate the density and proximity of food outlets around homes, schools, work or any other facilities [133, 134]. The literature was searched at first to identify published articles that have used relevant methods to measure the food environment around any facilities. Next, inclusion criteria were applied to restrict articles to those that considered schools, geographical location of food outlets and have been published in English. Exclusion criteria were set in order to omit any articles that considered other facilities such as home and work places and did not consider geographical location of food outlet or were not available in English. It was observed that there were variations in the methodology used in these articles to measure the food environments around schools. The results are described below.

2.8.1 Methods of literature review search

The Web of Science was searched between 1980 and January, 10, 2019, with terms including “takeaway" OR "take-away" OR "take away" OR "fast food" OR "fast-food" OR fastfood OR "food outlet*" AND “location*” OR “geograph*” OR “GIS*” OR “proximit*”. Over 700 articles were examined by their titles at first. Then, if the title was relevant, the abstract of these articles was screened. After that, those articles using geographical methods to measure food environments particularly around schools were further examined by reading the methods and results sections. It should be noted that the exact number of articles screened at each step is not known as this information was not recorded at the time. This search of the existing studies showed that studies have employed diverse methods to evaluate the food environment (density, proximity and accessibility of fast food outlets) around schools (Table **2-4**).

2.8.2 Summary of search findings

In England, tackling childhood obesity by introducing the ‘zoning laws’ to limit the number of fast food outlets has been endorsed by all of PHE, the British Medical Association and the Mayor of London [135]. Nevertheless, it was observed that most studies were conducted in the US, amounting to 22 out of 61 total studies. Canada came second with 14 studies, followed by the UK with nine studies. New Zealand published seven studies related to the food environment around schools using geographical methods for evaluative purposes (Table **2-4**). Moreover, in the UK, the impact of reducing fast-food outlet density near schools on health has not been evaluated to date [48, 50, 104]. There is a need for more research in the UK which may help to inform policy makers about the likelihood of the effectiveness of an intervention within their current policy toolkit [136].

Not only that, but there was a variation in the methodology used to measure the food environment (straight line *vs* road network distances, circular *vs* road network buffers and size of buffers used) between the studies either conducted in the same or different countries. There was also a variation in the type (definition) of outlets, participants (age/education level) and outcomes (eating behaviour, obesity and food purchasing) to be studied and investigated.

Table 2-4 List of studies evaluating food environment around schools from 2005 to 2018 using Web of Science database.

UK Studies						
No	**Author/Year**	**design**	**Participants**	**Methods used for the analysis**	**Type of outlets**	**Variable of interest**
1	Blow et al. (2017) [137]	Ecological	53 Schools, colleges and universities	400-m Euclidean buffer radius around schools	Takeaway food	Analyse the food environment
2	Harrison et al. (2011) [138]	Cross-sectional	Primary schools	Neighbourhoods around homes and schools were defined as the area within 800-m road network	Takeaway and others	BMI
3	Green et al. (2018) [139]	Longitudinal	Adolescents home and secondary schools	Circular buffers with a 1-km Euclidean (straight line) radius	Fast food, and other retailers	BMI
4	Caraher et al. (2016) [140]	Ecological	Secondary schools.	Using 200-m, 400-m and 800-m isochrones around schools	Fast food and takeaway outlets	Pupil food purchases
5	Williams et al. (2015) [141]	Cross-sectional	4-11 years children's school and residential home locations	• 800-m street network buffer of school centroids and within • Home LSOA boundaries	Takeaway and fast food outlets	BMI
6	Caraher et al. (2014) [142]	Cross-sectional	15 London Secondary schools	Straight-line boundaries of 400-m and 800-m around each school	Fast food outlets	Eating habits and Nutrient content
7	Griffiths, Frearson et al. (2014) [136]	Cross-sectional	Home & secondary schools locations	• Straight line distance from each child's home and school postcode centroid to the nearest food outlet • Commuting routes (home to school) were calculated according to the shortest straight line distance	Takeaways and other outlets	Childhood obesity

8	Smith et al. (2013) [143]	Longitudinal study	Secondary schools (Year 7)	400-m and 800-m road network distance from the schools	Fast food (takeaway) and others	Healthy or unhealthy diet score
9	Ellaway et al. (2012) [144]	Cross-sectional	Glasgow public secondary schools	With straight-line boundaries of 400-m and 800-m around each school	Takeaways and others	social disadvantage
				US Studies		
1	Dwicakson o et al. (2018) [145]	Ecological study	Middle school students	The number of vendors per square mile	Fast-food restaurant and others	Obesity
2	Watts et al. (2018) [146]	Cross-sectional	Adolescents	• Home: Network buffer distances of 1200-m to 1600-m. • School: network buffers of 800-m	Fast-food restaurants and others	Sugar sweetened beverage
3	Thornton et al. (2016) [147]	Cross-sectional	Primary/ secondary schools	• Density: 0.5, 1 and 2-Km road network buffers • Proximity: road network nearest outlet	Fast food outlets	Analyse the food environment
4	D'Angelo et al. (2016) [148]	Cross-sectional	Primary/middle and high schools	Density: Euclidean radial buffers 800-m	Fast food outlets	Analyse the food environment
5	Burgoine et al. (2015) [149]	Cross-sectional	5–11 years children residential home addresses and schools location	800-m street network buffers	Takeaway food outlets and others	Comparing GIS and GPS results
6	Tang et al. (2014) [150]	Cross-sectional	Middle & high schools locations	• Presence or absence within 0.25-mile roadway network radius • Count measured the number within a 0.25-mile Euclidean radius	Limited-service restaurants	Students' Weight Status

7	Walker et al. (2014) [151]	Cross-sectional	Pre-kindergarten to grade 12 children schools	• 800-m circular buffered area • Straight line distance	Fast food restaurants and others	Number of outlet near schools
8	Alviola et al. (2014) [152]	Cross-sectional	2nd, 4th, 6th, 8th and 10th grade schools	• Number within 1-mile • Distance to the nearest major highway	Fast-food restaurants	Measured BMI.
9	Richmond et al. (2013) [153]	Cross-sectional	6th, 7th, and 8th grade middle school students from 47 schools	400-m &1500-m buffer area (equivalent to a 15 minute walk)	Convenience stores and fast food outlets	SSB consumption
10	Rossen et al. (2013) [154]	Longitudinal	Six urban public elementary schools(grades3–5)	• Direct (shortest) route along streets (meter) from home to school • Number of outlets within buffers (*e.g.*, 100, 400, and 800-m)	Restaurants and others	child's height, body weight, and WC
11	Langellier (2012) [155]	Cross-sectional	Elementary, middle and high public schools	Half-mile road network buffer around each school	Fast food restaurants and others	Overweight prevalence and schools types
12	Harris et al. (2011) [156]	Cross-sectional	High schools	Within 2-km (and the closest store if there were no stores within 2-km)	Restaurant and others	BMI
13	Howard et al. (2011) [157]	Cross-sectional	public school students in 5th, 7th and ninth grade	800-m network buffers around the final geocoded school points	Fast food restaurants and others	Students' body composition
14	Laska et al. (2010) [158]	Cross-sectional	11-18 years participants from schools	• Density: 800, 1600 and 3000-m street network buffers • Proximity: distance to the nearest fast-food restaurant	Fast food restaurants and others	BMI Z-score and percentage body fat
15	Neckerman et al. (2010) [159]	Cross-sectional	1579 schools	400-m and 800-m street network buffers	Fast food restaurants and others	The school environment

16	Kwate and Loh (2010) [160]	Cross-sectional	817 elementary and secondary schools	400-m straight line and road network buffers	Fast food restaurants and others	The school environment
17	Simon et al. (2008) [161]	Cross-sectional	1684 elementary, middle and high schools	at 400-m and 800-m in radius	Fast food restaurant	neighbourhood income and school level
18	Sturm (2008) [162]	Cross-sectional	31622 middle and high schools	Radius of 400-m and 800-m from the main entrance of public secondary schools	Limited-service restaurants	Analyse the food environment
19	Davis (2009) [163]	Cross-sectional	Middle and high schools	Outlet within half mile of a school classified as near restaurant	Fast-food restaurants	BMI
20	Kipke et al. (2007) [164]	Cross-sectional	Public schools	Proximity: the number within 300-m and 500-m buffer around each school	Fast-food outlets and others	Analyse the food environment
21	Sturm and Datar (2005) [165]	Longitudinal outcome	elementary school	Nothing presented in the paper	Fast-food restaurants and others	BMI
22	Austin et al. (2005) [166]	Cross-sectional	Kindergartens and primary and secondary schools	• The number within 400-m-radius and 800-m-radius buffers around each school • bivariate K function method	Fast-food restaurants	Analyse the food environment
			Canadian studies			
1	Daepp and Black (2017) [167]	Cross-sectional	26 schools	• Density: 800-m line-based buffers • Proximity: shortest road distance	Food outlets including restaurants	Validation of data source
2	DuBreck et al. (2018) [168]	Cross-sectional	Elementary schools zones	800-m and 1600-m network buffers	Restaurants food take-out and others	Analyse the food environment

3	Fitzpatrick et al. (2017) [169]	Longitudinal	8-10 years children school addresses	750-m road network buffers	Fast-food restaurants and others	Analyse the food environment
4	Cutumisu et al. (2017) [170]	Cross-sectional	374 Public secondary Schools	750-m street network buffers	Fast food outlets	Junk food consumption at lunchtime
5	Ravensbergen et al. (2016) [171]	Cross-sectional	Activity location?	500-m road network buffer	Fast food outlets	SES schools and Density of FF
6	Laxer and Janssen (2014) [172]	Cross-sectional	255 Canadian schools	1-Km circular buffer	Fast food restaurants	Fast food consumption
7	Browning et al. (2013) [173]	Cross-sectional	436 Canadian schools	The number within 1-km of schools	Fast food restaurants and others	Evaluating the food environments of schools
8	He et al. (2012) [174]	Cross-sectional	Age 11-14 years from elementary schools	A 1-km straight line buffer centred on the main entrance of the school	Fast-food outlets and others	Overall diet quality
9	Van Hulst et al. (2012) [175]	Cross-sectional	Youth aged 8-10 years from schools	• Distance to the nearest outlet • 1-km network buffers around each child's residence and school	Fast-food restaurants and others	Assess dietary intake
10	Black and Day (2012) [176]	Cross-sectional	Public schools	• 800-m within schools • Distance to the nearest outlet	Fast food outlets and others	Number of outlets within specified distance

11	He et al. (2012) [177]	Cross-sectional	21 elementary schools	1-km straight line buffer centred on the main entrance of the school. A	Fast-food outlets and others	Food purchasing habits
12	Sadler and Gilliland (2015) [178]	Cross-sectional	9-13 years children home and school location	Circular and network buffers at 500, 800, 1000, and 1600-m	Fast food restaurants	Comparing proxy methods
13	Kestens and Daniel (2010) [179]	Cross-sectional	1168 primary and secondary schools	• Proximity: road-network distance to the nearest outlet • Density: The number within 750-m of each school	Fast-food outlets and others	Neighbourhood income and clustering
14	Seliske et al. (2009) [180]	Cross-sectional	Elementary and high schools	Within a 1 and 5-km radius were estimated for each school	Fast food restaurants and others	SES neighbourhoods
				European Studies		
1	Timmermans et al. (2018) [181]	Cross-sectional	Secondary school In Netherlands	400-m road network buffer	Fast food, takeaway and other outlets	Analyse the food environment
2	Virtanen et al. (2015) [182]	Cross-sectional	lower secondary schools locations in Finland	Euclidean distances from each school to all fast food restaurants	Fast-food outlets	Eating habits and overweight
3	Callaghan et al. (2015) [183]	Cross-sectional	63 post-primary schools in Ireland	1- km of schools	Fast food restaurants and others	Distribution around schools
4	Buck et al. (2013) [184]	Pilot study	6-to9-year-oldschool children in Germany	Service areas of 1.5-km around each school to measure kernel density (number per km)	Fast food restaurants and others	BMI

New Zealand Studies

1	Walton et al. (2009) [185]	Cross-sectional	Primary schools	2-km road distance buffer around each school	local fast food; multinational fast food	Outdoor food advert
2	Day et al. (2015) [186]	Cross-sectional	primary/intermediate, middle or secondary	800-m Euclidean buffer (approximately 10-min walking time)	Takeaway foods and other outlets	clustering of food outlets around schools
3	Clark et al. (2014) [187]	Cross-sectional	Secondary schools location	An 800-m and 1500-m circular buffer zone	Takeaways and others	Diet quality
4	Day and Pearce (2011) [95]	cross-sectional	Primary, middle and secondary schools	A 400-m and 800-m road network buffer of each school (proportions of outlets per 1000 students)	Fast food outlets and others	Neighbourhood sociodemographic characteristics
5	Pearce et al. (2007) [188]	Cross-sectional	2652 schools	The distance from each school to the closest fast-food outlet (road network)	Fast-food outlets and others	neighbourhood income and school level
6	Vandevijvere et al. (2018) [189]	Cross-sectional	950 primary/secondary schools	500-m road network	Junk foods	Food advertisements around schools
7	Vandevijvere et al. (2016) [190]	Cross-sectional	Primary, intermediate, and secondary schools	• Radial buffers of 250, 500, and 800-m • Buffer roads 250, 500, and 800-m from each school entrance • A network buffer of 250, 500, and 800-m around schools	Fast food, takeaway and other outlets	Analyse the food environment

			Other Studies			
1	Timperio et al. (2009) [191]	Cross-sectional	Primary schools reception to year 6 in Australia	800-m road network buffers around home and en-route to schools	Takeaway or fast foods	Fast food consumption
2	Coffee et al. (2016) [192]	Ecological	Primary/ secondary schools in South Australia	1000-m and 1500-m road network buffers around schools	Fast and takeaway food outlets	Socio-economic status and food environment
3	Chiang et al. (2011) [193]	Cross-sectional	Elementary Schools in Taiwan	A circular buffer of 500-m	Fast food restaurants and others	Growth and body composition
4	Choo et al. (2017) [194]	Cross-sectional	9-12 years children community centres in South Korea	200-m straight line buffers	Fast food and other outlets	Fast food and sugar-sweetened beverage intake
5	Joo et al. (2015) [195]	Cross-sectional	Elementary, middle and high schools locations in South Korea	200-m, 400-m and 800-m radius around schools 200-m considered as safety requirements	Fast food restaurants	Dietary health of children

According to Food Foundation, strengthening planning policies to discourage unhealthy fast food is a top-ten priority. More so, it is suggested that this can (and does) exert a significant influence on the reduction of diet-related diseases and obesity [196]. As such, an urgent need is warranted for the development and adoption of a consistent approach to the methods used in measuring density, proximity or accessibility of food outlets, particularly around schools. Furthermore, this may enhance the consistency of policies that are to be implemented by government organisations and all related stakeholders so that the impact of limiting the number of takeaway outlets around schools is more effectively evaluated. This challenge is taken up in this thesis, and is explored at greater depth in Chapter 6.

2.9 Conclusion

This chapter has provided an overview of obesity status around the world and how different factors may exert an impact on the prevalence of obesity and healthy eating. In addition, a brief background on UK adolescents' diet quality was provided. The consumption of meals out of home (fast food) was associated with lower diet quality, including lower intakes of fruits and vegetables. Takeaway (fast) food is known to be high in saturated fat, carbohydrates and sugars, which may be a contributor to overweight and obesity. The consumption of takeaway food was also linked to the surrounding environment and how the availability of takeaway food outlets could encourage adolescents to consume more takeaway food. In addition, evaluating the impact of takeaway food consumption on diet quality has mainly relied on assessing the intake of individual food items and nutrients, where evaluating the overall diet quality is required.

The policy for limiting the number of takeaway meals was also reviewed in this chapter. At both national (UK) and local (city councils/local authorities) levels, different methods have been utilised to implement the policy. Moreover, at the international level, no standard methods have been used to evaluate the food environment, particularly around schools. In addition, the impact of any policy has not yet been evaluated by any of the local authorities in the UK. The use of a consistent approach to evaluate the food environment would allow better comparisons between studies and therefore may help implement more effective policies in the future.

Chapter 3 Methodology

3.1 Introduction

This thesis uses two sources of data for the subsequent analysis in later chapters. The first dataset is the National Diet and Nutrition Survey (NDNS). Currently, the UK data service has just released the Years 1–9 NDNS data. Nevertheless, in this study, two waves of the NDNS are used, Year 1–6 data in chapter 4 and Years 1–8 data in Chapter 5. The second dataset is the Avon Longitudinal Study for Parents and Children (ALSPAC). As is the case with the NDNS, the ALSPAC data also have different waves. However, in the ALSPAC the same participants were followed for several years. The ALSPAC data are used in Chapters 6 and 7. In these two chapters, the ordnance survey data are also used to source the location of the HFTs.

3.2 Surveys in the UK

Before describing the actual data used in this thesis, it is imperative to review different sources of data related to diet, nutrition and activities and children. In the UK, several longitudinal and cross-sectional national surveys exist, which consider useful outcome variables, including measured height and weight (to calculate BMI z-score) and physical activity level. However, some of these surveys do not include the targeted adolescent age group (11–18 years), and none of them have collected geographical data regarding school location. The only exception is the HBSC study wherein the data do consider the required variables (Figure **3-1**). These surveys were:

1. HBSC

The Health Behaviour in School-aged Children (HBSC) is a collaborative survey organised by the WHO and several European countries, including England. It is cross-national and aims to obtain more information about adolescents' health behaviour. Importantly, it addresses the major required variables which help explore the relationship between the food environment and health outcomes (BMI) of secondary school adolescents. In fact, the HBSC study is one of the few sources of information detailing adolescent behaviours, including eating and social behaviour, as well as related factors (*i.e.* school environment and family). Put together, all such factors help implement suitable interventions and/or polices, thereby allowing existing health, social and environmental problems to be more appropriately addressed and solved. England has been involved in the past four HBSC surveys (starting in 1997). Currently, the survey is funded by the DOH. The HBSC study is hosted by the Centre for Research in Primary and Community Care (CRIACC), an integral part of the University of Hertfordshire[31].

Students from years 7 (11–12 years), 9 (13–14 years) and 11 (15–16 years) were recruited for this study [197]. Although the HBSC study is reported to be the only source of information considering secondary school students in England [197], it is important to mention that the questionnaires were all filled in by the students themselves (self-report) (Table 3-1). Despite the data being requested through the available channels found in the HBSC study website, the answer was unfortunately negative (the reason for not sharing the data was that they were simply confidential data). Hence, it was not feasible to share these data in this study.

Table 3-1 List of health and physical activity variables and their categorisation scheme from the HBSC dataset.

Variable of interest: Health	Categorisation
How often do you usually have breakfast (more than a glass of milk or fruit juice)? on weekdays?	Never/1 day a week/2 days/3 days/4 days/5 days
How many times a week do you usually eat and drink: fruits, vegetables, sweets (candy or chocolate), fizzy drinks, squash, energy drinks, vegetable?	Never/less than once a week/once a week/2–4 days a week/5–6 days a week/once a day, every day/ every day, more than once
Do you eat at least 5 portions of fruit or vegetables a day?	Yes/No
How often do you eat in a fast food restaurant? (*e.g.* McDonald's, Burger King, Subway, KFC)	Never/less than once a month/once a month/2–3 times a month/once a week/2–4 days/5 or more days a week)
Variable of interest: Physical activity	**Categorisation**

Over the past 7 days, on how many days were you physically active for a total of at least 1 hour (60 minutes) per day?	0/1/2/3/4/5/6/7
How often do you usually exercise in your free time so much that you get out of breath or sweat?	Every day/4–6 times/2–3 times/once a week/once a month/less than once a month/never)
Variable of interest: Health outcome	**Categorisation**
Weight	How much do you weigh without clothes?
Height	How tall are you without shoes?

2. National Child Measurement Programme (NCMP)

This survey is recognised as one of the world-class sources of public health status in the UK. Both height and weight are measured by trained professionals for all children (with their parents'/carers' authorisation) in reception year (5–6 years) and in Year 6 (10–11 years). The survey only focuses on children who are at the primary education level [198]. In this thesis, adolescents aged 11–18 years are the targeted age group. In contrast, the NCMP survey only included children aged 5–11 years. Therefore, this survey could not be used in this study.

3. Health Survey for England (HSE)

The Health Survey for England is an annual survey which started in 1991, and since 2002, the study has collected data for all age groups (from 0–15 years and 16 years and over). Although the HSE study is an annual survey that allows an examination of aggregate change over time (*e.g.* obesity trends), participants are not followed for the remaining years. Thus, it is a reported cross-sectional study, rather than a longitudinal study. The main reason for excluding the HSE as a source of data in this research was because one of the primary variables was not available in the dataset. This variable was the geographical location of schools, and it was not clear from their user guide and variable catalogue whether any spatial data regarding schools would be available or not. Therefore, an e-mail was sent to both the NHS team and NatCen Social Research, who were responsible for carrying out the HSE survey. The main question asked about geographical data; both NHS and NatCen teams stated that they did not collect school-level information as part of HSE.

4. UK Biobank

Between 2006 and 2010, the biobank study recruited 500,000 adults aged 40 to 69 years old with no age limit specified. All participants agreed to be surveyed for any health outcomes, and the data collection involved blood measurements, urine and saliva samples. Unfortunately, this study could not be used as younger age groups were not included in the Biobank survey. Therefore, it was not suitable for this study.

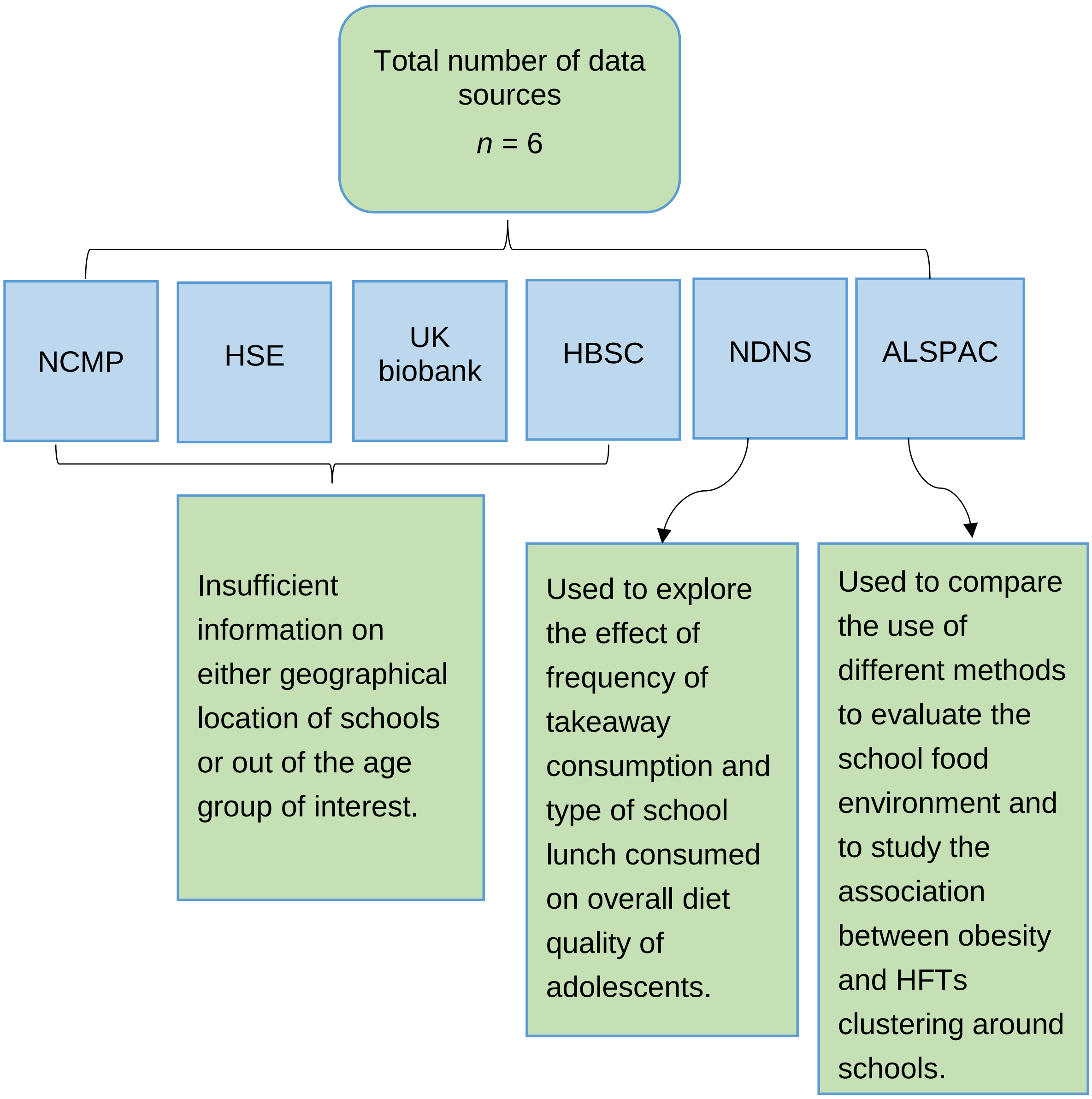


Figure 3-1 Potential sources of data in the UK.

There are several strengths to the different studies including HBSC, NCMP, HSE and UK biobank. The HBSC study was among the first international surveys on adolescent health and includes more than 40 countries and regions which allows for cross comparisons between countries. One of the main strengths of NCMP and HSE is the inclusion of large numbers of participants with measured height and weight which could help in tracking changes in weight status of the UK population. The biobank study also consists of a large sample and prolonged follow-up of participants. Nevertheless, these different sources of data also have some limitations. For example, HBSC, NCMP and HSE are all cross-sectional surveys. Therefore, the dietary behaviour of an individual is not captured over time due to the design of the study (captures a population at a single point in time only). Moreover, in the HBSC and biobank surveys, the questionnaires were all filled in by the participants themselves (self-reported) and that could lead to inaccurate answers regarding their weight, energy and food intake (introducing bias). Although these different sources of data consider useful outcome variables, including measured height and weight (to calculate BMI z-score) and physical activity level, these different studies could not be used in this thesis either because they did not include younger participants (11-18 years) or because they did not collect information regarding school geographical location.

In this thesis, the diet quality and BMI values of participating young people were the primary concerns and these were the focus in the NDNS and ALSPAC studies. Diet quality is assessed using a validated DQI designed to evaluate adolescents' dietary intake. Also, in this research, the BMIs for participants aged 12–18 years are based on a percentile growth chart that considers growth patterns, age and gender using the British 1990 growth reference. However, data sources used for assessing BMI (height and weight) need to be considered because many sources depend on self-reported data which can lead to bias [199]. This chapter discusses and explores in depth both the NDNS, ALSPAC, and the Ordnance survey (OS) data.

3.3 The NDNS

The NDNS is an annual programme that aims to assess the nutritional status of UK people living in private households aged 1.5 years upwards. In each year of the survey, samples of 500 adults (aged 19 years and over) and 500 children (aged 1.5–18 years) are recruited. This survey is conducted via the coordination of public health sector organisations, such as the DOH, PHE and Food Standards Agency (FSA), with the help of other organisations in different roles. The sample collection procedures are conducted randomly, representing the whole UK population by covering all four regions of the United Kingdom (England, Wales, Scotland and Northern Ireland) and being carried out throughout the year (four different quarters).

3.3.1 Collection of data for the NDNS

Totals of 21573, 8879 and 8848 addresses were drawn from a total of 799, 323 and 316 postcodes across the United Kingdom in the years 1–4, 5–6 and 7–8 rolling programme, respectively (Figure 3-2). To ensure that the survey was cost-effective, addresses were first clustered into smaller geographical areas for selection. Participants living at the selected addresses were randomly chosen, including one adult (19 years and over) and one child (1.5–18 years), and the other children were used as boosters for the number of children, particularly in Scotland and Northern Ireland. If there was more than one household in the same address post code, one of the houses was randomly selected. In total, 3450 adults and 3378 children in years 1–4, 1288 adults and 1258 children in years 5–6 and 1417 adults and 1306 children in years 7–8 gave a fully responsive interview.

Computer-assisted personal interviewing (CAPI; with an interviewer present) was carried out to collect information on height and weight, dietary habits, sociodemographic status, physical activity and lifestyle. Then, participants were asked to complete a 4-day food diary, and only those who completed at least a 3-day record were recruited in the analysis. Children aged 12 years and over had to complete the food diary independently, while parents or carers of younger children completed the food diary for them. Different versions of the food diary were designed to suit each age group, and participants were asked to report everything they ate or drank inside and/or outside of the house, including leftover foods. Interviewers checked the participants' procedure on the second or third day after the food diary was distributed either by phone or by visiting the participants' homes. Moreover, to improve the quality of the food recorded, tools like the food photograph atlas were used for children to provide information about portion sizes for about 44 commonly consumed foods. Then, the 'Diet In Nutrients

Out' (DINO) dietary assessment tool, in conjunction with the food composition NDNS databank, was used to enter recorded foods and convert them into nutrients [200].

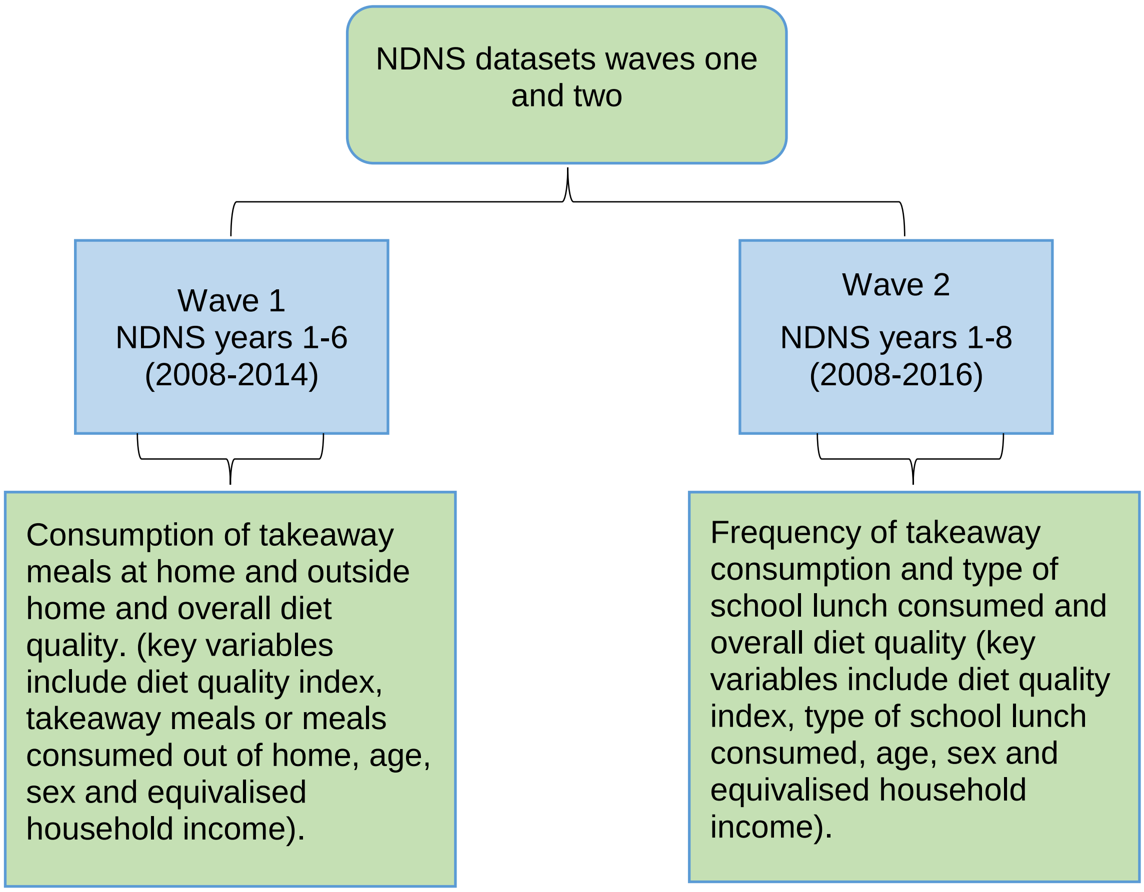


Figure 3-2 Different sources of NDNS data.

3.3.2 Processing data before analysis

The data were obtained from the UK data service website (**https://ukdataservice.ac.uk/**). The University of Leeds is part of the UK Access Management Federation (UKAMF), which allows all students to have access to the UK data service website and download available sets of data for free. Authors are required to fill in an online application and then the selected data can be downloaded in several formats. For more details, see Appendix 1.

3.3.3 Merging datasets from NDNS

The NDNS provided different sets of variables in different source datasets, merging options using statistical software (Stata) programme were used. The dietary dataset from NDNS was merged with either household or individual datasets. It was possible to combine two sets of data using 'ISERIAL' as the unique identifier for individuals (Figure 3-3) [(Appendix 2 – (1. Merging datasets)]. In addition, the datasets for Years 1–4, 5–6 and 7–8 were combined (Appended), as each of these was provided individually by NDNS [(Appendix 2 – (2. Append datasets)].

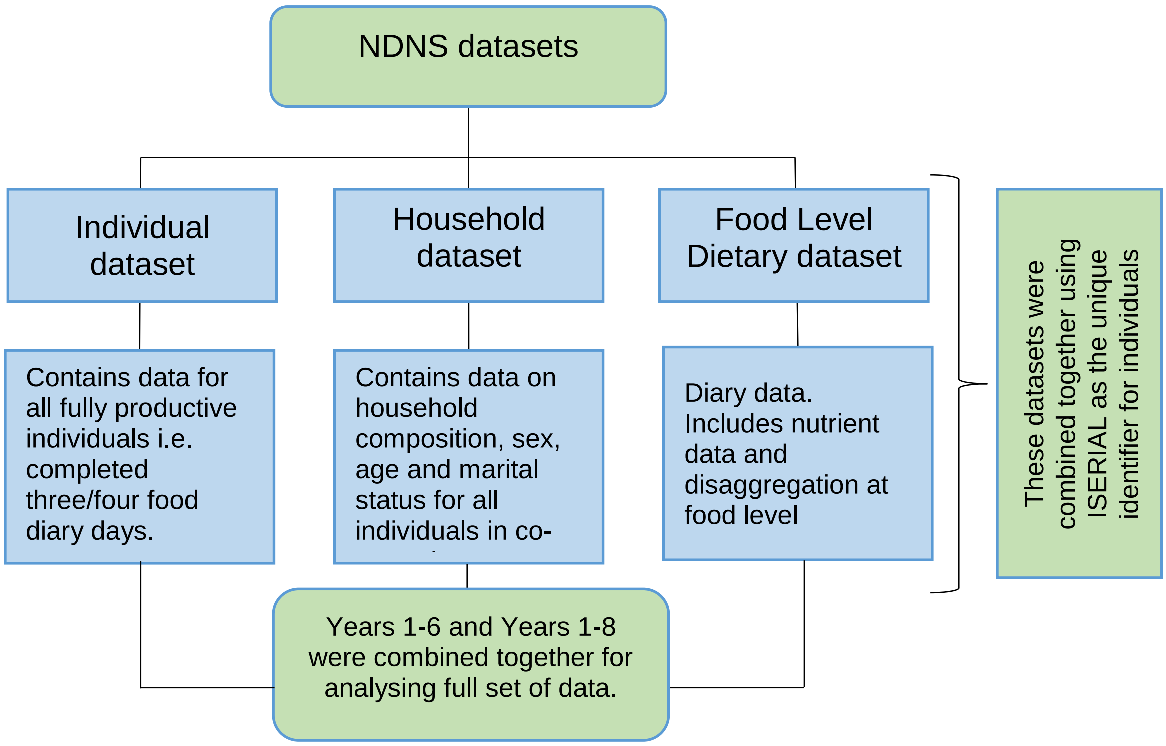


Figure 3-3 Illustration of construction of different sets of data from NDNS

3.3.4 Transferring the data

To calculate each diet quality component, it was most practical to transfer the mean amount and portion size of each of the food groups consumed in either the ‘food level dietary data’ dataset or the ‘personal level dietary data’ dataset from Stata software to an Excel sheet. In Excel, details of how food groups can be categorised and classified were examined. However, to avoid any possible human error using Excel, the score of each of the diet quality components and sub-components was calculated in Stata and merged with the original NDNS dataset for further analysis.

3.3.5 Weights

Applying weight analysis to a dataset is required to adjust for nonresponses, for example, in the NDNS for individual and/or household datasets. The weighting variable provided in the NDNS guideline report was used, allowing generation of an equal distribution of the selected population across the four parts of the UK; thus, the results obtained from the year 1 to year 8 surveys can be used together. However, because the years 1–4, years 5–6 and years 7–8 datasets were provided separately, each of these datasets requires a different calculation to ensure the weighting of each dataset in the correct proportion [(Appendix 2 – (3. weighting the data)].

3.3.6 Normal distribution

The distribution of variables was checked before any statistical test was performed, including comparison of means by the *t*-test, analysis of variance (ANOVA) comparison test and multiple or linear regression analysis.

3.3.7 Robust standard errors

The use of the robust standard errors is essential if we are using data where the same individual can provide information more than once (ignoring the fact that each of the individuals appears on average four times in the data). This can avoid the possibility of having statistically significant coefficients due to the underestimation of the standard errors of the coefficients of the independent variables. Simply, because individuals are clustered on their ID number (seriali) in the data, using the cluster command in Stata allows us to treat only those observations with different individual seriali as truly independent (*n* =2045). Therefore, within the regression model the cluster (seriali) option was used as in the following example:

```
reg overallDQIscore ib(last).Moutcon age Sex i.EHHIquantiles, cluster ( seriali )
```

Where

- overallDQIscore; Dietary quality component score
- Moutcon; Frequency of meals-out consumption
- Age; Age of participants in years
- Sex; gender of participants (male/female)
- EHHIquantiles; Equivalised household income in quantiles
- Seriali; Unique Id number of the NDNS participants

3.3.8 Collapsing the data

In order to calculate the mean score of the diet quality index, its components, age and Food energy intake, the collapsing command is needed. The mean score for each of the previously mentioned variables was calculated for each individual (*n* = 2045) by using the following command in Stata:

```
collapse (mean) overallDQcpercentage overallDQIscore , by (seriali Takeawaycon Moutcon )
```

Where

- OverallDQcpercentage; Dietary quality component score
- Takeawaycon; Frequency of takeaway meals consumption

By including the takeaway and meals-out variables, the mean score was not only sorted by the ID (seriali) but also by those variables. In addition, the variable after the seriali can be substituted based on the type of test that needs to be conducted. For example, the mean score of DQI-A was calculated based on gender (male/female) and the type of school lunch (School meals, packed lunch… *etc*). The commands used to process the data in Chapter 4 mentioned above were also used to process the data in Chapter 5.

3.4 Construction of the DQI-A

Many of the recent available diet quality assessment tools have been developed from existing indices such as HEI and DQI. DQIs are mainly developed to be used in specific populations; nevertheless many studies have used them (with or without modifications) for different populations and locations. The DQI was originally developed as a composite assessment of diet and consisted of measures relating to eight food groups and nutrient recommendations from the Committee on Diet and Health of the National Research Council Food and Nutrition Board [201]. The development of the original diet quality index and its updates were based on dietary recommendations for adults and therefore they are unsuitable for younger populations including children and adolescents [202].

The DQI-International, Mediterranean DQI, DQI for pre-schoolers and DQI for Adolescents (DQI-A) are adapted or updated tools from the original DQI. The need for a simple, easy-to-interpret tool, suitable for assessing the quality of adolescent diets without requiring intensive conversion analysis of foods to nutrients, resulted in the development of the DQI-A by Vyncke, Fernandez et al. (2013) [36]. The DQI-A is based on the intake of food groups without including the intake of nutrients. It was adapted itself from the validated index called the Diet Quality Index for Preschool Children which was derived from the original DQI. The DQI-A was mainly developed to assess the degree of adherence of an adolescent diet to the Food-based Dietary Guidelines (FBDGs) [43] as opposed to nutrient guidelines.

The FBDGs, also known as dietary guidelines, are used to provide information for different government sectors to implement and evaluate interventions encouraging healthy eating. These guidelines target the general (healthy) population and contain advice on what to eat in terms of foods rather than nutrients. For example, individuals should eat a variety of different food groups and eat five portions of fruits and vegetables each day [36].

The Flemish FBDG, was used by Vyncke, Fernandez et al. (2013) [36] to validate the DQI-A by comparing the associations with food and nutrient intake as well as a number of blood biomarkers. In this thesis, the Flemish FBDG was used to calculate the DQI-A due to the fact that the Eat-well guide did not provide recommendations on the maximum and minimum intakes of each of the food group listed in the guide. This is needed to calculate the dietary equilibrium component which is a key part of the overall diet quality index for adolescents. There is no direct relationship between the FBDG (which consists of nine food groups) and the UK Eat-well guide (which consists of seven food groups). Nevertheless, it is important to highlight the fact that both guidelines consist mostly of the same recommended food groups as can be seen in Figure 3-4. The Eat-well guide published in 2016 by PHE and consisting of seven main food groups: (1) potatoes, bread, rice, pasta and other starchy carbohydrates; (2) dairy and alternatives; (3) beans, pulses, fish, eggs, meat and other proteins; (4) fruit and vegetables; (5) oil and spreads; (6) water; and (7) confectionary and high fat and sugar snacks [44, 203]. Like the FBDG, the DQI-A relies on three main components, namely: the quality, diversity and equilibrium of the diet compared with the governmental dietary guidelines. Each component has its own definition and technique for the scoring criteria [36].

3.4.1 Dietary Quality component (DQc)

This component assesses diet based on the quality of the food obtained within the nine recommended food groups, namely: (1) water; (2) bread and cereal; (3) potatoes and grains; (4) vegetables; (5) fruits; (6) milk products; (7) cheese; (8) meat, fish and substitutes; (9) fat and oils. To calculate the score, the amount of food consumed (m) from each food group is multiplied by a weighting factor. The weighting factor is divided into three groups: the preference, intermediate and low-nutrient/energy-dense groups. Each weighting factor has an associated digit as follows: '+1' for the preference group, including cereal/brown bread, fish and fresh fruit; '0' for intermediate group, including white bread and minced meat; and '–1' for the low-nutrient/energy-dense group, including soft drinks, sweet snacks and chicken nuggets.

To calculate the dietary quality for a selected food group, the items in this group must be categorised. For example, the fruit group consists of six food items: fresh fruit, canned fruit, dried fruit, fruit juice, smoothies, and sugars, preserves and sweet spreads (Table 3-2 describes how the food items are categorised into each of the weighting factor groups). Given the above information, the dietary quality of this food group (fruit) for each individual is calculated using the following equation: the amount of the food item consumed (m) X weighting factor. Next, the final dietary quality score for this component is calculated using the following equation: ∑ (DQ) / ∑ m × 100%. Here, the sum of the diet quality score is divided by the sum of the total amount of food consumed (in grams) and multiplied by 100. For more details and examples of the classification of food items and the scoring criteria of the weighting factors, see published information [36]. In addition, more details can be found in Appendix 4 on how the “Food level dietary data” dataset was used to reclassify the food groups and provide an accurate calculation for the DQc.

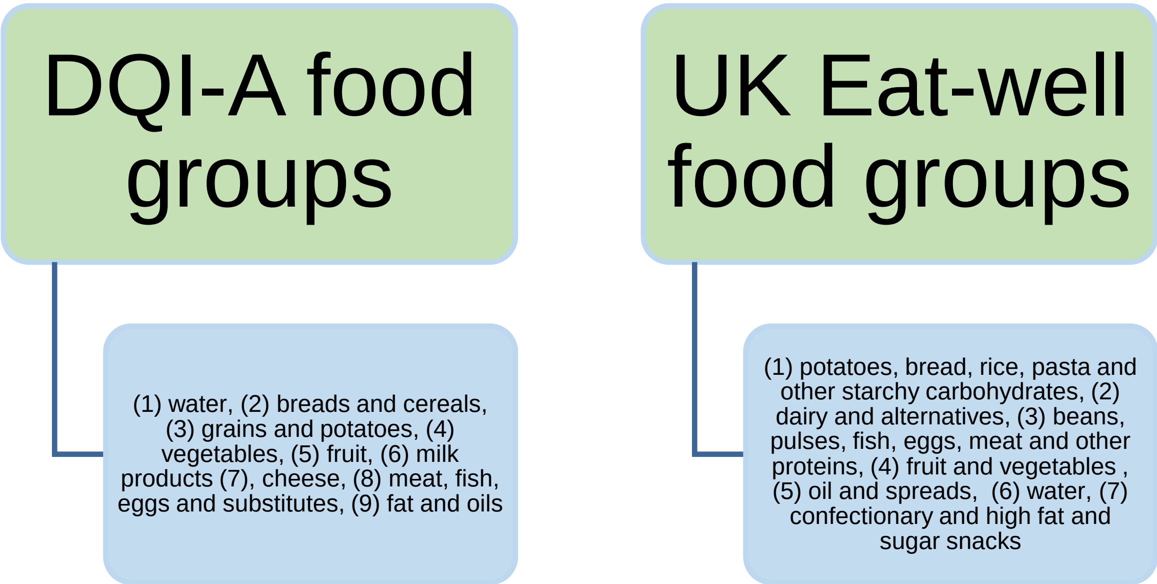


Figure 3-4 The difference between the numbers of groups in the Diet Quality Index for Adolescents (DQI-A) and UK Eat-well guide.

3.4.2 Dietary Diversity component (DDc)

The dietary diversity component (DDc) assesses the degree of variation in an adolescent diet, where the scoring range is from 0 to 9 points. Consuming at least one serving from each of the nine recommended food groups adds one point to the total score. For example, if an individual's mean consumption of the fruit group is more than 80 g, this individual's score is 1; otherwise, the score is 0. The final score for this component is calculated using the equation $\sum$ (DD) / 9 × 100% (sum of DD points for all nine food groups for each individual). The Eat-well guide does not provide information regarding portion and/or serving size for all the recommended food groups. Consequently, the portion size recommended by the British Dietetic Association (BDA) was used as follows: (1) water, 200 ml; (2) bread and cereal, 35 g; (3) potatoes and grains, 175 g; (4) vegetables, 80 g; (5) fruits, 80 g; (6) milk products, 200 ml; (7) cheese, 30 g (8) meat, fish and substitutes, 100 g; and (9) fat and oils, 4 g. To obtain a more accurate measurement of recommended portion sizes of these food groups, other reference sources were consulted, including those of the Food Standard Agency, especially, for adolescents age group [204, 205], and the British Nutrition Foundation (BNF) [206].

3.4.3 Dietary Equilibrium component (DEc)

The dietary equilibrium component (DEc) consists of two subcomponents: the adequacy component (diet adequacy, DAx) and the excess component (diet excess, DEx). These two subcomponents express the degree of adherence of an adolescent diet to the minimum and maximum intakes of each of the nine recommended food groups. The adequacy component represents the percentage of the minimum recommended intake of each of the nine food groups, converted to '1', whereas the excess component represents the percentage of the intake exceeding the upper limit of the recommendation (11 food groups, 9 recommended and 2 non-recommended), converted to '1' if larger than 1 and converted to '0' if below 0. In this context, the dietary equilibrium is calculated by subtracting DEx from DAx (*i.e.* DE = DAx – DEx), and the total dietary equilibrium score is calculated by dividing the sum of dietary equilibrium scores by 11 and multiplying by 100% ($\sum$ (DE) / 11 ×100%). The recommended daily intake of all food groups is based on the Flemish FBDG, where the minimum and maximum intakes of each of food group are listed. More details on how to calculate each of these subcomponents have previously been published [36].

The non-recommended food and drinks products listed in Table 3-3 have been mentioned based on guidelines provided by the Department of Health [203]. Tools such as the Eatwell plate were sources of information the researcher used to classify non-recommended food and drinks products.

3.4.4 Total DQI-A score

All three main components (dietary quality, dietary diversity and dietary equilibrium) are presented as percentages. The percentage ranges for both DDc and DEc are 0–100%, whereas the DQc percentage range is –100 to 100%. Therefore, the mean percentage of the three main components results in a DQI-A score ranging from –33 to 100%. A higher DQI-A percentage score reflects a better-quality diet.

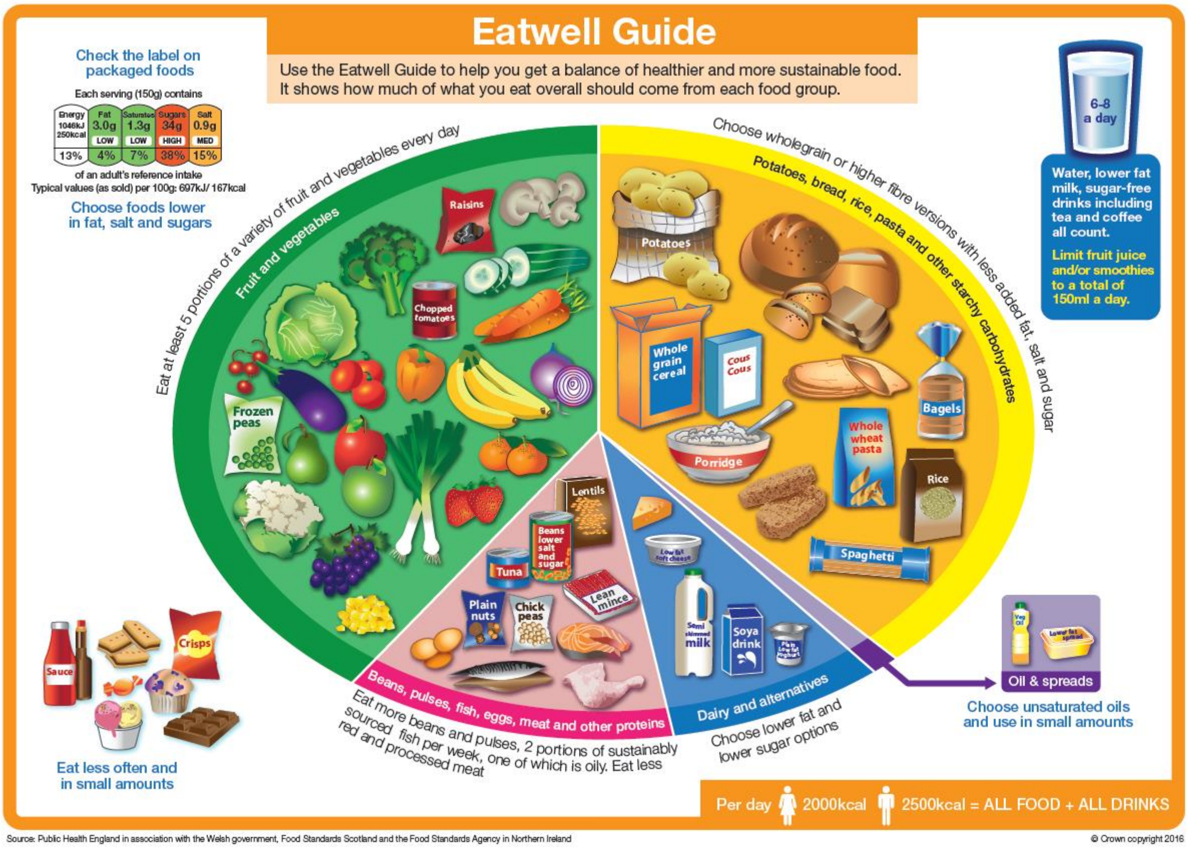


Figure 3-5 Recommended and non-recommended food groups in the Eat-well guide, the UK's Food-based Dietary Guideline (FBDG) [203]**.**

Although both the Flemish and US dietary guidelines have recommendations for the minimum and maximum daily intakes from food groups, the UK guidelines have a general recommendation on what a healthy plate should look like, including examples of healthy and unhealthy food choices (see, Figure 3-5) [207].

3.4.5 Food intake

Food intake was obtained from the 4-day diary records, and the mean value of the 4 days was calculated and used to assess the DQI of adolescents' participants. According to [36], the DQI-A score was calculated for each of the 4 days. In this study, adjusting for the fact that each individual has a 3- or 4-day diary record, the clustering command within the regression model was implemented. In addition, the average score of those daily 3 or 4 scores can be used to calculate each participant's score.

Therefore, the 'food-level dietary data' dataset has been used for the food group categorisation and the calculation of total intake of foods consumed by participants for each of the 4 days. In NDNS, each food group is labelled with the main food group code/name and subsidiary food group name/code (see, Appendix 3). The 'personal-level dietary data' dataset, wherein the mean intake of each food group was pre-calculated by the NDNS team, was also used to help in the food group categorisation and for calculating the mean DQI-A score (Table 3-4).

Table 3-2 Classification of food items in the nine recommended food groups from the National Diet and Nutrition Survey (NDNS) dataset, years 1–6.

	Weighting factors		
Food group	**Preference group (+1)**	**Intermediate group (0)**	**Low-nutrient, energy-dense group (–1)**
Water	1. Pure water	1. Other water, tea and coffee 2. Soup, homemade and retail	1. Soft drinks, low calorie 2. Spirits and liqueurs 3. Soft drinks, not low calorie 4. Wine 5. Beer, lager, cider and perry 6. Beverages dry weight
Bread and cereal	1. Wholemeal bread, 2. Brown granary and Wheat germ bread 3. High-fibre breakfast cereals	1. White bread 2. Other breakfast cereals 3. Other bread 4. Buns	1. Cakes 2. Pastries 3. Fruit pies, biscuits 4. Other puddings 5. Sugar confectionary 6. Non-dairy ice cream
Potatoes and grains	1. Nuts and seeds 2. Whole grains	1. Other potatoes and potato salad dishes 2. Other grain and cereals	1. Chips, fried and roasted potatoes 2. Crisps and savoury snacks
Vegetables	1. Beans and pulses 2. Yellow, green and red vegetables 3. Tomato 4. Brassicaceae 5. Other vegetables	1. Tomato puree 2. Tomato base 3. Tomato ketchup	1. None
Fruits	1. Fresh fruit	1. Dried fruit 2. Canned fruit 3. Fruit juice equal or less than 150 ml/d 4. Fruit smoothie equal or less than 150 ml/d	1. Fruit juice more than 150ml/d 2. Fruit smoothie more than 150ml/d 3. Sugars, preserves and sweet spreads

Milk products	1. Skimmed milk 2. Semi-skimmed milk 3. One per cent milk 4. Low-fat yogurt and fromage frais 5. Nutrition powders and drinks	1. Whole milk 2. Other yogurt, fromage frais and dairy desserts 3. Low-fat milk–based products	1. Dairy ice cream 2. Other milk and cream
Cheese	No cheese items, classified in preference group	1. Cottage cheese 2. Cheddar cheese 3. Other cheese	1. None
Meat	1. Beef and veal dishes 2. Other white fish, shellfish and fish dishes 3. Oily fish 4. Lamb and dishes 5. Chicken and turkey dishes	1. Eggs and eggs dishes 2. Liver dishes 3. Meat pies and pastries 4. Other meat and meat products 5. Pork and dishes	1. Burgers and kebabs 2. Coated chicken and turkey, manufactured 3. Bacon and ham, 4. Sausages 5. White fish, coated or fried
Oils and fat	1. Polyunsaturated fatty acid (PUFA) vegetable oils	1. Other margarine fats and oils 2. PUFA margarine 3. Reduced fat spread 4. Low fat spread	1. Butter 2. Chocolate confectionery

Table 3-3 Classification of food items in non-recommended food groups from the National Diet and Nutrition Survey (NDNS) dataset, years 1–6.

Foods	Drinks
Non-dairy ice-cream	Low calorie soft drinks
Other puddings	No low calorie soft drinks
Chocolate confectionary	Fruit juices > 150 ml/d
Sugar confectionary	Fruit smoothies > 150 ml/d
Buns and cakes	All alcoholic beverages
Biscuits	Beverages dry weight
Crisps and savoury snacks	
Butter	
Sugar preserves and sweet spreads	
Chips and fried potatoes	
Bacon and ham	
Burgers and kebabs	
Coated and fried chicken	
Sausages	
Dairy Ice-cream	
Other milk and cream	

Table 3-4 Details of food groups and/or products using the National Diet and Nutrition Survey (NDNS) 'Food-level Dietary Data' dataset.

Food group/product	Description
Pudding food products	Two different groups were generated: low-fat milk–based puddings and other puddings. All low-fat milk–based puddings were classified as intermediate food items within the milk food group; other puddings were classified as a low nutrient group in cereal based-products.
Yogurt, fromage frais and other dairy dessert food products	Two different groups were generated: the low-fat yogurt and fromage frais group and other yogurt and fromage frais group. All low-fat and free-fat yogurts were classified as preference food items in the milk food group, whereas other products were classified as intermediate nutrient foods in the milk food group due to their fat or sugar content.
Fruit	Two subgroups have been identified, one including fresh fruits and the other including canned and dried fruits. It is important to note that products like fruit juices and smoothies have also been categorised into two different groups (less than or equal to 150 ml/d and more than 150 ml/d).
Water	This food group was divided into two subgroups, the first including only tap water (preference group) and the second including all other water products (intermediate group).
Vegetable	Since canned, boiled, baked, fried and frozen vegetables were all classified as non-raw vegetables, it was difficult to differentiate the types of vegetables from the databank. Therefore, vegetable group categorisation was taken from the original NDNS databank without further classification. None of the vegetable food products were classified in the low-nutrient food group based on Flemish dietary guidelines. In addition, the NDNS team calculated the total vegetable intake of the recruited participants based on the following equation: TotalVeg = Beans g + Brassicaceae g + OtherVeg g + Tomatoes g + TomatoPuree g + YellowRedGreen g.
Cheese	Because none of the cheese products were labelled as less than 20% fat content, all types of cheese products were classified in the intermediate food group.

Ice cream products	Divided into two groups, dairy-based ice cream was categorised in the milk group, whereas non-dairy ice cream products were categorised within the low-nutrient cereal–based group due to high sugar content.
Meat	After assessing food subgroups and food names when required to calculate the dietary quality component (DQc) score, the description provided under the sub–food description for the meat group was clear and sufficient for categorisation, with the researcher cross-checking the use of individual Food Name variables.
Oil and fat	The polyunsaturated fatty acid (PUFA) margarine and oils group was classified as vegetable oil, as none of the participants consumed PUFA margarine when the study was conducted. Vegetable oil products included corn, sunflower and solid sunflower oils. Regarding the other oil and fat groups, no further exploration was needed.
Non-recommended food	According to the Flemish dietary guidelines, non-recommended food groups include snacks and candy, sugared drinks and fruit juice. However, with the use of the Eat-well guide (UK dietary guideline), non-recommended foods include products like cakes, ice cream, biscuits, crisps and chocolate. Therefore, both recommendations were used to assess the dietary excess component of the non-recommended food groups.
Grains and potato	This food group was divided into two subgroups, the first including wholemeal grains (preference group) and the second including all other grain and potato products (intermediate group).
Bread and cereal	The personal dietary data were used, where the mean daily intakes of all bread and cereal products were provided, as no further categorisation seemed necessary in this food group.
Milk group	All low-fat, milk–based puddings were classified as intermediate food items within the milk food group. Also, all low-fat and free-fat yogurts were classified as preference food items in the milk food group. It is fundamental to mention that nutrition powders and drinks products were categorised within the milk group.

3.5 ALSPAC data

The Avon region is the area where the main data used in our research in chapters 5 and 6 were collected (The Avon Longitudinal Study of Parent and Children – ALSPAC). A brief background of the study area and its obesity and demographic characteristics is useful.

3.5.1 Study area

The Avon region is a non-metropolitan county in the West of England and consists of four unitary authorities, including the City of Bristol, South Gloucestershire, North Somerset and Bath and North East Somerset [208]. Regarding the population, according to the latest statistics in 2016, the City of Bristol had the largest population, followed by South Gloucestershire, North Somerset and Bath, while North East Somerset had the smallest population in the Avon region [58]. On average, the total population across the local authorities in the Avon region has increased by 15.6% since 2005. This growth rate was higher than that observed in the entire population of the whole of England (10.7%). In addition, the population structure of the four local authorities was studied and compared with the population structure of England.

England

According to mid-2003 population estimates, 23.5% of the total population were young adolescents aged under 18 years living in England, whereas old people aged over 65 years represented only 15.9% of the total population. This structure remained true in England (mid-2016), as the percentage of young people of the total population aged under 18 years was 22.5% compared to 17.6% for old people aged over 65 years.

Bristol

In mid-2003, statistics showed that more children aged under 18 years were living in Bristol than were old people aged over 65 years.

Around 22% of the population in Bristol were young people aged 0-18 years as compared with 14.4% for older people.

Trends also showed that from mid-2005 to mid-2015, the greatest increase in population size was observed amongst children and adolescents aged 0-15 years.

These statistics were also true in mid-2016, as young people aged 0-18 years represented 21.7% of the total population compared with 13.1% for older people.

South Gloucestershire

In 2011, the urban area covered 80% of the total area of South Gloucestershire.

Similar to the City of Bristol, in mid-2003 the percentage of children and adolescents aged under 18 years was greater than that of those aged over 65 years with 23.7% of the total population.

Although the rate of older people aged over 65 years increased in mid-2016 (to reach 18.5% of the total population), children and young adolescents still represented a higher number with 22.0%.

North Somerset

In mid-2003, young people aged under 18 years old represented a greater percentage than did older people aged over 65 years, with 22.3% and 19.4% of the total population, respectively.

The mid-2016 statistics showed that a greater number of old people lived in North Somerset than did young people.

Although children and young adolescents represented 21.4% of the total population in 2016, North Somerset has a slightly different population structure, as 23.5% of the total population were people aged over 65 years.

Bath and North East Somerset

Also showed a young population profile, as 21.3% and 20.1% of the total population were young people aged under 18 years in mid-2003 and mid-2016, respectively.

Young people aged under 18 years were more than old people aged over 65 years in both mid-2003 and mid-2016.

Figure 3-6 Population structure of 4 local authorities and England [56-58].

3.5.2 Collection of data for the ALSPAC

ALSPAC is one of the world's leading birth cohort studies. More than 14500 pregnant women were recruited between April 1991 and December 1992 from the Avon region (City of Bristol, South Gloucestershire, North Somerset and Bath and Northeast Somerset). In the ALSPAC study, the total number of pregnant women's foetuses was 14676, which resulted in 14062 live births; 13988 children were alive at 1 year. Parents and their children were followed up intensively over a span of two decades to record all required information regarding their health, wellbeing and lifestyle (environmental and genetic information). Both questionnaire-based and clinical measurements were employed in the ALSPAC study. In this study, adolescents with a valid school ID (location) who completed food frequency questionnaires and/or attended clinic visits at 11,12, 13, 15 and 17 years of age were included [209].

Food frequency questionnaires and un-weighed diet records (for children only) were used to collect data about maternal and paternal diet, breastfeeding, weaning and childhood diet. Self-completion questionnaires (which included food frequency questionnaires) were sent to mothers and their partners at different times of the study; at 32 weeks of pregnancy and at 4, 8 and 12 years post-partum. Another postal questionnaire to assess children diets was sent to the mother once the child reached age 4, 6, 15 and 24 months. In addition, a full food frequency questionnaire was sent to the mother to complete when their child reached ages 3, 4, 7 and 9 years. If the questionnaires were not returned within 3 weeks, a reminder was sent to the mother followed by another reminder two weeks later. Finally, if there was no response after a month a telephone call was made. The food frequency questionnaire was enhanced during the study period by expanding the list of food groups to 56 (from a list of 43 food groups in the original questionnaire). More categories should help in providing a better assessment of the child’s and mother’s diet. Moreover, school meals consumed by children (provided by parents or the school) were also captured in the questionnaire.

In addition, about 10% of children at age 4, 8, 18 months, 3.5, 5 and 7 years were randomly selected and parents were asked to record (in a diary) all foods and drinks their child consumed over three individual days using un-weighed diet records. However, at age 10 and 13 years the children were asked to self-complete the diary with parental help. The fifth edition of McCance and Widdowson's food data tables was used to analyse the nutrient intake of the FFQ and diet records. Acceptable cut offs for intake were determined based on an inspection of the distribution of nutrients in the whole set to minimise misreporting of food intake. Nevertheless, due to a lack of time and funding, there has been a lack of rigorous validation of the dietary assessment methods used in the ALSPAC study which could affect the quality of the data.

3.5.3 Processing the data before analysis

The first step to request access to the ALSPAC data is to complete an online proposal form. This proposal should state the aim of the project, potential exposure and outcome and any possible confounders that need to be considered. Three postgraduate students were interested in the ALSPAC data, and therefore we decided to form a joint project data management plan which stated the aim of our projects, how data would be managed and stored and plans for data sharing (Appendix 5). Also, each of the researchers had to complete and sign an individual confidentiality from for access to ALSPAC data (Appendix 6).

All researchers were charged to gain access to the ALSPAC data. Briefly, the basic charge was £ 2715 for 50 standard variables and £ 170 for every additional 100 variables. An additional charge was requested as our research requires geographical variables, and we asked to gain access to school location and related variables, such as school deprivation level, percentage of free school meals and children deprivation score.

3.5.4 School identifiers

Pupils at key stages 2, 3, 4 and 5 (aged 11, 12, 13, 15 and 17 years) were involved in this study. For confidentiality purposes, the school codes could not be directly accessed by researchers; thus, ALSPAC derived a unique 9-digit school identifier (ALSPSCID). This identifier is available for key stages 2, 3, 4 and 5 (in key stage 5, the special code is called an 'establishment identifier' instead of 'school identifier'). For each of the three key stages, multiple records were identified and matched against the total of live born children. There were 12 233 at key stage 2, 10851 at key stage 3, 11764 at key stage 4 and 9449 at key stage 5. Therefore, each of the students recruited was allocated to a specific school identifier and mapped later in this study [210]. However, ALSPAC imposes a strict policy that must be followed to access geographical information (*i.e.* school location and home address). Their final decision made was, "no information on name of schools that each of students went to will be provided. Also, home addresses cannot be provided, due to ethical considerations (to prevent possibility that participants can be identified)". Therefore, the ALSPAC team reached a decision wherein names of schools that existed in 2005 were provided in random order where the researcher (AT) had to calculate density, proximity and accessibility scores for each of the schools in the Avon region. Subsequently, the ALSPAC team allocated the calculated scores for each adolescent based on the researcher's results.

3.5.5 Data processing and merging

Education data contain all the key stages (school identifier ID) information. All participants with missing and unavailable (applicable) data were dropped from the data set. After that, as was true of the NDNS data, both the education data set (individual IDs and key stages IDs) and school data sets (Key stages IDs and density, proximity and accessibility scores) were provided separately by the ALSPAC team in a format applicable for use with Stata software. Therefore, It was possible to combine (merge) these two data sets using the ‘’cidB27982’’ variable as the unique identifier for individuals. In addition, the same variable was used again to merge the newly generated dataset (the combined dataset containing both the density, proximity and accessibility of HFTs and key stages information) with data containing health outcome variables.

3.6 The ordnance survey (OS) database (City Councils)

Initially, historical data regarding hot food takeaways were not available from all city councils. The researcher sent a request to Gloucestershire City Council, asking for historical data pertinent to the number of hot food takeaways in the city. However, Gloucestershire City Council stated that only current data were available. Furthermore, it was not feasible to identify the numbers of hot food outlets year by year (historic data).

Several parameters have been used to classify and categorise food outlets by different agencies, such as commercial organisations (yellow pages) and local authorities (city councils). For example, studies may focus on specific types of outlet, including supermarkets or convenience stores, whereas others tend to focus on another kind of food outlet. such as restaurants or fast food outlets [211]. In addition to hot food takeaways, adolescents may have plenty of choices available to purchase unhealthy foods from shops around schools [48]. The Ordnance survey (OS) database ‘points of interests (POIs)’ includes all privately and publicly owned businesses in the UK. The database is updated four times every year. Therefore, a broad definition of fast food outlets and the most recent information can be secured. This database has previously been used to identify fast food outlets with an 81–100% accuracy level [212]. In addition, the POIs data have been validated against street audits in England and have shown a good agreement [213].

3.6.1 Collection of Ordnance Survey (OS) and Point of Interests (POIs) data

A request was submitted to the OS team to gain access to historic POIs data, covering the years 2003–2014. This request was granted under the university's OS Research Data Agreement, and the data were sent to the researcher by e-mail. In addition, the researcher was required to sign a Research Data Agreement with the Ordnance survey to obtain the data regarding the historical number of hot food takeaways in the Avon region (Appendix 7).

3.6.2 Classifying Point of Interests data

It is noteworthy that using a broad definition of takeaway (fast) food outlets may clash with most city councils' primary concern. Specifically, this concern focuses on the prevention of clustering of 'hot food takeaways' (fast food outlets) and not allowing a fast food outlet within 400 – 800 m of a secondary school. The Ordnance Survey has classified Points of Interests into 9 main groups and 52 categories; these groups and categories are broken down further into more than 600 classes. It was possible to obtain data regarding food outlets by referring to ''Eating and Drinking'' category from the Points of Interests dataset. Table 3-5 shows how this category was broken down into different classes. In this study, three classes within the eating and drinking category were considered hot food takeaways, namely: (1) Fast food and takeaway outlets, (2) Fast food delivery services and (3) Fish and chips shops. This was possible due to that fact that each of these classes has a unique ID code, which can be used to select the ones we are interested in examining (Table 3-5). This definition was also used by the PHE to identify the density of fast food outlets by local authorities [19].

Table 3-5 Classification scheme of Point of Interest data regarding eating and drinking category.

Main group (Accommodation, eating and drinking)		
Category	**Classes**	**Classification code**
Eating and Drinking	Banqueting and function rooms	0012
	Cafes, snack bars and tea rooms	0013
	Fast food and takeaway outlets	0018
	Fast food delivery services	0019
	Fish and chips shops	0020
	Internet cafes	0025
	Pubs, bars and inns	0034
	Restaurants	0043

3.6.3 Ordnance Survey POIs data analysis

During the data analysis in Avon, a sudden increase in the total number of hot food takeaways was identified in 2012 compared with the total number in previous years. Therefore, further communication took place with the POIs data supplier (Ordnance Survey), asking for more clarification on possible causes of this sudden change. The OS team stated that the misclassifying may be due to some data quality assurance at the time when the schema changed. The OS team also confirmed that the same 37 categories were used with a slightly more complex data structure [(Appendix 8 – (1. Response from OS team)].

However, when the researcher manually checked the data were (by comparing the names of the food outlets found in 2011 and 2012), misclassification was observed among some of the food outlets. Therefore, the food outlets' brand names were checked amongst all of the other classes within the eating and drinking category (Banqueting and function rooms, Cafes, snack bars and tea rooms, Internet cafes, Pubs, bars and inns and Restaurants) [Appendix 8 – (2.

Misclassification of some of the food outlets)]. Figure 3-7 illustrates some examples of the most well-known food outlets in the UK, which were categorised differently between the two different periods 2006–2011 and 2012–2017.

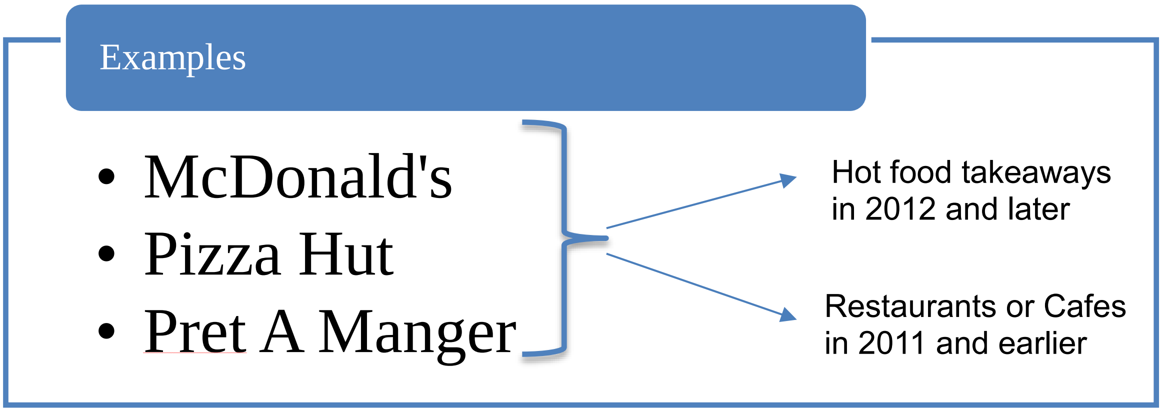


Figure 3-7 Categorisation or classification of some food outlets in two different years: 2011 and 2012.

Despite the data being rigorously checked by the researcher, no obvious explanation could be attained for this sudden increase. One plausibility could be because the fact that the company assigned to collect the data on behalf of the Ordnance Survey Company had a higher quality assurance. Alternatively, this sudden increase may have been a result of a genuine increase in the number of food outlets. Also, the POIs data are collected and updated quarterly every March, June, September and December [214] and the data obtained for conducting this research were supplied/collected in different months of the year (Table **3-6**).

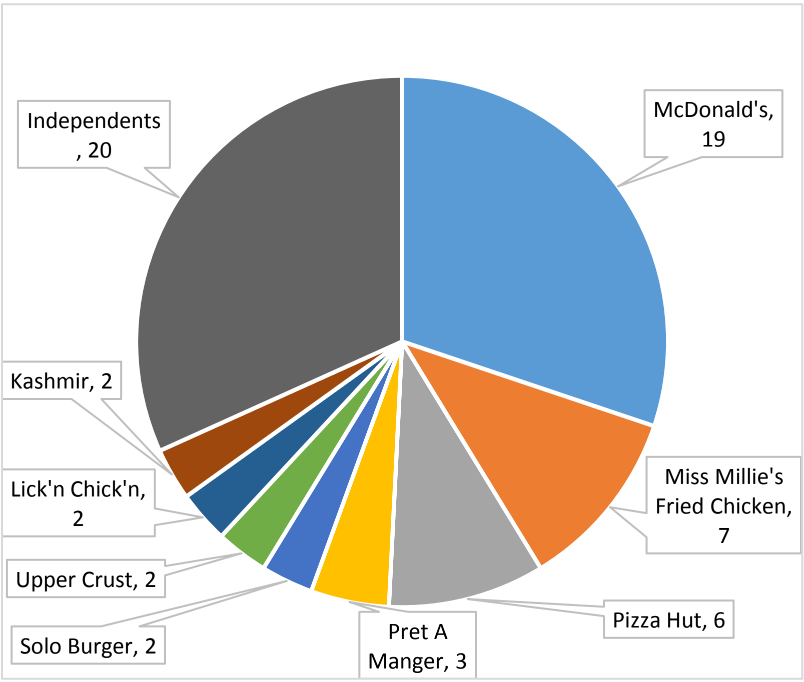
Table 3-6 Date of month when ordnance survey points of interest data were collected.

Year/s	Date and month of Supply
2006, 2007, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016 and 2017	1st of September
2005	28th of September
2008	1st of March

The 2012 reclassification resulted in an increase in the number of hot food takeaways in the following years: 2005, 2006, 2007, 2008, 2009, 2010 and 2011. The number of missing food outlets in each year before the data were checked manually is portrayed in Table **3-7** and Figure **3-8**.

Table 3-7 The number of misclassified restaurants and/or cafes in 2011 and earlier, with a breakdown of the names of the 63 missing food outlets in 2011.

Year	Number of missing HFTs
2005	30
2006	29
2007	31
2008	32
2009	49
2010	61
2011	63



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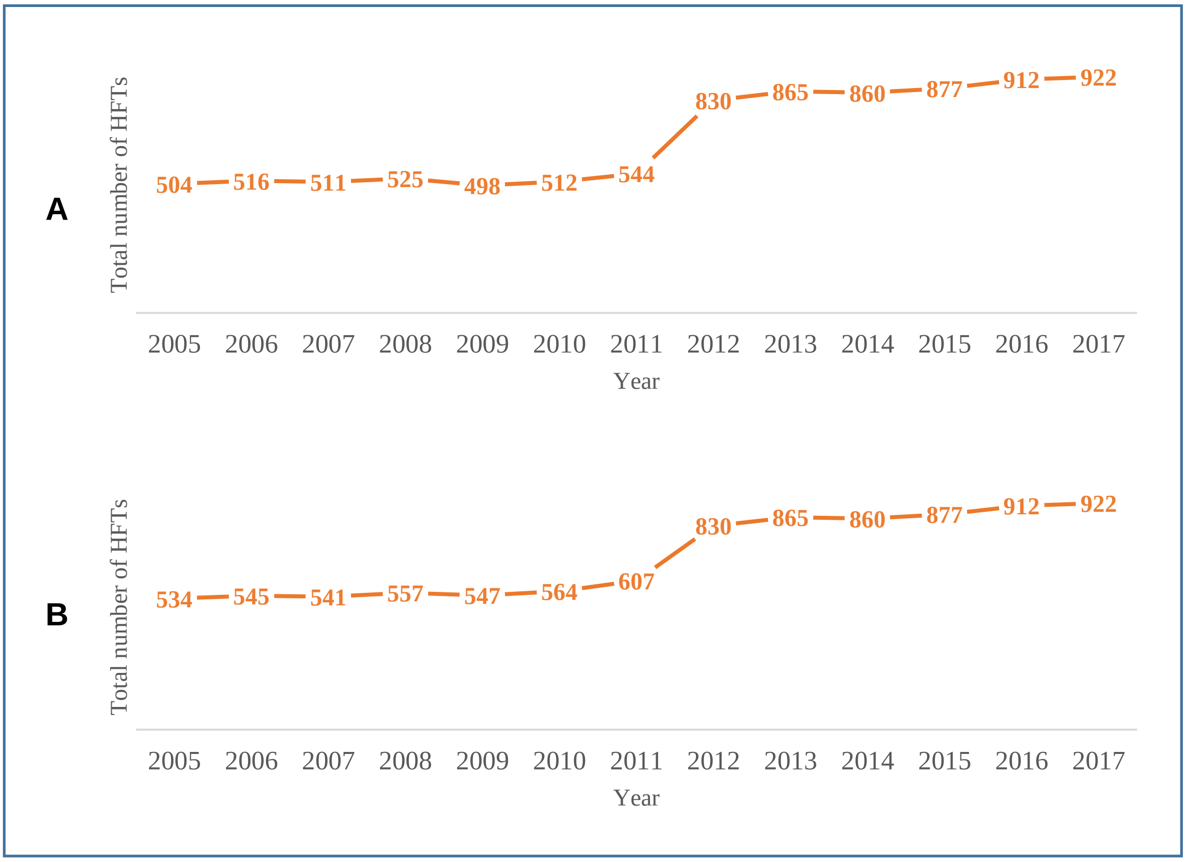


Figure 3-8 The total number of HFTs in the Avon region between 2005 and 2017 before (A) and after (B) class re-classification.

3.7 Schools

All secondary education phase schools in the Avon region were extracted from the Department for Education's official website (Gov.uk, Get Information About Schools). Only 'open' and 'open but proposed to close' schools were included in this list. In the ALSPAC data, closed schools were still included in the list provided. Figure 3-9 illustrates that some schools had to be excluded because they were located outside the study area of interest and were not secondary schools. The following exclusion criteria were additionally adopted:

1. Special education needs (SENs) schools, such as those concerned with communication and interaction; cognition and learning; social, emotional and mental health; and sensory and physical needs [215].
2. Pupil referral units (PRUs), which involve students unable to attend schools due to either short- or long-term illness [216].
3. Miscellaneous schools, due to lack of information regarding the total number of student's recruited and other related information.

Information on the number of students in each of the schools is required to calculate the density of HFTs based on student population numbers. The Department for Education's official website (Gov.uk, Get Information About Schools) was used for this purpose. The search engine available on the site allowed us to filter either by the name of the local authority or location using postcodes. Both filters were used to avoid any possible mistake that could take place during the search process. All relevant information about schools, including current status (closed or open), type of school, school capacity, education phase and age range, were obtained. This information was also used during subsequent data analysis. In the case of any of the information not being found on the Department for Education's website, the Google search engine was used to search for the individual school/college by its name. Then, from the school/college official website, the required information (such as the number of students on roll, type of school, school capacity and age range) was obtained.

In addition to obtaining historical data on the number of students registered in each of the schools, the Ofsted inspection reports for each of the schools were checked. Ofsted inspection reports contain information such as student number for that year, school type and age range allowed within this school. Using both data sources (Department for Education and Ofsted) reassured the quality of the information obtained, and this was later used to calculate the density of HFTs around schools in the Avon region. The number of students for that year for some schools was also checked with the official Department for Education's website (The National Archive). However, the lack of information for some schools (*e.g.* independent and special community schools) was one of the critical challenges faced during data collection. Therefore, if the required information could not be found on the official school's website, Department for Education's website, or from Ofsted inspection reports, the school capacity was used to represent the total number of students registered in that school.

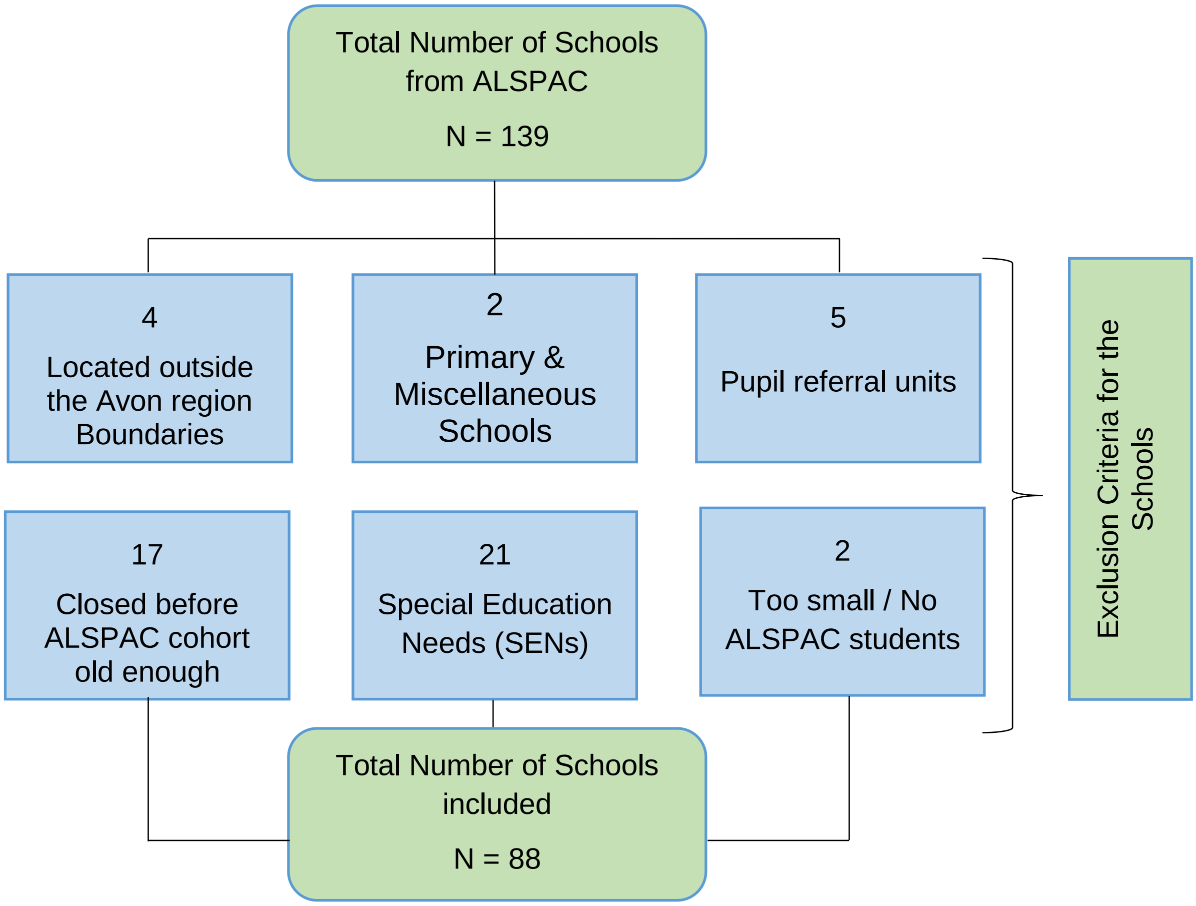


Figure 3-9 Exclusion criteria for the schools in the Avon region in the UK.

3.8 Index of Multiple Deprivation (IMD)

A score is commonly used to assess deprivation levels for census data, where a group of factors such as housing, level of employment, social class and owning a car are measured and combined. The Index of Multiple Deprivation (IMD) tool is used to assess deprivation levels of small areas (via Lower-Layer Super Output Areas; LSOAs). This is based on the 2011 census in England and starts from a score of 1 for the most deprived area to a score of 21,844 for the least deprived area. Generally, deprivation scores are usually categorised into 5 and/or 10 deciles, to simplify interpretation of results during analysis [217]. English indices of deprivation of the local authorities LSOAs were obtained for 2004, 2007, 2010 and 2015 from the National Archives of the Communities and Local Government [218]. The IMD scores were available as a continuous variable; therefore, the score was categorised into five quintiles. Using IMD that was calculated in different years (2004, 2007, 2010 and 2015) was essential because the numbers of HFTs were collected at different years. When the calculation was carried out to obtain the total number of HFTs in each year, two different census boundaries data were used, namely: LSOA 2001 and LSOA 2011. Each of the LSOAs located within the Avon region has a unique code. Therefore, it was possible to spatially represent the IMD score distribution using the quintiles classification in GIS (Figure 3-10 and Figure 3-11). Figure 3-10 and Figure 3-11 show that the IMD score of some of the LSOAs changed across the years. Importantly, this may help explore the historical context of changes that occur pertinent to the demographic and socioeconomic characterisations of the LSOAs throughout the years.

3.8.1 Number of HFTs by IMD quintiles

Each LSOA located in the Avon has a unique code. Furthermore, it was possible to identify the IMD score for each of the LSOAs. Therefore, to calculate the number of HFTs by IMD levels, the number of HFTs falling inside the LSOAs needs to be identified. This was done using the available feature in Geographical Information System (GIS) software “Select by Location” (Appendix 9).

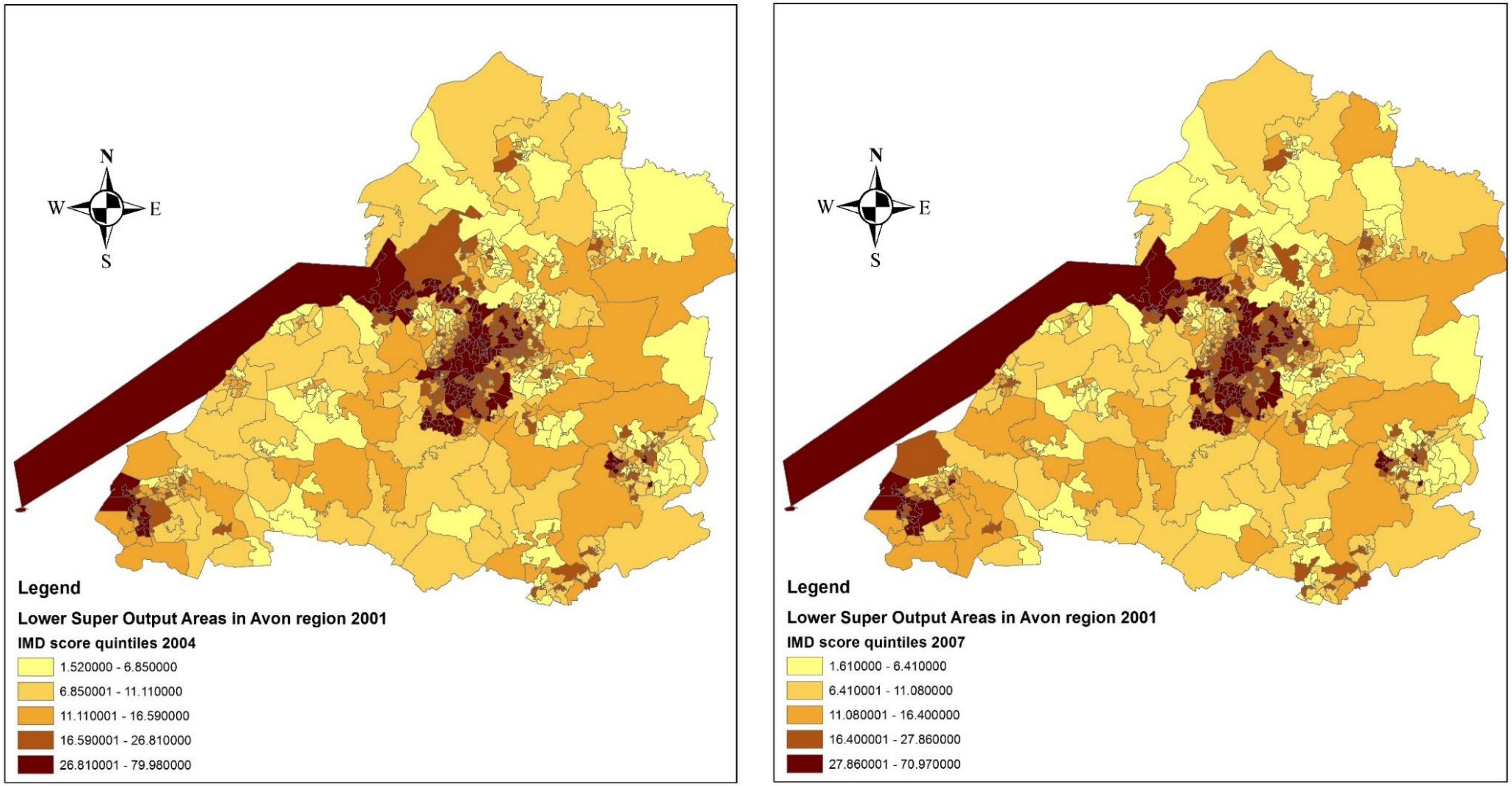
3.9 Overall strengths and weaknesses of the NDNS and ALSPAC data

The NDNS is considered a source of high-quality national data regarding food intake and people’s food behaviour and dietary habits. Therefore, the output results from the NDNS survey may inform government policies that need to be implemented to improve the health status of the UK population. In the NDNS, the dietary assessment method used was the four-day diary record. One of the main advantages of this dietary record assessment method is the potential to accurately collect the type and quantity of the foods consumed during the recording periods [219]. Data collection over four days for each person is also a strength.

This method also has some limitations. For example, the burden that both foods and amounts (portion size) have to be recorded might lead individuals to alter their dietary behaviour to make it easier to record or to hide poor eating habits. Turning the diaries recorded to dietary data is known to be time consuming and costly. Moreover, some food items, meals consumed and portion sizes of the foods might be forgotten or difficult to be record by the participants [219]. In addition, the NDNS is a repeat cross-sectional survey. Therefore, using it to explore causal relationships is not possible. Moreover, despite the steps taken to be as representative as possible some subgroups such as low income households, may be under-represented. Also, the sample does not fully represent the diverse ethnic groups in the UK, as 91% of NDNS participants are from a white background.

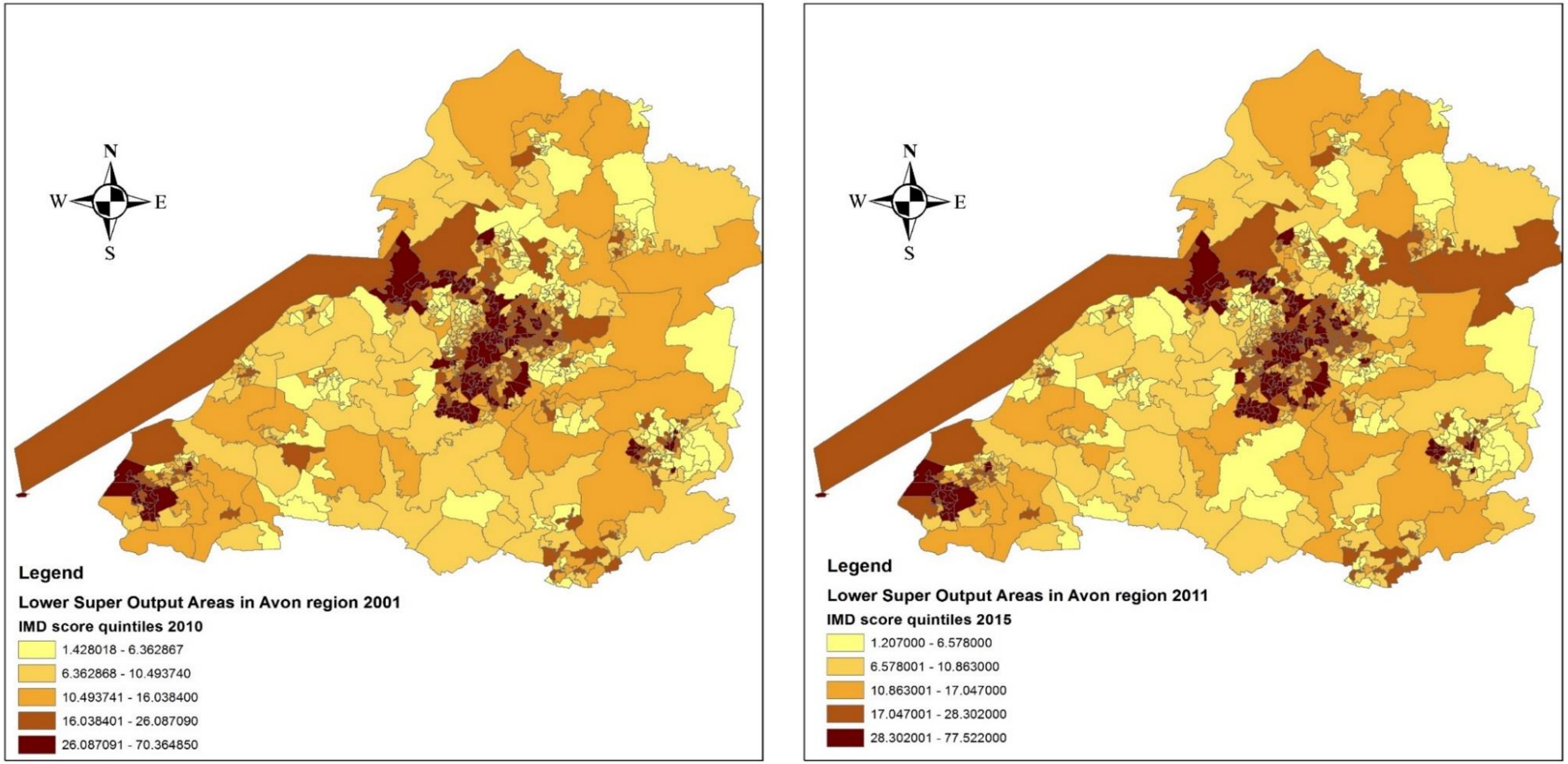
The ALSPAC is a longitudinal data set where both parents and their children were followed up for several years. Required information regarding their health, wellbeing and lifestyle (environmental and genetic information) were captured using both questionnaire-based and clinical measurements. There are several advantages to using the food frequency questionnaire. The first is low respondent burden (where completing the questionnaire can typically take around 10-20 minutes). In addition, it is relatively easy and flexible to run and has a low cost compared to other dietary assessment methods [220]. Nevertheless, this dietary assessment method also has some limitations. For example, the participant food intake reported is limited to the foods provided on the food list, where a broad list of all foods eaten cannot be included. The reporting of the food consumed mainly relies on the participant’s memory. Furthermore, over-reporting of the consumption of healthy foods may increase as the length of the food list provided increases and under-reporting of the consumption of unhealthy food can introduce bias to the data [220].

In this study, geographical location of the adolescent’s schools were available. However, the ALSPAC is secondary data (conducted and collected by other groups), and there was inconsistency in the methods used to collected data in the ALSPAC. For example, the method used to collect the physical activity level was changed during the study. The ALSPAC also does not represent a diverse ethnic group as 97% of the ALSPAC participants were from a white background.



A B

Figure 3-10: A choropleth (shaded) map of the Avon region based on Index of Multiple Deprivation scores (IMD); (A) 2004 and (B) 2007.



C D

Figure 3-11: A choropleth (shaded) map of the Avon region based on Index of Multiple Deprivation scores (IMD); (C) 2010 and (D) 2015.

3.10 Conclusion

This chapter has provided an overview of the data used in this thesis. A brief description of the limitations inherent to other data sources available in the UK was also provided. Details of how both the NDNS and ALSPAC data were processed and prepared to be used in this thesis were also discussed in this chapter. This is exemplified in the calculation of DQI-A score and cleaning of HFTs, POIs and school data in sections 1.4, 1.6 and 1.7. The NDNS data were used in chapters 4 and 5, whereas the ALSPAC data were used in chapters 6 and 7. In chapters 4 and 5, the relationship between the consumption of takeaway meals at home, outside the home and during a school day and the overall diet quality of UK adolescents will be investigated. In Chapter 6, the school information obtained from the ALSPAC study will be used to investigate the differences in using different methods to evaluate the food environment clustering around the secondary schools. In Chapter 7, the relationship between the density, proximity and accessibility of HFTs and BMI-z score and body fatness of UK adolescents will be investigated.

Chapter 4 The cross-sectional relationships between consumption of takeaway food, eating meals-outside the home and diet quality in British adolescents

Abstract

Background: Consumption of takeaway meals and purchase of food from outside the home rather than preparation of food at home is found to be negatively associated with diet quality. The aim of this study is to evaluate the association between the frequency of consuming takeaway meals and meals-out and diet quality of UK adolescents aged 11-18 years.

Methods: The diet quality index for adolescents (DQI-A) tool has been used to assess diet quality where adolescent's food intake was based on 4-Day diary records obtained from the NDNS rolling programme years 1-6. The DQI-A relies on three main components, specifically, quality, diversity and equilibrium, which reflect the degree of adherence of an adolescent diet with Food Based Dietary Guidelines (FBDG).

Results: Mean diet quality score for all adolescents was 20.4% (overall DQI-A score range: -33 to 100%). After adjusting for confounders, DQI-A% score was higher for low and moderate takeaway consumers by 7.4% (95% CI 5.5, 9.2; P<0.01) and 3.5% (95% CI1.9, 5.1; P<0.01), respectively, v. frequent consumers. Significant differences were also observed between low, moderate and frequent takeaway consumers among all DQI-A components and sub-components (P< 0-05), except for the diet adequacy sub-component (DAx). Results for frequent consumption of meals-out were similar but attenuated and not statistically significant for individual components before or after adjusting for confounders.

Conclusions: Frequent consumption of takeaway meals may have a negative impact on adolescents' diet quality and therefore policies to reduce the intake of takeaways should be considered in this age group.

4.1 Introduction

The significant global rise in diet-related non-communicable diseases indicates that there are serious nutritional issues in both developed and developing countries [1]. According to WHO, Cardio Vascular Disease (CVD) were responsible for the largest number of deaths in 2015 [3]. Many diseases exist not only as a result of increasing rates of obesity and overweight among children, but also because of the unhealthy diets of children [2]. Poor diet, particularly due to intake of foods high in sugar and fat, is one of the major threats to health and well-being [35]. The many different causes of childhood and adulthood obesity such as socio-economic inequalities also include factors related to deprivation, education level and ethnicity. In the UK, observational studies report that lower socio-economic groups consume less oily fish, fruits and vegetables, but more red and processed meats and foods and drinks high in free sugars (added sugar to food or drink) compared with higher socio-economic groups [53]. In addition, the food environment also plays a crucial role in individual behaviours and food choices. For example, the availability, accessibility, portion size and cost of different food types both at home and in surrounding food outlets are all influential [64].

The reasons for targeting the consumption of fast food and adolescent's age group were discussed in chapters 1 and 2. The main driver of overweight and obesity is believed to be the imbalance between energy intake and energy expenditure, mainly due to the overconsumption of energy-dense foods that are known to be high in fat and sugars as well as an increase in sedentary lifestyles [4]. Overconsumption of energy-dense foods derived from fast and convenience food outlets is believed to be an important contributor to the increased risk of obesity and type 2 diabetes among young generations [78, 79]. Two longitudinal prospective studies including young adults aged 18–30 years with 3 to 15 years follow-up, found that increased frequency of fast-food restaurant visits and consumption of fast food [84] can lead to increased body weight (follow-up *vs*. baseline). In fact, higher fat and total energy intakes are linked with consumption of takeaway and fast foods which offer a variety of ready-to-eat meals and energy-dense foods [82]. Consumption of fast food remains positively and significantly associated with total energy intake as well as intakes of total fat, saturated fat, carbohydrates, sugar and sugar-sweetened beverages [83].

Consumption of takeaway meals and food purchased outside the home (rather than food prepared at home) is found to be negatively associated with diet quality [84, 86]. In England, schoolchildren were observed to purchase foods from surrounding food outlets not only during lunch breaks but also during the journey going to and from school. Young people are specifically targeted for price promotion and many of those food outlets provide discounts on items such as sugar-sweetened drinks, hot food takeaways and confectionery [221]. A recent cross-sectional study based in three cities in England (London, Birmingham and Leicester) found that 28% of children aged 9 – 11 years from eighty-five primary schools consumed takeaway meals at least once per week. Low-density lipoproteins (LDL) cholesterol, fat mass index and total cholesterol were all observed to be higher among students who consumed takeaway meals (at least once per week) than among those who never or hardly consumed takeaway meals [222]. Nevertheless, the associations between the consumption of fast food and the intake of individual foods and nutrients, such as soft drinks, sodium, total fat and vegetables have been examined by several studies [46, 89]. Few published studies have used a diet quality index to assess the impact of fast food consumption at home or outside the home on overall diet quality [45, 46]. Examining the intakes of individual nutrients or food groups is not enough to assess diet quality, as both the quality and variety of the whole diet must be considered; thus, it is important to explore the relationship between individuals' whole dietary intake and their health status [36].

The need for a new tool to assess the overall diet quality particularly among adolescent age groups was outlined in Chapter 2. Previous research has assessed individual macro- and/ or micronutrients; however, the need for higher-quality data to strengthen the evidence for overall diet is required. Healthy eating indices (HEIs) and diet quality indices (DQIs) were both first developed to assess the quality of people's dietary intake and focus on concerns surrounding the major diet-related diseases [37, 38]. Both types of indices are based on assessment of a variety of food groups and nutrients and they are considered good tools to evaluate the quality of an individuals' overall diet [42]. A simple, easy-to-interpret tool to indicate the quality of a diet, without requiring intensive analysis of foods to nutrients in this age group, has resulted in the development of the Diet Quality Index for Adolescents (DQI-A) [36, 38]. The DQI-A is based on the intake of food groups without including the intake of nutrients and it was adapted from a validated index called the Diet Quality Index for Preschool Children. The validated DQI for preschoolers was derived from the original DQI. The DQI-A was developed mainly to assess the degree of adherence of adolescents' diet with food-based dietary guidelines (FBDG) [43]. FBDG, also known as dietary guidelines, are used to provide sufficient information for different governmental sectors to implement interventions towards healthy eating and lifestyles. Such interventions can focus on food and nutrition, polices regarding health and agriculture, and educational programs. Therefore, the primary role of FBDG is to provide advice to the general public, thereby enabling individuals to meet their daily dietary requirements of both nutrients and food groups; this will help in preventing chronic diseases and promoting healthy lifestyles[44]. Therefore, the aim of this study is to explore the relationships between consumption of takeaway (fast) food and diet quality using the DQI-A as an assessment tool for the quality of each individual's diet.

4.2 Methods

The data used came from the National Diet and Nutrition Survey (NDNS), an annual rolling program aiming to assess nutritional intake and status of people living in private households in the UK aged 1·5 years or above. In each year of the survey, a sample of 500 adults (aged 19 years or over) and 500 children (aged 1·5–18 years) was randomly recruited based on postcode. Randomly selected addresses were posted information leaflets describing the purpose of the NDNS and a consent form. These were followed up by a face-to-face visit by an interviewer. For children aged under 16 years, consent was sought from both the child and their parents for the interview and blood and urine sampling. For adults aged 16 years or above, parental consent was obtained for the blood and urine sampling. Ethical approval for the NDNS was obtained from the Oxfordshire A Research Ethics Committee [73]. In the present study, all participants aged 11–18 years from the NDNS data sets for 2008 to 2014 were included (Years 1–6). More information on how to access the NDNS data and on data collection and processing can be found in Appendix 1 and Chapter 3 – section 3.3 respectively.

4.3 Variables of interest

4.3.1 Takeaway meals and meals-out

The interviewers asked the participants two questions on fast food to collect data relating to their eating habits. In both questions, the interviewers provided further clarification for the terms ‘meals-out’ and ‘takeaway meals at home’. These questions were: ‘On average, how often do you/does your child eat meals-out in a restaurant or cafe?’, where the meals mean more than a beverage or bag of chips; and ‘On average, how often do you/does your child eat takeaway meals at home?’, where the meals mean more than a beverage or bag of chips including pizza, fish and chips, burgers, etc. Using frequency of consuming takeaway meals at home and consuming meals-outside the home, respondents were categorised as low consumers (including rarely/never), moderate consumers (including once or twice per month) and frequent consumers (including once or twice per week, three or four times per week, and five or more times per week). Participants with ‘do not know’ answers were excluded from the analysis. This method of categorisation has been used previously, as it has been reported that the risk of developing health-related diseases is linked with consuming fast food more frequently than once per week [47, 68].

4.3.2 Food intake

The intake of food was obtained from 4-day diary records. The diet quality score was calculated for each day, then the mean to assess the diet quality index of the adolescent participants. Some food items were excluded from the analysis, including commercial toddler drinks and foods. Those food items were excluded because the current study only involved adolescents aged 11-18 years and toddler foods and drinks are not typically consumed by older children

4.3.3 DQI-A

4.3.3.1 Background

The latest version of the FBDG in the UK is the Eatwell Guide, which was published in 2016 by Public Health England and consists of seven main food groups as follows: (i) potatoes, bread, rice, pasta and other starchy carbohydrates; (ii) dairy and alternatives; (iii) beans, pulses, fish, eggs, meat and other proteins; (iv) fruit and vegetables; (v) oil and spreads; (vi) water; and (vii) confectionery and high-fat and high-sugar snacks [44, 203]. The Flemish FBDG, which was used to validate the DQI-A, includes mostly the same recommended food groups mentioned in the Eatwell Guide. Like FBDG, the DQI-A relies on three main components, namely the quality, diversity and equilibrium of the diet compared with the governmental dietary guidelines. Each component has its own definition and technique for the scoring criteria [36].

4.3.3.2 Definitions and calculating each component and subcomponents

1. **Diet quality component**

The diet quality component (DQc) assesses diet based on the quality of the foods consumed within nine recommended food groups: (i) water; (ii) bread and cereal; (iii) potatoes and grains; (iv) vegetable; (v) fruits; (vi) milk products; (vii) cheese; (viii) meat, fish and substitutes; and (ix) fat and oils. To calculate the score, the amount of food consumed (m) from each food group is multiplied by a weighting factor. The weighting factor is divided into three groups, namely the preference, intermediate and low- nutrient/energy-dense groups. Each weighting factor has an associated digit, as follows: ‘ + 1’ for the preference group, including cereal/brown bread, fish and fresh fruit; ‘0' for the intermediate group, including white bread and minced meat; and ‘ -1’ for the low-nutrient/energy-dense group, including soft drinks, sweet snacks and chicken nuggets. First, the diet quality was calculated for each of the nine food groups and then the final score of this component was calculated using the equation: $\sum (DQ)/ \sum m \times 100\%$. More details and examples on the classification of food items and the scoring criteria of weighting factors can be found in Chapter 3 and elsewhere [36].

2. **Diet diversity component**

The diet diversity component (DDc) assesses the degree of variation in an adolescent's diet, where the scoring range is from 0 to 9 points. Consuming at least one serving from each of the nine recommended food groups adds 1 point to the total score. For example, if an adolescent's mean consumption for the fruit group is more than 80 g, then s/he gains a score of 1; otherwise, the score will be 0. The final score for this component can be calculated using the equation: $\sum (DD)/9 \times 100\%$ (sum of DD points for all nine food groups for each adolescent). In terms of serving size, because the Eatwell Guide does not provide information regarding portion and/or serving size for all the recommended food groups, the portion size recommended by the British Dietetic Association was used as follows: (i) water, 200 ml; (ii) bread and cereal, 35 g; (iii) potatoes and grains, 175 g; (iv) vegetables, 80 g; (v) fruits, 80 g; (vi) milk products, 200 ml; (vii) cheese, 30 g; (viii) meat, fish and substitutes, 100 g; and (ix) fat and oils, 4g. To gain a better and more accurate measurement of recommended portion sizes of these food groups among children and adolescents, other reference sources were used, such as those of the Food Standards Agency, especially for starchy food groups [204, 205].

3. **Diet equilibrium component**

The diet equilibrium component (DEc) consists of two sub-components, namely the adequacy component (diet adequacy, DAx) and the excess component (diet excess, DEx). These two sub-components express the degree of adherence of an adolescent's diet to the minimum and maximum intakes of each of the nine recommended food groups. The adequacy component represents the percentage of the minimum recommended intake of each of the nine food groups, converted to ‘1', whereas the excess component represents the percentage of the intake exceeding the upper limit of the recommendation (eleven food groups, nine recommended and two non-recommended), converted to ‘1' if larger than 1 and converted to ‘0' if below 0. Then, the dietary equilibrium is calculated by subtracting DEx from DAx (i.e. DE = DAx - DEx). Finally, the total diet equilibrium score can be calculated by dividing the sum of diet equilibrium scores by 11 and multiplying by 100: $\sum$ (DE)/11 X100%. The recommended daily intake of all food groups is based on the Flemish FBDG, where the minimum and maximum intakes of each of food group are provided. More details on how to calculate each of these sub-components can be found in published documents [36].

4.3.3.3 Total DQI-A score

All three main components - diet quality, diet diversity and diet equilibrium - are presented in percentages. The percentage ranges for both DDc and DEc are 0-100%, whereas the DQc percentage range is -100 to 100%. Therefore, the mean percentage of the three main components results in a DQI-A score ranging from -33 to 100%. A higher DQI-A percentage score reflects a better quality of diet. For more information about how each of the main components and subcomponents were calculated please see Chapter 3, sections 3.41-3.44.

4.4 Statistical analysis

All statistical analyses were carried out using the statistical software package Stata version 15.0. Different NDNS data sets were merged before analysis. The dietary data set was merged with either household or individual using ISERIAL as the unique identifier for individuals. In addition, the data sets for Years 1–4 and 5–6 were combined, as each of these was provided individually by NDNS. Applying weight analyses to a data set is required to adjust for non-responses, for example, in the NDNS for individual and/or household data sets. The weighting variable provided in the NDNS guideline report was used, allowing generation of an equal distribution of the selected population across the four parts of the UK; thus, the results obtained from the Year 1 to Year 6 surveys can be used together.

In addition, the distribution of variables was checked before any statistical test was performed, including comparison of means with the t test, ANOVA comparison test and multiple or linear regression analysis. Simple summary description was conducted to provide general information related to the study such as response rate, the proportion of participating males and females, ethnicity and survey year distribution. Mean scores and confidence intervals of DQI-A and its components were assessed. A comparison test was also carried out to examine the differences between dietary quality score and its components between each day of the diary records. Linear regression was then applied, taking into consideration the clustering effect of the adolescents by their unique identifier number, to estimate the association of the overall diet quality score or its components (outcome variables) with takeaway meals or meals consumed out of home (exposure variables). The results for the linear regression are presented as unadjusted values applied alone or as adjusted values after controlling for age, sex and equivalised household income. Selection of confounders was based on reviewing relevant existing literature. Equivalised household income is a standard methodology, required to adjust the differences in financial resources for differences in household type such as size [223]. Participants with missing data on household income and any participants with missing data related to any of the included confounders were dropped from the adjusted analysis model. P values of less than 0.05 were considered statistically significant for all tests and 95% CI are presented with results.

For general characteristics of the participant, the classification of socio-economic status of parents was based on the UK National Statistics-Socio-Economic Classification (NS-SEC). Participants were divided into eight NS-SEC categories in the NDNS and then reclassified into four categories: 1- managerial and professional, 2- intermediate, 3-routine and manual and 4- Never worked and other. This method has been used in previously published papers [224, 225]. Data were not available for all of the variables in the general characteristic of the participants including dieting, being a vegetarian, student's working status, ethnicity and socio-economic status of parents.

4.4.1 Sensitivity analysis

Takeaway meals and meals-out of home and diet quality

Physical activity and type of lunch consumed are an essential confounder to be included in the regression model. However, due to the fact than less than 50% (n = 2045) of the total participants provided a valid measurement regarding their physical activity level, a sensitivity analysis with a total of 701 participants was carried out to find out whether the inclusion of the variable physical activity and type of lunch (independent) in the model could attenuate the regression output results of the dependent variable (DQI-A). Any participants with missing data regarding any of the included confounders was dropped from the sensitivity analysis model.

4.5 Results

4.5.1 Background description

In total, 2045 adolescents were recruited into the NDNS and completed a minimum 3 day of diary records; 98% of these participants had 4 day diary records. The proportion of females was slightly higher than that of males, at 51.5% (*n* = 1033) and 49.5% (*n* = 1012), respectively; the mean age of both genders was 14.6 years. In terms of ethnicity, 90.8% of adolescents were reported to be white, while 9.2% were from non-white ethnic backgrounds. The weight measurement was valid for only 1981 participants and females had a significantly lower weight than males, by 2.3 kg (95% CI -3.7, -1.0 kg; P< 0.01). Males had significantly higher food energy intake than females, with a mean intake of 8138.9 kJ/d (95% CI 8005.4, 8272.5 kJ/d; P< 0.01; Table 4-1). The response rate for information on physical activity level was less than 50%, representing all age groups from both genders (data not shown).

Table 4-1 Summary description of age, weight and food energy intake among British adolescents aged 11–18 years from the National Diet and Nutrition Survey (NDNS) rolling programme, Years 1–6 (2008–2014).

		Total sample			Males			Females		
		n = 2045			*n* = 1012			*n* = 1033		
		Mean	95% CI		Mean	95% CI		Mean	95% CI	
Age (years)		14.6	14.5	14.7	14.5	14.3	14.6	14.7	14.5	14.8
Weight (kg)		59.1	58.4	59.7	60.2	59.2	61.3	57.9	57.0	58.8
BMI Z-score		0.66	0.61	0.72	0.66	0.58	0.73	0.67	0.60	0.74
BMI		21.1	20.8	21.4	20.5	20.1	20.9	21.7	21.3	22.1
Waist circumference (cm)		76.4	75.8	77.0	77.8	77.0	78.6	75.2	74.4	75.9
Food energy (kJ/d)		7357.8	7266.9	7448.7	8138.9	8005.4	8272.5	6592.6	6488.1	6697.0
Food energy (kcal/d)		1758.6	1736.8	1780.3	1945.3	1913.3	1977.2	1575.7	1550.7	1600.6
Overall DQI-A		20.4	19.7	21.0	19.9	19..0	20.9	20.8	19.9	21.7
General characteristics presented as percentage (%)										
Dieting/ n = 725		1.3	0.8	2.0	0.9	0.4	2.0	1.6	0.9	2.8
Vegetarian/ n = 2037		2.2	1.6	2.9	1.2	0.7	2.1	3.2	2.3	4.5
Student's working status/ n = 2045	Full-time school or college	91.0	89.6	92.1	89.6	87.6	91.4	92.3	90.5	93.7
	Full or part-time employment	4.9	4.1	6.0	5.8	4.5	7.5	4.1	3.0	5.5
Ethnicity/ n = 1497	White	91.5	90.0	92.8	91.4	89.2	93.2	91.6	89.4	93.4
	Non white	8.5	7.2	10.0	8.6	6.8	10.8	8.4	6.6	10.6
Socio-economic status of parent / n = 2040	Professional/Managerial	51.8	49.6	53.9	50.4	47.3	53.5	53.1	50.0	56.1
	Intermediate	19.1	17.5	20.9	19.9	17.6	22.5	18.4	16.1	20.8
	Routine/Manual	24.2	22.4	26.1	25.2	22.6	27.9	23.3	20.8	26.0
	Never worked and other	4.9	4.0	5.9	4.6	3.4	6.0	5.2	4.0	6.8

CI, Confidence Interval

4.5.2 Over all diet quality across the diary days and takeaway consumers

The overall DQI-A% score was broadly similar across the days with no statistically significant differences between the days (Table 4-2). However, there were small but significant differences in the percentage scores for the different components and sub-components, with significant differences in scores observed between the days for DDc, DEc, DAx and DEx, although not for DQc. Furthermore, participants who completed 4 day diary records had higher overall DQI-A% score by 4.6% (95% CI 0.9, 0.8%; P = 0.014) than participants who had 3 day diary records. Evaluation of the mean DQI-A% score and its components and sub-components among all three take-away and meals-out consumer groups can be seen in Table 4-3 and

Table 4-4. The UK adolescents had a mean diet quality score of 20.4% out of 100% (ranging from -24.2 to 67.2).

Dietary quality*	**Total sample**			**Frequent meals-out consumers**			**Moderate consu**	
	***n* = 2045**			***n* = 496**			***n* =**	
	Mean	**95% CI**		**Mean**	**95% CI**		**Mean**	
DQI-A Overall	20.4	19.7	21.0	18.0	16.7	19.4	21.4	2
Diet quality component (DQc)	-6.3	-7.7	-5.0	-10.2	-12.9	-7.4	-5.2	-7
Diet diversity component (DDc)	44.6	44.0	45.1	43.0	41.9	44.2	45.5	4
Diet equilibrium component (DEc)	22.9	22.6	23.3	21.2	20.4	21.9	23.8	2
Diet adequacy sub-component (DAx)	53.6	53.1	54.0	52.5	51.5	53.5	54.4	5
Diet excess sub-component (DEx)	20.9	20.6	21.2	21.8	21.1	22.4	20.7	2
Age (year)	14.6	14.5	14.7	15.2	15.0	15.3	14.4	1
Energy (Kcal/d)	1758.6	1736.8	1780.3	1793.3	1743.3	1843.3	1758.0	17
Food energy (kJ/d)	7358.0	7266.8	7448.8	7503.2	7294.0	7712.4	7355.5	72

DQI-A, Diet Quality Index for Adolescents; DQc, diet quality component; DDc, diet diversity compone DAx, diet adequacy sub-component; DEx, diet excess sub-component.
***Low consumption defined as rarely/never; moderate consumption defined as once or twice per mont as once or twice per week or more.**

Table 4-2 Mean scores of overall diet quality index and its components and sub-components (expressed as percentage) across the three or four days of diary records among British adolescents aged 11–18 years (*n* = 2045) from the National Diet and Nutrition Survey (NDNS) rolling programme, Years 1–6 (2008–2014).

	Total Number = 8145												Overall diet quality and it’s components score (mean of all days recorded)
	Day Number												
	1st			2nd			3rd			4th			
	n = 2045			*n* = 2045			*n* = 2045			*n* = 2010			
	Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI		Average
DQI-A %	21.2	20.4	22.0	20.6	19.8	21.4	19.9	19.0	20.7	20.0	19.1	20.8	20.4
DQc %	-6.4	-8.1	-4.7	-6.0	-7.7	-4.3	-6.4	-8.2	-4.7	-6.3	-8.1	-4.5	-6.3
DDc %	46.3	45.6	47.1	44.7	43.9	45.5	43.5	42.7	44.3	43.8	43.0	44.6	44.6
DEc %	23.7	23.2	24.2	23.0	22.5	23.5	22.5	22.0	23.0	22.5	21.9	23.0	22.9
DAx %	55.5	54.9	56.1	53.8	53.2	54.4	52.8	52.2	53.4	52.2	51.5	52.8	53.6
DEx %	21.7	21.3	22.1	21.0	20.6	21.5	20.6	20.2	21.1	20.2	19.8	20.7	20.9

CI, Confidence Interval; DQI-A, Diet Quality Index for Adolescents; DQc, Diet quality component; DDc, Diet diversity component, DEc, Diet equilibrium component; DAx, Diet adequacy sub-component; DEx, Diet excess sub-component

Table 4-3 Summary description of overall diet quality index and its component and sub-component scores (expressed as percentage), age and food energy intake according to frequency* of takeaway consumption among British adolescents aged 11–18 years (*n* = 2045) from the National Diet and Nutrition Survey (NDNS) rolling programme, Years 1–6 (2008–2014).

Dietary quality*	Total sample			Frequent takeaway consumers			Moderate takeaway consumers			Low takeaway consumers		
	n = 2045			*n* = 589			*n* = 906			*n* = 550		
	Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI	
DQI-A Overall	20.4	19.7	21.0	16.8	15.6	17.9	20.5	19.5	21.4	24.2	22.9	25.5
Diet quality component (DQc)	-6.3	-7.7	-5.0	-13.2	-15.7	-10.6	-6.4	-8.3	-4.5	1.1	-1.6	3.8
Diet diversity component (DDc)	44.6	44.0	45.1	42.3	41.3	43.3	44.6	43.8	45.5	46.9	45.8	48.0
Diet equilibrium component (DEc)	22.9	22.6	23.3	21.1	20.5	21.8	23.1	22.6	23.6	24.5	23.8	25.3
Diet adequacy sub-component (DAx)	53.6	53.1	54.0	52.7	51.9	53.5	53.7	53.0	54.4	54.3	53.3	55.2
Diet excess sub-component (DEx)	20.9	20.6	21.2	22.0	21.4	22.6	20.8	20.4	21.3	19.9	19.3	20.5
Age (year)	14.6	14.5	14.7	14.6	14.4	14.8	14.5	14.3	14.6	14.6	14.4	14.8
Energy (Kcal/d)	1758.6	1736.8	1780.3	1809.2	1767.1	1851.4	1756.5	1725.4	1787.6	1707.7	1664.8	1750.7
Food energy (kJ/d)	7358.0	7266.8	7448.8	7569.7	7395.5	7746.3	7349.2	7219.1	7479.3	7145.0	6965.5	7324.9

DQI-A, Diet Quality Index for Adolescents; DQc, diet quality component; DDc, diet diversity component, DEc, diet equilibrium component; DAx, diet adequacy sub-component; DEx, diet excess sub-component.
***Low consumption defined as rarely/never; moderate consumption defined as once or twice per month; and frequent consumption defined as once or twice per week or more.**

Table 4-4 Summary description of overall diet quality index and its component and sub-component scores (expressed as percentage), age and energy intake according to frequency* of consuming meals-out among British adolescents aged 11-18 years (*n* = 2045) from the National Diet and Nutrition Survey (NDNS) rolling programme, Years 1-6 (2008-2014).

Dietary quality*	Total sample			Frequent meals-out consumers			Moderate meals-out consumers			Low meals-out consumers		
	n = 2045			*n* = 496			*n* = 957			*n* = 592		
	Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI	
DQI-A Overall	20.4	19.7	21.0	18.0	16.7	19.4	21.4	20.4	22.3	20.8	19.6	22.1
Diet quality component (DQc)	-6.3	-7.7	-5.0	-10.2	-12.9	-7.4	-5.2	-7.1	-3.3	-4.9	-7.5	-2.3
Diet diversity component (DDc)	44.6	44.0	45.1	43.0	41.9	44.2	45.5	44.7	46.3	44.3	43.2	45.3
Diet equilibrium component (DEc)	22.9	22.6	23.3	21.2	20.4	21.9	23.8	23.3	24.3	23.0	22.4	23.7
Diet adequacy sub-component (DAx)	53.6	53.1	54.0	52.5	51.5	53.5	54.4	53.8	55.1	53.1	52.2	54.0
Diet excess sub-component (DEx)	20.9	20.6	21.2	21.8	21.1	22.4	20.7	20.3	21.2	20.4	19.8	21.0
Age (year)	14.6	14.5	14.7	15.2	15.0	15.3	14.4	14.2	14.5	14.4	14.2	14.5
Energy (Kcal/d)	1758.6	1736.8	1780.3	1793.3	1743.3	1843.3	1758.0	1727.8	1788.3	1730.3	1691.7	1768.8
Food energy (kJ/d)	7358.0	7266.8	7448.8	7503.2	7294.0	7712.4	7355.5	7229.1	7482.2	7239.6	7078.1	7400.7

DQI-A, Diet Quality Index for Adolescents; DQc, diet quality component; DDc, diet diversity component, DEc, diet equilibrium component; DAx, diet adequacy sub-component; DEx, diet excess sub-component.
***Low consumption defined as rarely/never; moderate consumption defined as once or twice per month; and frequent consumption defined as once or twice per week or more.**

4.5.3 Consumption of takeaways and meals-out

The frequent consumption of takeaways (once or twice per week or more) was reported by 29.8% (*n* = 589) of participants, whereas 24.3% (*n* = 496) of them reported to be frequent consumers of meals-out. The majority of participants were moderate consumers (once or twice per month) of takeaways (44.3%) and meals-out (46.8%). Those who reported to rarely or never consume takeaway meals or meals-out represented 26.9% and 29.0% of the total number of participants, respectively. The percentage of adolescents reporting frequent takeaway consumption was 37% and 28% for those who completed 3 day and 4 day diaries, respectively. Similarly, the percentage of adolescents reporting frequently consuming meals-out was 31% and 24% for those who completed 3 day and 4 day diaries, respectively. The proportion of participants who consumed takeaway meals once or twice per week or more was found to be higher among participants with the lowest equivalised household income compared with those with highest income. However, this was seen among the consumption of meals-outside the home. As can be seen in Figure 4-1, 13% (*n* = 68) of the frequent meals-out consumers were from lowest-income households, whereas 17% (*n* = 85) of them came from the highest-income households.

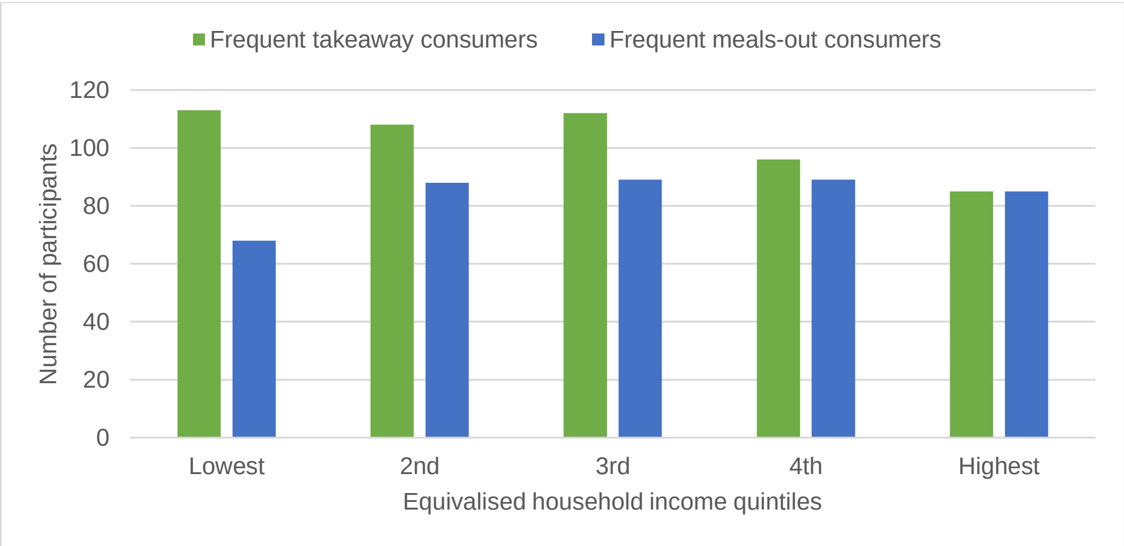


Figure 4-1 Number of frequent takeaway and meals-out consumers by equivalised household income quintile among British adolescents aged 11–18 years (*n* = 2045) from the National Diet and Nutrition Survey (NDNS) rolling programme, Years 1–6 (2008– 2014). *Frequent consumption defined as once or twice per week or more.

In addition, it was observed that the mean intake of vegetables was 134 g/d among low takeaway consumers compared with 102 g/d among frequent takeaway consumers. This difference was greatly attenuated among consumers of meals-out, where the mean intake of vegetables was 117 and 112 g/d among frequent and low consumers, respectively. The scores for the overall DQI-A and its components and sub-components were recalculated after increasing the intake of vegetables by one portion (80 g) to demonstrate the association of this typical change in diet on different components. It was observed that component scores for DQc, DDc, DEc and DAx increased on average by 2.9, 3.9, 1.8 and 2.1%, respectively. A mean increase of 2.9% in the overall DQI-A score was seen (data not shown).

4.5.4 Associations between diet quality and takeaway consumption

The results from the regression analysis indicated an association between the frequency of takeaway consumption and diet quality of UK adolescents. Significant differences were observed between low, moderate and frequent (the reference group) takeaway consumers in their DQI-A scores (Table 4-5). Low and moderate takeaway consumers had a higher overall DQI-A% score by 7.4% (95% CI 5.6, 9.2%; $P < 0.01$) and 3.7% (95% CI 2.2, 5.2%; $P < 0.01$) than frequent consumers, respectively. The results remained essentially unaltered after adjusting for age, gender and equivalised household income, and the overall DQI-A% score remained higher for low and moderate consumers compared with frequent takeaway consumers (Table 4-5). In addition, significant differences were observed between low, moderate and frequent takeaway consumers for most of the DQI-A components and sub-components (Table 5). For instance, low and moderate takeaway consumers had significantly higher DQc scores than frequent takeaway consumers by 14.2% (95% CI 10.5, 17.9%; $P < 0.01$) and 6.7% (95% CI 3.6, 9.9%; $P < 0.01$) respectively, before adjusting for confounders. This difference remained significant after adjusting for age, gender and equivalised household income. As indicated, not all diet quality components and sub-components were significantly affected by the frequency of takeaway consumption before and after adjusting for confounders (Table 4-5).

4.5.5 Associations between diet quality and consumption of meals-out

The results for frequent consumption of meals-out were similar but attenuated and not statistically significant for individual components, including DDc and Dax, before adjusting for confounders (Table 4-6). As was found with frequent takeaway consumers, the overall DQI-A% score was significantly higher among low and moderate consumers compared with frequent consumers of meals-out (the reference group), by 2.8% (95% CI 1.0, 4.6%; P<0.01) and 3.4% (95% CI 1.7, 5.0%; P<0.01), respectively. Moreover, after adjusting for confounders including age, gender and equivalised household income, statistically significant differences in overall DQI-A% score were observed for low, moderate and frequent consumption of meals-outside of home (Table 4-6). Although there were significant differences between low, moderate and frequent consumers of meals-out among some of the diet quality components, after adjusting for confounders those differences were observed to be bigger among some diet quality components (Table 4-6).

Table 4-5 Regression (clustered) analysis between takeaway consumption* and overall diet quality index and its component and sub-component scores (expressed as percentage) among British adolescents aged 11–18 years (*n* = 2045) from the National Diet and Nutrition Survey (NDNS) rolling programme, Years 1–6 (2008–2014).

	Unadjusted analysis n = 2045								Adjusted analysis *n* = 1779							
Frequent takeaway consumers as reference	**Low B**	**95% CI**		**p**	**Moderate B**	**95% CI**		**p**	**Low B**	**95% CI**		**p**	**Moderate B**	**95% CI**		**p**
Diet quality*																
DQI-A Overall	7.4	5.6	9.2	<0.01	3.7	2.2	5.2	<0.01	7.4	5.5	9.2	<0.01	3.5	1.9	5.1	<0.01
Diet quality component (DQc)	14.2	10.5	17.9	<0.01	6.7	3.6	9.9	<0.01	13.6	9.7	17.5	<0.01	6.5	3.2	9.9	<0.01
Diet diversity component (DDc)	4.6	3.1	6.1	<0.01	2.4	1.1	3.6	<0.01	5.1	3.5	6.7	<0.01	2.1	0.8	3.5	<0.01
Diet equilibrium component (DEc)	3.4	2.5	4.4	<0.01	2.0	1.2	2.8	<0.01	3.4	2.4	4.4	<0.01	1.8	0.9	2.7	<0.01
Diet adequacy sub-component (DAx)	1.6	0.3	2.8	0.02	1.0	-0.1	2.1	0.1	1.9	0.6	3.2	<0.01	0.7	-0.5	1.8	0.3
Diet excess sub-component (DEx)	-2.1	-3.0	-1.3	<0.01	-1.2	-1.9	-0.5	<0.01	-1.8	-2.7	-1.0	<0.01	-1.3	-2.0	-0.5	<0.01
Age (year)	0.03	-0.2	0.3	0.8	-0.1	-0.3	0.1	0.3	-0.01	-0.3	0.3	0.9	-0.2	-0.4	0.1	0.2
Energy (Kcal)	-102.4	-162.4	-42.5	<0.01	-52.8	-105.2	-0.3	0.05	-67.0	-126.6	-7.4	0.03	-43.9	-95.4	7.5	0.1

DQI-A, Diet Quality Index for Adolescents; DQc, diet quality component; DDc, diet diversity component, DEc, diet equilibrium component; DAx, diet adequacy sub-component; DEx, diet excess sub-component.
***Low consumption defined as rarely/never; moderate consumption defined as once or twice per month; and frequent consumption defined as once or twice per week or more.**
Adjusted model controlled for age, sex and household income.

Table 4-6 Regression (clustered) analysis between consumption of meals-out* and overall diet quality index and its component and sub-component scores (expressed as percentage) among British adolescents aged 11–18 years (*n* = 2045) from the National Diet and Nutrition Survey (NDNS) rolling programme, Years 1–6 (2008–2014).

	Unadjusted analysis n = 2045								Adjusted analysis *n* = 1779							
Frequent meals-out consumers as reference	**Low B**	**95% CI**		**p**	**Moderate B**	**95% CI**		**p**	**Low B**	**95% CI**		**p**	**Moderate B**	**95% CI**		**p**
Dietary quality*																
DQI-A Overall	2.8	1.0	4.6	<0.01	3.4	1.7	5.0	<0.01	3.3	1.3	5.4	<0.01	3.5	1.7	5.3	<0.01
Diet quality component (DQc)	5.3	1.6	9.1	<0.01	5.0	1.6	8.4	<0.01	6.5	2.4	10.7	<0.01	5.4	1.7	9.0	<0.01
Diet diversity component (DDc)	1.2	-0.4	2.8	0.1	2.5	1.1	3.9	<0.01	1.8	0.1	3.5	0.04	3.0	1.4	4.5	<0.01
Diet equilibrium component (DEc)	1.9	0.9	2.8	<0.01	2.6	1.7	3.5	<0.01	1.6	0.6	2.7	<0.01	2.1	1.1	3.0	<0.01
Diet adequacy sub-component (DAx)	0.6	-0.7	1.9	0.4	1.9	0.8	3.1	<0.01	0.5	-0.9	1.9	0.5	1.5	0.2	2.7	0.02
Diet excess sub-component (DEx)	-1.4	-2.2	-0.5	<0.01	-1.0	-1.8	-0.2	<0.01	-1.2	-2.2	-0.3	<0.01	-0.9	-1.7	0.0	0.04
Age (year)	-0.8	-1.0	-0.5	<0.01	-0.8	-1.0	-0.5	<0.01	-0.8	-1.0	-0.5	<0.01	-0.7	-1.0	-0.5	<0.01
Energy (Kcal)	-64.0	-126.9	-1.0	0.05	-35.2	-93.6	23.2	0.2	-50.6	116.3	15.1	0.1	-15.1	74.6	44.5	0.6

DQI-A, Diet Quality Index for Adolescents; DQc, diet quality component; DDc, diet diversity component, DEc, diet equilibrium component; DAx, diet adequacy sub-component; DEx, diet excess sub-component.
***Low consumption defined as rarely/never; moderate consumption defined as once or twice per month; and frequent consumption defined as once or twice per week or more.**
Adjusted model controlled for age, sex and household income.

4.5.6 Sensitivity analysis (Regression analysis)

In terms of takeaway consumption, it was found that after the inclusion of physical activity and type of lunch in the regression model, frequent takeaway consumers (reference group) had a lower DQI-A score than low consumers by 6.4% (CI= 3.5, 9.3, P<0.01) and moderate consumers by 2.8% (CI= 0.3, 5.3, P<0.01). Nevertheless, regarding other DQI components, also it was observed that low consumers had a statistically significant better diet quality components and subcomponents. For example, low take away consumers had a higher DDc and DEc in comparison to frequent consumers by 3.6% with (CI= 1.3 – 5.9, P<0.01) and 3.1% with (CI= 1.6 – 4.6, P<0.01), respectively. Regarding DAx sub-components, the results for frequent takeaway consumers were not statistically significant different in comparison to both low and moderate takeaway consumers. The results for food energy intake were similar, and no statistically significant difference were observed after the inclusion of the both variables in the regression model (Table 4-7).

Moving on to meals-out consumption, the overall DQI-A percentage score remained significantly impacted by the frequency of meals-out consumption. Regarding the other components and sub-components, the results were attenuated and not statistically significant after the inclusion of physical activity and type of lunch variables, except for DEc as low takeaway consumers had a higher dietary equilibrium component score than frequent consumers (reference group) by 1.8% with (CI= 0.0 - 3.5, P <0.01). No significant differences were observed in food energy intake between frequent, moderate and low consumers (Table 4-8).

Table 4-7 Regression (clustered) analysis between takeaway consumption and diet quality index for adolescents components and sub-components percentage score, age, sex, house-hold income, type of lunch during a school day and physical activity.

	Unadjusted analysis *n* = 2045								Adjusted analysis *n* = 702							
Frequent takeaway consumers as reference	**Low B**	**95% CI**		**p**	**Moderate B**	**95% CI**		**p**	**Low B**	**95% CI**		**p**	**Moderate B**	**95% CI**		**p**
Diet quality*																
DQI-A Overall	7.4	5.6	9.2	<0.01	3.7	2.2	5.2	<0.01	6.4	3.5	9.3	<0.01	2.8	0.3	5.3	<0.01
Diet quality component (DQc)	14.2	10.5	17.9	<0.01	6.7	3.6	9.9	<0.01	12.5	6.3	18.7	<0.01	5.3	0.2	10.5	<0.01
Diet diversity component (DDc)	4.6	3.1	6.1	<0.01	2.4	1.1	3.6	<0.01	3.6	1.3	5.9	<0.01	1.1	-1.0	3.2	0.3
Diet equilibrium component (DEc)	3.4	2.5	4.4	<0.01	2.0	1.2	2.8	<0.01	3.1	1.6	4.6	<0.01	2.0	0.6	3.3	<0.01
Diet adequacy sub-component (DAx)	1.6	0.3	2.8	0.02	1.0	-0.1	2.1	0.1	1.2	-0.8	3.1	0.2	0.4	-1.3	2.1	0.6
Diet excess sub-component (DEx)	-2.1	-3.0	-1.3	<0.01	-1.2	-1.9	-0.5	<0.01	-2.1	-3.5	-0.8	<0.01	-1.6	-2.8	-0.4	<0.01
Age (year)	0.03	-0.2	0.3	0.8	-0.1	-0.3	0.1	0.3	0.1	-0.2	0.5	0.5	-0.1	-0.4	0.2	0.5
Energy (Kcal)	-102.4	-162.4	-42.5	<0.01	-52.8	-105.2	-0.3	0.05	-122.7	-210.8	-34.7	<0.01	-71.3	-148.6	5.9	0.1

CI, Confidence Interval
*** Scores presented as %**

Table 4-8 Regression (clustered) analysis between meals-out consumption and diet quality index for adolescents components and sub-components percentage score, age, sex, house-hold income, type of lunch during a school day and physical activity.

	Unadjusted analysis n = 2045								Adjusted analysis *n* = 702							
Frequent meals-out consumers as reference	**Low B**	**95% CI**		**p**	**Moderate B**	**95% CI**		**p**	**Low B**	**95% CI**		**p**	**Moderate B**	**95% CI**		**p**
Dietary quality*																
DQI-A Overall	2.8	1.0	4.6	<0.01	3.4	1.7	5.0	<0.01	2.6	-0.5	5.8	0.1	3.7	0.9	6.5	<0.01
Diet quality component (DQc)	5.3	1.6	9.1	<0.01	5.0	1.6	8.4	<0.01	4.8	-1.6	11.2	0.1	5.1	-0.7	10.9	0.1
Diet diversity component (DDc)	1.2	-0.4	2.8	0.1	2.5	1.1	3.9	<0.01	1.2	-1.4	3.9	0.4	3.4	1.0	5.7	<0.01
Diet equilibrium component (DEc)	1.9	0.9	2.8	<0.01	2.6	1.7	3.5	<0.01	1.8	0.0	3.5	<0.01	2.7	1.1	4.2	<0.01
Diet adequacy sub-component (DAx)	0.6	-0.7	1.9	0.4	1.9	0.8	3.1	<0.01	0.5	-0.9	-1.6	2.7	2.2	0.3	4.1	<0.01
Diet excess sub-component (DEx)	-1.4	-2.2	-0.5	<0.01	-1.0	-1.8	-0.2	<0.01	-1.3	-2.8	0.1	0.1	-0.9	-2.2	0.5	0.2
Age (year)	-0.8	-1.0	-0.5	<0.01	-0.8	-1.0	-0.5	<0.01	-0.4	-0.8	-0.1	<0.01	-0.2	-0.6	0.1	0.1
Energy (Kcal)	-64.0	-126.9	-1.0	0.05	-35.2	-93.6	23.2	0.2	-38.7	-136.0	58.6	0.4	17.4	-74.8	109.5	0.7

CI, Confidence Interval
*** Scores presented as %**

4.6 Discussion

4.6.1 Summary of the findings

The present study is the first to assess the relationships between the consumption of takeaway foods and meals-out of home and diet quality in adolescents using an overall diet quality index and representative national data from the UK. The DQI-A was used to assess the adherence of British adolescents to dietary recommendations and healthy eating patterns. The results from the current cross-sectional study suggest that frequent consumption of takeaways in particular is negatively associated with overall diet quality and its components. A weaker but nevertheless significant association was seen with consumption of meals-out.

The mean diet quality score was 20.4% for all adolescents, lower than the score obtained from a previous study using the NDNS (data from Years 1–4, but excluding Years 5–6) which reported a score of 31.1% overall and also differences in some sub-components [226]. This may be due to the slightly different methodology used for the categorisation and classification of main food groups and sub-groups, including portion sizes, which influence each of the diet quality components and sub-components. For example, previous research excluded non-milk-based ice cream and beverages dry weight items from the analysis [226]. In the present study, both these food items were categorised within the low-nutrient weighting factor group. Alternatively, it may reflect a further worsening of diet quality in British adolescents which is already worse than in other European countries. According to previous European surveys, the mean diet quality of adolescents (DQI-A) from mainland Europe was considerably higher than for UK adolescents, with scores between 50 and 60% [36, 227].

4.6.2 Takeaway food and diet quality

The UK population prefers consuming food that is already prepared and currently has the highest rate of ready-meal consumption in Europe, double that of France and six times more than in Spain [228]. This trend is not showing any sign of abating. There has been a dramatic increase of 43% in the number of takeaway and fast-food outlets in the UK since 1990 [69, 229]. Typically, out-of-home meals from restaurants, cafes, takeaways, fast-food restaurants and sandwich shops are higher in saturated fat, sugar and total energy [7]. A cross-sectional study in England which included 332 secondary-school students aged 13-17 years showed that about 23% of the recommended energy intake of these students was obtained from foods purchased from fringe shops near schools. The nutritional quality of the purchased food items was found to comprise 38% saturated fat, 22% sugar and 15% non-milk extrinsic sugar [94]. Observational evidence from neighbouring Scotland carried out in five secondary schools showed that although the number of food outlets located within a 10 min walk varies from one school to another, during lunch break the majority of the students purchased unhealthy convenience foods from local shops such as fish and chips, pizzerias, kebab shops, cafes and supermarkets [99]. In the USA, a national representative survey that recruited children and adolescents aged 4-19 years stated that fast-food consumers had higher intakes of total fat, saturated fat, total carbohydrate and sugar- sweetened beverages. Moreover, lower intakes of fluid milk, fruits and non-starchy vegetables were observed among fast-food consumers [85]. The methodology used in the present study to calculate DQI-A score means that foods high in fat and sugar and sweetened beverages are more likely to be classified within low-nutrient food items 'non- recommended food products' that have a negative impact not only on overall DQI-A% score but also on its component scores. Conversely, food items such as liquid milk and fruit and vegetables enhance the overall DQI-A and its component scores.

4.6.3 Takeaway meals *vs* meals-out consumption

The associations of frequent takeaway consumption with diet quality were larger than the associations of frequent meals-out consumption both before and after adjusting for confounders. Different studies have used different definitions for the terms ‘out of home eating’ [15] and fast food [16] which may result in comparisons of effects on diet quality being difficult. However, despite the difficulties with defining fast food, studies have consistently found that fast food is of poor quality compared with other types of food purchased outside the home [230]. Results from a systematic review confirmed that eating out at a fast-food outlet had a larger impact on energy intake among both US adolescents [82] and Irish children [231] compared with eating out at a restaurant. A cross-sectional analysis of data from eleven different European countries 'including the UK' showed similar findings. Although the participants were adults aged 35 years or above, findings from that study confirmed that location of eating out of home 'including work and restaurants' affected not only energy intake but also intakes of other macronutrients such as carbohydrates, protein and fat [232]. Two further cross-sectional studies that analysed data among adult participants from ten European countries 'including the UK' showed that eating location such as restaurants, home or work had an impact on energy intake and its contribution to the total daily energy intake [232, 233]. The place where the food was consumed out of home was clearly reported in these studies. This may have helped the researchers in exploring the source of this impact whereas the NDNS has incomplete information regarding the source of food consumed for either takeaways or meals-out. Most of the UK studies included in the systematic review [82] did not report the sources where the food was consumed. In the present study eating takeaway- style food at home, such as fish and chips, is likely to have come from a takeaway/fast-food outlet 'delivery services'. Although both fast-food outlets and restaurants are associated with higher energy intake and poor dietary patterns, portion sizes for foods such as soft drinks and French fries are larger in fast-food outlets compared with restaurants and foods prepared at home. Restaurants were found to have smaller portions of foods including burgers and desserts [234, 235]. This may explain the differences observed in the present study for the association between takeaways and meals-out consumption and overall diet quality and its components. Another UK study examined the association between takeaway consumption and/or eating out and individual food groups and/or nutrients [68], whereas assessing individual dietary intake overall can be achieved through examining the dietary quality and variety of an individual daily diet [36, 37]. Overall diet quality may be a stronger predictor of health outcomes than individual food groups and nutrients. In addition, higher numbers of frequent takeaway consumers were from families with a low household income. A cross-sectional study showed that exposure to fast food seems to increase as the deprivation rate increases and this indicates that people living in areas with higher social and economic deprivation are more likely to select cheaper sources of food [68]. The higher price of healthy foods is one of the greatest barriers affecting low-income households' food choices [236]. Moreover, for people with lower household incomes who completed the Low Income Diet and Nutrition Survey 2005 [70], the most frequently reported barrier to healthy eating was the price of healthy foods.

In addition, many of the existing public health challenges such as obesity, smoking and diet quality remain despite the major investment in both research and policy over many years [237]. Traditionally, the evidence on how to overcome public health challenges has been based on tools and methods generated to focus on individuals and answer questions about the effectiveness of interventions on the individual, usually using linear models of cause and effect [237]. Much of the research funding, the activities and the published evidence are based on studies that attempt to identify individual-level health outcomes rather than complex and multiple population-level actions and outcomes. To improve population health, individual behaviours should be recognised as key elements that affect population health. Successful behaviour change interventions targeting individuals depend on improving the design and implementation of evidence-based practice and theoretical frameworks traditionally used in psychology are based on decision making and control. For example, behaviour change techniques (BCTs) have been used to increase physical activity levels and eating more healthily as well as reducing smoking. However, these techniques have shown that different interventions such as persuasion, incentivisation and environmental restructuring are needed, in addition to BCTs, to achieve a specified behavioural target [238]. Moreover, the effectiveness of interventions across different population groups is believed to depend on the level of agency. High agency interventions depend on individuals having to make many decisions before behaviour change occurs; for example cooking classes require a high level of agency as people might drop out at different stages either at recruitment or later. However an intervention to introduce planning zones would be an example of an intervention with low agency [239]. In this example, individuals do not have to be involved with any information or actively change their behaviour to benefit from the intervention. High-agency population interventions have the potential to be less effective in some groups and may increase socioeconomic inequalities as those individuals who are wealthier and more educated may be more able to find the time and financial resources to complete high agency interventions. For example, people with higher socioeconomic status and educational level are more likely to understand and benefit from public health messages such as eating less fast food and being able to afford alternative healthier foods even if they are more expensive and time-consuming to prepare. Although exclusion zones policies are considered to be a relatively weak intervention, if it has even a modest impact on a large number of people it can be considered effective at a population level. Suitability of health interventions for scaling up to a population level is also an important point to consider [240]. It would be difficult to engage takeaway chefs to improve healthy food options in the menu on a large scale, partly due to competitive reasons [241]. However, it might be easier to scale up alternative interventions such as planning polices to limit the clustering of hot food takeaways around schools, homes and other facilities. Guidance on how to scale up health interventions recommended by policy makers is needed in order to reach larger populations [240]. It is clear that a wider set of actions using a systems approach are required to identify, implement and evaluate effective responses to public health challenges [237, 242]. Changing behaviour based on responses to interventions to reduce intake of takeaways requires more than educating and motivating individuals to make better choices. Interventions to reduce the number of takeaways alone may not work, for example, if existing takeaway outlets lower the price of their food (making existing stores more attractive) and/or deliver meals to homes in response to limiting the number of takeaway outlets through policy intervention [237, 243]. To intervene without a thorough understanding of behavioural complexities (e.g., how they cause and respond to feedback loops, interactions, threshold effects, and unintended consequences) is to ignore a key part of the complex system of population health and to undermine the potential for effective interventions [242].

4.6.4 Strengths and limitations

There were notable strengths to the current analysis. First, the data analyses presented here were generated in duplicate by two independent researchers. Second, the NDNS is a national UK survey and is considered high quality, representative and containing up-to-date information on eating behaviour in the UK population. However, the data have limitations. In Year 1, more weekend days were included than in other survey years, which is considered to have an impact on estimates of nutrient and food intakes. In the NDNS data, it was possible to identify the participants who did actually consume takeaway foods at home and outside the home during the 4 d diary records.

However, this study also has some limitations including the cross-sectional and observational nature of the data due to measurement of the outcome and the exposures in the study participants at the same time [244]. In this study, individual's dietary intake and their overall diet quality were assessed at one point in time where some individuals with low diet quality might have altered their dietary behaviors (eating more preference food items) during the study time. Therefore, it is difficult to determine causal relationships between the exposures and outcome. Nevertheless, a cross-sectional study can provide useful information about the prevalence of the exposures or outcomes [244]. This information can be used for designing, for example, a cohort study where participants are selected based on the exposure status and followed for several years to measure the outcome.

In addition, foods such as burgers and kebabs, fried chicken, fried coated fish and others were labelled as prepared using home recipes, whereas foods such as pizza were not labelled as takeaway food or having been prepared at home, except for chips where participants indicated if they were purchased from a takeaway. This could have assisted in examining the effect of consuming takeaway foods on the DQI-A% score and its components for each of the four days by comparing days when takeaway food was consumed with days where no takeaway food had been consumed. Instead, the analysis of the DQI-A% score relied on the information on frequency of consuming takeaway food by participants, to categorise them as a frequent, moderate or low takeaway consumers. It is not possible to rely solely on the information collected with 4 d diaries to assess intake of takeaways as many people consume takeaway food less than once every 4 d. Two per cent of the participants collected data for only 3d and these participants had lower mean diet quality and higher reported intake of takeaway food. Participants who eat out more frequently may be more likely to find completing a 4 d diary difficult and therefore may be more likely to drop out of the study, introducing bias.

In addition, eating out of home can be defined differently, such as only food purchased and consumed outside the home or also including food consumed out of home but prepared at home. Additionally, there is no clear difference between restaurants and fast-food outlets as some fast-food outlets also have seating areas where customers can eat in [232]. Orfanos et al. [245] confirmed the ambiguous area in the definition of eating out of home while at work, which may lead to having inconsistent results. Only a brief general description of the difference was provided to participants in the NDNS leading to incomplete information being provided regarding takeaway meals at home such as pizza, fish and chips and burgers, which could have been prepared at home or delivered from a takeaway outlet. Similarly with consumption of meals-out, as the question focused on general examples such as restaurants or cafes, the importance of obtaining information regarding the source of food being purchased and consumed was ignored [246]. In addition, in the NDNS, school meals are excluded from being defined as a meal out.

The UK and other European countries, including Austria, Belgium, France, Italy and Germany, are following a similar approach to food group classification and have similar dietary recommendations such as the Eatwell Guide, food pyramids and recommended portion sizes. However, further recommendations on the maximum and minimum intakes from each food group are more common in non-UK dietary guidelines (such as the Flemish dietary guidelines). The language barrier (lack of availability of European guidelines in English) was another obstacle to understanding the way in which other European countries implement their dietary recommendations and guidelines [247]. Although studies have been conducted using diet quality indices in the UK population [248, 249], the types of indices used and the ages of the targeted groups were different, which made the findings obtained from the present study and the other UK-based studies difficult to compare. Also, those challenges made the calculation of UK adolescents' DQI-A and its component scores more difficult.

In addition, physical activity is an essential confounder to be included in the regression model, especially when weight (or BMI) is a health outcome of interest. However, because less than 50% of the total participants provided a valid measurement regarding their physical activity level, the analysis was carried out without the inclusion of the physical activity variable in the model.

4.6.5 Policy and recommendations

A recent report from the Organisation for Economic Co-operation and Development (OECD) noted that British adolescents have some of the worst diets in the world in terms of diet quality [250]. Consumption of takeaway food is common in adolescence, and is associated with lower quality diets and therefore needs to be addressed. The food environment in schools and retail outlets such as supermarkets has improved in the last 10 years with new school meal standards and food reformulation to reduce trans-fats, salt and sugar [23]; however, the fast-food environment has worsened. Of particular concern is the higher density of fast-food outlets in areas of social and economic deprivation and larger portion sizes of fast food [48, 69]. Reducing the density of fast-food outlets near schools may be one method of achieving this as recommended by Public Health England, although the impact on health has not been evaluated to date [48, 50, 104]. Therefore, policies to reduce availability, accessibility, and opening hours of fast food outlets may help to reduce consumption of fast food among this age group. However, many of those outlets are already in existence and the introduction of new policies can only prevent the opening of new outlets in the future [77]. Nevertheless, the implementation of such planning policies, especially for long-term effectiveness and their impact on health have not been explored in the UK [49, 50]. Findings are based on a mixture of quasi-experiments where researchers do not have full control over the time of the study or allocation of the participants to groups [251]. In an ideal environment, the ideal study design would be to conduct a randomised control trial. Randomised controlled trials (RCTs) are considered to be the gold standard for evaluating the effectiveness of an intervention [252]. However, this is not always possible particularly when evaluating the effectiveness of health policies and programmes at population level. There are a number of alternative methods, such as quasi experimental trials, to evaluate the effectiveness of a health intervention [252]. A useful method of this type includes Interrupted time series analysis, which takes account of any existing trends in outcomes due to additional policies or programmes. This method is also appropriate for evaluating a natural experiment (where "exposure to the event or intervention of interest has not been manipulated by the researcher") [251]. However, natural experiments rely on data being routinely recorded and weight and height data are not currently collected nationally in the UK for this age group.

One of the intervention approaches that local authorities have considered is working directly with takeaway food outlets owners and managers to improve healthiness of offered food and drinks in the menu. This could be achieved mainly by providing cooking training courses for the working staff [77]. Education-based interventions on how to make wise food related decisions also showed improvement of adolescent's fast food choices (the healthier option) and decreased consumption of unhealthy snacks [253]. In addition, recommendations and campaigns to increase the skills and awareness of young people concerning the benefits of preparing meals at home; and selecting healthier options when purchasing food from outside home could also help. According to the Department of Health and Social Care (2018), only about one quarter of cafes and restaurants provide calorie labelling at the point of choice for the food purchased to consume outside the home [254]. Availability of nutritional information to the public can help them to make healthier choices [254] and therefore the adoption of easy-to-understand nutritional information leaflets in food outlets, specifically designed for adolescents, could also help in part to increase their knowledge about healthy food choices [255]. Public health interventions aiming at controlling the availability, palatability and exposure to inexpensive energy-dense food and drinks are likely to be more effective strategies to reduce consumption. However, with no universally accepted portion sizes of healthy and unhealthy foods it is difficult to make recommendations. This would help in designing more widely acceptable FBDG and more robust diet quality assessment methods [256].

4.7 Conclusion

In conclusion, UK adolescents have a poor-quality diet, particularly those who report frequent consumption of takeaway meals and to a lesser extent frequent consumption of meals-out. The negative associations of takeaway food with the diet quality of UK adolescents may lead to long-term health impacts on young people in the UK, although I did not include research to confirm this here. Further interventions such as actions to improve the fast- food environment near schools are needed to improve dietary behaviour in young people. These results from the NDNS survey, are also likely to be useful for informing future governmental policies to improve the dietary behaviour and health status of young people in the UK. The next chapter will investigate the associations between the student’s choice for lunch during a school day and the overall diet quality score. This will help to expand our knowledge about the effect of the food environment outside and inside the school premises.

Chapter 5 Cross-sectional associations between lunch type consumed on a school day and British adolescents' overall diet quality

Abstract

Background: Diet quality of children consuming school meals tends to be better than that of children consuming packed lunches (from home) or food bought outside school. This study investigates the association between different types of lunch consumed in a school day and diet quality of UK adolescents.

Methods: A total of 2118 British adolescents were included from the National Diet and Nutrition Survey (Years 1-8; between 2008 and 2016). All participants attended school and were aged 11-18 years with valid 3 or 4-day diary records. The Diet Quality Index for Adolescents (DQI-A) tool consisting of three components; diet quality, diversity and equilibrium, was used to assess adherence to dietary recommendations. Overall DQI-A scores range from –33 to 100%. Overall mean

Results: DQI-A score for all adolescents was low at 21.0%. Fewer adolescents reported buying lunches from cafés and shops but they had the lowest DQI-A% score of 14.7%. Adolescents having cooked school meals (reference group) had a higher overall DQI-A% of 21.8%. Diet quality scores of adolescents having packed lunches and shop/café-bought lunches were 1·6% higher (CI 0.1 to 3.2%; p =0.04) and 8·2% lower (CI 6.2 to 10.2%; p<0.01) than school meals respectively, after adjusting for confounders.

Conclusion: UK adolescents generally consume a poor quality diet and adolescents purchasing lunches from outside the school gates have the lowest diet quality. Unlike younger children, there is little difference between school meals and packed lunches. Regulation policies on food outlets around secondary schools as well as improving food choices within school premises are needed.

5.1 Introduction

The type and quality of food consumed by children and young people during a school day is a primary concern in many countries. The total number of secondary state school students in England is 3.2 million; and students spend nearly 190 days (approximately half) of the whole year in school [257]. Legislation exists across the UK to improve the school food environment including cutting down sales of foods that are high in fat, salt and sugars, as well as providing better food choices [258]. Evidence has consistently shown that the dietary quality of primary school children consuming school meals is better than those consuming packed lunches (food brought from home) [259, 260] although the research on secondary schools is less consistent [261-263]. The revised requirements for School Food Regulations came into force in 2015 in England and are solely food based having dropped nutrient-based standards introduced in 2009 [258]. These regulations focus on menu planning and provision of school foods and drinks, including types and portion sizes of starchy foods, fruit and vegetables, protein-rich foods and foods high in fats, sugars and salt that can be provided as a part of school lunch [258, 264]. However, the number of children who consume school meals has decreased in England, particularly in secondary schools and there is concern that alternative lunch types are lower in quality. In many cases secondary schools allow older children to leave school premises during the lunchtime break [48] which may account for some of the reduction in school meals take-up. Previous work on takeaway food purchased at any time of the day highlighted the negative impact of consuming takeaway meals on adolescents' overall diet quality scores [265]. Therefore, one of the factors preventing students from eating a healthy lunch is likely to be the proximity of fast food outlets to secondary schools. Limiting the establishment of new fast food outlets, especially around schools, is a primary goal of health organisations, such as the Chartered Institute for Environmental Health and Department of Health (DOH) [8, 196].

5.1.1 Overall diet quality

As discussed earlier in chapters 2 and 4, measuring diet quality is challenging, but one validated tool is the Diet Quality Index for Adolescents (DQI-A). It assesses diet quality based on intake of food groups and Food-Based Dietary Guidelines (FBDG) [43], without the need for the intensive conversion of foods to nutrients [36, 38]. The role of the FBDG are to help individuals to meet their daily dietary requirements by providing guidelines and advice to the public on frequency and portion sizes of specific food groups. These guidelines can also help to provide information for government and other related stakeholders to implement effective interventions toward healthy eating behaviours [44]. Although several UK studies have investigated the relationship between having a packed lunch and a school meal and energy intake and individual nutrients of primary [259, 260] and secondary [261, 262] aged students, none have examined the impact of each school lunch type consumed during a school day on British adolescents' overall diet quality score.

5.1.2 Aims

The aim of the this chapter is to support our findings from the previous analysis in Chapter 4 about the imapct of being a frequent takeaway food consumer and mainly to evaluate the associations between different types of lunch consumed during a school day and the overall diet quality of UK adolescents using school meals as the reference group. Differences by age were also investigated.

5.2 Methods

The same NDNS data were used in this chapter and in Chapter 4. Nevertheless, the NDNS data from rolling programmes years 6–7 and 7–8 were also used and combined with the previous data years 1–6 during the data analysis in this chapter. The data were obtained from the National Diet and Nutrition Survey (NDNS) rolling programme years 1–8 (2008–2016). The NDNS is an annual programme that aims to assess the nutritional status of UK people living in private households aged 1·5 years and above. It involves random sampling throughout the year and represents the whole UK population by covering all four regions of the United Kingdom (England, Wales, Scotland and Northern Ireland) [266]. All NDNS participants aged 11–18 years and attending secondary school, including Sixth Form colleges, were included. Merging of separate data sets was required to obtain all relevant data. More information about NDNS data can be found in Chapter 3, section 3.3.

5.2.1 Lunch type and food intake

The interviewers asked all participants the following question “On a school/college day, what do you / does (child’s name) usually have for lunch?” to obtain information about the type of lunch being consumed during a school day. The interviewers made it clear that the lunch did not include snacks such as confectionary, crisps or fruit. Also, the interviewers explained that the main information required from this question was the meal consumed and not the time at which this meal was eaten. The options provided in the questionnaire were as follows (1) “cooked school meal”, (2) "Cold school meal (including sandwiches, salads)", (3) "Packed lunch (from home)", (4) "Buy lunch from shop/cafe", (5) "Go home" and (6) "Do not eat lunch".

All NDNS participants were asked to complete a four-day food diary, and the analysis included only those who completed at least a 3-day record. Adolescents completed the diary themselves and participants were asked to keep a record of all foods and drinks consumed at home or outside the home including leftovers. Commercial toddler drinks and foods items were excluded from the analysis as this age group do not typically consume these foods.

5.2.2 Diet Quality Index for adolescents (DQI-A)

In the UK, the latest version of the FBDG is the Eat-well guide, which was published in 2016 by Public Health England. The Eat-well guide consists of seven main food groups, as follows: (1) potatoes, bread, rice, pasta and other starchy carbohydrates; (2) dairy and alternatives; (3) beans, pulses, fish, eggs, meat and other proteins; (4) fruit and vegetables; (5) oil and spreads; (6) water; and (7) confectionary and high fat and sugar snacks [44, 203]. The Flemish FBDG, which was used to validate the DQI-A, includes almost the same recommended food groups mentioned in the Eat-well guide. The DQI-A relies on three main components, namely the (1) Quality, (2) Diversity and (3) Equilibrium of the diet compared to the governmental dietary guidelines. The Diet quality Component (DQc) assesses diet based on the quality of the obtained food within the nine recommended food groups, namely (1) water; (2) bread and cereal; (3) potatoes and grains; (4) vegetables; (5) fruits; (6) milk products; (7) cheese; (8) meat, fish and substitutes and (9) fat and oils. The Diet Diversity component (DDc) assesses the degree of variation in an adolescent's diet, where the scoring range is from 0 to 9 points. Consuming at least one serving from each of the nine recommended food groups adds 1 point to the total score. The Diet Equilibrium component (DEc) consists of two subcomponents: (1) the adequacy component (diet adequacy, DAx) and (2) the excess component (diet excess, DEx). These two subcomponents express the degree of adherence of an adolescent's diet to the minimum and maximum intakes of each of the nine recommended food groups. The adequacy component represents the percentage of the minimum recommended intake of each of the nine food groups, whereas the excess component represents the percentage of the intake exceeding the upper limit of the recommendation (11 food groups, 9 recommended and 2 non-recommended).

The percentage ranges for both DDc and DEc are 0–100%, whereas the DQc percentage range is –100 to 100%. Therefore, the mean percentage of the three main components, result in a total DQI-A score ranging from –33 to 100%. A higher DQI-A percentage score reflects a better quality of diet. More details on the calculations for each of the components and sub-components can be found in chapters 3, 4 and in previously published studies [36, 265].

5.3 Statistical analysis

All statistical analyses were carried out using Stata statistical software, version 15·0 (College Station, TX: Stata Corp LLC). The data was weighted to adjust for nonresponses and to ensure the data was representative for the UK. The percentage of males and females and ethnicity (white/non-white) were presented. The mean age in years, Energy intake in kJ and weight in kg were also calculated for both males and females. A Directed Acyclic Graph (DAG) [267] (Figure 5-1) with type of lunch consumed on a school day as the main exposure and Diet quality index and its components and sub-components (continuous) as the outcome was generated to predict confounding variables. Linear and multiple regression analyses were conducted taking into account the clustering effect resulting from the 4-day diary records. According to minimal sufficient adjustment sets, age (years), equivalised household income, reduced price or subsidised school meal (at lunchtime) and gender (male/female) were needed to estimate the associations of lunch on a school day and DQI-A and its components. The residuals were plotted against fitted values of the predicted variable to check assumptions for regression were met. P-values of less than 0·05 were considered as statistically significant for all tests, and 95% confidence intervals were presented with the results. The number of adolescents consuming each lunch type were analysed by age. Diet quality components and subcomponents were reported for each lunch type. Changes in overall DQI-A% score and percentage of consumption of lunch type were assessed over time. The assessment was smoothed by combing the results of two survey years together (Figure 5-2).

For general characteristics of the participant, the classification of socio-economic status of parents was based on the UK National Statistics-Socio-Economic Classification (NS-SEC). Participants were divided into eight NS-SEC categories in the NDNS and then reclassified into four categories: 1- managerial and professional, 2- intermediate, 3-routine and manual and 4- Never worked and other. This method has been used in previously published papers [224, 225]. Data were not available for all of the variables in the general characteristic of the participants including dieting, being a vegetarian, student's working status, ethnicity and socio-economic status of parents.

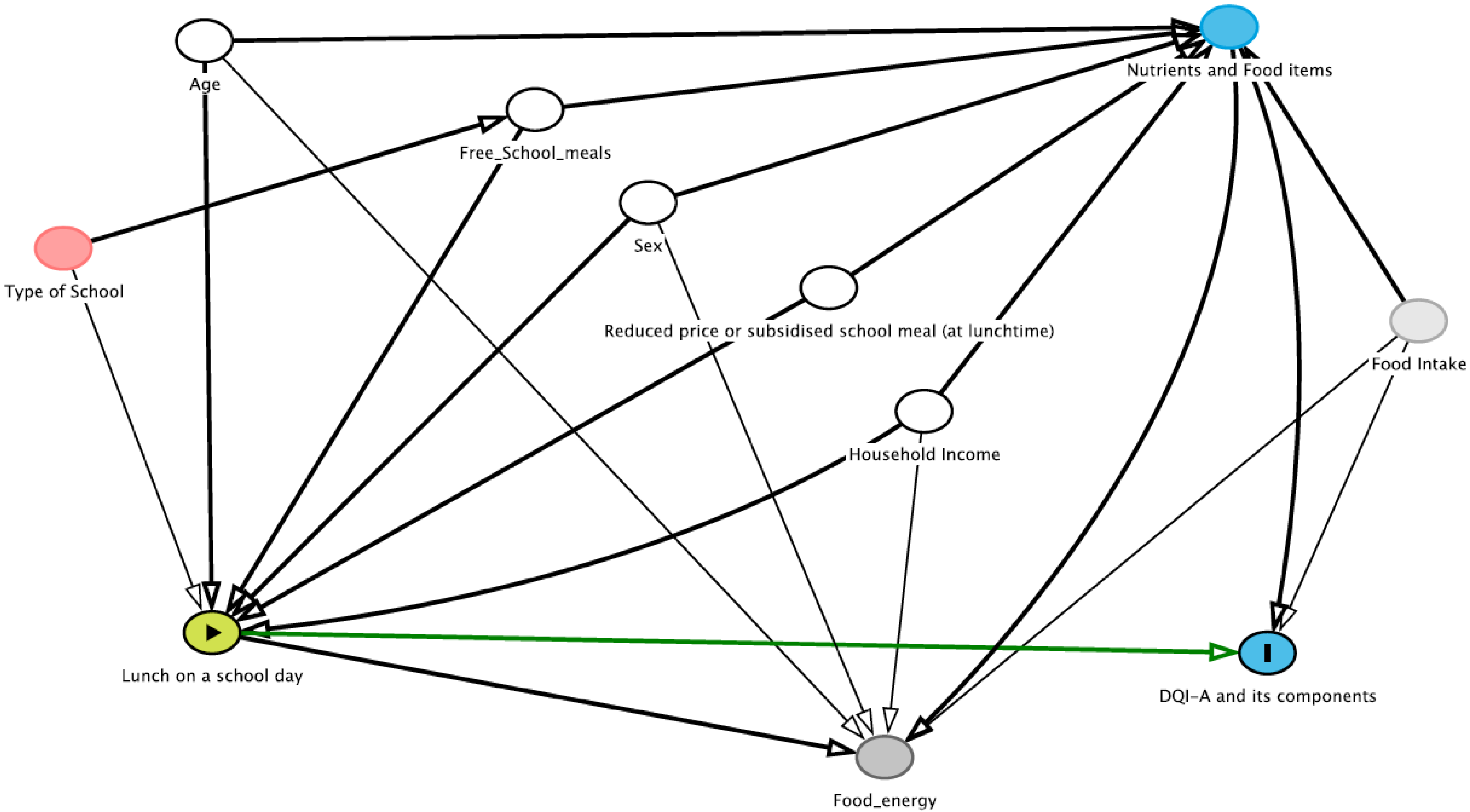


Figure 5-1 A Directed Acyclic Graph (DAG) with type of lunch consumed on a school day as the main exposure and Diet quality index and its components and sub-components as the outcome with prediction of potential confounding variables.

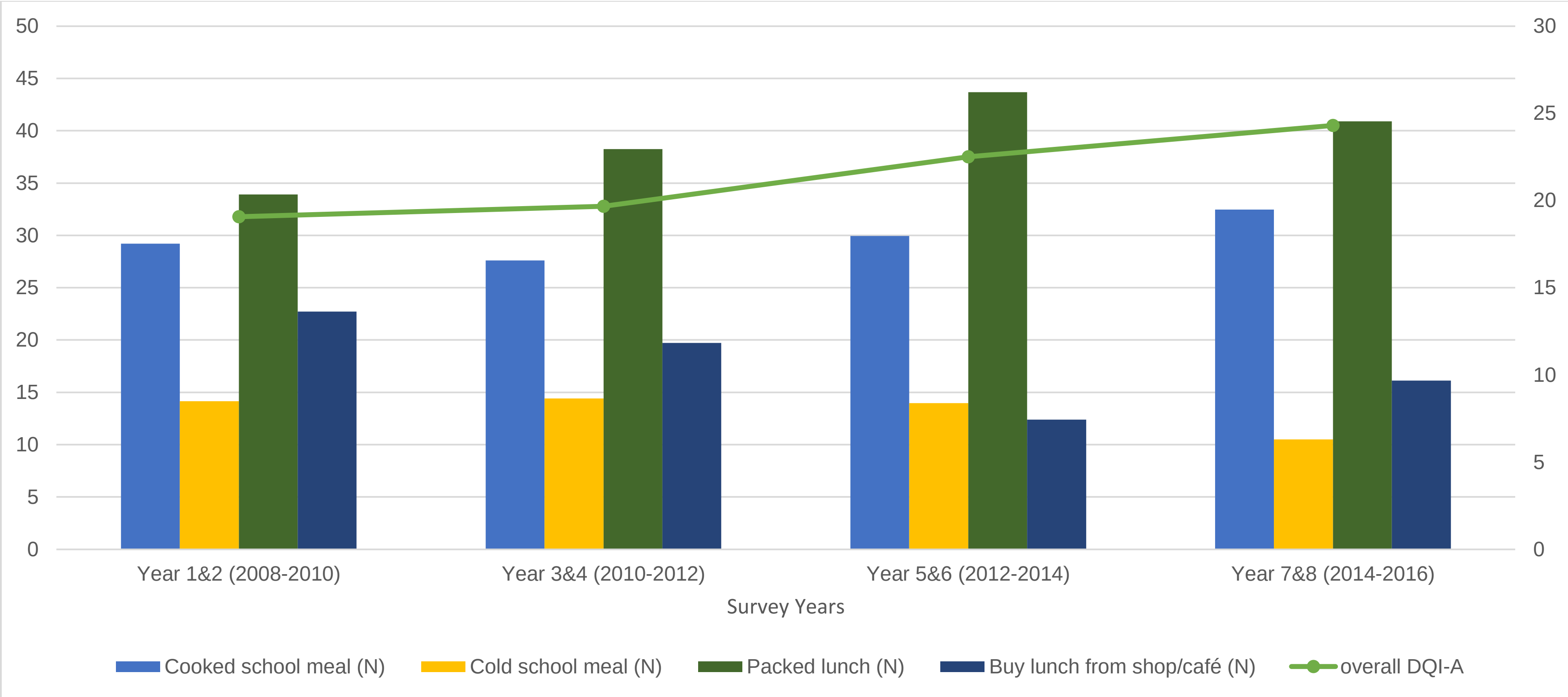


Figure 5-2 The mean score of overall DQI-A%, and percentage of consumption for each type of lunch consumed on a school day over smoothed survey years (Year 1–8).

5.4 Results

5.4.1 Background description

A total of 2118 adolescents were included in the analysis. From the initial sample, 469 were excluded due to attending primary not secondary school. Ninety-eight percent of participants had 4-day diary records. The proportion of females was slightly higher than that of males, at 52% (n = 1096) and 48% (n = 1022), respectively; the mean age of both genders was 14.4 years. In terms of ethnicity, out of 1206 adolescents who included information; 91% of them reported being white. The overall mean weight was 57.4 kg, and males had a higher weight than females (Table 5-1). The overall mean intake of food energy was 7370 kJ, and males also had a higher energy intake than females (Table 5-1). The percentage of under-reporters was high overall at 73.0% and was higher in the older age group for both males (78.6%) and females (76.8%).

In addition, the overall mean DQI-A score varied across the four days recorded according to the type of usual lunch type reported by the students (Table 5-2). No significant differences were observed in the overall diet quality score between male and female students (Table 5-2).

Table 5-1 Summary description of age, weight and food energy intake among adolescents (11–18 years) from the National Diet and Nutrition Survey (NDNS).

		Total sample			Males			Females		
		***n* = 2118**			***n* = 1022**			***n* = 1096**		
		Mean	95% CI		Mean	95% CI		Mean	95% CI	
Age (years)		14.5	14.4	14.6	14.5	14.3	14.6	14.5	14.4	14.6
Weight (kg)		57.4	56.6	58.2	58.6	57.4	59.9	56.2	55.2	57.2
BMI		21.1	20.8	21.3	20.6	20.2	20.9	21.6	21.2	21.9
Waist circumference (cm)		55.7	54.2	57.2	56.2	54.0	58.5	55.2	53.2	57.3
Food energy (kJ)		7370.3	7278.6	7461.9	8155.8	8019.1	8292.5	6637.8	6531.7	6743.9
Overall DQI-A%		21.1	20.5	21.8	20.7	19.3	22.0	21.5	20.3	22.8
General characteristics presented as percentage (%)										
Dieting/ n = 594		1.2	0.7	2.0	0.7	0.3	1.8	1.6	0.9	2.9
Vegetarian/ n = 2110		2.5	1.9	3.3	1.2	0.7	2.1	3.7	2.8	5.0
Student's working status/ n = 2118	Full-time school or college	100.0	-	-	100.0	-	-	100.0	-	-
	Full or part-time employment	NA	-	-	NA	-	-	NA	-	-
Ethnicity/ n = 1206	White	91.1	89.4	92.6	90.8	88.1	92.9	91.4	89.0	93.4
	Non white	8.9	7.4	10.6	9.2	7.1	11.9	8.6	6.6	11.0
Socio-economic status of parent/ n = 1112	Professional/Managerial	53.8	51.7	56.0	52.7	49.6	55.8	54.9	51.9	57.8
	Intermediate	18.1	16.5	19.8	18.9	16.6	21.5	17.4	15.2	19.7
	Routine/Manual	23.6	21.9	25.5	24.2	21.7	27.0	23.1	20.7	25.6
	Never worked and other	4.4	3.6	5.4	4.1	3.1	5.5	4.7	3.6	6.1

CI, Confidence Interval

Table 5-2 The diet quality score across all days for each participant according to the type of usual lunch type reported and differences in the overall diet quality score by gender.

What do you usually have for lunch?	Mean overall DQI-A%				Overall diet quality score (mean of all days recorded)	Gender differences in the overall diet quality score (meal of all days recorded)			
	Day Number								
	Day 1	Day 2	Day 3	Day 4					
	n = 2118	*n* = 2118	*n* = 2118	*n* = 2084	*n* = 2118	*n* =2118			
						Male as reference group			
Cooked school meal	22.3	22.4	21.3	21.3	21.8	B	CI		P-value
						-0.4	-2.8	1.9	0.7
Cold school meal	20.6	20.8	20.4	20.0	20.5	B	CI		P-value
						-0.3	-3.7	3.2	0.9
Packed lunch (from home)	25.3	23.9	23.2	23.1	23.8	B	CI		P-value
						0.9	-1.3	3.0	0.4
Buy lunch from shop/café	16.3	14.6	14.6	13.7	14.8	B	CI		P-value
						1.8	-1.3	4.9	0.2
Go home	22.4	23.3	21.4	19.2	21.6	B	CI		P-value
						-1.6	-10.7	7.5	0.7
Do not eat lunch	16.7	19.4	22.2	18.1	19.1	B	CI		P-value

All but 5 participants provided information on type of lunch consumed. Eating lunch at home or skipping lunch were reported by fewer than 5% of participants. Purchasing cold school meals and buying lunch from shops or cafes (takeaway meals) was reported by 12.9% and 17.5% of participants, respectively. The remaining participants reported having a cooked school meal (28.4%) or bringing a packed lunch from home (36.7%). Less than 10% of the total participants mentioned they were receiving free school meals or reduced-price meals at lunchtime. Therefore, those two variables were excluded from the model.

The overall mean DQI-A score was 21%. The mean overall diet quality score (DQI-A) varied across different lunch types (Table 5-3). Although few adolescents reported not eating lunch in a school day (n = 37), these participants had the second lowest mean DQI-A% score with 18.9%, whereas takeaway consumers (n = 369) who bought lunch from cafés and shops had the lowest DQI-A% score with 14.8%. Participants who consumed cooked (n = 600) and cold (n = 272) school meals and having lunch at home had a relatively higher percentage for the overall DQI-A score with 21.8 and 20.5 and 21.5%, respectively. Adolescents who brought packed lunches (n = 776) from home had a higher score with 23.9%.

Table 5-3 Summary description of overall diet quality index and its component and sub-component scores, age and energy intake according to type of meal usually consumed during school lunch among British adolescents aged 11–18 years (*n* = 2587) from the National Diet and Nutrition Survey (NDNS) rolling programme, Years 1–8 (2008–2016).

Dietary quality*	Total sample			Cooked school meal			Cold school meal			Packed lunch (from home)			Buy lunch from shop/cafe			Go home			Do not eat lunch		
	n = 2118			*n* = 600			*n* = 272			*n* = 776			*n* = 369			*n* = 59			*n* = 37		
	Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI		Mean	95% CI	
DQI-A Overall	21.1	20.5	21.8	21.8	20.6	23.0	20.5	18.8	22.2	23.9	22.8	24.9	14.8	13.2	16.3	21.5	17.0	26.0	18.9	12.9	25.0
(DQc)	-4.3	-5.7	-3.0	-2.4	-4.9	0.1	-5.3	-9.1	-1.6	-0.1	-2.3	2.1	-15.9	-19.2	-12.6	-3.1	-13.0	6.9	-4.2	17.1	8.6
(DDc)	44.5	44.0	45.0	44.7	43.7	45.7	43.9	42.6	45.3	46.5	45.6	47.5	40.6	39.3	41.8	45.7	42.3	49.1	39.2	34.8	43.7
(DEc)	23.2	22.8	23.5	23.2	22.5	23.8	22.8	21.9	23.6	25.2	24.6	25.7	19.6	18.8	20.4	21.9	19.7	24.0	21.8	19.0	24.6
(DAx)	53.5	53.0	53.9	53.7	52.8	54.5	53.0	51.8	54.2	55.6	54.8	56.3	49.8	48.8	50.9	52.3	49.5	55.1	48.5	45.4	51.7
(DEx)	20.6	20.3	20.9	20.8	20.2	21.3	20.6	19.7	21.5	20.3	19.8	20.8	21.1	20.4	21.9	21.0	19.1	22.8	17.9	15.8	20.1
Age (year)	14.5	14.4	14.6	13.8	13.7	14.0	14.3	14.1	14.5	14.3	14.2	14.5	15.7	15.5	15.9	15.9	15.5	16.4	15.4	14.9	15.9
Energy (KJ)	7370.3	7278.6	7461.9	7493.0	7321.1	7665.0	7348.8	7080.8	7616.8	7303.7	7161.0	7446.4	7396.8	7153.4	7640.2	7368.9	6795.9	7941.9	6783.4	6223.9	7342.9

CI, Confidence Interval; DQI-A, Diet Quality Index for Adolescents; DQc, Diet quality component; DDc, Diet diversity component; DEc, Diet equilibrium component; DAx, Diet adequacy sub-component; DEx, Diet excess sub-component
*** Scores presented as%**

5.4.2 Associations between diet quality and lunch type consumed

The results from the regression analysis indicated an association between school lunch type and diet quality of UK adolescents. After adjusting for confounders including age, gender and equivalised household income, significant differences were observed between consumption of cooked school meal (reference group) and packed lunches and takeaways in their DQI-A scores (Table 5-4). Consuming a packed lunch had a higher overall DQI-A score by 1.6% (95% CI 0.1, 3.2%; P = 0.04) than consuming a cooked school meal. On the other hand, consuming a takeaway meal had a lower overall DQI-A% than consuming a cooked school meal by -8.2% (95% CI -10.2, -6.2%; p < 0.01). No significant differences were observed between adolescents who reported to have a cooked school meal (reference group) and those who have cold school meal, lunch at home or did not have lunch (Table 5-4).

In addition, significant differences were observed between cooked school meal consumers and packed lunches and takeaway consumers for most of the DQI-A components and subcomponents. For example, packed lunch consumers had a higher DDc%, DEc% and DAx% than cooked school meal consumers. Conversely, takeaway consumers had a lower DQc%, DDc%, DEc% and DAx% than cooked school meal consumers. No statistically significant differences were observed between cooked school meal consumers and cold school meal or lunch at home consumers among any of the diet quality components and sub-components. Although there were some non-significant differences observed between the cooked school meal consumers and other lunch types consumers among some of the diet quality components, unadjusted analysis showed similar results to the adjusted analysis (Table 5-5).

5.4.3 The impact of age

The percentage of students consuming the most common types of lunch during a school day varies by age (Figure 5-3). It can be seen from Figure 5-3 that the number of students consuming school meals (cooked and cold) decrease as the age increase. Conversely, the number of students consuming takeaway meals increases with age. The percentage of packed lunch consumers fluctuated between the age of 11 and 16 years with a drop at the age of 17 and 18 years.

Table 5-4 Regression (clustered) analysis between Diet quality index and its components and subcomponents and type of lunch consumed on a school day for adolescents aged 11–18 years from the NDNS rolling programme.

	Adjusted* analysis																			
	Cold school meal				Packed lunch (from home)				Buy lunch from shop/cafe				Lunch at home				Do not eat lunch			
	B	95% CI		P	B	95% CI		P	B	95% CI		P	B	95% CI		P	B	95% CI		P
DQI-A%	-1.6	-3.7	0.4	0.1	1.6	0.1	3.2	0.04	-8.2	-10.2	-6.2	<0.01	-1.6	-6.2	3.0	0.5	-3.7	-9.7	2.3	0.2
DQc%	-3.8	-8.3	0.7	0.1	1.0	-2.3	4.3	0.5	-16.3	-20.5	-12.0	<0.01	-3.7	-13.7	6.4	0.5	-4.0	-16.6	8.6	0.53
DDc%	-0.7	-2.4	0.9	0.4	1.8	0.5	3.2	0.01	-5.3	-7.0	-3.6	<0.01	-0.3	-3.8	3.2	0.9	-6.2	-10.7	-1.7	0.01
DEc%	-0.3	-1.4	0.8	0.3	2.0	1.2	2.9	<0.01	-3.1	-4.2	-2.0	<0.01	-0.9	-3.1	1.4	0.5	-1.0	-3.7	1.8	0.5
DAx%	-0.3	-1.7	1.1	0.7	2.3	1.2	3.4	<0.01	-3.7	-5.2	-2.3	<0.01	-1.4	-4.3	1.5	0.3	-4.8	-8.0	-1.6	<0.01
DEx%	0.1	-0.9	1.1	0.9	-0.2	-0.9	0.5	0.6	0.1	-0.9	1.0	0.9	-0.3	-2.2	1.6	0.8	-3.0	-5.2	-0.7	0.01

CI, Confidence Interval; DQI-A, Diet Quality Index for Adolescents; DQc, Diet quality component; DDc, Diet diversity component; DEc, Diet equilibrium component; DAx, Diet adequacy sub-component; DEx, Diet excess sub-component
***Adjusted for age, gender and equivalised household income**

Table 5-5 Regression (clustered) analysis between Diet quality index and its components and subcomponents and type of lunch consumed on a school day for adolescents aged 11–18 years from the NDNS rolling programme.

	Unadjusted analysis																			
	Cold school meal				Packed lunch (from home)				Buy lunch from shop/cafe				Lunch at home				Do not eat lunch			
	B	95% CI		P	B	95% CI		P	B	95% CI		P	B	95% CI		P	B	95% CI		P
DQI-A%	-1.4	-3.4	0.7	0.2	2.0	0.5	3.6	0.01	-7.1	-9.0	-5.1	0.0	-0.3	-4.8	4.2	0.9	-2.9	-8.8	3.0	0.3
DQc%	-2.9	-7.4	1.5	0.2	2.3	-1.0	5.6	0.2	-13.5	-17.6	-9.4	0.0	-0.7	-10.6	9.3	0.9	6.4	14.3	10.6	0.77
DDc%	-0.8	-2.5	0.9	0.4	1.8	0.5	3.2	0.01	-4.1	-5.8	-2.5	0.0	1.0	2.4	4.5	0.6	-5.5	-9.8	-1.1	0.01
DEc%	-0.4	-1.5	0.7	0.5	2.0	1.2	2.9	0.0	-3.5	-4.5	-2.5	0.00	-1.3	-3.5	0.9	0.2	-1.4	-4.1	1.3	0.3
DAx%	-0.7	-2.1	0.8	0.4	1.9	0.8	3.0	0.0	-3.8	-5.2	-2.5	0.0	-1.3	-4.2	1.5	0.4	-5.1	-8.3	-2.0	0.00
DEx%	-0.1	-1.2	0.9	0.8	-0.46	0.2	-1.2	0.28	0.4	-0.6	1.4	0.4	0.2	-1.6	2.0	0.8	-2.8	-5.0	-0.7	0.01

CI, Confidence Interval; DQI-A, Diet Quality Index for Adolescents; DQc, Diet quality component; DDc, Diet diversity component; DEc, Diet equilibrium component; DAx, Diet adequacy sub-component; DEx, Diet excess sub-component
***Adjusted for age, gender and equivalised household income**

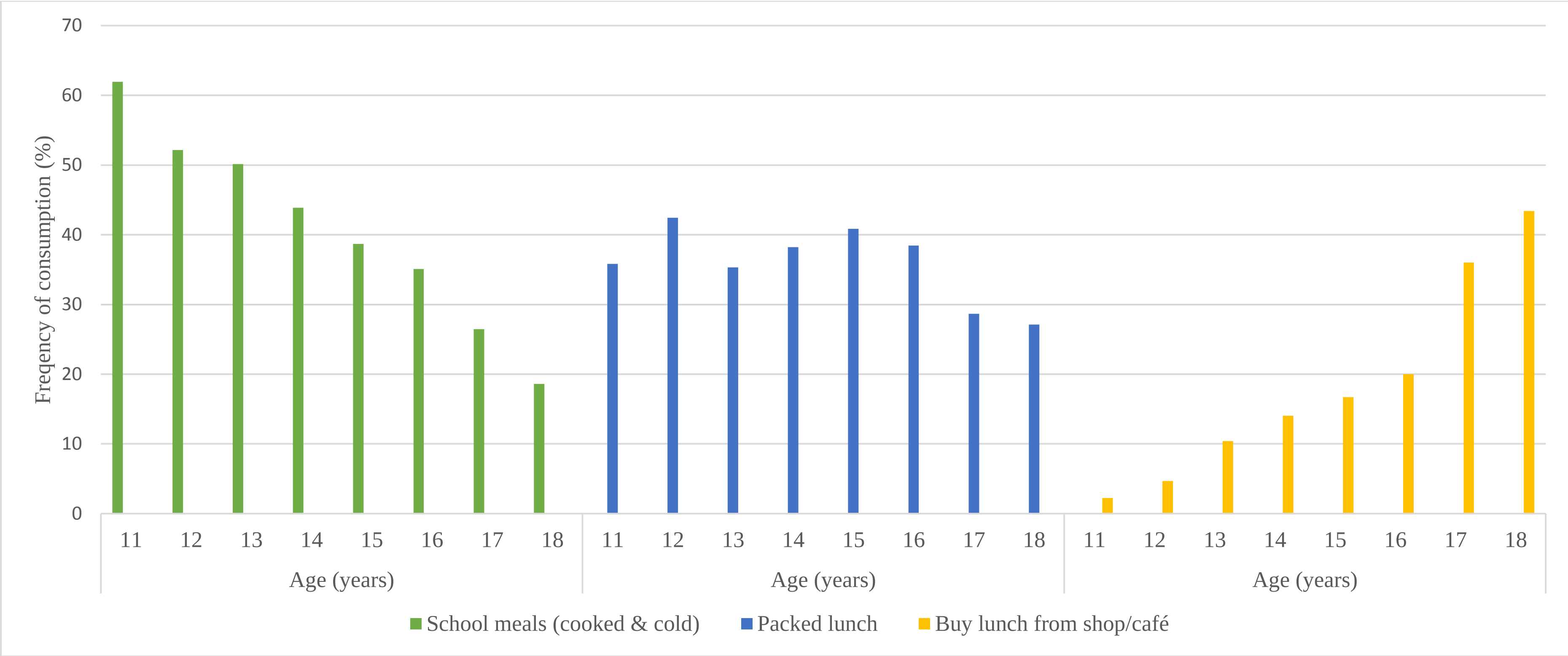


Figure 5-3 Frequency of consumption of the most common types of school lunch on a school day by adolescent's age from the NDNS rolling programme (Year 1–8).

5.5 Discussion

This is the first study to evaluate the associations between type of lunch on a school day and diet quality in adolescents using representative national UK data. The results suggest that the type of school lunch consumed during lunch break is associated with overall diet quality and adolescents consuming lunches from cafes or shops have the worst diet quality. Unlike younger children, packed lunch consumers had the highest overall diet quality score, closely followed by school meals. In addition, the consumption of shop/café-bought lunches increases with age, whereas the consumption of school meals decreases.

5.5.1 Comparison between school meals and packed lunches

The impact of school lunch type on diet quality appears to vary by age. Previous research in younger children indicates that children between 5 to 11 years having a school meal have a better diet quality and nutrient intake than packed lunch consumers (food brought from home) both in the UK [260] and in the US [268]. However, previous evidence from secondary schools in England reported that school meals are usually better quality than packed lunches, although they only looked at lunchtime intakes and not intakes over the whole day [261]. Although school meals improved after the introduction of standards in 2008-9 both in younger [269] and older age groups[262], studies show that both packed and school lunches of secondary school students fail to provide the recommended levels of energy and nutrients [270]. A study outside the UK, in the Republic of Ireland, also found that packed lunches of Irish secondary students were closer to UK school lunch standards than purchases from outside school for several micronutrients [271].

The revised version of the school food standards introduced in January 2015 in the vast majority of schools [261, 270, 271] maintained food based standards but dropped nutrient based standards. This may partly explain the increase seen in the overall DQI-A% score in 2015-2016 (Figure 5-2). Some schools outside council control are not required to adhere to the school food standards regulations but can sign up for the school meal standards voluntarily [258]. Those schools could provide other food and drink options during the lunch for the students that do not necessarily comply with school food standards.

The lack of a difference between school meals and packed lunches in secondary school students compared with primary schools could be due to the differences in the style of operation between these schools in the UK [262, 270]. The similarity between school meals and packed lunches is more likely to be explained by the fact that school meals are poorer quality rather than packed lunches are higher quality. Secondary school children choose their lunch in the school canteen on the day of purchase rather than choosing in advance and this may influence the choices made. Menus in secondary schools have a much wider selection of foods available for children to choose from, compared to primary schools allowing secondary students to choose food from a wider range of items for their lunch with different prices and nutritional content for each of the selected food item. A study of two secondary schools that held “National Healthy Schools Status”, showed that the main food items being selected by the adolescent students during lunch at school were Pizza, Pasta, sandwiches, desserts and beverages. The healthier choices (freshly prepared foods) were also available, but less than 10% of the students selected the healthier options [263]. Furthermore, a higher proportion of secondary school students prefer to bring their own packed lunch to school [272] or purchase food and drinks out of school [273].

5.5.2 Comparisons between lunch purchased inside and outside school

An important factor is that older children are more likely to be permitted to leave the school premises at lunchtime. The number of older adolescents who consume school meals decreases as some adolescents leave the school premises during lunchtime [48]. This is mainly due to students preferring to have control of their food choice and not being restricted [262, 272, 273]. This may confirm the fact that the food environment and student’s preferences could have a large impact on food and beverage[264] choices, particularly among adolescent students, despite the restriction been introduced by the UK school lunch standards [271]. In addition, several studies have highlighted that the price of food items [274, 275] offered at school, the length of the queue to purchase a school meal [275] and appearance and taste of the food [274] may affect secondary school student’s food choices. For example, a UK qualitiative study including seven secondary schools found that many of the students were willing to shop around the school in order to buy food or drinks that were tasty and a reasonable price. Moreover, the crowded and, to some students, unwelcoming environment and feeling uncomfortable within the school canteens were also influencing the students to leave the school at lunch time and purchase food while meeting with school friends and receiving a quicker service at the same time [274]. Another qualitative study conducted in England among secondary school students also found that the taste of the food and the uncomfortable dining environment within the school canteens drove students to have packed lunches or to purchase food beyond the school gates [275]. Indeed, in this study, about 17% of students bought lunches from a café or a shop and they had the lowest overall diet quality and the lowest score among all diet quality components and sub-components, except Diet excess sub-component (DEx). Similar results were reported from a study in Northern England [276] and Canada [91].

In the UK, secondary schools have independent policies on whether they allow students to leave the school site during the lunch break [93] which regulates accessibility to outlets. They have a limited period of time to purchase and consume lunch and the number of food outlets located within a 10 minute walk varies from one school to another [99]. The study also reported that the majority of the students purchased unhealthy convenience foods from local shops such as fish and chips, cafes, pizzerias, kebab shops and supermarkets during the lunch break [99]. The lower diet quality score of adolescents purchasing food from food outlets indicates that this lunch choice has a negative impact on an adolescent’s diet quality. An Irish cross-sectional study found products such as meat, chips and high caloric drinks were more frequently obtained from the school and out of home food sources [271] and a further study showed that around 23% of the recommended energy intake of secondary school students was obtained from foods purchased from fringe shops. The nutritional quality of the purchased food items was found to comprise 38% saturated fat, 22% sugar and 15% non-milk extrinsic sugar [94]. A reduction in diet quality of 8% seen here is substantial. The DQI-A score typically reduces by about 3% for each reduction of a portion of vegetables or other healthy food component.

5.5.3 Strengths and limitations

Several studies have examined the impact of school and packed lunches and school meal policies on the intake of individual foods and nutrients such as soft drinks, sodium, total fat and vegetables. A few studies have used overall diet quality index to assess the impact of takeaway consumption or source of school lunches on adult's and children's overall diet quality. Only one Canadian cross-sectional study examined the associations between the source of school-lunch on a school day including off-campus lunches and adolescent's diet quality using healthy eating index score. But, this study used old data obtained from the 2004 Canadian Community Health Survey (CCHS) where only 11% of the adolescents observed to consume foods from the school during school lunchtime. However, none of the previously published work has assessed the association of different types of school lunch including shop/café-bought lunches consumed during a school day and the overall diet quality using DQI-A% score and up to date representative national UK data, particularly among secondary school adolescents.

This study also has some limitations including the cross-sectional and observational nature of the data and the difficulties of measuring diet quality. Similar to Chapter 4, in this study, individual's dietary intake and their overall diet quality were assessed at one point in time and it is difficult to know the origin of any causal relationships between the exposures and outcome. Dietary behaviour (consumption of school meals, packed lunches and purchasing takeaway meals) of students could alter over time, which would have an impact on their overall diet quality. For example, individuals who have poor diet quality at the time of data collection could have started to exercise more or altered their eating habits such as consuming more healthy foods resulting in the true relationship being attenuated.

In addition, the source of the food consumed outside of the home was not mentioned for all types of food consumed [265], and in this study school meals (of all types) may be considered as one source of the out of home meals. In addition, when the participants reported the place where the food was actually eaten, the majority (63%) reported to consume food at home, while 8.9% and 9.1% reported eating the food at school and takeaway outlets, respectively. Also, in year 1, more weekend days were included in the study compared with other years of the survey, which may considered to have an impact on estimates of nutrient and food intake.

5.5.4 Recommendations

School meal standards have been introduced to all state primary and secondary schools in the UK. The effectiveness of such standards is well established among younger children attending primary schools by evaluating their dietary intake. The school food-based standards came into force in 2015 in England and studies showed that dietary behaviour of older adolescents are more difficult to control, especially with the surrounding food environment outside the school gates which has an impact on adolescent's food choices. In addition, examining the intakes of individual nutrients or food groups is not enough to assess diet quality, as both the quality and variety of the whole diet must be considered. Thus, it is important to explore the relationship between individuals' whole dietary intake and their health status.

Policies already exist in the UK to improve the quality of food sold within schools although many children choose not to purchase healthy foods offered such as fruits and vegetables. Packed lunches are rarely regulated although they are similar in quality to school food for this age group. However less attention has focussed on improving the food environment outside schools. Some cities are introducing policies to restrict easy access to high-density foods [48]. However, due to the lack of evidence demonstrating the effects of opening a takeaway shop close to schools, the Department Management Policy (DM10) in Bristol has recommended allowing the establishment of hot food takeaways within 400 metres radius from premises where young people are gathering [126]. This recommendation may result in clustering of takeaway outlets around schools and therefore encourage students to eat unhealthy foods. Nevertheless, it is believed that HFTs are part of the problem, and other outlets such as cafes, supermarkets and convenience stores could also affect the choice of unhealthy foods (which was seen in this study) and, therefore, students' health [126]. For example, in Scotland, an observational study showed that the number of food outlets located within a 10 minute-walk varies from one school to another. However, the results also stated that most students purchased unhealthy convenience foods during lunch break, and these were largely from local shops, such as fish and chips shops, cafes, pizzerias, kebab shops and supermarkets.

In addition, although many authorities have plans in place to control the clustering of hot food takeaways near schools [48] and strengthening planning policies to discourage unhealthy fast food is in the top 10 priorities of these organisations, many of those outlets are already in existence and therefore outside the remit of these policies which target future applications. The implementation of such planning policies, especially for long-term effectiveness and their impact on health have not been evaluated yet. [49, 50]. Moreover, it was mentioned in Chapter 4, choosing the appropriate type of study design is crucial particularly to evaluate the effectiveness of a health intervention at population level.

Working in collaboration with takeaway food outlet managers by providing, for example, cooking training courses for takeaway outlet staff has been considered as an alternative approach by local authorities to improve healthy food options provided on menus [77]. In addition, improvements in adolescent’s food choices (more healthier options) and decreases in consumption of unhealthy snacks from fast food outlets were also observed in education based interventions on how to choose food wisely [253]. Furthermore, increases in the skills and awareness of young people on the benefits of preparing meals at home, as well as how to make better choices when purchasing food from outside home, could be helpful. Only small number of cafes and restaurants provide menu labelling at the point of choice and availability of nutritional information of the meals could help consumers make healthier choices either as part of menu labelling [247] or information leaflets [248]. Public health interventions that strive to control the availability, palatability and exposure to inexpensive energy-dense food and drinks, may have a significant influence on mitigating diet-related diseases and obesity given that children’s lunches purchased outside school are poor quality compared with school meals and packed lunches [196].

5.6 Conclusions

Similar to the findings in Chapter 4 and using the NDNS years 1-6 datasets, UK adolescents consume a poor quality diet and the type of lunch they choose on school days is important. Purchasing foods from food outlets outside school has a negative impact on their diet quality score compared with choosing a school meal or packed lunch. These results suggest that for secondary school children, unlike primary school children, regulation policies focussing on food outlets including shops near secondary schools are needed in addition to improvements in school meals.

The shop/café-bought lunch have the lowest diet quality score. Despite some authorities focusing on exclusion zones policies, where no hot takeaway food shops are allowed within 400 or 800 metres of primary and secondary schools, many adolescents still eat lunch outside school. The success of such a policy is not fully evaluated yet but we know that adolescents not eating lunch at school appear to have worse diets. Unlike younger children in the UK, diet quality was similar for those having packed lunches as it was for those having school meals. Improving the food environment inside and outside the school premises is especially important for this age group. In Chapter 2, the variations in the methodology used to evaluate the food environment particularly around schools was outlined. The next chapter will investigate the differences in using different methods to measure the school food environment.

Chapter 6 Describing the food environment around secondary schools in the Avon region of the UK: comparison between methods

Abstract

Background: The location of takeaway food shops is becoming increasingly studied in the UK with growing concerns around diet and obesity. UK planning policies to limit takeaways have been ad-hoc to date and poorly thought out compared to other countries. This study aims to examine the differences in using different methods to measure the food environment particularly around secondary schools in the Avon region in the UK. Also, to examine the agreement and correlation between those methods used to measure the food environment.

Methods: Geographical Information System was used to locate all of the 88 state funded schools and takeaways in the Avon region and to measure the density and proximity scores, applying both road network and straight-line methods. In addition, the Hansen Index was used to measure the accessibility score of each schools to all takeaways in the region (not just the nearest).

Results: More than 50% of the schools had no takeaway shops within 200-m, 400-m, or 600-m when the road network buffer was used. Statistically significant differences in the density and proximity of hot food takeaways were observed between the road network and the straight-line methods. Also, the agreement between straight-line and road network densities within 800-m and 1000-m were fair and moderate, respectively. The agreement between both methods to measure the proximity was fair to moderate. In addition, the accessibility score was not dependent on the distance between the school and the nearest takeaway outlet using both the straight-line and road network proximities.

Conclusions: The statistical significant differences found between the methods used to measure the proximity and density of hot food takeaways strengthen the evidence of the need for a consistent approach to the methods used to measure the food environment, particularly around schools. Also, accessibility index is another method considering both the total number and proximity which could also be used to evaluate the food environment.

6.1 Introduction

Obesity is a global, national and local problem that needs to be tackled and relying alone on increasing awareness and education of individuals to choose food wisely without improving the food environment is unlikely to have the desired impact on food choices [109]. Several sources of evidence have shown that to shape the dietary habits and preferences of a population, the surrounding environment is a key factor to consider [48]. However, addressing obesity at the local level is complicated and no single intervention can completely solve the problem, leaving public health authorities to consider multiple solutions [102]. Attention is now being drawn to the influence of the school and home neighbourhood on food choices [7] and one approach is to target fast food outlets as these offer meals that are cheap, energy dense but which lack nutritional value, typically offering 60% of the recommended daily energy intake. Indeed, many local authorities in the UK have focussed on exclusion zones, where no hot takeaway food shops are allowed within 400-m or 800-m of primary and secondary schools, youth facilities, children’s playing fields or parks and leisure centres [104, 117].

6.1.1 Takeaway food and UK local authorities

In 2014, there were more than 50000 hot food takeaways (HFTs) including fast food takeaways, fast food delivery services and fish and chips outlets in England and these are more commonly situated in deprived areas [34]. A study illustrated that people living in areas with higher social and economic deprivation are more likely to select cheaper sources of food [68]. Meals offered by quick service restaurants (fast food outlets) are found to be cheaper than those of other restaurants, hotels and pubs [35]. In addition, around a quarter of takeaway outlets are located within a five-minute walk (400-m walking distance) from a school in the UK [277] and secondary schools had more fast food outlets nearby than primary schools [147]. Frequent consumption of takeaway meals is negatively associated with the diet quality of British adolescents [265] and adolescents’ dietary decisions may be impacted by the proximity of fast food takeaways and other eateries [95, 278]. The Food Environment Policy Index (Food-EPI) believes that strengthening planning policies to discourage unhealthy fast food is a priority, and this will have a significant effect on mitigating diet-related diseases and obesity [196]. However, the Food-EPI showed that UK planning policies to limit takeaways near schools have a poor record compared with other countries. Part of the problem is the lack of clarity on how to measure access and what difference it makes when using alternative definitions. A review of existing studies shows that different studies have used different methods to evaluate density, proximity and accessibility of fast food outlets [111, 279]. In the UK, many other local authorities are still evaluating the arguments concerning the effectiveness of limiting the number of takeaway or fast food shops particularly around schools [280]. More information about UK local authorities' action and the policy regarding takeaway outlets can be found in Chapter 2, section 2.5.2.

6.1.2 Existing Studies

A review of the existing studies showed that different studies have used different methods to evaluate density, proximity and accessibility of fast food outlets around secondary schools (see Chapter 2, section 2.7). To make successful policies, the appropriate tools to measure density, proximity or accessibility in order to determine the number of fast food outlets available within walking distances need to be described [132]. Worldwide, there are no standardised measures used to calculate the density and proximity of food outlets around homes, schools, work or any other facilities [133, 134]. That said, many studies have measured the proximity and density of fast food outlets around schools, home or workplace in the last two decades. Results from a systematic review showed that out of the 73 studies exploring the density and proximity of fast food outlets from 2004 to 2017, only six studies were from the UK [135]. Out of those six studies, only two (1 cross-sectional [136] and one longitudinal [139]) study performed by the same research group looked at adolescents from secondary schools. More research has been done in the US, where researchers have used distances of 0.5 miles, 1.0 miles, 2.0 miles and 5.0 miles [281, 282]. These distances were believed to be reached within a short period by foot or motor vehicle (more applicable to the US population). Similarly, in Europe, no standardised method exists to measure the density of an outlet within a certain distance of any premises. Previous studies conducted in the Netherlands [283] used 500-m straight-line buffers whilst in Denmark a road distance of 300-m from schools was used [284]. Moreover, similarly to the US and other European studies, the few UK studies have used different distances to calculate the density (accessibility) scores of fast food outlets including an 800-m road distance buffer [138, 285] which corresponds to a 10-minute walk [138, 167] and 1-km road network distance [212] or 1-km radius buffer [139]. Another study [143], used a road network buffer of both 400-m and 800-m. Burgoine et al. (2013) [286] investigated the differences between density and proximity metrics using both straight-line and road network methods across different buffers (400-m, 800-m and 1000-m). The road network and Euclidean buffers used to measure food outlets density and proximity were based on population-weighted centroids of the lower super output areas. Given such variations, researchers need to choose the appropriate method to conduct a study, as their selection could have an impact on the overall results of that study. Therefore, to raise the awareness, in this study we are comparing the results from using different methodologies to measure the food environment for our case study area of Avon in the UK.

6.1.3 Aims

1. To explore the differences in using three different methods to measure access: the density, proximity and accessibility of HFTs around secondary schools in the Avon region of the UK.
2. To suggest the appropriate methods to recommend for future policy guidelines and suggest policy recommendations on what to use in the concluding sections.

6.2 Materials and methods

6.2.1 The study area

The Avon region is a non-metropolitan county in the West of England and consists of 4 unitary authorities including city of Bristol, South Gloucestershire, North Somerset and Bath and North East Somerset [208]. The average population of adolescents aged under 18 years living in the study area (Avon region) in 2016 were broadly similar to those of the rest of England with 21.6% and 22.5%, respectively [58].

6.2.2 Schools data

The analysis in this chapter benefits from the availability of data associated with the Avon Longitudinal Study of Parents and Children (ALSPAC) from the University of Bristol. They identified 134 schools in the region. After omitting special schools and private schools (no data available) 88 schools remained for analysis. To assure the anonymisation of ALSPAC data, the school identifier ID was used in Table 6-3 and Table 6-5 in place of school names. Ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee (IRB00003312) and Local Research Ethics Committees (see Appendix 6). More information about school data can also be found in Chapter 3, section 3.7

6.2.3 Hot food takeaways (HFTs) data

The Ordnance Survey (OS) was the source of data regarding food outlets in this study. The OS Points of Interest (POIs) database includes all privately and publicly owned businesses in the United Kingdom. The database is updated four times per year. The definition of HFTs is based on category A5 (eating and drinking) which includes all "Premises where the existing primary purpose is the sale of hot food to take away" [126]. Although major food franchises such as McDonalds, Miss Millie's Fried Chicken and Pizza Hut were classified as restaurants in previous editions of OS, the most up to date POIs data were used in this study where these common food franchises are now classified as HFTs, similar to previously published study [69]. The A5 category thus comprises HFTs (including the main franchises), fast food delivery services and fish and chip shops. The OS database has been used before to identify fast food outlets and showed 81–100% accuracy when ground truthed [212]. For more information about OS and HFTs data, please check Chapter 3, section 3.6.

6.2.4 Geographical analysis

In this study, all the schools obtained from the ALSPAC and the HFTs were geocoded using their X and Y coordinates using the Geographical Information System (GIS) Software (ArcGIS 10.4.1). GIS has been widely used among local authorities, governmental agencies and planners to help in developing policies related to diet and health [287, 288]. For this research, the location of HFTs was obtained for the year 2017. The boundary data and integrated transport network (with the path lines network) were obtained from the Ordnance Survey via the Digimap UK website. The road network was then built using the Network Analyst in ArcGIS to enable us to measure the number of HFTs within a specific area (zone) using the road distance. The built road network in this study was cross-checked with the road network from Google maps around five randomly selected schools. This was checked by comparing the road network (pathway) given using the Google map from a certain school to a fast food outlet with the road network given using the network built in GIS.

6.2.5 Variables of interest

Three different methods for measuring the nearness of HFTs to secondary schools as seen in the literature were used.

A. The proximity of HFTs

The proximity measure represents the distance in metres from each of the schools' centroid (centre of the school location) to the closest hot food takeaway shop. Previous studies have either used straight-line (Euclidean) [134, 289] or road network [290, 291] distance to evaluate the proximity of food takeaway outlets. Both methods result in different distances, which may lead to having a completely different understanding of the food environment (Figure 6-1) The Closest Facility tool in ArcGIS in the Network Analyst tab was used to calculate the road network distance (unit; metres), and the Near Distance tool was used to calculate the straight-line distance (unit; metres).

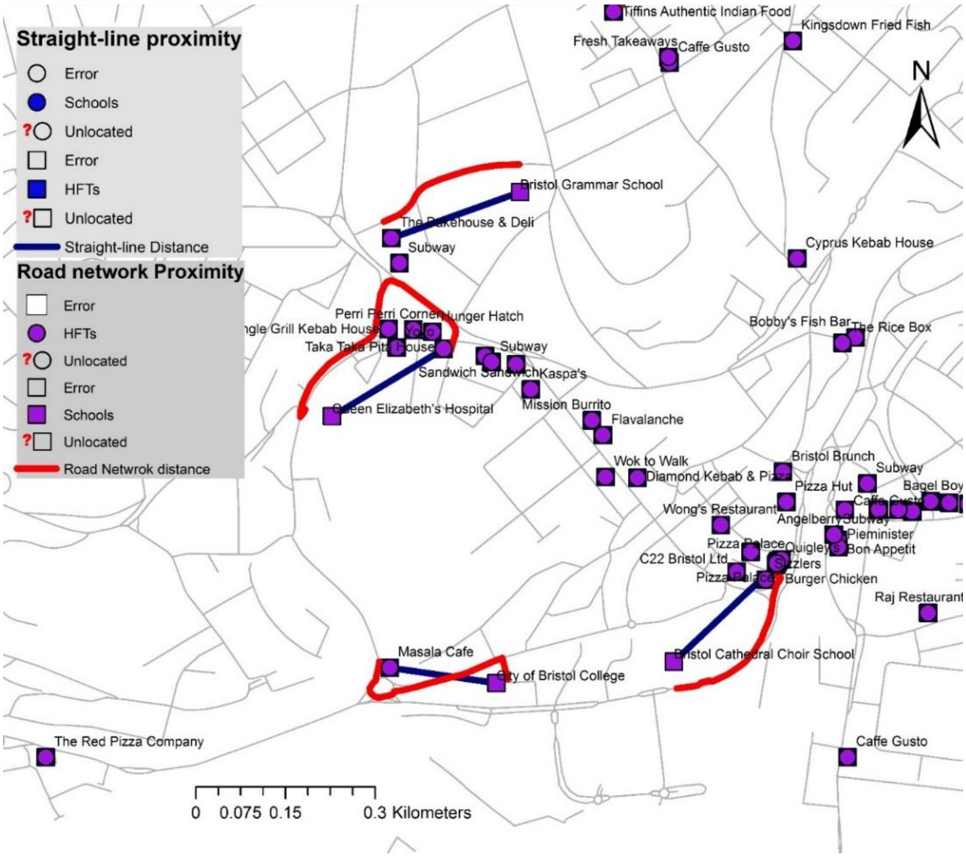


Figure 6-1 Example of distance between a school from ALSPAC data and fast food outlet in Bristol using a straight-line method (blue line) and road network method (red line).

B. The density of HFTs

Circular and road network buffers of 800-m and 1000-m were created around the centroid of each school. Similar to the method used to measure proximity, both the road network and straight-line distance were used to measure the density of HFTs around each school. The number of HFTs was calculated by using the Service Area tool available in Analyst network in the ArcGIS software 10.4.1. (Figure 6-2). The density of HFTs was calculated by using the following formula:

$$\left(Total\ Number\ of\ HFTs \setminus \frac{Number\ of\ students\ of\ the\ selected\ school}{1000\ (population\ rate)}\right)$$

This method had been validated and used previously by other researchers [95, 133] and Public Health England [19].

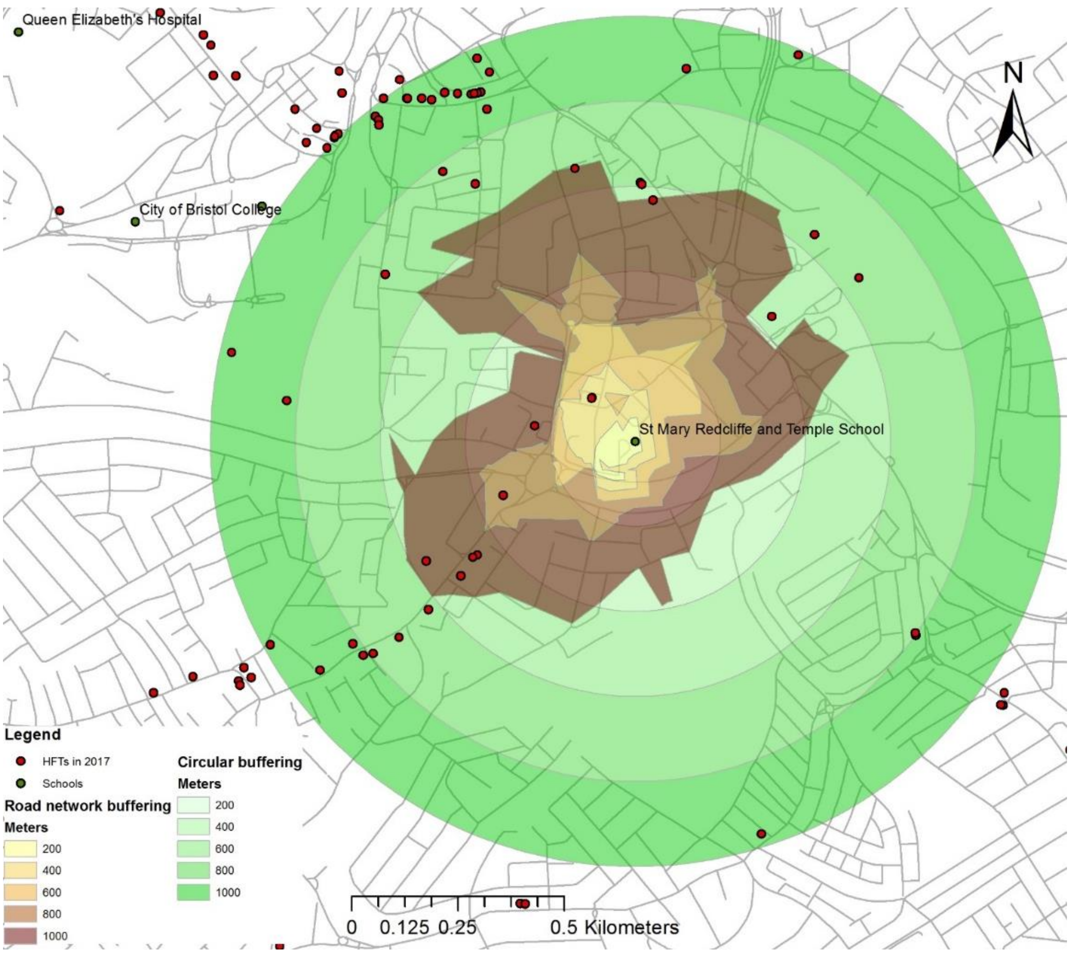


Figure 6-2 Example of buffers around a school from ALSPAC data and number of fast food outlets in Bristol using a straight-line buffer (green circles) and road network buffer (brown graded shapes).

C. Hansen accessibility scores

In the literature it is also useful to look at indicators that take account of access to all HFTs rather than the nearest one only. In general, accessibility is a measurement of the spatial distribution of activities about a point with respect to all other points in the system [292, 293]. Although accessibility indices can be computed in a variety of ways [294], they have most often been measured by a Hansen-type accessibility measure (Hansen, 1959), especially in geographical studies of health care accessibility. [294]. Fotheringham (1986) [295] also notes its common occurrence in retail studies, suggesting the indictor is easy to compute and it usually conforms to our expectations regarding relative location [295].

Why is estimating an access score useful? For some areas it may be sufficient simply to use distance to nearest provider as estimated above. However, in most urban areas using the nearest facility only as a measurement of accessibility ignores the full range of available provider locations elsewhere in the city. The Hansen access indicator takes that full range of facility locations into consideration [294]. It is theoretically close to the 'gravity models' widely used in geographical studies of movement and accessibility, especially in land use planning models [296]. Gravity models for human interactions were originally derived from Newtonian physics which (amongst other things) stated that the measurement of the gravitational force between planets is a function of the mass of the planets and the distance between them. When applied to spatial interactions between origin zones and destinations in cities or regions then, for each demand location, it measures the combined attractiveness of all service destination facilities (the 'mass' term usually measured as size) against the distance travelled to give a zonal access score for each origin zone (Accessibility index in the Hansen formula) [296]. Guagliardo, Ronzio et al. (2004) [296] explain their choice of using the Hansen index when studying access to paediatric services:

''Gravity'' models, initially developed for land use planning (Hansen, 1959) are also a combined indicator of distance and availability, and can provide the most valid measures of spatial accessibility. Gravity models assess the potential spatial interaction between any population point and all service points within a reasonable distance. Accessibility improves as the number of provider points increases, the capacity at any provider location increases, the distance to provider decreases, or the travel friction decreases. Computing the Hansen accessibility index over a field of population points is considered as informative method to study geographic variation in accessibility.

Many geographical studies of health accessibility have used a Hansen style gravity model specification to measure accessibility. For example, the indicator was used in Aberdeen to examine distance to GP locations from census wards [297]. In Brazil, the accessibility index was also used to determine accessibility for grocery retailers and food service facilities [298].

The Hansen Index [292] to calculate an accessibility score for each of the schools using the following equation:

$$A_i = \frac{S_j}{d_{ij}}$$

where

- A_i is a measure of accessibility for pupils in school i
- Sj is the service available in zone j (e.g. number of HFTs)
- d_{ij} is the distance/time/cost to get between school i and HFT j

The accessibility score was calculated using an Excel spreadsheet matrix. At first, a full distance matrix to measure how close the schools are to individual takeaway outlets using the straight line distance was conducted. Then, another matrix was conducted to estimate the provision or access scores taking into consideration the access to all takeaway outlets. As can be seen from the equation above the index provides a score for each school based on the number of surrounding HFTs. It is a relative score rather than an absolute one, with a high score meaning that a school has many HFTs in close proximity whilst a low score indicates few HFTs in the vicinity of the school. To illustrate how the indicator works more fully let’s assume we have two schools A and B and six HFTs. For school A there is one HFT within one mile of the school, no HFTs between one and two miles with the remaining five HFTs between two and three miles. For school B there are no HFTs within one mile, but all six HFTs lie between one and two miles from the school. The Hansen access score would be higher for school B than school A, even though school A has one HFT close by. School B has more HFTs closer to it overall than school A and so will have a higher score.

6.3 Statistical tests

All statistical analyses were carried out using Stata statistical software, version 15.0 (College Station, TX: Stata Corp LLC). The histograms of the differences were checked for normally distributed data before and after the log transformation. The non-parametric ’Wilcoxon signed rank sum test was used to investigate if there were any significant differences between density and proximity measures using the road network and straight-line methods. Similar to proximity and density measures, the accessibility score was also not normally distributed, and the non-parametric Spearman’s rank correlation was used to determine the relationship between the road network/straight-line proximity and accessibility score. The correlation test was used to assess the strength of the relationship between two pairs of variables (strength of linear relationship). Results were compared that were obtained from observers on two different subjects (proximity and accessibility) [299].

Lin’s concordance correlation coefficient test was used to measure the extent of agreement between straight-line and road network methods (used to measure both the density and proximity of HFTs). Lin’s concordance coefficient measures the strength of agreement by assessing the bias (mean differences) and 95% limits of agreement between both methods (straight-line and road network). The 95% limit of agreement was calculated based on the mean difference between the two methods ± 2 x standard deviation of the differences (SD). The limits of agreement can also be described by plotting the Bland–Altmon (B&A) graph [299, 300]. The advantage of the concordance correlation coefficient is that it assesses the differences between the readings obtained by two observers (straight-line and road network) on the same subject (density or proximity) [299, 301]. Table **6-1** presents the interpretation of the concordance correlation coefficient, as described by McBride (2005) [302].

Table 6-1 Lin's concordance correlation coefficient test interpretation.

Concordance correlation coefficient (CCC)	Strength of agreement
< 0.90	Poor
0.90 to 0.95	Moderate
0.95 to 0.99	Substantial
> 0.99	almost perfect

The number of schools with one or more takeaway outlets increased as the buffer size increased for both circular and road network buffer methods (Figure 6-3 and Figure 6-4). Nevertheless, it was observed that more than 50% of the schools had no takeaway foods within 200-m, 400-m and 600-m when the road network buffer was used. Therefore, based on these criteria, findings from the Wilcoxon signed rank sum test, the agreement test for density and the total number of hot food takeaways were only conducted for 800-m and 1000-m. All tables and figures in the results section include data licensed from PointX © Database Right/Copyright 20nn and Ordnance Survey© Crown Copyright 20nn. All rights reserved. Licence number 100034829.

6.4 Results

6.4.1 General background

The majority of the Avon schools had no takeaways within 200-metre using the circular (n = 82) and road network (n = 73) buffer method (Figure 6-3). Moreover, more than 50% of the schools had no takeaways within 400-m when the circular and road network methods were used. Among the circular method, the percentage of schools with no takeaway outlets decreased to 28%, 13% and 11% within 600-m, 800-m and 1000-m, respectively. This was not seen among the road network method, as more than 50% of schools remain with no takeaways within 600-m. The number (%) of schools that had no takeaways was higher for the road network method compared to the circular buffer method. This was also true among the remaining distances of 400-m, 600-m, 800-m and 1000-m (Figure 6-3 and Figure **6-4**). The median of the number of HFTs within 200-m and 400-m and 600-m was observed to be zero or close to zero for both methods (circular and road network); (Table 6-2). For the circular method, the median of the density of HFTs within 800-m and 1000-m was 4.7 and 6.8, receptively whereas for the road network method, the median of the density of HFTs decreased to 0.9 for 800-metre and 2.5 for 1000-m. Similarly, among the proximity of HFTs, the median of the proximity was higher for circular method compared to road network method (Table 6-2). In general, the use of straight line (circular) method resulted in a higher number and density of hot food takeaways compared to road network method. Similarly for proximity, as straight line method resulted in a shorter distance compared to the road network method.

Table 6-2 General description of the number, density and proximity of hot food takeaways (HFTs) around the 88 Bristol and Avon secondary schools in 2017.

	Circular buffer	Mean	Median	Interquartile range		Min	Max	Total
Number of takeaways	200-m	0.3	0	0	0	0	5	28
	400-m	2.4	0	0	2	0	26	214
	600-m	5.6	2	0	6	0	43	492
	800-m	9.6	4	1.5	12.5	0	56	842
	1000-m	14.8	6	3	17.5	0	80	1306
	Road network buffer							
	200-m	0.1	0	0	0	0	3	8
	400-m	0.8	0	0	0	0	10	68
	600-m	2.1	0	0	2	0	24	182
	800-m	3.8	1	0	3	0	32	333
	1000-m	6.8	3	0.5	8.5	0	50	596
Density of HFTs per 1000 students	800-m circular buffer	22.4	4.7	1.4	11.4	0.0	666.7	NA
	1000-m circular buffer	31.1	6.8	3.1	24.2	0.0	750.0	
	800-m road network buffer	10.9	0.9	0.0	3.7	0.0	444.4	
	1000-m road network buffer	18.9	2.5	0.3	7.1	0.0	694.4	
proximity of HFTs in metres	Road network distance	883.9	708.1	382.0	1011.5	12.6	6227.3	
	Straight-line distance	630.5	465.4	289.9	696.9	93.8	5334.5	

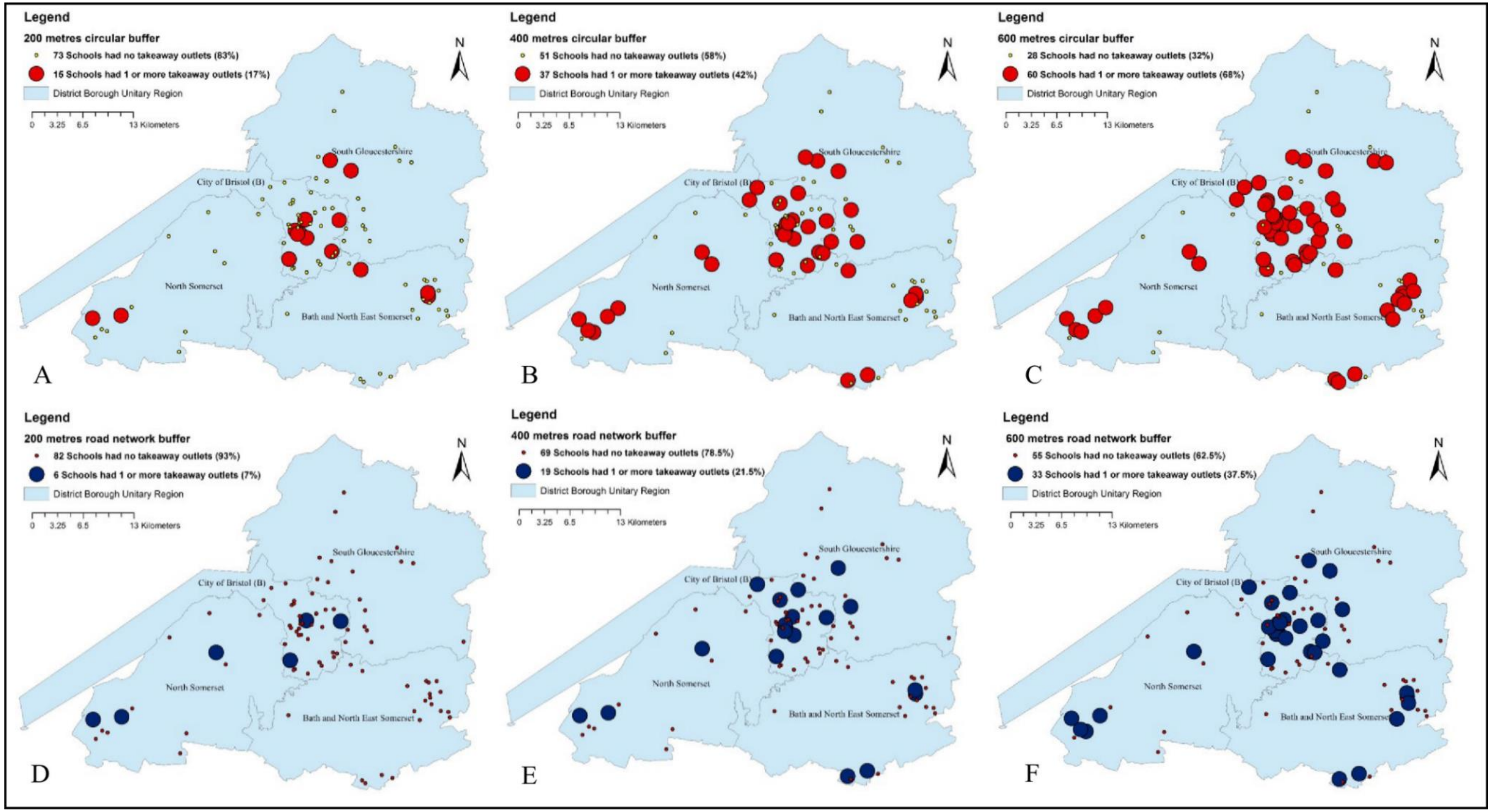


Figure 6-3 (A, B and C) All schools (n = 88) with no takeaway outlet or with at least one takeaway outlet within 200-m, 400-m and 600-m using circular buffers; (D, E and F) All schools (n = 88) with no takeaway outlets or with at least one takeaway outlet within 200-m, 400-m and 600-m using road network buffers.

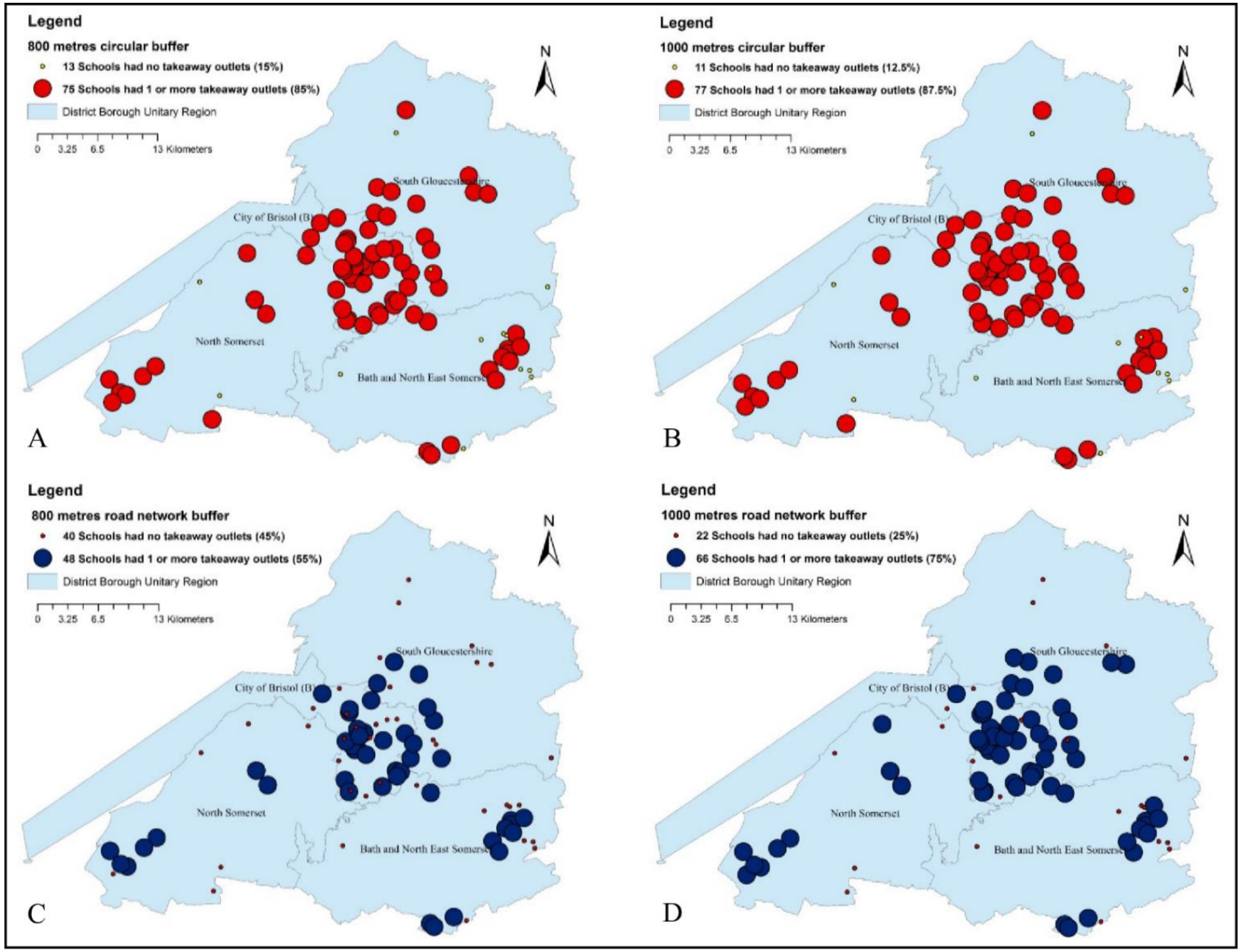


Figure 6-4 (A and B) All schools with no takeaway outlet or with at least one takeaway outlet within 800-m and 1000-m using circular buffers; (C and D) All schools with no takeaway outlets or with at least one takeaway outlet within 800-m and 1000-m using road network buffers.

6.4.2 Buffer size and schools

As can be seen from Figure **6-4**, within 800 and 1000 straight-line and road network metres, the majority of the schools had one or more takeaway outlets located in Bristol. Fewer schools had one or more HFTs in Bath and North East Somerset, North Somerset and South Gloucestershire. In addition, for both 800-m and 1000-m, School 6 (in Bristol) was observed to have the highest number of HFTs using straight-line buffers whilst for road network buffers School 1 (in Bath and North East Somerset) had the highest number of HFTs (Table 6-3). Both schools are located in more deprived areas. In addition, Table 6-3 shows the top 10 school with the highest number of HFTs within 800-m and 1000-m in the Avon region. These are the schools for which further analysis would be recommended, especially in relation to health outcomes.

Table 6-3 Top ten schools at higher risk (having the highest number of HFTs) within 800 and 1000 road network metres buffers and their locations.

No	Local authority	School identifier (ID)	Number of HFTs	
			800-m	1000-m
1	Bath and North East Somerset	School 1	32	50
2	Bath and North East Somerset	School 2	30	39
3	North Somerset	School 3	27	40
4	Bristol	School 4	24	27
5	Bristol	School 5	21	38
6	Bristol	School 6	19	37
7	Bristol	School 7	19	34
8	Bristol	School 8	15	19
9	Bristol	School 9	14	19
10	Bristol	School 10	14	25

6.4.3 Differences between Euclidean and road network methods

A. Proximity measures

The mean proximity from the schools to the closest HFTs was higher when road network distance was used compared to straight-line distance (Table 6-2). Nevertheless, results for the Wilcoxon signed ranked test showed that the proximity measure was significantly higher for the road network distance method compared to the straight-line distance method. The median of the difference between the road network and straight-line proximity was 203.2 (CI 144.6, 261.9; P-value < 0.001) (Table 6-4).

Table 6-4 Description of Wilcoxon signed ranked test results among the density and proximity measures using road network and straight-line methods from the 88 schools.

Variables	Observation number	Percentile	Centile	CI		P-value
Differences in density (800-m)	88 schools	50	2.3	1.2	3.9	<0.001
Differences in density (1000-m)			4.1	2.6	5.9	
Differences in proximity (m)	88 schools	50	203.2	144.6	261.9	<0.001

In addition, the results showed that the mean difference between the road network and straight-line proximity was 266 metres. The Lin's Concordance test showed that the strength of the agreement between both methods (Euclidean and road network) was moderate with a concordance correlation coefficient (CCC) value of rho_c = 0.91 and with mean difference= 253.4 (CI 201.6 to 305.1). Moreover, the Bland & Altman plot showed the limits of agreements was found to range between -235.0 to 741.8. Although the limits of agreement was narrower compared to range of variables (55.0 to 5780.9) the mean difference (bias) was found to be statistically significant (p<0.01), see Figure 6-5.

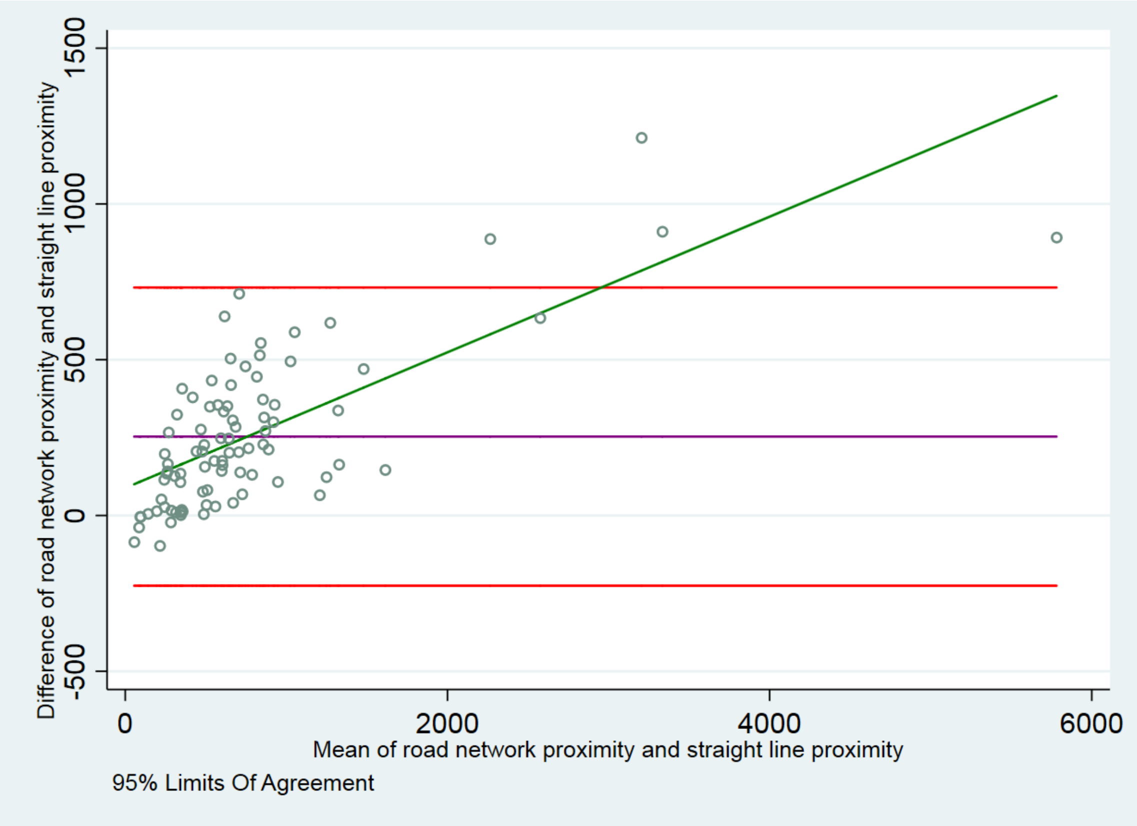


Figure 6-5 Bland and Altman plot for proximity for both methods

B. Density measures

The differences in the mean density measure obtained from both the circular and road network methods were noticeable within 800-m and 1000-m (Table 6-2). Nevertheless, the Wilcoxon signed ranked test showed statistical significant differences in the density of HFTs between both methods (circular and road network buffer). For example, the median of the difference between the road network and straight-line density within 800-m and 1000-m were 2.3 (CI 1.2, 3.9; P-value < 0.001) and 4.1 (CI 2.6, 5.9; P-value < 0.001), respectively (Table 6-4).

In addition, the mean differences between the Euclidean and road network methods was 11.5 and 12.2 metres within 800-m and 1000-m buffers, respectively. The Lin's Concordance test showed that the strength of the agreement between both methods (Euclidean and road network) was poor for 800-m buffer with a concordance correlation coefficient (CCC) value of rho_c = 0.87 and with mean difference= 11.5 (CI 4.83 to 18.20). Moreover, the Bland & Altman plot showed the limits of agreements was found to range between -50.2 to 73.2. Although the limits of agreement was narrower compared to range of variables (0 to 555.6) the mean difference (bias) was found to be statistically significant (p<0.01), see Figure 6-6.

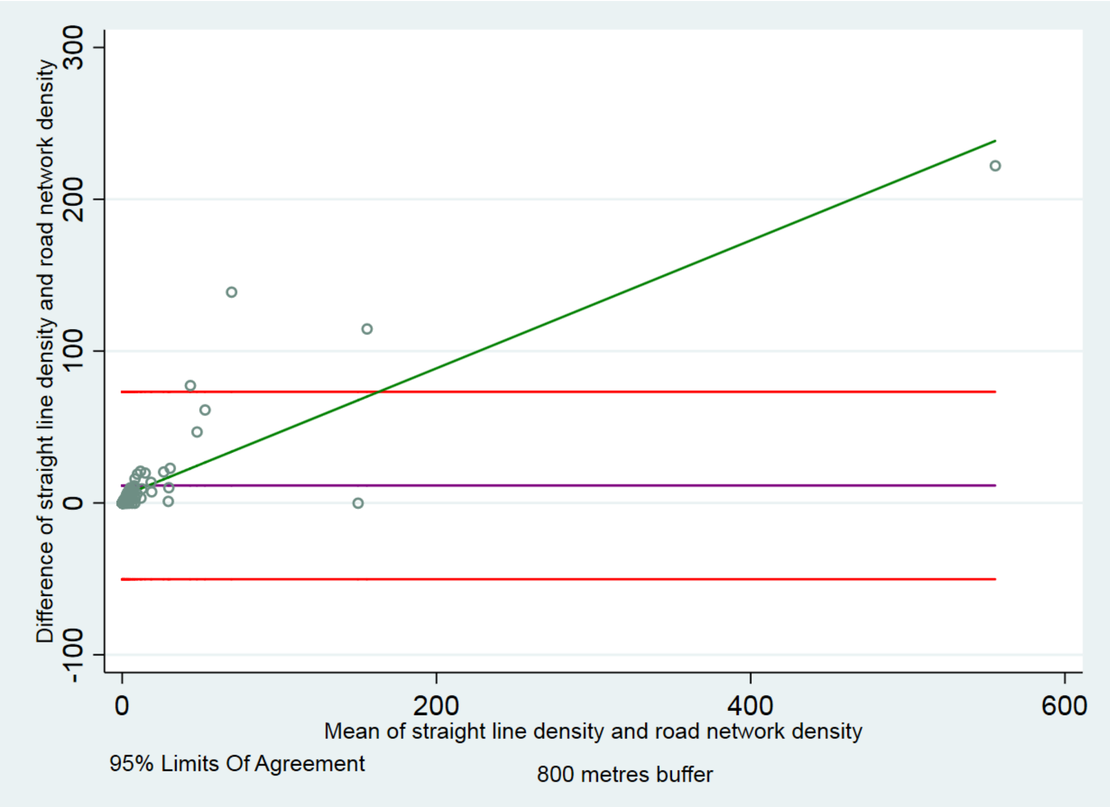


Figure 6-6 Bland and Altman plot for density score for both methods within 800 metres buffer

Nevertheless, the strength of the agreement for 1000-m buffer was observed to be moderate with a concordance correlation coefficient (CCC) value of rho_c = 0.93 and with mean difference = 12.2 (CI 6.0 to 18.4). Moreover, the Bland & Altman plot showed the limits of agreements was found to range between -46.3 to 70.7. Although the limits of agreement was narrower compared to range of variables (0 to 722.2) the mean difference (bias) was found to be statistically significant (p<0.01), see Figure 6-7.

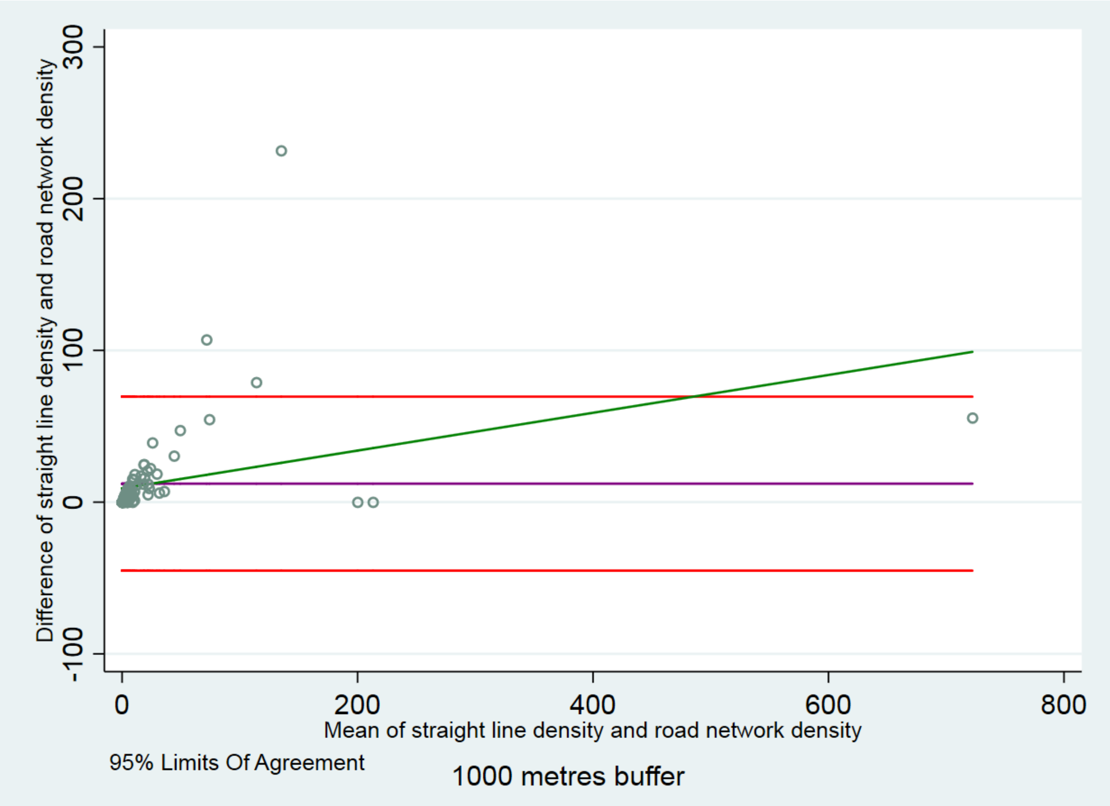


Figure 6-7 Bland and Altman plot for density score for both methods within 1000 metres buffer

C. Accessibility Score

The mean accessibility score for the 88 schools was 21 (as noted above this is a relative not an absolute measure and in this case the score ranges from 0.06 to 80.5). The results showed that both the straight-line and road network proximity were negatively correlated to the accessibility measure with rho = -0.5 (CI: -0.6 to -0.3; P < 0.01) and rho= -0.5 (-0.6 to -0.3; P < 0.01). Therefore, the accessibility score was not dependent on the distance between the school and the nearest takeaway outlet using both the straight-line and road network proximities. For example, a school with an accessibility score of 2.5 (very low provision) had a takeaway outlet 349 metres from the school. On the other hand, another school located 655 metres away from the nearest takeaway outlet had a higher accessibility score of 32.5. Table 6-5 4 lists the top ten schools with the highest accessibility score in the Avon region. The top 10 schools were located in Bristol and some new schools become problematic in this new list (schools 11, 12 and 13) as compared to the school list with the highest number of HFTs (Table 6-3).

Table 6-5 Top ten schools at higher risk (with highest accessibility score) and their locations

No.	Local Authority	School identifier (ID)	Accessibility score
1	Bristol	School 6	80.5
2	Bristol	School 5	72.5
3	Bristol	School 11	72.4
4	Bristol	School 7	70.4
5	Bristol	School 12	67.9
6	Bristol	School 13	67.6
7	Bristol	School 8	65.6
8	Bristol	School 4	65.5
9	Bristol	School 9	64.5
10	Bristol	School 10	56.6

6.5 Discussion

6.5.1 Summary of the findings

The methods used to measure the food environment around any facilities, including workplaces, homes and schools, vary across the literature. Nevertheless, focusing on schools in the UK the findings from this study also confirmed that the straight-line (circular) method resulted in a higher density and proximity of HFTs around secondary schools. In addition, the accessibility score can be used as another method to measure the food environment. Previous research has recommended the use of both measures, especially with the weak to moderate correlation between the density and proximity metrics [134].

6.5.2 Evaluation of the school food environment

In this study, the percentage of secondary (high) schools with one or more HFTs was observed to increase as the size of the selected buffer increased, similar to a US-based study [161]. The percentage of schools with one or more fast food outlets using a 400-m circular buffer was lower than the percentage of schools using an 800 metres circular buffer, at 30% and 71%, respectively. This was also observed in a New Zealand-based study [95], where within a 400-m and 800-m road network buffer, the proportion of secondary schools with at least one fast food outlet was 22% and 68%, respectively. UK studies have used the 400-m and 800-m road network buffer [138, 141, 143] and 1000-m circular buffer [139] because these distances are known to approximately correspond to a 5-, 10- and 20-minute walk, respectively. Moreover, another study has used a 400-m and 800-m road network buffer to reflect a five- and 10-minute walk, respectively [95]. In addition, the results from this study confirmed the type (circular or road network) and size (200-m, 400-m, 600-m, 800-m or 1000-m) of buffers used has an impact on the number of schools with more than one takeaway outlet. This may also have a large impact on the priority list of schools at higher risk (with the highest number of HFTs). However, in our study, more than 50% of the schools were found to have no HFTs within 200-m, 400-m and 600-m using the road network buffer, similar to a US cross-sectional-based study [159]. More than 50% of high schools were found to have no fast food restaurant within a 600-m road network buffer, and this percentage decreased to less than 30% among the 800-m road network buffer. Therefore, the 800-m and 1000-m (circular and road network) buffers around secondary schools may be more appropriate to explore the relationships between fast food accessibility and diet or health relationships or for evaluating the policy actions implemented by councils.

6.5.3 Road network and circular buffer methods

The road network method may reflect the actual walking path that the student is likely to take to reach the food outlet, whereas the circular buffer method uses the shortest straight line to reach the same food outlet. Therefore, the road network method should be used for evaluating the food environment, especially around schools. In this study, the density of HFTs around the 88 schools across the 800-m and 1000-m buffer size was significantly higher among circular buffers compared to road network buffers. This was also seen in a large Canadian study of secondary schools [303]. In addition, the proximity measure in this study showed that the road network method resulted in a longer distance between the food outlet and the school compared to the straight-line method, similar to a UK-based study [286]. The proximity measure was observed to be higher when the road network distance was used compared to the Euclidean (straight-line) distance [286]. This also confirms that using the road network distance reflects the actual distance (pathway) from the school to the point of interest (takeaway), whereas the straight-line distance represents the minimum distance from the school to the takeaway outlet.

However, the results from Burgoine, Alvanides et al. (2013) [286] stated that levels of ‘pseudo-individual’ density were similar whether using the straight-line or road network methods. This similarity remained across all the buffer sizes, including 400-m, 800-m and 1000-m. In addition, Burgoine and his colleagues concluded that there was a substantial degree of comparability between the road network and straight-line methods in measuring proximity. This degree of comparability was based on correlation results, with a coefficient of 0.865 and P–value less than 0.001. Conversely, the results from this study also clearly showed that there were statistical differences in density and proximity measures when the road network method was used compared to the straight-line method. It was also observed that the degree of agreement was not strong between the two methods used to measure the density of HFTs across both buffer sizes (800-m and 1000-m). The straight-line method was observed to give a higher reading by between 4.83 and 18.20 for 800-m and 6.0 to 18.4 for 1000-m. Burgoine, Alvanides et al.

(2013) [286] also stated that Euclidean buffers were more strongly correlated (comparable) with larger street network buffers, which may explain the poor agreement found in this current study. Nevertheless, poor– moderate agreement was also seen among the proximity measure using the road network and straight-line distances. The results from this study also showed that the limits of agreement for all the 800-m and 1000-m density measures and proximity were not small. Therefore, using straight-line methods cannot be used in the place of the road network method. Although the straight-line (Euclidean) distance is widely used in the literature [304], it is believed that the Euclidean distance underestimates road distance and travel time [305]. Previously published studies in the UK have used the straight-line method to measure the relationship between the proximity, density or accessibility of food outlets with health outcomes, such as Body Mass Index (BMI) and fat percentage or waist circumferences [136, 139, 306]. Although not all these studies found positive associations, the straight-line (circular) method was used to conduct the analysis of the results. It is stated that the selection of the method (circular or road network buffers and distance) to measure the characteristics of a certain point (land) influences the results of the analysis [307]. Therefore, it is advised that researchers should carefully consider the appropriate methods to be used for the data analysis.

6.5.4 Accessibility of HFTs

Different studies have used different methods to measure the accessibility of the food environment [212]. In this study, when the Hansen Index was used to measure the accessibility of HFTs around ALSPAC schools, it was not associated with the proximity measures or total number of HFTs within a certain zone, as this index measures access from each school to all HFTs in the study area, not just the nearest. A study used the Hansen Index to measure the individual spatial accessibility to each of the fast food shops near the individual’s home address and 300-m around their homes. The study found no associations between accessibility to fast food shops and the individual’s obesity, overweight and body mass index. Nevertheless, individuals with high accessibility score had 2.1 times the odds of stating that fast food shops were available but without necessarily using them. Moreover, those individuals with a high accessibility score had 2.3 times the odds of stating that fast food shops were available and reporting that they used them [308]. In our study the Hansen index took into consideration all of the takeaway outlets that existed near each of the schools including those existing within and more than 1000-m buffer. This accessibility score measures, for each school, proximity to not just the nearest takeaway but also all takeaways in the region. Thus, it provides a useful alternative, more holistic, measure to those most often used: nearest takeaway or number of takeaways in a buffer surrounding the school. For example, this measure would pick up a case where there was no takeaways in the immediate vicinity of the school but many takeaways within for example 2-5 miles in all directions. If there are any takeaways in the region then a zero score cannot be obtained. The actual score is relative – the more HFTs in the region the higher the score. Therefore, the Hansen index may be considered another useful way of measuring the food environment around schools with caveats on, for example, selecting the appropriate area size and understanding the consumption/purchasing behaviour of the targeted groups to be studied.

6.5.5 Strengths and limitations

Although this study is not the first to distinguish the differences between the methods used to measure the food environment around a location [134, 286], nevertheless, raising the awareness of the importance of choosing the appropriate methods and to the importance of using a consistent method to measure the food environment particularly around schools is needed. This analysis consequently may help policy makers to determine the appropriate methods to recommend for future policy guidelines and whether to regulate the clustering of HFTs around schools or not. The use of the agreement test (Lin's [1989, 2000] concordance correlation coefficient) to assess the agreement between two continuous measures obtained by two methods (straight line and road network) on the same subject strengthens the findings from this study [299, 301]. However, the agreement test is not providing an absolute measure of how strong these two methods are on agreement. The strength of the agreement varies, based on the criteria set by the researcher to assess the agreement [301]. For example, Altman (1990) [309] and McBride (2005) [302] have each reached different guidelines for interpreting Lin’s concordance correlation coefficient to assess the strength of agreements. To our knowledge, none of the previously published studies has assessed the strength of the agreement between the road network and straight-line methods. Therefore, results from the agreement test in this study were based on our understanding of the methods used to measure and evaluate the food environments. Moreover, the cross-sectional data used are one of the limitations to consider in this study. The use of longitudinal data (long-term changes) of HFTs could strengthen the findings from this study (road network vs. straight-line methods). The use of OS data ensures the use of the most recent data available regarding the number of takeaway outlets, as the number of food outlets changes over the years. Nevertheless, previous research stated children could buy sweets and other high-calorie food from shops located near schools. Focusing only on HFTs could result in a lack of evidence that may help to understand the link between policy actions and outcomes.

6.5.6 Recommendations

In the UK, more than 20 local authorities have considered restrictions on HFTs [109]; nonetheless, some authorities have allowed takeaway shops to locate close to a school [110]. The main reason for this has been a lack of evidence demonstrating that opening a single takeaway shop would have a direct relationship with the health status of school students [48]. The absence of best-practice methods to measure the density, proximity and accessibility of the food environment around homes, schools and workplaces has been highlighted by Wilkins, Morris et al. (2017) [111]. Even though using a universal standard to measure the food environment may not be practicable or appropriate [286], the availability of best-practice methods locally (across UK local authorities) would help to explore the food environment in a consistent way and, therefore, lead to suggest or recommend a more practical policies [310, 311]. In the UK, although the impact of reducing the density of fast-food outlets near schools on health has not been evaluated to date, Public Health England recommended this method, which may be one method of achieving this [48, 50]. However, the use of standardised methods to measure the density, proximity and accessibility of the food environment around schools in the UK is needed.

Based on our findings, I suggest the use of an 800-m and/or 1000-m road network to measure the density and proximity of food outlets around secondary schools. The road network method was selected based on the fact that the road network may represent the actual walking distance to be travelled by students to get to the outlet. The 800-m and/or 1000-m distances were selected based on the fact that secondary school students are willing to travel for a longer time and distance than younger children to a shop and buy what they want to eat for their lunch during lunch break. UK studies have used different distances to calculate the density (accessibility) scores of fast food outlets including an 800m road distance buffer [138, 285] which corresponds to a 10-minute walk [138, 167] and 1km road network distance [212] or 1km radius buffer [139]. Moreover, the use of 800-m and or 1000-m buffer size can assure the inclusion of all existing takeaway outlets within all off the 200-m, 400-m, 600-m as well as the 800-m or 1000-m buffers. For future studies, researchers need to consider the type of method to be used taking into consideration multiple factors such as the targeted group and the location to be explored. In addition, the availability of best-practice methods would help to explore the food environment in a consistent way and lead to more successful policies [310, 311]. Nevertheless, the Hansen index is another metric that may be used if the aim of the study is to consider multiple locations when evaluating HFTs and school locations. Moreover, though this study only focused on secondary schools, these recommendations may be universally applied to include primary schools and other venues where young people congregate.

6.6 Conclusions

There are statistical differences when the road network distance is used compared to the straight-line distance. The buffer size also has a significant impact on the number of schools with more than one takeaway outlet being around a secondary school. Government organisations, sectors and all related stakeholders should recommend consistent methods to be used to measure the density and/or the proximity of food outlets, especially around schools. This may help to evaluate the impact of policy actions such as limiting the number of takeaway outlets from schools using similar methods to provide a consistent platform to enable policy makers to prioritise policies that need to be implemented in regard to the clustering of takeaway outlets. The Hansen accessibility index is a new tool which could also be added to the literature that considers both the nearness of the subject as well as the availability of the subject within a certain zone.

This chapter has discussed the differences in using different methods to measure the food environment particularly around secondary schools in the UK. Recommendations and suggestions regarding the most appropriate method and buffer size to be used were also highlighted. The next chapter (7) will explore the relationship between the number (density), proximity and accessibility of hot food takeaways and BMI z-score and body fat percentage of secondary school adolescents. This will help to expand our understanding of the impact of clustering of food outlets around the schools.

Chapter 7 Relationships between school adolescents' BMI and body fat percentage and takeaway meal outlets: A longitudinal analysis

Abstract

Background: Frequent consumption of takeaway meals has been found to be negatively associated with the diet quality of British adolescents. The Food Environment Policy Index believes that strengthening planning policies to discourage unhealthy fast food is a priority and will have a significant influence on mitigating diet-related diseases and obesity. The clustering of hot food takeaways (HFTs) around schools is known to exist in the UK, but few studies have explored the longitudinal associations with health outcomes among adolescents attending secondary school.

Aims: This study investigated the relationships between the density, proximity and accessibility of takeaway outlets and the BMI and body fat percentage of UK adolescents from the Avon Longitudinal Study of Parents and Children study conducted between 2005 and 2011.

Methods: A total of 1382 participants (44.5% male) were included in this study. A Geographical Information System (GIS) was used to locate all schools and takeaways in the region and to measure the density and proximity scores, applying the road network method. In addition, the Hansen Index was used to measure the accessibility score of each school to all takeaways in the region (not just the nearest). The statistical analysis tests, including linear and logistic regression tests, were conducted using Stata software, Version 15.0.

Results and conclusion: Both linear and logistic adjusted regressions showed some significant associations between availability of HFTs and BMI z–score and body fat percentage. Proximity of HFTs showed no associations with BMI z–score. Accessibility of HFTs showed small negative but significant associations with BMI z–score and attenuated results with body fatness. Overall results showed conflicting findings, and further exploration is still needed, particularly using recent outcome data to investigate the true relationships with the food environment around secondary schools.

7.1 Introduction

Obesity and overweight rates among school-aged children and adolescents have become a common issue which needs to be urgently considered in many countries [95]. Statistics show that, from 1993 to 2003, UK persons aged 15 years and older had the highest rate of obesity and overweight, compared with other European countries, including the Netherlands, Spain, Sweden, Italy and Germany [312]. In 2014, a report from the NHS showed that the UK still had the highest rate of obesity among people aged 15 years and older, compared to other European countries, except Hungary (obesity rate was nearly 30%) [60]. In the UK, the obesity rate among adolescents aged 11–15 years was observed to be higher compared to that of children aged 10–11 years, with 19.1% and 37.2%, respectively [61]. The cause of obesity and overweight is complex, and multiple factors are believed to be involved, including physical activity and exercise, dietary intake and behaviours, income and the surrounding obesogenic environment [313]. One of the most important environmental factors is the location of fast food outlets. A recent cross-sectional study in the UK, including children aged 9–11 years from 85 primary schools across London, Birmingham and Leicester, found that 28% of students consumed takeaway meals once or more times per week. The low-density lipoprotein (LDL) cholesterol, fat mass index and total cholesterol were observed to be higher among students who consumed takeaway meals (equal to or more than once per week) compared to those who never or hardly consumed takeaway meals [222]. In addition, as age increases (moving from primary to secondary school), the number of students consuming lunch at school decreases, as in some cases secondary school students are allowed to leave school premises during lunch break times [48].

Takeaways are one of the factors that may result in the inequality of health, particularly childhood obesity. This is mainly because children are highly sensitive to cost, and takeaways can offer foods at a very low price (up to 900 calories can be purchased for £1) [280]. In 2014, there were more than 50,000 hot food takeaways in England, including fast food, takeaway, fast food delivery services and fish and chips outlets [34]. The overall density of food outlets was lower in the Avon region compared to the density in all England, with 88.2 and 78.3 per 100,000 people, respectively. Nevertheless, Bristol showed a higher density than both the Avon region and all England, with a rate of 109.8 per 100,000 people

[34]. According to the latest UK House of Commons Health Committee report, the government and local authorities must take stronger actions to prevent widening health inequalities, especially among people from the most deprived areas. Limiting the clustering of takeaways, especially around schools, has been one of the top five priorities for most local authorities. However, Public Health England stated that most of the authorities lack information on where and how to implement the best action on food environments [221].

Until now, no country has been successful in reversing obesity rates [102]; evidence for effective action to tackle obesity is needed. From 1990 to 2009, many researchers studied the obesogenic environment and its impact on people's health outcomes [314]. However, out of 14 studies that included a measure of weight and height, only five measured weight, whereas the other eight studies used self-reported heights and weights [314]. Moreover, a recent systematic review showed that most previous studies were conducted in countries other than the UK. Out of 73 studies, only six were conducted in the UK [135]. Most previous studies done the UK, focusing on the school food environment and obesity or diet quality as an outcome, were either cross-sectional [136] or studies targeting primary school students [138, 141]. In addition, three studies [212, 229, 315] have examined the relationship between the food environment around children's, adolescents' and adults' residential addresses and obesity or diet quality. Longitudinally, in the UK, Smith, Cummins et al. (2013) [143] examined the impact of the school food environment and adolescents' diet quality. Only one paper [139] has studied the longitudinal relationship between the density of fast food outlets around schools and homes and adolescent obesity. Nevertheless, the results remain unclear respecting the impact of the geographical location of fast food outlets (hot food takeaways) and obesity, especially amongst the adolescent age group. In addition, a recent study found that, out of 325 local government areas, 164 had takeaway food planning policies. Only 56 of these 164 local government areas had health focus planning policies [49]. The implementation of such planning policies, especially for long-term effectiveness and their impact on health, should be studied and explored [49, 50]. Therefore, the aim of this study is to investigate the longitudinal relationship between the density, proximity and accessibility of hot food takeaways (HFTs) and health outcomes (BMI z–score and body fat percentage) of secondary school adolescents using the Avon Longitudinal Study of Parents and Children (ALSPAC).

7.2 Methodology

7.2.1 Source of data

More than 14500 pregnant women were involved in the Avon Longitudinal Study of Parents and Children (ALSPAC) between April 1991 and December 1992. The average population of adolescents aged under 18 years living in the study area (Avon region) in 2016 was broadly similar to the rest of England, with 21.6% and 22.5%, respectively [58]. Both questionnaire-based and clinical measurements were involved in the ALSPAC study. In this study, adolescents were involved if they had a valid school ID, completed a food frequency questionnaire and attended clinic visits between 2007 and 2011 at age 13–14 years (years 8 and 9), at age 15–16 years (years 10 and 11) and at age 17 years (year 12) and stayed at the same school during the study.

7.2.2 Schools data

The initial total number of included schools was 134 in the Avon region. As mentioned in the previous chapter (6), after omitting special schools and private schools, 88 schools remained. Out of these 88 schools, 53 included ALSPAC participants. To ensure the anonymisation of ALSPAC data, the school identifier ID was used instead of the school name or location.

7.2.3 Hot food takeaways (HFTs) data

The Ordnance Survey (OS) was the source of data on food outlets in this study. The OS database has been used before to identify fast food outlets and has shown 81–100% accuracy [212]. The definition of HFTs is based on category A5 (eating and drinking), which includes all "Premises where the existing primary purpose is the sale of hot food to take away" [126]. In this study, data on the number of HFTs were obtained for all the following years: 2005 (students aged 11 years), 2007 (students aged 13 years), 2009 (students aged 15 years) and 2011 (students aged 17 years).

7.2.4 Geographical analysis

All the schools and HFTs were geocoded using their X and Y coordinates and Arc Geographical Information System (GIS) Software (ArcGIS 10.4.1). GIS has been widely used among local authorities, governmental agencies and planners to help develop policies related to diet and health [287, 288]. The boundary data and integrated transport network (with the path lines network) were obtained from the Ordnance Survey via the Digimap UK website. The road network was then built using the Network Analyst in ArcGIS to enable us to measure the number of HFTs within a specific area (zone) using the road distance. The built road network in this study was cross-checked with the road network from Google maps around five randomly selected schools.

7.2.5 Variables of interest

Three methods for measuring the nearness of HFTs to secondary schools have been previously reported in the literature.

A. The proximity of HFTs

The proximity measure represents the distance in metres from the centroid of each of the schools to the closest hot food takeaway shop. In this study, the Closest Facility tool in ArcGIS in the Network Analyst tab was used to calculate the road network distance (unit; metres).

B. The density of HFTs

Road network buffers of 800-m and 1000-m were created around the centroid of each school. The number of HFTs was calculated using the Service Area tool available in the Analyst network in ArcGIS software 10.4.1. This method had been used previously by other researchers [95, 133] and Public Health England [19]. The 800-m and 1000-m distance was selected based on the fact that secondary school students are willing to walk for longer distance and therefore further than younger children to shops, and purchase what they want to eat for their lunch during the lunch break. UK studies have used different distances to calculate the density (accessibility) scores of fast food outlets including an 800-m road distance buffer [138, 285] which corresponds to a 10-minute walk [138, 167] and 1-km road network distance [212] or 1-km radius buffer [139]. The use of 800-m and or 1000-m buffer size includes of all existing takeaway outlets within the 200-m, 400-

m, 600-m as well as the 800-m or 1000-m buffers. Moreover, most of the schools had zero HFTs within 600-m or fewer and the analysis would be less robust.

The data for total number of HFTs around schools was observed to be right skewed because of the high number of schools with no HFTs. Therefore, the number of HFTs was categorised into two groups (reference group; 0 = schools with no takeaway outlets; and 1 = schools with takeaway outlets). For example, if there was at least one HFT outlet within 800-m or 1000-m around the school, the neighbourhood was defined as having an availability of HFT outlets. This method has been used previously [316].

C. Accessibility scores

Less common in the literature are indicators that consider access to all HFTs rather than the nearest one only. To contribute to the literature, therefore, I added the Hansen Index [292] to calculate an accessibility score for each school using the following equation:

$$A_i = \frac{S_j}{d_{ij}}$$

Where

A_i is a measure of accessibility for pupils in school i
Sj is the service available in zone j (e.g. number of HFTs)
d_{ij} is the distance/time/cost to get between school i and HFT j

As seen from the equation above, the index provides a score for each school based on the number of surrounding HFTs. It is a relative score, rather than an absolute one, with a high score meaning that a school has many HFTs in close proximity, whilst a low score indicates few HFTs in the vicinity of the school.

7.2.6 Health outcomes

7.2.6.1 BMI

Both the height and weight of all adolescents were measured at five clinic visits. Height was measured in centimetres (to the last complete mm) using Harpenden Stadiometer equipment. Weight was measured in kilograms using the Tanita Body Fat Analyzer (model TBF 401A and 305). Subsequently, the height and weight were used to calculate BMI, which is usually referred to as the *centile* or *z–score* (BMI standard deviation score, or BMSDS). Based on the British growth reference, participants with a BMI above the 85th percentile were deemed overweight (BMI z–score ≥ 1.04 – < 1.64), and those with a BMI above the 95th percentile were considered obese (BMI z– score ≥ 1.64) [317].

7.2.6.2 Body fat

Adolescents at all clinic visits were also invited to do a whole-body scan using scan stands for dual-energy x-ray absorptiometry (DEXA) equipment, where a lunar prodigy narrow fan-beam densitometer measured lean and fat mass and bone content. After each test, the examiner checked all DEXA scans manually for quality assurance. Then the body fat percentage was calculated using the following equation: fat mass (kilograms)/total body mass (kilograms) X 100 [212].

7.2.6.3 Physical activity

Adolescents were asked to wear an activity monitor during the clinic visit for seven consecutive days. The Acti-graph devices were used, and the data was considered valid when the device was worn at least three days for at least 10 hours. At the second visit, no measurements were taken, and at the fifth visit, most students either refused or had invalid measurements. For the Actigraph monitor, the most commonly used derived variable is count per minute (CPM) which measures the average count per minute over a period of valid recordings [210].

7.2.6.4 Deprivation

In ALSPAC, the index of individual multiple deprivation (IMD 2004, 2007 and 2010) was available in five quintiles [318]. In this study, the IMD was used to assess the deprivation level of small areas; a score of 1 represents the most deprived areas (quantile 1), whilst a score of 21,844 (quantile 5) represents the least deprived areas [217].

7.2.7 Data processing

The ALSPAC team provided both the education data set (individual IDs and key stages IDs) and school data sets (key stages IDs and density, proximity and accessibility scores) separately. Education data is available for all key stages (school identifier ID) information. All participants with missing and not available (applicable) data were dropped from the data set. It was possible to combine (merge) the two datasets using the ‘’cidB27982’’ variable as the unique identifier for individuals. In addition, the same variable was used again to merge the newly generated data with data containing health outcome variables.

7.2.8 Statistical analysis

General characteristics variables were generated for all subjects (aged 11–17 years) included by the ALSPAC study and/or the school attended. A general description of the number of HFTs around the schools was also generated. All statistical analyses were conducted using STATA/IC version 15. Only students remaining at the same schools during the compulsory secondary stage were included in this analysis. The BMI z–score and body fat percentage were used at age 15 and 17 years to explore the associations with availability of HFTs at baseline in 2007 (HFT available yes/no) within 800-m and 1000-m, proximity and accessibility score. The normality of data distributions was checked for both BMI z–score and body fat percentage by plotting histograms. The BMI z–score and body fat percentage were used as a continuous variable in the model. The BMI z–score was also transformed to a binary categorical variable with two classifications: 0 ‘Non-obese’ and 1 ‘Obese’

A linear regression for continuous outcomes (BMI z–score and body fat percentage) was conducted, taking into consideration the clustering effect of the adolescents within schools, to explore the associations between availability, proximity and accessibility of HFTs at baseline (2007) when the adolescents were 13 years and BMI z–score and body fat percentage status at 15 and17 years in 2009 and 20011. Logistic regression was also performed for the binary outcome (non-obese and obese) at age 15 and 17 years, using exposures at baseline. For all analyses, two models (univariable and multivariable) were undertaken. The multivariable model was adjusted for confounders including gender, ethnicity, individual home deprivation level at outcome phase, physical activity level at age 13 years (due to drop in number of participants with valid measurements at age 15 and 17 years) and baseline BMI z–score and body fat percentage.

The hypotheses of the study were as follows:

1- For the number of HFTs I hypothesised that the BMI z–score would increase with availability of outlets.

2- For proximity of HFTs I hypothesised that the BMI z–score would decrease with increase in proximity (in metres).
3- For Accessibility score I hypothesised that the BMI z–score would increase with increase in accessibility of outlets.

According to the US International Obesity Task Force, “A BMI z score reduction in the range of 0.15 to 0.25 is a suitable threshold for clinically important change” and associated with improvements in cardiovascular and metabolic risk factors [319]. A sample size calculation was conducted based on a mean difference in BMI z–score of 0.2 and standard deviation of 1 unit based on a typical value obtained from cohorts of childhood BMI z–scores. This data here produced standard deviation values between 0.5 and 0.7 for the different ages and the longitudinal study conducted by Green, Radley et al. (2018) [139] reported a value of 1.2. The intra class correlation (variation at the school or cluster level) was taken into account although it was low at 1.4%. The sample size used here of 1382 participants meant there was very high power of >99% chance of detecting a change in BMI z scores in the region of 0.2 if there was a true change. (See Appendix 14).

7.2.9 Stratified analyses

A. Stratifying based on IMD level

A stratified analysis was also conducted to consider the impact of deprivation level, as living in more deprived areas is linked with increased risk of being obese and having a higher density of takeaway outlets. According to Public Health England, in 2018/2019 childhood obesity prevalence was closely associated with socioeconomic status [320]. In addition, severe obesity prevalence among Year 6 children in the most deprived of areas in England is higher than the prevalence in the least deprived areas This is also seen among reception children [320]. Although the socioeconomic status is considered as a potential confounder (associated with both the exposure and outcome), I was interested in investigating if sub-group analysis by individual deprivation level would have an impact on the overall results. Therefore, I conducted the stratified analysis to explore if an ALSPAC participant living in a more deprived area would be more likely to be at higher risk of being obese.

The data were stratified by each individual's IMD level based on home census data provided by ALSPAC to examine the impacts of deprivation on the BMI z–score and body fat percentage. The IMD level was provided in five quintiles, and the data were stratified into two groups. Quintiles 1 and 2 were coded with 0 – most deprived students, and quintiles 3, 4 and 5 were coded with 1 – the least-deprived students. The IMD quintiles were split unequally to generate similar numbers of students in each group. Similar to the previous models, univariable and multivariable linear regressions were performed to explore associations between availability of HFTs and change in BMI z–score and body fat percentage.

7.3 Results

7.3.1 General description

In total, 52 state-funded schools with 1382 participants (44.5% male) were included in this study. From the initial sample (53 schools), one school was excluded as participants moved to another school during the study time (number of observations excluded = 45). In 2007 using the 800-m buffer, out of 1382 students, 850 attended schools with zero HFTs, 303 with one HFTs, 104 with two HFTs and 125 with more than two HFTs. The number of schools with zero HFTs decreased when using the 1000-m buffer.

Height and weight measurements were available for all 1382 participants at the ages of 11, 12, 13, 15 and 17 years. The mean BMI value increased with age, but the BMI z–score did not show a continuous increase for both genders. The prevalence of overweight and obesity was observed to decrease across the years, except for a slight increase at age 17. About 25.5%, 24.5%, 23.0% 21.2% and 22.8% of participants were observed to be overweight and obese at ages 11, 12, 13, 15 and 17. Females had a higher mean BMI and body fat% than males across all age groups. Body fat measurements were not available for all 1382 participants at the ages of 11 years (n= 1364), 12 years (n= 1381), 13 years (n= 1365), 15 years (n= 1370) and 17 years (n= 1353). In addition, general characteristics of participants aged 15 and 17 years can be seen in table (Table 7-4).

In terms of ethnicity, approximately 97% of participants were white, and the remaining were from non-white ethnic backgrounds. Due to the dramatic decrease in the number of participants with a valid physical activity measurement throughout the years, the results obtained from clinic visits one and three were used to represent the physical activity level of the participants attending clinic visits two, four and five, respectively (Table **7-1**).

Concerning eating habits, at age 13 years, 82.8% out of 1220 were observed to ‘never consume’ or ‘consume fast food from restaurants’ once a month. About 14% reported eating fast food once in two weeks. Less than 5% reported consuming fast food one to two and three to four times per week. Moreover, approximately 92% of participants reported never buying food outside the school when it was in term, and the other 8% reported purchasing food from outside school from one (4.2%) to five (0.9%) times per week. A similar number of participants (80.9% out of 1217) reported that they ‘never consume’ or ‘consume food in other cafes or food outlets’ once a month. In addition, 15.6% reported eating food ‘in other cafes’ once every two weeks. Less than 5% reported eating food ‘in other cafes’ one to two times or more per week.

Table 7-1 Characteristics of the 1382 participants from the ALSPAC study, the Avon, UK, for each of the five clinic visits.

Visit 1 (F11)	Males (*n* = 616)		Females (*n* = 766)	
	Mean	**SD**	**Mean**	**SD**
Age (years)	11.1	0.2	11.0	0.2
BMI	18.5	3.0	18.9	3.1
Body fat%	22.4	8.9	26.8	7.9
BMI z–score	0.3	1.2	0.2	1.1
Physical activity Level (CPM)/*n* = 1225	631.0	168.3	539.3	143.2
Visit 2 (TF1)				
Age (years)	12.1	0.3	12.1	0.3
BMI	19.1	3.0	19.7	3.2
Body fat%	17.3	7.0	25.6	6.3
BMI z–score	0.3	1.1	0.2	1.1
Physical Activity Level (CPM)	NA			
Visit 3 (TF2)				
Age (years)	13.1	0.3	13.1	0.3
BMI	19.5	2.9	20.3	3.1
Body fat%	18.5	8.7	27.8	7.6
BMI z–score	0.2	1.1	0.2	1.1
Physical Activity Level (CPM)/*n* = 1118	586.7	189.6	484.0	157.2
Visits 4 (TF3)				
Age (years)	15.0	0.1	15.0	0.2
BMI	20.5	2.9	21.2	3.1
Body fat%	15.9	8.1	29.8	7.4
BMI z–score	0.2	1.1	0.2	1.0
Physical Activity Level (CPM)/*n* = 732	529.4	191.1	428.0	133.4
Visit 5 (TF4)				
Age (years)	17.1	0.4	17.2	0.4
BMI	22.1	3.5	22.3	3.6
Body fat%	17.3	8.7	32.1	7.5
BMI z–score	0.2	1.1	0.2	1.2
Physical Activity Level (CPM)	NA			

7.3.2 Change in number of HFTs over time

In regards to the school food environment, the total number of HFTs around the 52 schools within 800 metres increased between 2005 and 2011. In 2011, the range of the total number of HFTs increased from 0–7 to 0–12 outlets. Similarly, within 1000 metres, the total number of HFTs increased in 2011, and similarly to 800 metres, the range of HFTs increased from 0–9 to 0–16 food outlets (Table **7-3**). In terms of proximity and accessibility measures, there was no consistent increase or decrease in the mean and median of both the proximity and accessibility of takeaway outlets and schools. Nevertheless, the mean of the accessibility score was higher in 2011 compared to the rest of the years (Table **7-3**).

Table 7-2 shows the total number of schools with zero, one, two and more than two hot food takeaway outlets. It can be seen that the number of schools with no outlet within 800 and 1000 metres decreased in 2011 compared to other years. In addition, more schools had two or more than two outlets within 1000 metres compared to 800 metres, which is visible across all years.

Table 7-2 Categorisation of schools based on the total number of HFTs within 800 and 1000 metres in 2005, 2007, 2009 and 2011.

Number of schools with:	**800 metres**				**1000 metres**			
	2005	2007	2009	2011	2005	2007	2009	2011
Zero outlets	31	30	30	28	17	20	20	16
One outlet	8	11	8	10	12	9	7	10
Two outlets	8	6	8	7	9	8	12	11
More than two outlets	5	5	6	7	14	15	13	15

Table 7-3 Total number, distance and accessibility score of HFTs from Avon secondary schools across the years.

Total Number of Schools = 52				
	Number of HFTs			
800-m road network buffer	**2005**	**2007**	**2009**	**2011**
Total	48	46	54	58
Median	0	0	0	0
Interquartile range	0–1.5	0–1	0–2	0–2
Min–Max	0–7	0–8	0–8	0–12
1000-m road network buffer				
Total	101	99	106	118
Median	1	1	1	1.5
Interquartile range	0–3	0–3	0–2.5	0–3
Min–Max	0–9	0–10	0–10	0–16
Road network proximity (m)	**2005**	**2007**	**2009**	**2011**
Mean	981.9	1052.6	1069.1	1013.1
Median	824.5	825.4	850.7	825.4
Interquartile range	544.3–1091.4	549.9–1117.2	549.9–1180.7	520.3–1148.6
Min–Max	12.6–3794.5	12.6–6205.1	12.6–6205.1	12.6–4215.5
Accessibility score				
Mean	8.1	8.1	8.1	9.1
Median	5.6	5.5	5.5	5.9
Interquartile range	3.4–10.2	3.1–10.3	3.7–10.3	3.6–11.2
Min–Max	0.20–35.8	0.04–36.1	0.04–32.8	0.10–40.6

Table 7-4 Characteristics of participants at 15 years and those who remained at the same school at age 17 years

At age 15 years	Mean	SD	At age 17 years	Mean	SD
BMI z-score/ n = 1381	0.2	0.03	BMI z-score/ n = 865	0.2	0.04
Body fat percentage/ n = 1370	23.6	0.3	Body fat percentage/ n = 848	24.9	0.4
Male (%)/ n= 1381	44.6	1.3	Male (%)/ n= 864	47.1	1.7
Individual's IMD level / n= 1366	1.9	0.03	Individual's IMD level/ n = 857	1.8	0.03
Physical activity level (CPM)/ n= 1121	528.9	5.4	Physical activity level (CPM)/ n= 698	533.4	6.6
Ethnicity White (%)/ n = 1295	96.8	0.5	Ethnicity white (%)/ n = 810	97.5	0.5

7.3.3 Total number of HFTs and health outcomes

The associations between availability of HFTs within 800 road network metres and BMI z–score and body fat percentage at 15 and 17 years are shown in Table 7-5. After adjusting for baseline levels of BMI z–score or body fat percentage, gender, individual IMD, physical activity level and ethnicity, no significant associations were observed between availability of HFTs within 800-m and BMI z–score and body fat percentage at age 15 and 17 years. For example, individuals attending schools with HFTs available had a very slightly higher BMI z–score of $3.25E^{-03}$ (95% CI; -0.06, 0.07) and a slightly lower BMI z–score of 0.08 (95% CI; -0.21, 0.05) at 17 years. (Table 7-5). Results for unadjusted models, adjusted only for baseline values of the outcome, were similar to adjusted models (Table 7-5). Similar to the 800-m results, both unadjusted and adjusted linear regressions also showed no significant associations between availability of HFTs within 1000-m and BMI z–score and body fat percentage at 15 and 17 years (see appendix 10).

The adjusted logistic regression showed no significant associations between availability of HFTs within 800-m and risk of being obese at 15 years but significant associations were observed among the 17 year group. For example, the odds of being obese and attending schools with HFTs were 0.72 (95% CI; 0.43, 1.19) at age 15 years and 0.56 (95% CI; 0.41, 0.76) at age 17 years (Table 7-6). The lower odds of being obese at 15 and 17 years with higher availability of HFTs is the opposite of what was hypothesised in this study. Results for the unadjusted model, adjusted only for baseline values of outcome were similar but attenuated (Table 7-6). For the 1000-m results, adjusted logistic regressions also showed significant associations between availability of HFTs and risk of being obese at age 17 years, similar in direction to the results for 800-m. Furthermore, similar results were observed for the unadjusted model. (see appendix 10).

7.3.4 Proximity and accessibility of HFTs and health outcome

Adjusted regressions for food outlet proximity showed no significant associations with BMI z–score at age 15 and 17 years (Table 7-5). For example, for every 100-m increase in proximity (increase in distance) a slightly higher BMI z–score of 1.24^{E-03} (95% CI; 3.03^{E-05}, 2.44^{E-03}) was observed at 15 years and 0.02 (95% CI;

-0.01, 0.04) at 17 years; again, the opposite of what was hypothesised in this study. Results for the unadjusted model were similar for both 15 years and 17 years (Table 7-5). However, significant associations were observed between increase in proximity and higher body fat percentage among the 15 year old group.

Opposite to the hypothesis of the study, adjusted regressions for accessibility of HFTs showed some significant but negative associations with BMI z–score and body fat percentage at 15 years and 17 years (Table 7-5). For example, for every unit increase in accessibility score, BMI z–score lowered by 3.56^{E-03} (95% CI; -0.01, -1.10^{E-03}) at 15 years and by 0.01 (95% CI; 0.01, $-2.11E^{-03}$) at 17 years. Results were attenuated for unadjusted models (Table 7-5).

Table 7-5 Linear (clustered) regression analysis between availability of HFTs at baseline within 800 metres road network school buffer and BMI z–score and body fat percentage at 15 and 17 years.

	Unadjusted models								Adjusted models							
Mean age 15 years	**BMI Z-score**				**Body fat percentage**				**BMI Z-score**				**Body fat percentage**			
	Coeff	**CI**		**P**	**Coeff**	**CI**		**P**	**Coeff**	**CI**		**P**	**Coeff**	**CI**		**P**
Takeaway available	0.03	-0.03	0.08	0.33	0.02	-0.65	0.70	0.94	3.25E-03	-0.06	0.07	0.92	-0.35	-0.96	0.27	0.26
Proximity (m)	2.98E-04	-1.22E-03	1.82E-03	0.70	-1.94E-03	-0.03	0.02	0.88	1.24E-03	-3.03E-05	2.44E-03	0.05	0.02	2.83E-03	0.04	0.03
Accessibility score	-2.00E-03	-4.37E-03	3.66E-04	0.10	-0.03	-0.06	0.01	0.11	-3.56E-03	-0.01	-1.10E-03	0.01	-0.04	-0.06	-0.02	<0.01
Mean age 17 years																
Takeaway available	-0.07	-0.19	0.06	0.29	-0.66	-2.13	0.82	0.37	-0.1	-0.2	0.1	0.2	-1.2	-2.6	0.2	0.1
Proximity (m)	3.71E-03	-1.19E-04	7.53E-03	0.06	0.02	-0.04	0.08	0.48	0.02	-0.01	0.04	0.2	0.5	-0.01	0.9	0.1
Accessibility score	-5.72E-03	-9.04E-03	-2.39E-03	<0,01	-0.04	-0.11	0.03	0.25	-0.01	-0.01	-2.11E-03	0.01	-0.1	-0.13	0.01	0.1

Both models were adjusted for BMI z–score at baseline; Adjusted analysis for gender, ethnicity, individual deprivation level and physical activity level

Table 7-6 Logistic (clustered) regression between availability of HFTs at baseline within 800 metres and risk of being obese at age 15 and 17 years.

Takeaway available	Unadjusted analysis				Adjusted analysis			
Risk of being obese	**OR**	**CI**		**P**	**OR**	**CI**		**P**
Mean age 15 years	0.74	0.44	1.22	0.23	0.72	0.43	1.19	0.19
Mean age 17 years	0.68	0.46	1.01	0.05	0.56	0.41	0.76	<0.01

Both models were adjusted for being obese or not at baseline; Adjusted analysis for gender, ethnicity, individual deprivation level and physical activity level

7.3.5 Results from stratified analyses

After stratifying the analyses by individual home IMD level and adjusting for gender, ethnicity, physical activity level and baseline BMI z–score and body fat percentage, no significant associations were observed between availability of HFTs within 800-m and BMI z–score and body fat percentage at 15 and 17 years among both the most and least deprived group (Table 7-7 and Table 7-8). Nevertheless, the stratified analysis showed a lower body fat with increase in takeaway availability in the most deprived areas. This was not seen in the least deprived areas. Results were similar for unadjusted models (Table 7-7 and Table 7-8).

Similarly, for 1000 metres, after adjusting for confounders; no significant associations were observed between availability of HFTs and in BMI z–score and body fat percentage at 15 and 17 years among the most and least deprived groups (Appendix 11). Results were similar for the unadjusted model (Appendix 11).

Table 7-7 Linear (clustered) regression analysis between availability of HFTs at baseline within 800 metres road network school buffer and BMI z–score and body fat percentage at 15 and 17 years, among students from the most deprived areas

Variable of interest	Unadjusted model								Adjusted model							
Mean age 15 years	**BMI Z-score**				**Body fat percentage**				**BMI Z-score**				**Body fat percentage**			
	Coeff	**CI**		**P**	**Coeff**	**CI**		**P**	**Coeff**	**CI**		**P**	**Coeff**	**CI**		**P**
Takeaway available	3.71^{E-03}	-0.05	0.06	0.90	-0.48	-1.22	0.27	0.20	-0.02	-0.09	0.05	0.62	-0.67	-1.39	0.05	0.07
Mean age 17 years																
Takeaway available	-0.05	-0.16	0.05	0.31	-0.73	-1.86	0.40	0.20	-0.08	-0.21	0.05	0.22	-1.31	-2.44	-0.17	0.03

Both models were adjusted for BMI z–score at baseline; Adjusted analysis for gender, ethnicity, individual deprivation level and physical activity level

Table 7-8 Linear (clustered) regression analysis between availability of HFTs at baseline within 800 metres road network school buffer and BMI z–score and body fat percentage at 15 and 17 years, among students from the least deprived areas

Variable of interest	Unadjusted model								Adjusted model							
Mean age 15 years	**BMI Z-score**				**Body fat percentage**				**BMI Z-score**				**Body fat percentage**			
	Coeff	**CI**		**P**	**Coeff**	**CI**		**P**	**Coeff**	**CI**		**P**	**Coeff**	**CI**		**P**
Takeaway available	0.08	-0.02	0.18	0.11	1.12	-0.01	2.26	0.05	0.06	-0.04	0.17	0.23	0.56	-0.25	1.37	0.17
Mean age 17 years																
Takeaway available	-0.12	-0.36	0.13	0.34	-0.67	-3.79	2.45	0.66	0.02	-0.23	0.26	0.89	0.27	-2.65	3.19	0.85

Both models were adjusted for BMI z–score at baseline; Adjusted analysis for gender, ethnicity, individual deprivation level and physical activity level

7.4 Discussion

7.4.1 Summary of the findings

This is the first study to investigate the relationship between the food environment around schools and adolescents' BMI and body fat percentage using longitudinal exposure and health outcomes in the UK. No significant associations were observed between availability of HFTs and BMI z–score and body fat percentage at 15 or 17 years when using either an 800- or 1000-metre buffer.

An adjusted logistic regression showed non-significant associations between availability of HFTs within 800-m and 1000-m and risk of being obese at 15 years. However, adjusted logistic analysis showed protective effects between availability of HFTs within 800-m and 1000-m and risk of being obese, particularly at 17 years which was the opposite effect that was expected.

The proximity of takeaway outlets showed no significant impact on BMI z–score at 15 or 17 years. However, the results from this study show small but negative associations between the accessibility of HFTs and adolescents' BMI z–scores at 15 and 17 years which was also the opposite of what was expected. Stratified analyses showed no significant associations between availability of HFTs within 800-m or 1000-m and BMI z–scores in the most deprived group, at 15 or 17 years.

7.4.2 Associations between HFTs and health outcomes

Although other studies have found a positive cross-sectional association between the availability of fast food outlets (particularly around secondary schools) and BMI, most of those studies have been conducted in the US [97, 321-323]. However, one of the studies suggested that the proximity of fast food outlets did not show a positive association with BMI among all adolescent participants where ethnicity and income affected overall associations (Black and Hispanic students and those from low-income schools showed four times higher associations) [322]. In this current study, most participants (97%) were from a white ethnic background, and stratifying the analysis by ethnic group was not possible. Moreover, results from the stratified analysis in this study showed that the associations between availability of HFTs and BMI z–score and body fat percentage were not affected by individual IMD level. This may be because some of the least-deprived areas in Bristol, for example the city centre of Bristol, are areas with a high density of HFTs. In addition, it was observed that the prevalence of overweight and obesity in the studied population decreased across the years, which may reflect the fact that obese children had a higher chance of dropping out of the study before reaching 15 years old. Although a bigger proportion of those students came from deprived areas, caution must be taken when interpreting those results. This is mainly because the IMD level is representing a relative measure of deprivation of small areas (Lower Super Output Areas) in England, and the schools included in this study may not be located within this area [217]. However, several studies from different countries which included schools, adolescents and BMI as their variables of interest, also have had conflicting results (mixed or negative/null associations) [135].

In the UK, a previously published cross-sectional study conducted by Griffiths, Frearson et al. (2014) [136] among secondary school students (aged 11–12 years) stated no associations were observed between the total number and proximity of takeaway outlets with BMI z–score, except for one of the quartile that showed negative associations. In addition, another longitudinal study conducted by Green, Radley et al. (2018) [139] in the UK including students aged 11, 13 and 15 showed no significant associations between the number of fast food outlets within 1000 straight-line metres and BMI z–score. Conflicting findings were also seen among our results, even though both cross-sectional [136] and longitudinal [139] studies used different methodologies to measure the total number and proximity of food outlets around schools and homes. Previous studies have either used straight-line (Euclidean) [134, 136, 139, 289] or road network [290, 291] distance to measure the proximity of food takeaway outlets. Both methods result in varying distances, which may lead to a completely different understanding of the impact of the food environment. Additionally, Green, Radley et al. (2018) [139] and Griffiths, Frearson et al. (2014) [136] used different definitions of takeaway outlets than the one used in this current study. For example, in Green, Radley et al. (2018) [139], a straight-line distance of 1-km was used to calculate the accessibility score. In addition, hot food takeaways were classified according to the Leeds City Council (LCC), which defined ‘A3’ properties as hot food outlets (serving hot products to be consumed on or off site). It is believed that HFTs are part of the problem, and other outlets such as supermarkets, retailers and convenience stores could also affect the choice of unhealthy foods and, therefore, students' health. In 2008, an increase in the number and density of HFTs was observed in many local authorities across the UK and in close proximity to schools. However, a study stated that school children were aiming at fringe shops such as convince stores and takeaway outlets to get the food from [94].

In addition, policies vary between schools regarding allowing their students to leave school premises during the school lunch break [126, 136]. Nevertheless, limiting the definition to include only HFTs, 'A5' properties, was necessary to ensure that this study follows the current planning strategy recommended by most local authorities in the UK. In 1995, older students were more likely to be allowed to leave secondary school premises during their lunch break. However, in 2017, most secondary schools (88%) did not allow their students to leave the school premises during lunch break [324]. This may highlight the fact that school students would not have the opportunity to leave the school premises until a certain age (*i.e.* over 15 years). Other factors other than limiting the number of HFTs could also have an impact on students' food choices such as food available inside the school, available supermarkets around the school and food brought by the students from home or on the way to school.

Even though the Hansen index provides a relative score considering both the total number and close proximity of HFTs and schools. Accounting for the number and nearness of available takeaway outlets when calculating the accessibility score. In this study the accessibility score, using the Hansen Index, showed the associations between the accessibility score and BMI z–were small but negative (the opposite of what was expected). This may highlight the fact that other outlets such as supermarkets, convenience stores and local retailers could also influence students' food choices, which this study did not account for. Furthermore, a study showed that individuals attending schools with a high accessibility score stated that fast food shops were available but that they didn't necessarily use them [308]. Taking into account school policies and modes of transport students were using may have provided a more robust analysis of the relationship between the accessibility score and indices of body fatness.

The results from the current study showed a high percentage of the students never buy food from outside school premises at age 13. In addition, most students aged 13 stated to never or only consume once a month fast food from a restaurant or cafes. A cross-sectional study conducted in Sunderland also observed a dramatic decrease in the percentage of students consuming lunch from takeaway outlets, from about 22% in 2008 to less than 2% in 2012 among the 12- to 13-year group. However, information regarding eating habits for older groups were not captured in this current study. The results obtained from this and the Sunderland [276] study may reflect that the participants involved may be representing a healthier sample compared to other UK regions [222, 265]. For example, a recent UK cross-sectional study using national data (NDNS) found 29.8% of 11–18-year-old participants consumed takeaways one or twice per week and 24.3% consumed meals outside the home [265]. Nevertheless, the Sunderland study also found that older students aged 14–15 years (year 10) were more likely to leave school during lunch compared to those aged 12– 13 (year 8). A higher percentage of students (especially boys) from the older age group (14–15 years) were more likely to eat takeaway meals compared to younger students at both years (about 42% in 2008 and 14% in 2012) [276].

In this current study, results for the 17-year old group should be interpreted with caution, as at this age, the number of participants dropped by approximately 40% because those participants were more likely to move to another place at this age, such as a sixth-form college. The estimates were therefore potentially biased as the 15 year olds could have moved from an area with high availability of HFTs to a low availability area. There are no obvious explanations to account for the conflicting findings. However, it is possible that important confounding factors were missing such as school policies on whether students were permitted to leave school. The complexity of the food environment, including the lack of adjustment for the availability of other outlets, such as supermarkets and retailers, and many other independent factors, such as school deprivation level and eligibility of free school meals, may also have had an influence on the overall null/negative associations found in this study. A systematic review conducted in 2019 highlighted that the literature lacks reports of intervention studies designed to change the food environment around schools [325]. Most of the existing studies focus on determining whether there are correlations between the exposure (consumption of fast food and geographical location of fast food outlets) and the outcome (anthropometric measures such as BMI and body fatness and individuals dietary behaviour). In the UK, planning policies are taking place in many local authorities to reduce exposure to fast food for many parts of the population, not only school children. In order for governments to take actions towards planning policies, such as limiting the number and controlling operation hours of fast food outlets, sufficient evidence needs to be accumulated from multiple intervention studies [251].

In addition, the relationship between availability, proximity and accessibility of HFTs and BMI z–scores and body fat percentage could be non-linear. A non-linear relationship can be obtained when one variable of interest (availability of HFTs) is not parallel with the other variable of interest (BMI z–scores or body fat percentage). One of the methods that could differentiate a linear relationship from a nonlinear relationship is by mapping the two variables of interest on a graph which was not conducted in this study [326].

7.4.3 Strengths and limitations

This is the first study in the UK investigating the longitudinal associations between the food environment around secondary schools and the weight status of secondary school adolescent students. In this study, the road network method was used to measure the density and the proximity of HFTs. Using a road network method is believed to be more accurate than using straight-line (circular) buffers and distance to measure the density and proximity of fast food outlets. Nevertheless, this study has some limitations, including the under-representation of the non-white population, which may affect the generalisation of the findings. Walking routes from home to school and from school to home were found to affect the BMI of adolescent students [327]. However, in this study, about 40–80% of the information regarding walking from and to home was missing across the years. Therefore, it was not possible to include this important confounder in the model for analysis. Information such as school location, home IMD scores and percentage of pupils eligible for free school meals was not used in this study due to the privacy regulations imposed by ALSPAC. The location of a school and home IMD score could provide more detailed information regarding the total number of HFTs within the lower super output area and home deprivation level. This catchment area is important, as it is known that students may purchase food while travelling to and from school. In addition, the A5 category comprises HFTs (including the main franchises), fast food delivery services, and fish and chip shops, similar to previously published studies [69]. However, several food choices are provided within the school premises where the food choices made are not always healthy including school cafeterias, vending machines and school tuck shops [95]. Although all local authorities that have an interest in limiting the number of HFTs around schools and places where young people gather use this definition, this study did not account for the fact that outlets such as supermarkets, convenience stores and local retailers will also influence students' food choices. It is not definite that being exposed to the food environments around the school have a bigger impact on children and adolescents health and food choices than food options within the school [283]. Despite the fact that, the ALSPAC data provider did not permit identification on which schools were included in our study, the most important confounders were able to be included in the analysis. However, a major limitation of this study was not accounting for additional, potentially important confounders such as the availability of other food outlets near schools, such as supermarkets, that offer both healthy and unhealthy food products as well as food options available inside the school.

In addition, using old data regarding adolescents' eating habits, health outcomes including BMI and body fat percentage, and the number of HFTs, it is likely that fast food intake has increased since 2007 – 2011 among adolescents. A dramatic increase also was observed in the number of fast food outlets in the UK, particularly in the Avon region, after 2012. Nevertheless, the frequency of consumption of takeaway meals was only captured once in the ALSPAC study. Therefore, being in a school surrounded by more takeaway outlets does not reflect that those students will consume takeaway meals.

In addition, the ALSPAC data have been studied intensively to investigate whether or not the sample is truly representative of both the whole UK and the Avon region. In terms of the population of mothers with 1 year of age infants, the Avon area shares broadly similar characteristics with the UK as a whole in terms of proportion of owner occupiers, car ownership and proportion of married couples [328]. However, when comparing the ALSPAC sample with the Avon population, the ALSPAC sample showed a slightly greater percentage of affluent families and lower percentages of ethnic minority mothers. This may highlight the fact that findings from this study may not be generalizable to other parts of Avon region but ALSPAC data reports very similar results to the UK 1990 data regarding weight and height measurements [328].

7.4.4 Recommendations

In 2016, out of all the local authorities in England (n = 325), Bristol has the eighth highest number of takeaway outlets [109]. In 2017, the City Council of Bristol asked to evaluate the impact of limiting the number of HFTs around schools and places where young people gather on health [109]. However, the effectiveness of such a policy has not been investigated in depth using recent data regarding both the exposure and outcome variables.

Although results from cross-sectional and longitudinal studies are available [325], natural experiments are often used to conduct population health interventions, although their evaluation is more challenging to interpret than a randomised controlled trial [251, 293]. This is because researchers do not typically conduct or design the study in natural experiments. The ideal study design would be to conduct a randomised control trial to explore the true relationship between policies to reduce fast food outlets and BMI z- score, which would generate strong evidence for a particular intervention. However, this is often not feasible when evaluating the effectiveness of health policies and programmes conducted in different regions. There are a number of alternative methods such as quasi-experimental (non-randomised) trials where researchers are involved in the design and evaluation of regional policies but not where the intervention is conducted; and therefore regions are non-randomly allocated to the intervention or control groups. A non-randomised intervention study can still determine true causes of an outcome despite risks of bias. For example, comparing the effectiveness of an existing policy on health outcomes between cities where the policy is to limit clustering of takeaways exist and cities with no policy to limit the clustering of takeaways can be carried out. The design can be further strengthened using time series analysis where data are collected over many time points in both the intervention and the control group. This is easier when data on health outcomes are routinely collected [325]. This provides one argument for the importance of conducting a national survey for secondary school students similar to the National Child Measurement Programme (NCMP) in the UK, which the World Health Organization has recommended since 2006. This would allow researchers to conduct and evaluate studies considering the current situation regarding the food environment and health status of secondary school students; and therefore, strengthen the evidence and the effectiveness of limiting the number of fast food outlets, particularly around schools. Moreover, variations in the policy between local authorities make the comparison between the results from published studies more difficult. For example, some local authorities have implemented an additional guideline where no HFTs are allowed to open before and after school time. Limiting the opening hours of takeaway outlets may also have an equivalent effect regarding limiting the number of HFTs. Nevertheless, it is also important to understand the methodologies used to evaluate the food environment. Additionally, up-to-date surveys measuring the health outcomes of secondary school students are needed.

7.5 Conclusions

There were some significant but inconsistent findings from our results between availability, proximity and accessibility of HFTs and adolescents' BMI z–score or body fat percentage. This may reflect the fact that many schools do not let children go out until the sixth form in this region. Nevertheless, within 1000 metres, the results were attenuated and no significant associations were observed. Moreover, the accessibility score showed small but significant negative associations with BMI z–score. Hence, the results from the current study were conflicting and may not support the hypothesis that limiting the number of HFTs would reduce the risk of being obese or having a higher body fat percentage for all three different methods used to measure the school food environment. An intensive understanding of the effect of the food environment, particularly around secondary schools, is needed, especially using more recent data for both the exposure and health outcomes. In addition, considering those outliers with both a high prevalence of obesity and high number of takeaway outlets may help to understand the complicity of the food environment. Factors other than hot food takeaway outlets should be considered, such as the availability of other food outlets, including supermarkets and retailers, their opening hours, school policies to allow students to leave school premises, eligibility for free school meals, and school and home deprivation level (family income).

Chapter 8 Overall discussion and conclusions

8.1 Introduction

A recent report from the United Nations International Children's Emergency Fund (UNICEF) in October 2019 confirmed that adolescence is crucial period of physical and psychosocial developments in which both boys and girls have higher nutrient needs to adopt a proper growth rate. In 2020, the total number of adolescents (aged 10–19 years) is estimated to be 1.25 billion (250 million more compared to 30 years ago). This age group is known to fail to meet their nutrient needs, consume more unhealthy foods, skip breakfast, and eat lunch outside the home. The school environment also plays an important role in many countries, for example by promoting unhealthy foods in school cafeterias or outside schools' premises. Moreover, there is a lack of understanding concerning the nutritional status of adolescents. UNICEF also highlighted the importance of tracking all dietary (nutritional) behaviour and physical activity, as well as measuring the obesity or thinness of adolescents [329].

8.2 Aims

The aim of this chapter is to summarise and discuss the main findings of the thesis and factors that may have an impact of the overall results obtained from this thesis. Furthermore, the strengths and limitations of the thesis will be highlighted. Finally, recommendations based on the findings will be suggested. I also will present future work that should be conducted to overcome some of the thesis's limitations and to gain a better understanding particularly of food environments.

8.3 Summary of findings

A literature review was first conducted to identify the main gaps to be filled in this area (diet quality, obesity and takeaways). This thesis has two main phases; the first phase is related to overall diet quality and takeaway food, whereas the second phase is related to the clustering of takeaway outlets around secondary schools and the risk of obesity.

Takeaway food and diet quality

Studies are limited in the UK that specifically focus on adolescents' age group (11 to 18 years), their dietary intake and factors affecting their food choices. In addition, the quality of any diet is usually evaluated by the individual dietary intake of individual food items such as fruit and vegetables and certain types of meals. Other studies have also used the intake of micro-nutrients as another indicator to evaluate the quality of diets. However, the need for a simple tool to evaluate the quality of a diet is important, and the idea of using the Diet Quality Index for Adolescents tool was to indicate the quality of an adolescent's diet without the need to measure their micro-nutrient intake or being involved in the intensive conversion of food groups. Therefore, in the first phase, the thesis investigated the negative impact of takeaway food consumption on the overall diet quality score of UK adolescents, as covered in Chapter 4. Furthermore, the relationship between takeaway consumption on a school day and UK adolescents' overall diet quality was explored for the first time in the UK in Chapter 5.

8.3.1 Associations between consumption of takeaway food, eating meals outside the home and diet quality

What I already knew

The increased consumption of takeaway meals could be due to inherited eating habits, particularly of the UK population, by for example higher palatability of ready-to-eat meals [228]. The associations of takeaway food consumption with the intake of individual macronutrients, micronutrients and food items are well established. Several factors, such as the price of healthy foods [35], food availability at home and en-route to school [154], and the education level of parents and adolescents may also affect an adolescent's dietary intake.

What I did

NDNS data years 1–6 rolling programme were used to investigate associations between takeaway food, eating meals outside the home and overall diet quality. The Diet Quality Index for Adolescents (DQI–A) tool was used to assess the diet quality of the NDNS adolescent population. In the regression analysis, both univariable and multivariable analyses were conducted using takeaway meals or meals out as the exposure variables and overall diet quality or its components as outcome variables. A sensitivity analysis was also carried out, and potential confounders were considered in all of the multivariable models.

What I added to the literature

In the NDNS adolescent (11–18 years) population (n = 2,045), the percentage of the frequent consumption of takeaway foods and meals out was 29.8% and 24.3%, respectively. The findings indicate that being a frequent takeaway and meals-out consumer has a negative association with overall diet quality and that the consumption of takeaways had a larger impact on the overall diet quality score than consuming meals out. Frequent takeaway consumers had a lower overall diet quality score, by 7.4% and 3.5%, than low and moderate consumers. In contrast, frequent meals-out consumers had a lower overall diet quality by 3.3% and 3.5% than low and moderate meals-out consumers. Moreover, the percentage of frequent takeaway consumers was observed to be higher among adolescents who came from the lowest-income families than adolescents with the highest income. Therefore, the source (type) and the consumption location of the obtained food needs to be considered during data collection. In general, results from Chapter 4 showed that UK adolescents have the lowest diet quality compared to adolescents from mainland Europe.

8.3.2 Associations between lunch type consumed on a school day and diet quality

What I already knew

The associations between consuming school meals and packed lunches brought from home and dietary intake are well established among children attending primary schools. Similar to the previous results chapter, the impacts of being a takeaway consumer on the intake of individual nutrients and food items are also well established. Evidence suggests that the dietary quality of children consuming school meals tends to be better than that of children consuming packed lunches or food brought from outside school gates.

What I did

NDNS data from the year 1–8 rolling programme was used to investigate the associations between the lunch type consumed on a school day and diet quality. Similar to Chapter 4, the Diet Quality Index for Adolescents (DQI–A) tool was also used to assess the diet quality of the NDNS adolescent population. The rolling programmes year 7 and year 8 were added to the data for this chapter to attain eight years of combined data from the rolling programme.

In the regression analysis, both univariable and multivariable analyses were conducted using the type of lunch consumed as the exposure variables and overall diet quality or its components as the outcome variables. In this chapter (Chapter 5), age was considered as a potential confounder, as it is known that the percentage of children consuming school meals decreases as they move from primary to secondary schools. Therefore, the percentage consuming each type of meal was analysed by age. In 2015, school meal standards were updated, and it was worthwhile to evaluate the change occurring in the overall diet quality score and consumption rates for each type of lunch over time.

What I added to the literature

Cooked school lunch meals and packed lunches were the most popular lunch type. Although few adolescents reported not eating lunch on a school day (n = 30), these students had the second-lowest mean DQI-A% score, whereas those who bought lunch from a café or shop had the lowest DQI-A% score (14.1%). The overall mean DQI–A score for UK adolescents was low, with a score of 20.4%, similar to the earlier results obtained from Chapter 4. Nevertheless, as discussed in Chapter 4, the source and location where the food was purchased and consumed needs to be considered. The type of lunch consumed during a school day had a significant impact on the overall diet quality of UK adolescents attending school. Food outlet consumers had a lower overall DQI-A% than cooked school meal consumers by 7.5%, cold school sandwich consumers by 5.2% and packed lunch brought from home consumers by 9.6%.

In addition, it was observed that, as age increases, the percentage of adolescents purchasing takeaway meals during a school day increases. In contrast, the percentage of adolescents consuming school meals (hot and cold) decreases as the age increases. There were fluctuations by age in the percentage of adolescents who consumed packed lunches brought from home. Older adolescents may have more freedom to leave school premises during their lunch break and to decide on their food choices. Moreover, it was observed that a higher score of overall diet quality was observed among participants consuming school meals. Although some adolescents were purchasing food from shops or cafes, school meals have a more positive impact on overall diet quality.

The food environment (takeaway food) and risk of obesity

Several studies have examined the associations between the food environment and BMI and other health outcomes such as waist circumference and body fat. The relationship between the clustering of takeaway outlets, BMI z–score and body fat is still not clear, particularly among adolescents attending secondary school. Besides that, the methods used to evaluate and measure the food environment around any facilities, including workplaces, homes and schools, vary across the literature. Therefore, in the second phase, the thesis explored the distinctions between using different methods to evaluate the food environment around UK secondary schools, as covered in Chapter 6. In addition, the longitudinal relationship between the density, proximity and accessibility of the takeaway environment, BMI z–score and the body fatness of UK adolescents was investigated in Chapter 7.

8.3.3 Comparison of methods

What I already knew

Takeaway shops are more clustered around secondary than primary schools, and the UK's planning policies to limit takeaways show poor implementation compared to international examples and good practice statements. A major concern is that, worldwide, there are no standardised measures to assess the food environment around homes, schools, work or other facilities. Studies have used different methods to evaluate the food environment (density, proximity and accessibility of fast food outlets) around schools.

What I did

A Geographical Information System (GIS) was used to locate all schools and takeaways in the region and to measure the density and proximity scores, applying both the road network and straight-line methods. In addition, the Hansen Index was used to measure the accessibility score of each school to all takeaways in the region, not just the nearest. Nonparametric statistical analysis tests including the Wilcoxon test and correlation test were carried out, as well as Lin's concordance correlation coefficient test (agreement test) to measure the extent of agreement between the straight-line and road network methods.

What I added to the literature

It was observed that more than 50% of the schools had no takeaway shops within 200, 400 and 600 metres when the road network buffer was used. Statistical differences were observed between the road network and the straight-line methods. For example, the median of the difference between the straight-line and road network density within 1000 metres was 4.1. The median of the difference between the road network and straight-line proximity was 203.2. Moreover, the agreement between straight-line and road network densities within 800 (CCC = 0.87) and 1000 (CCC = 0.93) metres was poor and moderate, respectively. The agreement between both methods to measure the proximity was moderate (CCC = 0.91). In addition, the correlation results showed that both the straight-line and road network proximity were negatively correlated to the accessibility score measured. Our findings suggest that the 800- and 1000-metre (as a walkable distance) road network density and proximity may be more appropriate to explore the relationships between fast food accessibility and diet or health relationships.

In addition, the Hansen index is another metric that may be used if the aim of the study is to consider multiple locations when calculating an accessibility score. For future studies, researchers need to consider the type of method to be used taking into consideration multiple factors such as the targeted group and the location to be explored. In addition, the availability of best-practice methods would help to explore the food environment in a consistent way and lead to more successful policies [310, 311].

8.3.4 Longitudinal relationships between the takeaway food environment and secondary school adolescents

What I already knew

The prevalence of overweight and obesity is a major concern in many countries. In 2015, according to Health Survey for England (HSE), the UK population had one of the highest rates of overweight and obesity compared to other European countries, such as the Netherlands, Spain and Sweden [60, 312]. Many city councils in the UK believe that limiting the number of takeaway food outlets, particularly around schools, could help to reduce the risk of childhood obesity. Nevertheless, the health impact of banning the opening of takeaway outlets within a certain zone has not yet been evaluated, especially among secondary school adolescents in the UK.

What I did

Similar to Chapter 6, all schools and hot food takeaways were located using the GIS. In this study, as suggested in Chapter 6, the road network method was used to measure the total number (density) and the proximity of takeaway outlets. In addition, the Hansen Index was used to assess the accessibility scores.

Both linear and logistic regression analyses were conducted to investigate the relationships between the takeaway outlets around schools using the three methods mentioned earlier and adolescents' BMI z–score and body fat. In the regression analysis, both univariable and multivariable analyses were conducted using either availability, proximity or accessibility of HFTs as the exposures and BMI z–score or body fat percentage as health outcomes. In this chapter, a stratified analysis was also conducted to consider the impact of deprivation level, as living in more deprived areas is linked with increased risk of being obese and having a higher density of takeaway outlets.

What I added to the literature

Some significant associations were observed, particularly between the change in number of takeaway outlets, change in BMI z–score and body fat percentage using both linear and logistic regression. However, the results also showed negative associations with BMI z–score or body fat percentage. This may serve as an alarm regarding the effects of living near fast food outlets on health. A better understanding of the food environment is needed, and many other factors should be considered during data analysis such as the availability of other food outlets near schools (supermarkets, that offer both healthy and unhealthy food products) as well as food options available inside the school (school canteen/ cafeteria). In addition, understanding how adolescents behave in regards to food availability is important, as the results from this study did not support the use of 1,000 meters as a buffer size to measure the total number of takeaway outlets. Reducing hot food takeaways alone is unlikely to lead to a reduction in obesity prevalence.

8.4 Strengths and limitations

In this thesis, each result chapter has discussed its strengths and limitations. However, this section will summarise the strengths and limitations of the whole thesis.

8.4.1 Strengths

The primary strength of this thesis is analysing diet issues for the adolescent age group. This age group is considered to be vital for shaping future dietary and eating behaviour. Focusing on secondary school students also helped in identifying the age range to be included in some chapters in this thesis. Existing studies that considered the use of an overall diet quality index tool and the use of different methods to measure the food environment, particularly around schools, were also examined in Chapter 2.

To our knowledge, this thesis is the first to use the overall diet quality index for adolescents (DQI–A) tool to evaluate the impact of takeaway consumption on adolescents' diet quality. Another strength is using the DQI–A tool that helps to assess the overall diet quality of the UK adolescents. This tool assesses the overall quantity, quality and variety of the food consumed where examining the intakes of individual nutrients or food groups is not enough to assess the overall diet quality. Moreover, the DQI-A is a simple and easy-to-interpret tool which can be used to indicate the quality of a diet without requiring intensive conversion analysis of foods to nutrients [36, 38]. Therefore, it is important to explore the relationship between individuals' whole dietary intake and their health status [36]. In addition, the principal of DQI-A based on assessing the adherence of an adolescent diet to the Food-based Dietary Guidelines (FBDGs) [43]. The FBDGs are used to provide information for different government sectors to implement interventions toward healthy eating and lifestyles and also to provide advice to the general public, thereby enabling individuals to meet their daily dietary requirements of both nutrients and food groups. Consequently, this may have the potential to prevent chronic disease and promote a healthy lifestyle [44].

In addition, national (NDNS) data was used to assess the impact of being a takeaway consumer on overall diet quality score. The NDNS is considered a source of high-quality data regarding food intake and people's food behaviour and dietary habits. Therefore, the output results from the NDNS survey may inform government policies that need to be implemented to improve the health status of the UK population. Additionally, adolescents' food intake was based on four-day diary records, and when the overall diet quality index for adolescents was calculated, the food intake of the participants was calculated for each of the four days. Then, the mean value of the four days was calculated. The results in Chapter 4 showed broadly similar scores for overall diet quality across the four days. However, a difference (bias) of -4.25 was observed when assessing the strength of agreements between using the mean intake (method 1) and intake for each individual day (method 2), which was statistically significant (more detail can be found in Appendix 12).

Regarding the methodological comparison study, this study is not the first to distinguish the differences between the methods used to measure the food environment around a location [134, 286]. However, raising the awareness of the importance of choosing the appropriate methods and the importance of using consistent methods to measure the food environment particularly around schools is needed. In addition, longitudinal exposures and outcomes to investigate the association between the clustering of takeaway outlets and health outcomes is conducted for the first time in the UK. Using the Ordnance survey as a source of hot food takeaways enabled us to obtain historical data (2005–2017). In this thesis, three classes within the eating and drinking category were considered hot food takeaways from POI data, namely: (1) Fast food and takeaway outlets, (2) Fast food delivery services and (3) Fish and chips shops. This was possible due to that fact that each of these classes has a unique ID code, which can be used to select the ones we are interested in examining. The way the POI (Point of Interest) data were categorised helped to identify the misclassifications found in the POI data where major franchises such as McDonald's, Burger King and Subway were identified as restaurants from 2005 to 2011. An increase has been observed in the number of food outlets such as Subway and Macdonald's during the ALSPAC study time (2005 - 2017). Although there is no clear explanation for the increase in the number of those outlets, this misclassification could lead to an underestimation of the number of food outlets that have to be considered when studying the school, home and any other categories of food environment.

In addition, Wilkins, Radley et al. (2017) [213] have concluded that the use of a POI classification scheme to help classify food outlets is an accurate method and can save time and costs when used instead of manual classifications. Concerning statistical analysis, the use of Lin's Concordance Coefficient Correlation (CCC) to assess the agreement between two methods measuring the density and proximity (the same outcome) of UK schools (straight line and road network density and proximity) added a strength to the analysis.

8.4.2 Limitations

The NDNS is a repeated cross-sectional survey. Therefore, finding causal relationships was not possible. In addition, there is always a question about the simplicity of calculating diet quality indices. Few studies in Europe have used the DQI–A tool, which made the calculation of the overall diet quality score and its components and sub-components more difficult. Although both UK and Flemish dietary guidelines have similar food groups, in the UK, there are no guidelines regarding the maximum and minimum intake of each food group. This information was required to calculate both dietary adequacy and dietary excess subcomponents for the DQI–A. Therefore, the Flemish dietary guidelines were used to complete the calculation of the overall DQI–A score. In addition, in Chapter 5, the NDNS data did not identify those participants who actually purchase (consume) takeaway meals from cafés or shops. Moreover, information was not available about schools' policy regarding allowing their students to leave school premises during lunchtime.

One of the main limitations regarding the use of the ALSPAC study as a source of data is the fact that the frequency of consumption of takeaway meals was only captured once during the study time. Therefore, being in a school surrounded by more takeaway outlets does not reflect the fact that those students will consume takeaway meals. The over-consumption of takeaway meals is linked with increasing the intake of energy-dense food which, therefore, heightens calorie consumption. This excess calorie intake is believed to increase the risk of several diseases, such as type 2 diabetes, hypertension and obesity [4].

Conflicting findings were also observed from the results in different chapters in the thesis. In Chapter 4 for example, a negative cross-sectional association was found between high consumption of takeaway food and the diet quality of UK adolescents. Furthermore, in Chapter 5, purchasing foods from food outlets outside school was negatively associated with diet quality score in cross-sectional analysis compared with choosing a school meal or packed lunch. Studies have stated that children who consume fast food have higher intakes of energy and fat and lower intakes of milk and vegetables compared with children who did not consume fast food. Consequently, those who consume fast food could potentially be more likely to consume a higher energy intake (positive energy balance) which could lead to weight gain [68]. However, longitudinal results from Chapter 7 showed null, or in some cases, negative associations between adolescents BMI and body fat percentage and clustering of fast food outlets around schools. There is no conclusive evidence from this work that being more exposed to the food environment around the school has a bigger impact on children and adolescent health and food choices than food options within the school or at home [283].

Nevertheless, in both ALSPAC and NDNS data, the sample does not represent the diverse ethnic groups in the UK, as 97% of ALSPAC and 91% of NDNS participants were from a white background (selection bias). Moreover, both the NDNS and ALSPAC are secondary data (conducted and collected by other groups), and there was inconsistency in the methods used to collected data in both the NDNS and ALSPAC. For example, in the NDNS in year one (rolling programme one), more weekend days were included when participants' food intake was recorded (chapters 4 and 5). This may increase the prevalence of the consumption of takeaway meals, meals out and, thus, overall food intake. In ALSPAC, the method used to collect the physical activity level was changed during the study (Chapter 7).

Finally, although adjusting for potential confounders was carried out using different techniques such as searching the existing literature and the use of the directed acyclic graph (DAG), there is always the issue of incomplete adjustment for confounding. For example, variables such as school deprivation score, percentage of students receiving free school meals, schools policy regarding allowing students to leave school premises, and the source of consumed foods were unavailable. In addition, although geographical information regarding the NDNS data were only available at regional level (i.e. England, Scotland, Wales and Northern Ireland), participant's geographical location was not considered in this thesis which may strengthen the analysis.

8.5 Overall discussion and future work

In this thesis, the cross-sectional analysis conducted in chapters 4 and 5 confirmed the negative associations between both being a frequent takeaway or meals-out consumer and purchasing a takeaway meal during a school day and the overall diet quality of UK adolescents. Moreover, results from Chapter 6 showed the impact of using different methods to evaluate the food environment.

Finally, in Chapter 7, the study showed that inconsistency in the results between being exposed to takeaway outlets and obesity or body fat is still an issue. Next, I discuss and recommend actions, factors or plans relevant to the overall results of the whole thesis.

8.5.1 Assessing overall diet quality

The development of simpler tools (simpler than the DQI–A) to evaluate the quality of overall diet is needed. This will enable both public health policy makers and other users to gain a better understanding of how to improve dietary behaviour and, hence, diet quality. An example can be obtained from a researcher who investigated and developed a tool which consisted of five items to assess the quality of an (adult) individual overall diet in population-level surveillance [330]. Briefly, different models were set to identify the key items that are important in predicting diet quality such as fruit , vegetables , wholemeal bread , coated chicken and turkey and soft drinks (not low calorie, diet, sugar free). This simple tool (Brief Diet Quality Assessment Tools) was predictive and may encourage public health policy makers to adopt such methods to assess diet quality. However, Roberts (2017) [330] also confirmed the need for a tool to be developed for use when dealing with children, which is considered a high priority for public health in the UK. The diet quality of adolescents in chapters 4 and 5 was based on four-day diary records. Introducing simple tools will open the way to adopting other dietary assessment tools, for example a national survey. This work is still in progress, and this area still needs more research to design a simple tool that can be used with a simple dietary assessment tool to assess the diet quality of the population.

8.5.2 Assessing dietary intake, behaviour and habits

Based on the findings in Chapter 4, the percentage of being a frequent takeaway and meals-out consumer dropped by 9% and 7%, respectively, for those who completed four-day diary records compared to adolescents who completed three-day diary records. The adolescent ages are known to be one of the most difficult periods to deal with concerning collecting information about teenagers' food intake and lifestyle. This may highlight the fact that, the longer the survey, the less attention will be gained from this age group. Therefore, a careful assessment regarding their eating behaviour is needed to assure the quality of the collected data. In addition, being exposed to a takeaway outlet (the clustering of takeaway outlets) near schools does not mean those students will actually consume takeaway foods. However, a study conducted on adults and addressing home and work places showed that the frequency of consuming takeaway food was associated with the exposure to takeaway outlets [229]. In this thesis (Chapter 7), eating behaviour was only captured twice at age 10 and 13 years from ALSPAC. The presence of takeaway outlets does not reflect that students will pass the outlet and purchase a meal. In the future, obtaining information regarding individual eating habits and behaviour is crucial, particularly among adolescents.

8.5.3 Assessing the food environment (types of food outlets)

The definition used in this thesis to identify takeaway food outlets was in line with the definition used by many city councils in the UK [106-108]. Focusing on and addressing one point (hot food takeaways) can be achieved more easily than assessing a combined measure (supermarkets, retail outlets and cafes) [331]. However, many studies highlight the fact that 'unhealthy' foods, including sweets, crisps and energy- dense sandwiches, can be bought from other shops located near schools [136, 188, 332]. In addition, before the major updates on the food environment assessment tool (Feat) were released (September 2019), bakeries, for example were identified and listed as a takeaway outlet. Additionally, in the updated version of Feat, researchers can search for several types of food outlets, including cafes, convenience stores, restaurants, supermarkets and specialty outlets [10]. This may confirm that energy-dense foods can also be obtained from sources other than hot food takeaways. Therefore, other shops should be considered in the future when evaluating the impact of the food environment around schools on health outcomes of school students.

8.5.4 Assessing the food environment (age of data)

The total number of takeaway outlets and deprivation level vary over the years. Moreover, it was observed the total number of HFTs is increasing over time. A pilot analysis was conducted in this thesis which found an overall increase in the number of HFTs in Bristol by 59% between 2011 and 2017. Similarly, among other local authorities in the Avon, growth rates of 49%, 38% and 45% were seen in the number of HFTs in Bath and North East Somerset, North Somerset and South Gloucestershire, respectively. In addition, differences in the number of HFTs were also observed by the deprivation level of Lower Super Output Areas (LSOAs) in Avon (see Appendix 13). This may confirm the need for more recent health outcome data to investigate the effect of this observed increase in the number of HFTs (unhealthy food outlets), considering the effect of the deprivation level. HBSC is an example of a more recent dataset, although participants self-reported health outcomes such as height and weight, which tend to be less valid.

8.5.5 Assessing the food environment (methodology-wise)

The main aim was to investigate the relationship between the clustering of takeaway outlets around secondary schools and health outcomes of students attending those schools. Nevertheless, it was observed that the methods used to measure the food environment around schools (Chapter 2; section 2.7.2) (HFTs in this study) are heterogeneous [111]. Therefore, investigating the variations in using different methods for evaluating the HFTs around schools was important. In this thesis (chapters 6 and 7), the most common software (GIS) used in the field relevant to policy development was adopted to measure the food environment around Avon schools [111, 136, 287]. This thesis used the Geo-FERN checklist proposed by Wilkins, Morris et al. (2017) [111] when studies in chapters 6 and 7 were conducted. Moreover, concerning GIS software, the differences between the generalised and detailed polygons would be minimal when considering an urban area with a gridlike network [333]. However, a specified distance of 50 meters was used in one study when a post code was used to spatially locate the schools to overcome the error introduced by using their centroid to create more sophisticated polygons around schools [147]. In the current study, the default parameters available in the service area tool were used to measure the density of HFTs. I do not know how much bias was introduced to our results by using the 100 meters as a specified distance when creating the generalised polygons around the schools. A recommendation might be to include all parts of the buildings in the future as, for example parts of large buildings may not be captured when the buffer is built based on the centroid of that building. In addition, the road network was the method used to assess the density (total number) and proximity of hot food takeaways in chapters 6 and 7. Nevertheless, different types of network can also be used such as footpaths, which is an important consideration when the polygon (buffer) is built. Future work in this area needs to explore the associations between the food environment and health outcomes by using more accurate methods to understand the eating behaviour of adolescents attending schools [111].

In addition, findings are based on a mixture of quasi-experiments where researchers do not have full control over the time of the study or allocation of the participants to groups [251]. Moreover, comparing areas with and without a policy was not possible for our case in the Avon region, which could have helped in investigating the association between the policy and adolescent's dietary behaviour and health outcome. In an ideal environment, the ideal study design would be to conduct a randomised control trial, which could generate a strong evidence-base for a particular intervention [251, 293]. Randomised controlled trials are considered to be the gold standard for evaluating the effectiveness of interventions [252]. However, this is not always possible. Quasi-experimental trials where a researcher conducts the study by, for example, non-randomly allocating participants to groups are more feasible in this type of evaluation [252]. Interrupted time series analysis is a type of quasi experimental trial that takes into account any existing trends in the outcome before the policy is introduced. Although results from cross-sectional and longitudinal studies are available [325], natural experiments are often used to conduct population health interventions, but their evaluation is challenging and they rely on routine collection of relevant data [251, 293].

The ALSPAC data was collected between 2004 and 2011 in the Avon region where the policy for limiting the number of HFTs did not exist at this period. Another source of data consisting of schools with and without policy, adolescents and their dietary and purchasing behaviour, health outcomes (BMI and body fatness) and related socioeconomic variables could help in having a better understanding of the effectiveness of limiting the number of takeaway outlets particularly around schools.

8.5.6 Assessing change in obesity

Concerning health outcomes (BMI z–score) in Chapter 7, the main aim of this chapter was to assess the change in the number of HFTs and obesity longitudinally. Nevertheless, a study found that BMI is an obvious scale indicator that can be used to assess adiposity change, particularly longitudinally. The use of the BMI z–score cross-sectionally is useful for assessing adiposity. However, the BMI z–score is not the ideal variable to be used to conduct a study investigating adiposity changes over time because the changes get smaller the more overweight the child. Therefore, in the future, it is always important to seek the appropriate method to assess obesity, particularly when changes are being investigated over time [334, 335].

8.5.7 Assessing physical activity level

The percentage of participants dropping from a longitudinal study (ALSPAC) increased over the years, particularly when physical measurements were involved. For example, the physical activity level was measured by various methods during the study (ALSPAC) period, and the rate of missing values was reported to be 11.2%, 18.9% and 47.2% out of 1,416 participants in clinic visits 1, 3 and 4, respectively. Changing the method used to measure physical activity was also seen in NDNS data. The physical activity level (intensity, frequency and type) is a potential confounder, especially when assessing obesity [336]. In Chapter 7, the imputation of missing data and using existing measurements from previous years were both used when regression analysis was conducted and resulted in similar outcomes. Nevertheless, bias may also be introduced here, as participants may be less or more active during the year. The use of accelerometers results in more accurate measurements than using questionnaire-based methods. Although ALSPAC has used a validated method (Actigraph accelerometer) for children to measure their physical activity level [337], the adoption of newer technology in different survey years (ALSPAC study) to assess physical activity level may influence the overall results [336]. Moreover, it is recommended to harmonise the questionnaires and methods used to assess the physical activity level when conducting a survey, which is also recommended by WHO [338]. In the future, it is recommended that investigators consult an expert in the field of physical activity to plan and choose the appropriate method to be used based on the research or survey needs and goals [336, 337].

8.6 Public health implications

The current project confirms that the percentage of frequent takeaway consumers among the NDNS adolescents is not showing any sign of reduction [228]. Takeaway food can be consumed at home, outside the home and at school. It is known that takeaway food is generally higher in saturated fat and sugars, including non-milk extrinsic sugars [94]. A reduction in the consumption of takeaway food may help to improve the overall diet quality of the UK population. Moreover, in the UK, school food-based standards came into force in 2015, and studies have shown the dietary behaviour of older adolescents is more difficult to control, especially with the surrounding food environment, which has its impact on adolescent food choices. Although restrictions on the availability of desired ‘unhealthy’ food items in places where young people gather is recommended and suggested by WHO [255], the findings from this project also strengthen the fact that adolescents may still purchase food from inside and outside the school, despite the restrictions employed by many local authorities regarding not allowing the new establishment of takeaway outlets within 400 or 800 metres around schools [104]. An implication of this is that guidelines and campaigns are needed to increase the skills, awareness and education of the young generation concerning the benefits of preparing meals at home and how to make better choices when purchasing food from outside home. This may include the adoption of easy-to-understand nutritional information leaflets specifically designed for children and adolescents [255].

The second implication is not directly related to public health. Nevertheless, it may have a major implication for achieving a reduction in the consumption of takeaway foods. This is regarding the variations observed in the methods used to measure the food environment. The availability of best-practice methods would help to explore the food environment in a consistent way and lead to more effective policies [310, 311].

Even though the results from this thesis internally conflicted regarding the impact of the clustering of takeaway outlets on obesity and body fatness, it was shown that being exposed to takeaway outlets was linked with the increased consumption (purchasing) of takeaway foods among other studies [143, 174]. In addition, it was observed that the total number of takeaways is increasing dramatically, particularly in our case study (Avon region), and within more deprived areas. Policies to restrict the number of takeaway outlets in more deprived areas [48] may result in an increase in the availability of affordable unhealthy options to people from those areas. This could be solved by providing better food choices to adolescents at an acceptable cost, particularly in those deprived areas. Limiting the number of fast food outlets (banning the opening of new outlets) by law could cause multiple issues for the local economy. For example, restricting supply may lead to higher prices, poorer food quality and limited choices for the consumers [135]. Moreover, fast food companies employ large numbers of workers all over the world. For example, in the US the number of fast food restaurant industry employees was more than 37 million in 2018 [339]. In the UK, more than 800 thousands employees were working in the food industry including restaurants, cafes and takeaway food shops. Therefore, policies to limit the number of takeaway food shops could also result in job losses and reductions in incomes and living quality [340].

8.7 Overall conclusions

In this thesis, I explored the associations between takeaway consumption and the food environment, including analysing diet quality, obesity and body fat percentage, using two main sources of datasets (NDNS and ALSPAC). The first phase of this thesis used the NDNS data to explore the association between takeaway food and diet quality. Being a frequent takeaway or meals-out consumer was associated with lower overall diet quality score. Moreover, it was associated with lower scores among some diet quality components and subcomponents. Nevertheless, the size of the impact was attenuated between takeaway and meals-out consumers. This finding may help to set guidelines to identify the actual source of obtained food and type of food purchased when assessing individual dietary intake. In addition, purchasing food from a café or shop (takeaway food) during a school day was also associated with lower overall diet quality and some of the diet quality component scores. This may help to suggest recommendations to improve the dietary intake of young people at home, outside the home, at schools and outside school. Next, I used large longitudinal data (ALSPAC) to explore the associations between the clustering of hot food takeaway outlets and secondary school adolescents' health outcomes (obesity and body fat). However, when the methodology to measure the food environment was designed, I observed variations between the selected methods among worldwide studies and among UK city councils. Differences between one of the most common types of GIS methods was investigated in this thesis. This finding may highlight the importance of using a consistent method when evaluating the food environment around home, workplaces or schools. Finally, conflicting results were obtained regarding the relationships between hot food takeaway outlets and obesity or body fat percentage. These findings show the need for future research to increase the depth of understanding about how the food environment is interacting with adolescent dietary behaviours. The conclusion overall suggests that both home and school environments may affect adolescents' overall diet quality. Nevertheless, the effect of the food environment is complex, and more exploration is needed using more recent and accurate data designed specifically for assessing the impact of different aspects of the food environment on adolescent health outcomes.

List of References

1. FSA *National diet and nutrition survey for Northern Ireland: Appendices and Tables*. 2016.
2. WHO. *WHO/Europe approaches to obesity* 2017 [cited 2017 16 February]; Available from: http://www.euro.who.int/en/health-topics/noncommunicable-diseases/obesity/obesity.
3. WHO. *The top 10 causes of death. Fact sheet*. 2017 [cited 2017 15 March]; Available from: http://www.who.int/mediacentre/factsheets/fs310/en/.
4. WHO. *Obesity and overweight: Key facts*. 2018 [cited 2019 24 June]; Available from: http://www.who.int/mediacentre/factsheets/fs311/en/.
5. (CDC), C.f.D.C.a.P. *Overweight & Obesity*. 2020 [cited 2020 27 April]; Available from: https://www.cdc.gov/obesity/index.html.
6. Alison Tedstone, *Public health matters: Putting healthier food environments at the heart of planning*, Public Health England, Editor. 2018, Department of Health.
7. Public Health England, *Childhood obesity plan: PHE's role in implementation*. 2016, HM Government: UK.
8. Rochdale Borough Council. *Guidelines & Standards for Hot Food Takeaway Uses Supplementary Planning Document (Consultation Draft)*. 2014 [cited 2016 6 December]; Available from: https://consultations.rochdale.gov.uk/strategic-planning/hot_food_takeaway_spd_november_2014/supporting_documents/Guidelines%20%20Standards%20for%20Hot%20Food%20Takeaway%20Uses%20SPD%20Consultation%20Draft%20November%202014.pdf.
9. Mohr, P., et al., *Personal and lifestyle characteristics predictive of the consumption of fast foods in Australia.* Public Health Nutrition, 2007. **10**(12): p. 1456-1463.
10. CEDAR. *Find our Feat: CEDAR launches upgrade to the Food environment assessment tool*. 2019 [cited 2019 20 September]; Available from: https://www.cedar.iph.cam.ac.uk/find-our-feat-cedar-launches-upgrade-to-the-food-environment-assessment-tool-feat/.
11. Keynote. *Fast-Food & Home-Delivery Outlets*. 2016 [cited 2016 14th of November]; Available from: https://www.keynote.co.uk/market-report/food/fast-food-home-delivery-outlets?page=1.
12. CDC. *National Center for Health Statistics: Caloric Intake From Fast Food Among Children and Adolescents in the United States, 2011–2012*. 2017 [cited 2017 15 January]; Available from: https://www.cdc.gov/nchs/products/databriefs/db213.htm.
13. St-Onge, M.P., K.L. Keller, and S.B. Heymsfield, *Changes in childhood food consumption patterns: a cause for concern in light of increasing body weights.* American Journal of Clinical Nutrition, 2003. **78**(6): p. 1068-1073.
14. The Strategy Unit Cabinet Office. *Food: an analysis of the issues*. 2008 [cited 2019 19 September]; Available from: http://webarchive.nationalarchives.gov.uk/+/http://www.cabinetoffice.gov.uk/media/cabinetoffice/strategy/assets/food/food_analysis.pdf.
15. Bezerra, I.N., C. Curioni, and R. Sichieri, *Association between eating out of home and body weight.* Nutrition Reviews, 2012. **70**(2): p. 65-79.
16. Fraser, L.K. and K.L. Edwards, *The association between the geography of fast food outlets and childhood obesity rates in Leeds, UK.* Health & Place, 2010. **16**(6): p. 1124-1128.

17. French, S.A., L. Harnack, and R.W. Jeffery, *Fast food restaurant use among women in the Pound of Prevention study: dietary, behavioral and demographic correlates.* International Journal of Obesity, 2000. **24**(10): p. 1353-1359.
18. FSA. *The 2014 Food and You Survery. UK Bulletin 3. Eating outside the home*. 2014 [cited 2016 17 October]; 1-29]. Available from: https://www.food.gov.uk/sites/default/files/food-and-you-2014-uk-bulletin-3_0.pdf.
19. Public Health England. *Density of fast food outlets by local authority in England: map and area deprivation chart*. 2016 [cited 2016 2 March]; Available from: https://www.gov.uk/government/publications/obesity-and-the-environment-briefing-regulating-the-growth-of-fast-food-outlets.
20. Ikeda, J.P., P.B. Crawford, and G. Woodward-Lopez, *BMI screening in schools: helpful or harmful.* Health Education Research, 2006. **21**(6): p. 761-769.
21. Creanor, S., et al., *Detailed statistical analysis plan for a cluster randomised controlled trial of the Healthy Lifestyles Programme (HeLP), a novel school-based intervention to prevent obesity in school children.* Trials, 2016. **17**(1): p. 599.
22. Public Health England. *Child Obesity*. 2016 [cited 2016 26 October]; Available from: http://www.noo.org.uk/NOO_about_obesity/child_obesity.
23. Department of Health. *Childhood obesity: a plan for action*. 2016 [cited 2016 13 October]; Available from: https://www.gov.uk/government/publications/childhood-obesity-a-plan-for-action.
24. Department of Health. *Obesity: Foresight - Tackling Obesities - Future Choices Project* 2007 [cited 2017 26 January]; Available from: http://webarchive.nationalarchives.gov.uk/+/www.dh.gov.uk/en/Publichealth/Healthimprovement/Obesity/DH_079713.
25. WHO. *Adolescent development*. 2016 [cited 2016 30 November]; Available from: http://www.who.int/maternal_child_adolescent/topics/adolescence/dev/en/.
26. WHO. *Adolescent health*. 2019 [cited 2019 21 June]; Available from: https://www.who.int/maternal_child_adolescent/adolescence/en/.
27. WHO *Social determinants of health and well-being among young people*. Key findings from the Health Behaviour in School-aged Children (HBSC) study: international report from the 2009/2010 survey, 2016.
28. Merten, M.J., A.L. Williams, and L.H. Shriver, *Breakfast Consumption in Adolescence and Young Adulthood: Parental Presence, Community Context, and Obesity.* Journal of the American Dietetic Association, 2009. **109**(8): p. 1384-1391.
29. Dietz, W.H., *The obesity epidemic in young children - Reduce television viewing and promote playing.* British Medical Journal, 2001. **322**(7282): p. 313-314.
30. Food Foundation. *Childhood Obesity Summit 2016*. 2016 [cited 2017 13 February]; Available from: http://foodfoundation.org.uk/event/2989/.
31. Brooks., F., et al., *HBSC England National Report 2014*. 2015, University of Hertfordshire: Hatfield, UK.
32. British Nutrition Foundation. *Teenagers*. 2017 [cited 2017 23 July]; Available from: https://www.nutrition.org.uk/nutritionscience/life/teenagers.html?limit=1&start=2.
33. Heary, C.M. and E. Hennessy, *The use of focus group interviews in pediatric health care research.* Journal of Pediatric Psychology, 2002. **27**(1): p. 47-57.
34. Public Health England. *Health matters: obesity and the food environment*. 2017 [cited 2018 8 March]; Available from: https://www.gov.uk/government/publications/health-matters-obesity-and-the-food-environment/health-matters-obesity-and-the-food-environment--2.
35. Food Foundation, *FORCE-FED: Does the food system constrict healthy choices for typical British families?* 2016.

36. Vyncke, K., et al., *Validation of the Diet Quality Index for Adolescents by comparison with biomarkers, nutrient and food intakes: the HELENA study.* British Journal of Nutrition, 2013. **109**(11): p. 2067-2078.
37. USDA. *Healthy Eating Index*. 2016 [cited 2016 28 November]; Available from: https://www.cnpp.usda.gov/healthyeatingindex.
38. FAO. *Measuring Diet Quality: Where we are and where we might want to go*. 2017 [cited 2017 23 January]; Available from: http://www.fao.org/search/en/?cx=018170620143701104933%3Aqq82jsfba7w&q=DQI&cof=FORID%3A9.
39. Huijbregts, P., et al., *Dietary pattern and 20 year mortality in elderly men in Finland, Italy, and The Netherlands: longitudinal cohort study.* BMJ, 1997. **315**(7099): p. 13-7.
40. Wirt, A. and C.E. Collins, *Diet quality - what is it and does it matter?* Public Health Nutrition, 2009. **12**(12): p. 2473-2492.
41. Kranz, S. and G.P. McCabe, *Examination of the five comparable component scores of the diet quality indexes HEI-2005 and RC-DQI using a nationally representative sample of 2-18 year old children: NHANES 2003-2006.* J Obes, 2013. **2013**: p. 376314.
42. Tur, J.A., D. Romaguera, and A. Pons, *The Diet Quality Index-International (DQI-I): is it a useful tool to evaluate the quality of the Mediterranean diet?* British Journal of Nutrition, 2005. **93**(3): p. 369-376.
43. Huybrechts, I., et al., *Reproducibility and validity of a diet quality index for children assessed using a FFQ.* British Journal of Nutrition, 2010. **104**(1): p. 135-144.
44. FAO. *Food-based dietary guidelines*. 2016 [cited 2016 14 December]; Available from: http://www.fao.org/nutrition/nutrition-education/food-dietary-guidelines/en/.
45. Smith, K.J., et al., *Takeaway food consumption and its associations with diet quality and abdominal obesity: a cross-sectional study of young adults.* International Journal of Behavioral Nutrition and Physical Activity, 2009. **6**.
46. Au, L.E., et al., *Eating School Lunch Is Associated with Higher Diet Quality among Elementary School Students.* Journal of the Academy of Nutrition and Dietetics, 2016. **116**(11): p. 1817-1824.
47. Adams, J., et al., *Frequency and socio-demographic correlates of eating meals out and take-away meals at home: cross-sectional analysis of the UK national diet and nutrition survey, waves 1-4 (2008-12).* Int J Behav Nutr Phys Act, 2015. **12**: p. 51.
48. Public Health England, *Healthy people, healthy places briefing Obesity and the environment: regulating the growth of fast food outlets.* 2014, HM Government: UK.
49. Keeble, M., et al., *How does local government use the planning system to regulate hot food takeaway outlets? A census of current practice in England using document review.* Health Place, 2019. **57**: p. 171-178.
50. House of Commons Health Committee. *Childhood obesity: follow-up. Seventh Report of Session 2016–17.* 2017 [cited 2017 22 June]; Available from: https://publications.parliament.uk/pa/cm201617/cmselect/cmhealth/928/928.pdf.
51. OECD. *Obesity Update 2017*. 2017 [cited 2019 9 December]; Available from: https://www.oecd.org/els/health-systems/Obesity-Update-2017.pdf.
52. Public Health England. *PHE data and analysis tools: Obesity, diet and physical activity*. 2019 [cited 2019 24 June]; Available from: https://www.gov.uk/guidance/phe-data-and-analysis-tools#obesity-diet-and-physical-activity.
53. Public Health England. *Health inequalities* 2016 [cited 2016 26 October]; Available from: http://www.noo.org.uk/NOO_about_obesity/inequalities.
54. NHS Digital. *National Child Measurement Programme - England, 2016-17* 2017 [cited 2018 9 January]; Available from: https://digital.nhs.uk/catalogue/PUB30113.

55. NHS Digital. *Health Survey for England 2017 [NS]*. 2018 [cited 2019 3 October]; Available from: https://webarchive.nationalarchives.gov.uk/20190303200516/https://digital.nhs.uk/data-and-information/publications/statistical/health-survey-for-england/2017.
56. South Gloucestershire Council. *Key facts and figures*. 2018 [cited 2018 18 January]; Available from: http://www.southglos.gov.uk/council-and-democracy/census/key-facts-and-figures/.
57. North Somerset Council. *Changing Population*. 2018 [cited 2018 15 January]; Available from: https://www.n-somerset.gov.uk/wp-content/uploads/2015/11/population-chapter.pdf.
58. Office for National Statistics. *Population estimates for UK, England and Wales, Scotland and Northern Ireland*. 2018 [cited 2018 8 January]; Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/annualmidyearpopulationestimates/mid2016#uk-population-continues-to-age.
59. Public Health England. *Public Health Outcomes FrameWork*. 2016 [cited 2016 7 November]; Available from: http://www.phoutcomes.info/public-health-outcomes-framework#page/10/gid/1938132983/pat/6/par/E12000004/ati/102/are/E06000015/iid/91872/age/1/sex/4.
60. NHS Digital. *Statistics on Obesity, Physical Activity and Diet - England, 2017* 2017 [cited 2018 9 January]; Available from: https://digital.nhs.uk/catalogue/PUB23742.
61. NHS digital. *Health Survey for England, 2016* 2017 [cited 2018 2 February]; Available from: http://digital.nhs.uk/catalogue/PUB30169.
62. **PHE**. *Chapter 6: wider determinants of health*. 2020 [cited 2020 7 July]; Available from: https://www.gov.uk/government/publications/health-profile-for-england-2018/chapter-6-wider-determinants-of-health.
63. Government Office for Science. *Reducing obesity: future choices. Foresight report looking at how we can respond to rising levels of obesity in the UK.* 2007 [cited 2020 7 July]; Available from: https://www.gov.uk/government/publications/reducing-obesity-future-choices.
64. Public Health England. *Causes of Obesity*. 2016 [cited 2016 23 October]; Available from: http://www.noo.org.uk/NOO_about_obesity/causes.
65. Houses of Parliament. *Barriers to Healthy Food*. 2016 [cited 2017 3 April]; Available from: https://researchbriefings.files.parliament.uk/documents/POST-PN-0522/POST-PN-0522.pdf.
66. Michael Marmot, J.A., Tammy Boyce, Peter Goldblatt, Joana Morrison, *Health equity in England: The Marmot Review 10 years on*. 2020, Institute of Health Equity: London.
67. NHS *National Child Measurement Programme*. 2016.
68. Fraser, L.K., et al., *Fast food, other food choices and body mass index in teenagers in the United Kingdom (ALSPAC): a structural equation modelling approach.* Int J Obes (Lond), 2011. **35**(10): p. 1325-30.
69. Maguire, E.R., T. Burgoine, and P. Monsivais, *Area deprivation and the food environment over time: A repeated cross-sectional study on takeaway outlet density and supermarket presence in Norfolk, UK, 1990-2008.* Health & Place, 2015. **33**: p. 142-147.
70. NHS, *Knowledge and attitudes towards healthy eating and physical activity: what the data tell us*. 2011. p. 1-39.
71. Jones, N.R.V., et al., *The Growing Price Gap between More and Less Healthy Foods: Analysis of a Novel Longitudinal UK Dataset.* Plos One, 2014. **9**(10).
72. CDC, C.f.D.C.a.P. *Overweight & Obesity:* . Prevalence of Childhood Obesity in the United States, 2011-2014 2016 [cited 2016 2 November]; Available from: https://www.cdc.gov/obesity/data/childhood.html.
73. PHE&FSA, *National Diet and Nutrition Survey Results from Years 1, 2, 3 and 4 (combined) of the Rolling Programme (2008/2009 – 2011/2012).A survey*

carried out on behalf of Public Health England and the Food Standards Agency. 2014: GOV.UK. p. 1-158.

74. PHE&FSA. *NDNS: results from Years 5 and 6 (combined): Results of the National Diet and Nutrition Survey (NDNS) rolling programme for 2012 to 2013 and 2013 to 2014.* 2016 [cited 2016 14 October]; Available from: https://www.gov.uk/government/statistics/ndns-results-from-years-5-and-6-combined.
75. Buijsse, B., et al., *Fruit and vegetable intakes and subsequent changes in body weight in European populations: results from the project on Diet, Obesity, and Genes (DiOGenes).* American Journal of Clinical Nutrition, 2009. **90**(1): p. 202-209.
76. Department of Health. *National Diet and Nutrition Survey. Headline results from Years 1 and 2 (combined) of the Rolling Programme (2008/2009 – 2009/10)*. 2011 [cited 2016 5 October]; Available from: https://www.gov.uk/government/publications/national-diet-and-nutrition-survey-headline-results-from-years-1-and-2-combined-of-the-rolling-programme-2008-9-2009-10.
77. British Nutrition Foundation. *Feasibility and acceptability of a Takeaway Masterclass aimed at encouraging healthier cooking practices and menu options in takeaway food outlets*. 2019 [cited 2020 May 20]; Available from: https://www.nutrition.org.uk/nutritionscience/researchspotlight/research-spotlight-2019-issue-1-the-takeaway-masterclass.html?__cf_chl_jschl_tk__=98af62ae69f2b6ee357b129fab46de11bd8fd854-1591273031-0-AbRhRwLGjsF5XLTOC3km1Jl3ehaRz8Fnks5e1xeMk-FotXHxdiwIGnpxpeKxxYEsU5ur7WnVqvAKU3mKp9No0DK9UpfaYw8opj1sdsWeyFommQTxODAaG7rs7US_J2nUg5Wmz40FfNLGOKV-Ip2U-2TQ7Jwv5WwFgxb3LWYqUPqyG9lG2d0SzEzvi-rYvB8edk6SfM45ztOEKKE7yyORRQcoqbz_kRjs_OCNFv_6IrLQup1RbT-XIYKm_8ZWQIxHCiTnyqdO-bsUL2pDhNDZsRfvz7VzmqnJ0vQWh7WjrQjnxkSn_EN9lHIYw_ySAwW1wLMeVUEzyHH2yixjzG8nU4Tm2qGt3MXxyaL0LpEztIxofXHo3FVmm-4ISnKKjhUxue7okJGKvjuwQWVSU9p4eM3WMruM7Q8MN9sBDRSAzYdNbtPassPOj8MCooy5AtH_ArRnopG5J8T6tckCW16JThg.
78. Anderson, P.M. and K.F. Butcher, *Childhood obesity: Trends and potential causes.* Future of Children, 2006. **16**(1): p. 19-45.
79. Food Trust. *What We Do: In Schools*. 2016 [cited 2016 5 Ocotber]; Available from: http://thefoodtrust.org/what-we-do/schools.
80. Pereira, M.A., A.I. Kartashov, and C.B. Ebbeling, *Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis (vol 365, pg 36, 2005).* Lancet, 2005. **365**(9464): p. 1030-1030.
81. Duffey, K.J., et al., *Differential associations of fast food and restaurant food consumption with 3-y change in body mass index: the Coronary Artery Risk Development in Young Adults Study.* American Journal of Clinical Nutrition, 2007. **85**(1): p. 201-208.
82. Lachat, C., et al., *Eating out of home and its association with dietary intake: a systematic review of the evidence.* Obes Rev, 2012. **13**(4): p. 329-46.
83. Bowman, S.A., et al., *Effects of fast-food consumption on energy intake and diet quality among children in a national household survey.* Pediatrics, 2004. **113**(1): p. 112-118.
84. Woodruff, S.J. and R.M. Hanning, *Effect of Meal Environment On Diet Quality Rating.* Canadian Journal of Dietetic Practice and Research, 2009. **70**(3): p. 118-124.
85. Bowman, S.A., et al., *Effects of fast-food consumption on energy intake and diet quality among children in a national household survey.* Pediatrics, 2004. **113**(1 Pt 1): p. 112-8.

86. Moore, L.V., et al., *Fast-Food Consumption, Diet Quality, and Neighborhood Exposure to Fast Food.* American Journal of Epidemiology, 2009. **170**(1): p. 29-36.
87. Nestle, M., *Food politics : how the food industry influences nutrition and health*. Rev. and expanded ed. California studies in food and culture. 2007, Berkeley: University of California Press. xviii, 486 p.
88. Fraser, L.K., et al., *The geography of Fast Food outlets: a review.* Int J Environ Res Public Health, 2010. **7**(5): p. 2290-308.
89. Caruso, M.L. and K.W. Cullen, *Quality and Cost of Student Lunches Brought From Home.* Jama Pediatrics, 2015. **169**(1): p. 86-90.
90. Schroder, H., et al., *Association of fast food consumption with energy intake, diet. quality, body mass index and the risk of obesity in a representative Mediterranean population.* British Journal of Nutrition, 2007. **98**(6): p. 1274-1280.
91. Tugault-Lafleur, C.N., J.L. Black, and S.I. Barr, *Lunch-time food source is associated with school hour and school day diet quality among Canadian children.* Journal of Human Nutrition and Dietetics, 2018. **31**(1): p. 96-107.
92. Secretary of State for Education, *The Requirements for School Food Regulations 2014 and come into force on 1st January 2015*. 2015.
93. UK Government and Parliament. *Allow Secondary School Students to leave school for lunch*. 2016 [cited 2016 1 December]; Available from: https://petition.parliament.uk/petitions/130923.
94. Sarah Sinclair and J T Winkler, *The School Fringe: What Pupils Buy and Eat from Shops Surrounding Secondary Schools*. 2008, London: London Metropolitan University, Nutrition Policy Unit.
95. Day, P.L. and J. Pearce, *Obesity-Promoting Food Environments and the Spatial Clustering of Food Outlets Around Schools.* American Journal of Preventive Medicine, 2011. **40**(2): p. 113-121.
96. Paeratakul, S., et al., *Fast-food consumption among US adults and children: Dietary and nutrient intake profile.* Journal of the American Dietetic Association, 2003. **103**(10): p. 1332-1338.
97. Currie, J., et al., *The Effect of Fast Food Restaurants on Obesity and Weight Gain.* American Economic Journal-Economic Policy, 2010. **2**(3): p. 32-63.
98. Burgoine, T., et al., *Does neighborhood fast-food outlet exposure amplify inequalities in diet and obesity? A cross-sectional study.* American Journal of Clinical Nutrition, 2016. **103**(6): p. 1540-1547.
99. Crawford, F., et al., *Observation and assessment of the nutritional quality of 'out of school' foods popular with secondary school pupils at lunchtime.* BMC Public Health, 2017. **17**(1): p. 887.
100. Public Health England. *Childhood obesity: applying All Our Health*. 2015 [cited 2016 13 October]; Available from: https://www.gov.uk/government/publications/childhood-obesity-applying-all-our-health/childhood-obesity-applying-all-our-health.
101. Local Government Association. *Public Health Perceptions Survey*. 2018 [cited 2018 14 March]; Available from: https://www.local.gov.uk/sites/default/files/documents/Public%20Health%20Perceptions%20Survey%20Report%202018.pdf.
102. Local Government Association. *Making obesity everybody’s business: A whole systems approach to obesity*. 2017 [cited 2017 5 December]; Available from: https://www.local.gov.uk/making-obesity-everybodys-business-whole-systems-approach-obesity.
103. Royal Society for Public Health (RSPH). *Nutrition, Obesity*. 2019 [cited 2020 May 22]; Available from: https://www.rsph.org.uk/about-us/news/rsph-welcomes-report-from-sustain-on-using-planning-powers-to-make-communities-healthier.html.
104. Andrew Ross. *Obesity-based policies to restrict hot food takeaways: progress by local planning authorities in England*. 2013 [cited 2017 8 November];

Available from: http://www.medway.gov.uk/pdf/Obesity-based%20policies%20to%20restrict%20hot%20food%20takeaways-%20progress%20by%20local%20planning%20authorities%20in%20England.pdf.
105. Department of Health. *National Planning Policy Framework: The revised National Planning Policy Framework sets out government's planning policies for England and how these are expected to be applied.* 2020 [cited 2020 20 August]; Available from: https://www.gov.uk/government/publications/national-planning-policy-framework--2.
106. Bradford Council. *The Hot Food Takeaway Supplementary Planning Document (SPD)*. 2014 [cited 2016 22 Novmber]; Available from: https://www.bradford.gov.uk/planning-and-building-control/planning-policy/the-hot-food-takeaway-supplementary-planning-document-spd/.
107. Warrington Borough City Council. *Hot Food Takeaways Supplementary Planning Document*. 2014 [cited 2016 22 November]; Available from: https://www.warrington.gov.uk/site/scripts/google_results.php?q=hot+food+takeaway.
108. Newcastle City Conuncil, *Hot Food Takeaway Supplementary Planning Document*. 2016, Newcastle City Conuncil: UK.
109. Kitty Webster. *Too many takeaways? How the food environment affects the health and wellbeing of communities*. 2016 [cited 2017 7 December]; Available from: http://www.bristol.ac.uk/policybristol/policy-briefings/too-many-takeaways/.
110. BBC News. *Takeaway ban near Denbighshire schools rejected*. 2015 [cited 2017 31 January]; Available from: http://www.bbc.co.uk/news/uk-wales-north-east-wales-32318171.
111. Wilkins, E.L., et al., *Using Geographic Information Systems to measure retail food environments: Discussion of methodological considerations and a proposed reporting checklist (Geo-FERN).* Health & Place, 2017. **44**: p. 110-117.
112. Brighton and Hove City Council. *Appendix 2: Consultation Responses – Panel Topics*. 2009 [cited 2016 7 Novmber]; Available from: http://present.brighton-hove.gov.uk/Published/C00000165/M00002648/AI00016518/$Item21Appendix2.docA.ps.pdf.
113. Birmingham Newsroom. *Takeaway limit helps Birmingham tackle obesity*. 2015 [cited 2016 7 November]; Available from: http://birminghamnewsroom.com/takeaway-limit-helps-birmingham-tackle-obesity/.
114. Hurst, B. *Birmingham takeaway ban 'begins to pay off'*. 2014 [cited 2017 25 October]; Available from: http://www.birminghampost.co.uk/news/local-news/birmingham-takeaway-ban-begins-pay-6887243.
115. Peterborough City Council, *PETERBOROUGH: A HEALTHY CITY?* 2015.
116. Liverpool City Council. *The Draft: Liverpool Local Plan: September 2016*. 2016 [cited 2016 7 November]; Available from: http://liverpool.gov.uk/media/1355685/the-draft-liverpool-local-plan-september-2016-bc.pdf.
117. Liverpool City Council. *Liverpool Local Plan 2013 -2033: Pre-submission draft*. 2018 [cited 2019 5 February]; Available from: https://liverpool.gov.uk/media/1356834/01-local-plan-january-2018-final.pdf.
118. Bath and North East Somerset Council. *Local Plan 2016-2036: Options Consultation*. 2018 [cited 2019 12 March]; Available from: https://www.bathnes.gov.uk/sites/default/files/sitedocuments/Planning-and-Building-Control/Planning-Policy/LP20162036/banes_local_plan_2018_final_website.pdf.
119. Manchester City Council. *Hot Food Takeaway Supplementary Planning Document March 2017*. 2019 [cited 2019 8 March]; Available from: https://www.manchester.gov.uk/downloads/download/6651/hot_food_takeaway_supplementary_planning_documents.

120. Halton Borough Council. *Hot Food Takeaway: Supplementary Planning Document*. 2012 [cited 2019 8 March]; Available from: https://www3.halton.gov.uk/Pages/planning/policyguidance/pdf/Supplementary%20Planning%20Documents/Adopted/Hot_Food_SPD_final_v4.pdf.
121. Gateshead Council. *Hot Food Takeaway Supplementary Planning Document*. 2015 [cited 2019 8 March]; Available from: https://www.gateshead.gov.uk/media/1910/Hot-Food-Takeaway-SPD-2015/pdf/Hot-Food-Takeaway-SPD-2015.pdf?m=636669063713470000.
122. Leeds City Council. *Revised Draft Hot Food Takeaway Supplementary Planning Document*. 2018 [cited 2019 8 March]; Available from: https://www.leeds.gov.uk/docs/001%20Hot%20Food%20Takeaway%20SPD.pdf.
123. Salford City Council. *supplementary planning document: Hot food fake aways*. 2014 [cited 2019 11 March]; Available from: https://www.salford.gov.uk/media/385433/hfta_spd_final_with_amendment_to_rj.pdf.
124. Barking and Dagenham Council. *Saturation Point: Addressing the health impacts of hot food takeaways: Supplementary Planning Documen*. 2010 [cited 2019 11 March]; Available from: https://www.lbbd.gov.uk/sites/default/files/attachments/Saturation-Point-SPD-Addressing-the-Health-Impacts-of-Hot-Food-Takeaway.pdf.
125. Medway Council. *Hot Food Takeaways in Medway - A Guidance Note* 2014 [cited 2019 11 March]; Available from: https://www.medway.gov.uk/downloads/file/2333/hot_food_takeaways_in_medway_-_a_guidance_note.
126. Bristol City Council. *Neighbourhoods Scrutiny* 2017 [cited 2017 7 December]; Available from: https://democracy.bristol.gov.uk/documents/s13120/10hotfoodtakeawayscompletereport.pdf.
127. South Gloucestershire Council. *Policies, Sites and Places (PSP) Plan - Proposed Submission publication*. 2018 [cited 2019 12 March]; Available from: https://consultations.southglos.gov.uk/consult.ti/PSP_ProposedSubmission/viewCompoundDoc?docid=6606132&sessionid=&voteid=&partId=6609364.
128. Nottingham City Council. *LOCAL PLAN PART 2 :LAND AND PLANNING POLICIES DOCUMENT*. 2015 [cited 2019 12 March]; Available from: http://gossweb.nottinghamcity.gov.uk/dave/dawn/new/LocalPlanPart2.pdf.
129. Wakefield Council. *Retail and Town Centre Local Plan: A new vision for developing wakefield district Hot Food Takeaways Position Statement*. 2016 [cited 2019 12 March]; Available from: http://www.wakefield.gov.uk/Core%20documents/RTC12.2%20Hot%20Food%20Takeaways%20Position%20Statement.pdf.
130. London Assembly. *New London Plan - Consultation draft: Policy E9 Retail, markets and hot food takeaways* 2019 [cited 2019 13 March]; Available from: https://www.london.gov.uk/what-we-do/planning/london-plan/new-london-plan/draft-new-london-plan/chapter-6-economy/policy-e9-retail-markets-and-hot-food-takeaways.
131. Food Foundation. *Food Environment Policy Index: Final Report*. 2016 [cited 2017 10 February]; Available from: http://foodfoundation.org.uk/publications.
132. Patterson, R., A. Risby, and M.Y. Chan, *Consumption of takeaway and fast food in a deprived inner London Borough: are they associated with childhood obesity?* Bmj Open, 2012. **2**(3).
133. Reitzel, L.R., et al., *Density and Proximity of Fast Food Restaurants and Body Mass Index Among African Americans.* American Journal of Public Health, 2014. **104**(1): p. 110-116.
134. Apparicio, P., M.S. Cloutier, and R. Shearmur, *The case of Montreal's missing food deserts: Evaluation of accessibility to food supermarkets.* International Journal of Health Geographics, 2007. **6**.

135. Snowdon, C., *FAST FOOD OUTLETS AND OBESITY: What is the evidence?* 2018, The Institute of Economic Affairs.
136. Griffiths, C., et al., *A cross sectional study investigating the association between exposure to food outlets and childhood obesity in Leeds, UK.* International Journal of Behavioral Nutrition and Physical Activity, 2014. **11**.
137. Blow, J., S. Patel, and R. Gregg, *Geographical proximity of takeaway food outlets to schools, colleges and universities in a low-socioeconomic ward in Manchester.* Proceedings of the Nutrition Society, 2017. **76**(OCE4): p. E215-E215.
138. Harrison, F., et al., *Environmental correlates of adiposity in 9-10 year old children: considering home and school neighbourhoods and routes to school.* Soc Sci Med, 2011. **72**(9): p. 1411-9.
139. Green, M.A., et al., *Is adolescent body mass index and waist circumference associated with the food environments surrounding schools and homes? A longitudinal analysis.* Bmc Public Health, 2018. **18**.
140. Caraher, M., et al., *Secondary school pupils' food choices around schools in a London borough: Fast food and walls of crisps.* Appetite, 2016. **103**: p. 208-220.
141. Williams, J., et al., *Associations between Food Outlets around Schools and BMI among Primary Students in England: A Cross-Classified Multi-Level Analysis.* Plos One, 2015. **10**(7).
142. Caraher, M., S. Lloyd, and T. Madelin, *The "School Foodshed": schools and fast-food outlets in a London borough.* British Food Journal, 2014. **116**(3): p. 472-493.
143. Smith, D., et al., *Does the local food environment around schools affect diet? Longitudinal associations in adolescents attending secondary schools in East London.* Bmc Public Health, 2013. **13**.
144. Ellaway, A., et al., *Do obesity-promoting food environments cluster around socially disadvantaged schools in Glasgow, Scotland?* Health & Place, 2012. **18**(6): p. 1335-1340.
145. Dwicaksono, A., et al., *Evaluating the Contribution of the Built Environment on Obesity Among New York State Students.* Health Education & Behavior, 2018. **45**(4): p. 480-491.
146. Watts, A.W., et al., *Multicontextual correlates of adolescent sugar-sweetened beverage intake.* Eating Behaviors, 2018. **30**: p. 42-48.
147. Thornton, L.E., K.E. Lamb, and K. Ball, *Fast food restaurant locations according to socioeconomic disadvantage, urban-regional locality, and schools within Victoria, Australia.* SSM Popul Health, 2016. **2**: p. 1-9.
148. D'Angelo, H., et al., *Sociodemographic Disparities in Proximity of Schools to Tobacco Outlets and Fast-Food Restaurants.* American Journal of Public Health, 2016. **106**(9): p. 1556-1562.
149. Burgoine, T., et al., *Associations between BMI and home, school and route environmental exposures estimated using GPS and GIS: do we see evidence of selective daily mobility bias in children?* International Journal of Health Geographics, 2015. **14**.
150. Tang, X.Y., et al., *Associations between Food Environment around Schools and Professionally Measured Weight Status for Middle and High School Students.* Childhood Obesity, 2014. **10**(6): p. 511-517.
151. Walker, R.E., J. Block, and I. Kawachi, *The Spatial Accessibility of Fast food Restaurants and Convenience Stores in Relation to Neighborhood Schools.* Applied Spatial Analysis and Policy, 2014. **7**(2): p. 169-182.
152. Alviola, P.A., et al., *The effect of fast-food restaurants on childhood obesity: A school level analysis.* Economics & Human Biology, 2014. **12**: p. 110-119.
153. Richmond, T.K., et al., *Middle school food environments and racial/ethnic differences in sugar-sweetened beverage consumption: Findings from the Healthy Choices study.* Preventive Medicine, 2013. **57**(5): p. 735-738.

154. Rossen, L.M., et al., *Food Availability en Route to School and Anthropometric Change in Urban Children.* Journal of Urban Health-Bulletin of the New York Academy of Medicine, 2013. **90**(4): p. 653-666.
155. Langellier, B.A., *The Food Environment and Student Weight Status, Los Angeles County, 2008-2009.* Preventing Chronic Disease, 2012. **9**.
156. Harris, D.E., et al., *Location of Food Stores Near Schools Does Not Predict the Weight Status of Maine High School Students.* Journal of Nutrition Education and Behavior, 2011. **43**(4): p. 274-278.
157. Howard, P.H., M. Fitzpatrick, and B. Fulfrost, *Proximity of food retailers to schools and rates of overweight ninth grade students: an ecological study in California.* Bmc Public Health, 2011. **11**.
158. Laska, M.N., et al., *Neighbourhood food environments: are they associated with adolescent dietary intake, food purchases and weight status?* Public Health Nutrition, 2010. **13**(11): p. 1757-1763.
159. Neckerman, K.M., et al., *Disparities in the Food Environments of New York City Public Schools.* American Journal of Preventive Medicine, 2010. **39**(3): p. 195-202.
160. Kwate, N.O.A. and J.M. Loh, *Separate and unequal: The influence of neighborhood and school characteristics on spatial proximity between fast food and schools.* Preventive Medicine, 2010. **51**(2): p. 153-156.
161. Simon, P.A., et al., *Proximity of fast food restaurants to schools: Do neighborhood income and type of school matter?* Preventive Medicine, 2008. **47**(3): p. 284-288.
162. Sturm, R., *Disparities in the food environment surrounding US middle and high schools.* Public Health, 2008. **122**(7): p. 681-690.
163. Davis, B.C., C., *Proximity of Fast-Food Restaurants to Schools and Adolescent Obesity.* American Journal of Public Health, 2009. **99**(3): p. 505-510.
164. Kipke, M.D., et al., *Food and park environments: Neighborhood-level risks for childhood obesity in east Los Angeles.* Journal of Adolescent Health, 2007. **40**(4): p. 325-333.
165. Sturm, R. and A. Datar, *Body mass index in elementary school children, metropolitan area food prices and food outlet density.* Public Health, 2005. **119**.
166. Austin, S.B., et al., *Clustering of fast-food restaurants around schools: A novel application of spatial statistics to the study of food environments.* American Journal of Public Health, 2005. **95**(9): p. 1575-1581.
167. Daepp, M.I.G. and J. Black, *Assessing the validity of commercial and municipal food environment data sets in Vancouver, Canada.* Public Health Nutrition, 2017. **20**(15): p. 2649-2659.
168. DuBreck, C.M., et al., *Examining community and consumer food environments for children: An urban-suburban-rural comparison in Southwestern Ontario.* Social Science & Medicine, 2018. **209**: p. 33-42.
169. Fitzpatrick, C., et al., *School food environments associated with adiposity in Canadian children.* International Journal of Obesity, 2017. **41**(7): p. 1005-1010.
170. Cutumisu, N., et al., *Association between junk food consumption and fast-food outlet access near school among Quebec secondary-school children: findings from the Quebec Health Survey of High School Students (QHSHSS) 2010-11.* Public Health Nutrition, 2017. **20**(5): p. 927-937.
171. Ravensbergen, L., et al., *"Socioeconomic inequalities in children's accessibility to food retailing: Examining the roles of mobility and time".* Social Science & Medicine, 2016. **153**: p. 81-89.
172. Laxer, R.E. and I. Janssen, *The proportion of excessive fast-food consumption attributable to the neighbourhood food environment among youth living within 1 km of their school.* Applied Physiology Nutrition and Metabolism-Physiologie Appliquee Nutrition Et Metabolisme, 2014. **39**(4): p. 480-486.
173. Browning, H.F., R.E. Laxer, and I. Janssen, *Food and Eating Environments In Canadian Schools.* Canadian Journal of Dietetic Practice and Research, 2013. **74**(4): p. 160-166.

174. He, M.Z., et al., *Obesogenic neighbourhoods: the impact of neighbourhood restaurants and convenience stores on adolescents' food consumption behaviours.* Public Health Nutrition, 2012. **15**(12): p. 2331-2339.
175. Van Hulst, A., et al., *Associations Between Children's Diets and Features of Their Residential and School Neighbourhood Food Environments.* Canadian Journal of Public Health-Revue Canadienne De Sante Publique, 2012. **103**(9): p. S48-S54.
176. Black, J.L. and M. Day, *Availability of Limited Service Food Outlets Surrounding Schools in British Columbia.* Canadian Journal of Public Health-Revue Canadienne De Sante Publique, 2012. **103**(4): p. E255-E259.
177. He, M.Z., et al., *The Influence of Local Food Environments on Adolescents' Food Purchasing Behaviors.* International Journal of Environmental Research and Public Health, 2012. **9**(4): p. 1458-1471.
178. Sadler, R.C. and J.A. Gilliland, *Comparing children's GPS tracks with geospatial proxies for exposure to junk food.* Spatial and Spatio-Temporal Epidemiology, 2015. **14-15**: p. 55-61.
179. Kestens, Y. and M. Daniel, *Social Inequalities in Food Exposure Around Schools in an Urban Area.* American Journal of Preventive Medicine, 2010. **39**(1): p. 33-40.
180. Seliske, L.M., et al., *Density and type of food retailers surrounding Canadian schools: Variations across socioeconomic status.* Health & Place, 2009. **15**(3): p. 903-907.
181. Timmermans, J., et al., *'Obesogenic' School Food Environments? An Urban Case Study in the Netherlands.* International Journal of Environmental Research and Public Health, 2018. **15**(4).
182. Virtanen, M., et al., *Fast-food outlets and grocery stores near school and adolescents' eating habits and overweight in Finland.* European Journal of Public Health, 2015. **25**(4): p. 650-655.
183. Callaghan, M., et al., *Food for thought: analysing the internal and external school food environment.* Health Education, 2015. **115**(2): p. 152-170.
184. Buck, C., et al., *Clustering of unhealthy food around German schools and its influence on dietary behavior in school children: a pilot study.* International Journal of Behavioral Nutrition and Physical Activity, 2013. **10**.
185. Walton, M., J. Pearce, and P. Day, *Examining the interaction between food outlets and outdoor food advertisements with primary school food environments.* Health & Place, 2009. **15**(3): p. 841-848.
186. Day, P.L., J.R. Pearce, and A.L. Pearson, *A temporal analysis of the spatial clustering of food outlets around schools in Christchurch, New Zealand, 1966 to 2006.* Public Health Nutrition, 2015. **18**(1): p. 135-142.
187. Clark, E.M., et al., *Is the food environment surrounding schools associated with the diet quality of adolescents in Otago, New Zealand?* Health & Place, 2014. **30**: p. 78-85.
188. Pearce, J., et al., *Neighborhood deprivation and access to fast-food retailing - A national study.* American Journal of Preventive Medicine, 2007. **32**(5): p. 375-382.
189. Vandevijvere, S., et al., *Unhealthy food marketing around New Zealand schools: a national study.* International journal of public health, 2018. **63**(9): p. 1099-1107.
190. Vandevijvere, S., et al., *Obesogenic Retail Food Environments Around New Zealand Schools A National Study.* American Journal of Preventive Medicine, 2016. **51**(3): p. E57-E66.
191. Timperio, A.F., et al., *Children's takeaway and fast-food intakes: associations with the neighbourhood food environment.* Public Health Nutrition, 2009. **12**(10): p. 1960-1964.
192. Coffee, N.T., H.P. Kennedy, and T. Niyonsenga, *Fast-food exposure around schools in urban Adelaide.* Public Health Nutrition, 2016. **19**(17): p. 3095-3105.

193. Chiang, P.H., et al., *Fast-food outlets and walkability in school neighbourhoods predict fatness in boys and height in girls: a Taiwanese population study.* Public Health Nutrition, 2011. **14**(9): p. 1601-1609.
194. Choo, J., H.J. Kim, and S. Park, *Neighborhood Environments: Links to Health Behaviors and Obesity Status in Vulnerable Children.* Western Journal of Nursing Research, 2017. **39**(8): p. 1169-1191.
195. Joo, S., S. Ju, and H. Chang, *Comparison of fast food consumption and dietary guideline practices for children and adolescents by clustering of fast food outlets around schools in the Gyeonggi area of Korea.* Asia Pacific Journal of Clinical Nutrition, 2015. **24**(2): p. 299-307.
196. Food Foundation. *Food Environment Policy Index: Policy Briefing*. 2016 [cited 2017 13 February]; Available from: http://foodfoundation.org.uk/publications.
197. Public Health England. *Obesity and Overweight Surveillance in England: what is measured and where are the gaps?* 2009 [cited 2016 12 December]; Available from: http://www.noo.org.uk/uploads/doc/vid_4483_Obesity_surveillance_data_-_Final_draft_12_11_09.pdf.
198. NHS Digital. *National Child Measurement Programme*. 2018 [cited 2018 9 January]; Available from: https://digital.nhs.uk/search?q=National+Child+Measurement+Programme+&s=s.
199. Connor Gorber, S., et al., *A comparison of direct vs. self-report measures for assessing height, weight and body mass index: a systematic review.* Obes Rev, 2007. **8**(4): p. 307-26.
200. Alison Lennox, E.F., Clare Whitton, Caireen Roberts and Celia Prynne, *Appendix A. Dietary data collection and editing* 2017: Department of Health.
201. Patterson, R.E., P.S. Haines, and B.M. Popkin, *Diet Quality Index - Capturing a Multidimensional Behavior.* Journal of the American Dietetic Association, 1994. **94**(1): p. 57-64.
202. Manios, Y., et al., *Development of a diet-lifestyle quality index for young children and its relation to obesity: the Preschoolers Diet-Lifestyle Index.* Public Health Nutrition, 2010. **13**(12): p. 2000-2009.
203. Department of Health. *Guidance: The Eatwell Guide*. 2017 [cited 2017 19 January]; Available from: https://www.gov.uk/government/publications/the-eatwell-guide.
204. British Dietetic Association. *Food Fact Sheet: Portion Sizes*. 2016 [cited 2016 16 December]; Available from: https://www.bda.uk.com/foodfacts/portionsizesfoodfactsheet.
205. NHS. *Portion sizes and food groups*. 2016 [cited 2016 16 December]; Available from: http://www.nhs.uk/change4life/Documents/PDF/Schools%20cooking%20resources/SchoolFoodStandardsGuidance.PDF.
206. British Nutrition Foundation. *Find your balance - get portion wise! : Why think about portion size?* 2019 [cited 2019 20 September]; Available from: https://www.nutrition.org.uk/healthyliving/find-your-balance/portionwise.html.
207. American Heart Association. *Suggested Servings from Each Food Group*. 2017 [cited 2017 12 May]; Available from: http://www.heart.org/HEARTORG/HealthyLiving/HealthyEating/HealthyDietGoals/Suggested-Servings-from-Each-Food-Group_UCM_318186_Article.jsp#.WTVm_02GOCN.
208. West of England. *The West of England*. 2017 [cited 2017 5 December]; Available from: http://westofenglandlep.co.uk/about-us/the-west-of-england/.
209. University of Bristol. *Avon Longitudinal Study of Parents and Children*. 2017 [cited 2017 2 January]; Available from: http://www.bristol.ac.uk/alspac/.
210. University of Bristol. *Avon Longitudinal Study of Parents and Children: Researchers* 2017 [cited 2017 17 January]; Available from: http://www.bristol.ac.uk/alspac/researchers/.

211. Lake, A.A., et al., *The foodscape: Classification and field validation of secondary data sources.* Health & Place, 2010. **16**(4): p. 666-673.
212. Fraser, L.K., et al., *Fast food and obesity: a spatial analysis in a large United Kingdom population of children aged 13-15.* Am J Prev Med, 2012. **42**(5): p. e77-85.
213. Wilkins, E.L., et al., *Examining the validity and utility of two secondary sources of food environment data against street audits in England.* Nutrition Journal, 2017. **16**.
214. Ordnance Survey. *Points of Interest*. 2018 [cited 2018 12 March]; Available from: https://www.ordnancesurvey.co.uk/business-and-government/products/points-of-interest.html.
215. Department for Education. *Types of school* 2018 [cited 2018 20 April]; Available from: https://www.gov.uk/types-of-school.
216. Department for Education. *Pupil referral units: converting to alternative provision academies* 2018 [cited 2018 20 April]; Available from: https://www.gov.uk/guidance/pupil-referral-units-converting-to-alternative-provision-academies.
217. UK Data Service. *Deprivation Data*. 2016 [cited 2016 24 November]; Available from: https://census.ukdataservice.ac.uk/get-data/related/deprivation.
218. Communities and Local Goverment. *Communities and neighbourhoods: Indices of deprivation 2004* 2018 [cited 2018 12 March]; Available from: http://webarchive.nationalarchives.gov.uk/20100407164233/http://www.communities.gov.uk/archived/general-content/communities/indicesofdeprivation/216309/.
219. NIHR. *Estimated food diaries*. 2020 [cited 2020 19 August]; Available from: https://dapa-toolkit.mrc.ac.uk/diet/subjective-methods/estimated-food-diaries.
220. NIHR. *Food frequency questionnaires*. 2020 [cited 2020 20 August]; Available from: https://dapa-toolkit.mrc.ac.uk/diet/subjective-methods/food-frequency-questionnaire.
221. Public Health England. *Strategies for Encouraging Healthier 'Out of Home' Food Provision: A toolkit for local councils working with small food businesses*. 2017 [cited 2018 8 March]; Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/604912/Encouraging_healthier_out_of_home_food_provision_toolkit_for_local_councils.pdf.
222. Donin, A.S., et al., *Takeaway meal consumption and risk markers for coronary heart disease, type 2 diabetes and obesity in children aged 9-10 years: a cross-sectional study.* Arch Dis Child, 2017.
223. Office for National Statistics. *Chapter 3: Equivalised income*. 2018 [cited 2018 16 April]; Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/compendium/familyspending/2015/chapter3equivalisedincome#background-notes.
224. Winpenny, E.M., et al., *Diet Quality through Adolescence and Early Adulthood: Cross-Sectional Associations of the Dietary Approaches to Stop Hypertension Diet Index and Component Food Groups with Age.* Nutrients, 2018. **10**(11).
225. Lai, H.T., J. Hutchinson, and C.E.L. Evans, *Non-Milk Extrinsic Sugars Intake and Food and Nutrient Consumption Patterns among Adolescents in the UK National Diet and Nutrition Survey, Years 2008-16.* Nutrients, 2019. **11**(7).
226. Llaurado, E., et al., *The effect of snacking and eating frequency on dietary quality in British adolescents.* Eur J Nutr, 2016. **55**(4): p. 1789-97.
227. Ortega, F.B., et al., *Health Inequalities in Urban Adolescents: Role of Physical Activity, Diet, and Genetics.* Pediatrics, 2014. **133**(4): p. E884-E895.
228. Jackson, P. and V. Viehoff, *Reframing convenience food.* Appetite, 2016. **98**: p. 1-11.
229. Burgoine, T., et al., *Associations between exposure to takeaway food outlets, takeaway food consumption, and body weight in Cambridgeshire, UK:*

population based, cross sectional study. Bmj-British Medical Journal, 2014. **348**.
230. Prentice, A.M. and S.A. Jebb, *Fast foods, energy density and obesity: a possible mechanistic link.* Obes Rev, 2003. **4**(4): p. 187-94.
231. Burke, S.J., et al., *An examination of the influence of eating location on the diets of Irish children.* Public Health Nutrition, 2007. **10**(6): p. 599-607.
232. Naska, A., et al., *Eating out, weight and weight gain. A cross-sectional and prospective analysis in the context of the EPIC-PANACEA study.* International Journal of Obesity, 2011. **35**(3): p. 416-426.
233. Orfanos, P., et al., *Eating out of home and its correlates in 10 European countries. The European Prospective Investigation into Cancer and Nutrition (EPIC) study.* Public Health Nutr, 2007. **10**(12): p. 1515-25.
234. Nielsen, A.J. and B.M. Popkin, *Patterns and trends in food portion sizes, 1977-1998.* Jama-Journal of the American Medical Association, 2003. **289**(4): p. 450-453.
235. NHS. *Restaurant dining 'as calorific as fast food'* 2014 [cited 2017 2 December]; Available from: https://www.nhs.uk/news/food-and-diet/restaurant-dining-as-calorific-as-fast-food/.
236. Public Health England. *National Obesity Observatory: Knowledge and attitudes towards healthy eating behaviour and physical activity*. 2011 [cited 2016 15 October]; Available from: http://www.noo.org.uk/uploads/doc/vid_11171_Attitudes.pdf.
237. Rutter, H., et al., *The need for a complex systems model of evidence for public health.* Lancet, 2017. **390**(10112): p. 2602-2604.
238. Michie, S., M.M. van Stralen, and R. West, *The behaviour change wheel: A new method for characterising and designing behaviour change interventions.* Implementation Science, 2011. **6**.
239. Adams, J., et al., *Why Are Some Population Interventions for Diet and Obesity More Equitable and Effective Than Others? The Role of Individual Agency.* Plos Medicine, 2016. **13**(4).
240. Lee, K., et al., *The Intervention Scalability Assessment Tool: a pilot study assessing five interventions for scalability.* Public Health Research & Practice, 2020. **30**(2).
241. NIHR School for Public Health. *Transforming the 'foodscape': development and feasibility testing of interventions to promote healthier take-away, pub or restaurant food*. 2017 [cited 2020 20 September]; Available from: https://sphr.nihr.ac.uk/research/foodscape/.
242. Sniehotta, F.F., et al., *Complex systems and individual-level approaches to population health: a false dichotomy?* Lancet Public Health, 2017. **2**(9): p. E396-E397.
243. *Cavill N, Rutter H. Obesity and the environment: regulating the growth of fast food outlets. London; 2014. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296248/Obesity_and_environment_March2014.pdf. Accessed 4 Apr 2018*.
244. Setia, M.S., *Methodology Series Module 3: Cross-sectional Studies.* Indian Journal of Dermatology, 2016. **61**(3): p. 261-264.
245. Orfanos, P., et al., *Eating at restaurants, at work or at home. Is there a difference? A study among adults of 11 European countries in the context of the HECTOR* project.* European Journal of Clinical Nutrition, 2017. **71**(3): p. 407-419.
246. FSA. *Appendix D Interviewer (stage 1) overview of elements and documents*. 2018 [cited 2018 18 April]; Available from: https://www.food.gov.uk/northern-ireland/researchni/ndns-ni-appendices-tables.
247. Montagnese, C., et al., *European food-based dietary guidelines: A comparison and update.* Nutrition, 2015. **31**(7-8): p. 908-915.

248. Golley, R.K., et al., *An index measuring adherence to complementary feeding guidelines has convergent validity as a measure of infant diet quality.* J Nutr, 2012. **142**(5): p. 901-8.
249. Emond, A., et al., *Feeding Symptoms, Dietary Patterns, and Growth in Young Children With Autism Spectrum Disorders.* Pediatrics, 2010. **126**(2): p. E337-E342.
250. OECD. *Healthy lifestyles among children*. Health at a Glance 2017 2017 [cited 2017 4 December]; Available from: http://www.oecd-ilibrary.org/social-issues-migration-health/health-at-a-glance-2017_health_glance-2017-en.
251. Ogilvie, D., et al., *Using natural experimental studies to guide public health action: turning the evidence-based medicine paradigm on its head.* Journal of Epidemiology and Community Health, 2020. **74**(2): p. 203-208.
252. Bernal, J.L., S. Cummins, and A. Gasparrini, *Interrupted time series regression for the evaluation of public health interventions: a tutorial.* International Journal of Epidemiology, 2017. **46**(1): p. 348-355.
253. Ochoa-Aviles, A., et al., *A school-based intervention improved dietary intake outcomes and reduced waist circumference in adolescents: a cluster randomized controlled trial.* Nutrition Journal, 2017. **16**.
254. Department of Health and Social Care. *Childhood obesity: a plan for action, chapter 2*. 2018 [cited 2020 21 August]; Available from: https://www.gov.uk/government/publications/childhood-obesity-a-plan-for-action-chapter-2.
255. WHO Regional Office for Europe. *ADOLESCENTS' DIETARY HABITS*. 2016 [cited 2019 6 December]; Available from: http://www.euro.who.int/__data/assets/pdf_file/0006/303477/HBSC-No.7_factsheet_Diet.pdf?ua=1.
256. Kearney, J.M., K.F. Hulshof, and M.J. Gibney, *Eating patterns--temporal distribution, converging and diverging foods, meals eaten inside and outside of the home--implications for developing FBDG.* Public Health Nutr, 2001. **4**(2B): p. 693-8.
257. Department for Education. *Schools, pupils and their characteristics: January 2019*. 2019 [cited 2019 25 June]; Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/812539/Schools_Pupils_and_their_Characteristics_2019_Main_Text.pdf.
258. Department for Education. *School food in England: Departmental advice for governing boards*. 2019 [cited 2019 1 February]; Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/551813/School_food_in_England.pdf.
259. Harrison, F., et al., *Food and drink consumption at school lunchtime: the impact of lunch type and contribution to overall intake in British 9-10-year-old children.* Public Health Nutrition, 2013. **16**(6): p. 1132-1139.
260. Evans, C.E.L., et al., *Impact of school lunch type on nutritional quality of English children's diets.* Public Health Nutrition, 2016. **19**(1): p. 36-45.
261. Pearce, J., L. Wood, and M. Nelson, *Lunchtime food and nutrient intakes of secondary-school pupils; a comparison of school lunches and packed lunches following the introduction of mandatory food-based standards for school lunch.* Public Health Nutrition, 2013. **16**(6): p. 1126-1131.
262. Prynne, C.J., et al., *The quality of midday meals eaten at school by adolescents; school lunches compared with packed lunches and their contribution to total energy and nutrient intakes.* Public Health Nutrition, 2013. **16**(6): p. 1118-1125.
263. Ensaff, H., J. Russell, and M.E. Barker, *Meeting school food standards - students' food choice and free school meals.* Public Health Nutrition, 2013. **16**(12): p. 2162-2168.

264. Ensaff, H., J. Russell, and M.E. Barker, *Adolescents' beverage choice at school and the impact on sugar intake.* European Journal of Clinical Nutrition, 2016. **70**(2): p. 243-249.
265. Taher, A.K., N. Evans, and C.E. Evans, *The cross-sectional relationships between consumption of takeaway food, eating meals outside the home and diet quality in British adolescents.* Public Health Nutrition, 2019. **22**(1): p. 63-73.
266. UK Data Service. *National Diet and Nutrition Survey Years 1-9, 2008/09-2016/17*. 2019 [cited 2018 21 December]; Available from: https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=6533.
267. Textor, J., et al., *Robust causal inference using directed acyclic graphs: the R package 'dagitty'.* International Journal of Epidemiology, 2016. **45**(6): p. 1887-1894.
268. Vernarelli, J.A. and B. O'Brien, *A Vote for School Lunches: School Lunches Provide Superior Nutrient Quality than Lunches Obtained from Other Sources in a Nationally Representative Sample of US Children.* Nutrients, 2017. **9**(9).
269. Wickramasinghe, K., et al., *Environmental and nutrition impact of achieving new School Food Plan recommendations in the primary school meals sector in England.* Bmj Open, 2017. **7**(4).
270. Stevens, L., et al., *School lunches v. packed lunches: a comparison of secondary schools in England following the introduction of compulsory school food standards.* Public Health Nutrition, 2013. **16**(6): p. 1037-1042.
271. Browne, S., et al., *School lunches in the Republic of Ireland: a comparison of the nutritional quality of adolescents' lunches sourced from home or purchased at school or 'out' at local food outlets.* Public Health Nutrition, 2017. **20**(3): p. 504-514.
272. Addis, S. and S. Murphy, *'There is such a thing as too healthy!' The impact of minimum nutritional guidelines on school food practices in secondary schools.* J Hum Nutr Diet, 2019. **32**(1): p. 31-40.
273. Macdiarmid, J.I., et al., *Food and drink purchasing habits out of school at lunchtime: a national survey of secondary school pupils in Scotland.* International Journal of Behavioral Nutrition and Physical Activity, 2015. **12**.
274. Wills, W., et al., *Socio-Economic Factors, the Food Environment and Lunchtime Food Purchasing by Young People at Secondary School.* International Journal of Environmental Research and Public Health, 2019. **16**(9).
275. Sahota, P., et al., *Factors influencing take-up of free school meals in primary- and secondary-school children in England.* Public Health Nutrition, 2014. **17**(6): p. 1271-1279.
276. McInnes, A. and D. Blackwell, *Self-reported Perceptions of Weight and Eating Behavior of School Children in Sunderland, England.* Frontiers in Public Health, 2017. **5**.
277. BBC News. *Reality Check: Why ban fast food within 400m of schools?* 2017 [cited 2017 11 December]; Available from: http://www.bbc.co.uk/news/health-42172579.
278. Williams, J.L., *Spaces between home and school: The effect of eating location on adolescent nutrition.* Ecology of Food and Nutrition, 2016. **55**(1): p. 65-86.
279. Charreire, H., et al., *Measuring the food environment using geographical information systems: a methodological review.* Public Health Nutrition, 2010. **13**(11): p. 1773-1785.
280. UK PARLIAMENT. *Childhood obesity: Time for action* 2018 [cited 2018 20 June]; Available from: https://publications.parliament.uk/pa/cm201719/cmselect/cmhealth/882/88202.htm.
281. Sharkey, J.R., et al., *Association between proximity to and coverage of traditional fast-food restaurants and nontraditional fast-food outlets and fast-food consumption among rural adults.* International Journal of Health Geographics, 2011. **10**.

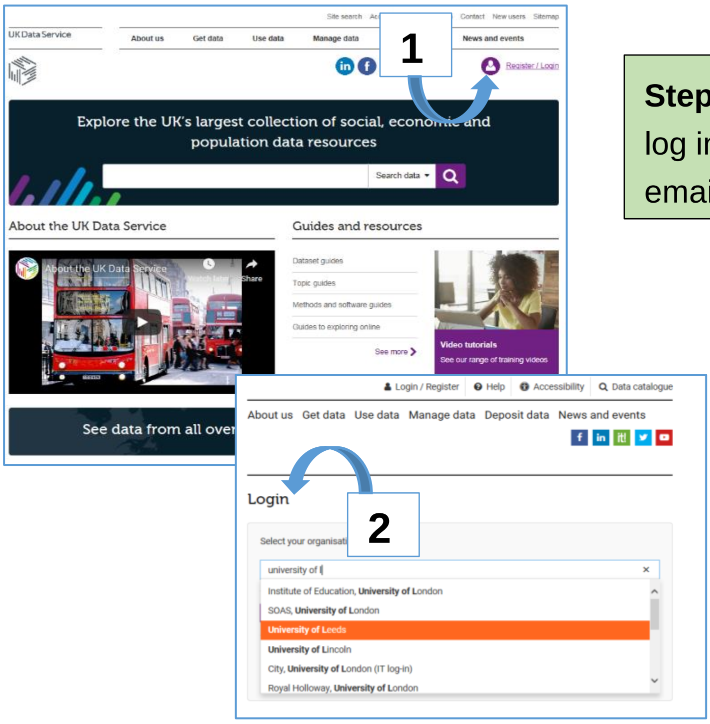
282. Jeffery, R.W., et al., *Are fast food restaurants an environmental risk factor for obesity?* International Journal of Behavioral Nutrition and Physical Activity, 2006. **3**.
283. van der Horst, K., et al., *The school food environment - Associations with adolescent soft drink and snack consumption.* American Journal of Preventive Medicine, 2008. **35**(3): p. 217-223.
284. Svastisalee, C.M., B.E. Holstein, and P. Due, *Fruit and vegetable intake in adolescents: association with socioeconomic status and exposure to supermarkets and fast food outlets.* J Nutr Metab, 2012. **2012**: p. 185484.
285. Williams, J., et al., *A systematic review of the influence of the retail food environment around schools on obesity-related outcomes.* Obesity Reviews, 2014. **15**(5): p. 359-374.
286. Burgoine, T., S. Alvanides, and A.A. Lake, *Creating 'obesogenic realities'; do our methodological choices make a difference when measuring the food environment?* International Journal of Health Geographics, 2013. **12**.
287. Glanz, K., et al., *Built environment assessment: Multidisciplinary perspectives.* Ssm-Population Health, 2016. **2**: p. 24-31.
288. Caspi, C.E., et al., *The local food environment and diet: A systematic review.* Health & Place, 2012. **18**(5): p. 1172-1187.
289. Bodor, J.N., et al., *Neighbourhood fruit and vegetable availability and consumption: the role of small food stores in an urban environment.* Public Health Nutrition, 2008. **11**(4): p. 413-420.
290. Zenk, S.N., et al., *Neighborhood racial composition, neighborhood poverty, and the spatial accessibility of supermarkets in metropolitan Detroit.* American Journal of Public Health, 2005. **95**(4): p. 660-667.
291. Block, J.P., et al., *Proximity to Food Establishments and Body Mass Index in the Framingham Heart Study Offspring Cohort Over 30 Years.* American Journal of Epidemiology, 2011. **174**(10): p. 1108-1114.
292. Hansen, W.G., *How Accessibility Shapes Land-Use.* Journal of the American Institute of Planners, 1959. **25**(2): p. 73-76.
293. Universitat Politècnica de Catalunya. *Part 1: Measures of accessibility*. 2020 [cited 2020 24 August]; Available from: https://upcommons.upc.edu/bitstream/handle/2099.1/6327/03.pdf?sequence=4&isAllowed=y.
294. Pirie, G.H., *Measuring Accessibility - Review and Proposal.* Environment and Planning A, 1979. **11**(3): p. 299-312.
295. Fotheringham, A.S., *Further Discussion on Distance-Deterrence Parameters and the Competing Destinations Model.* Environment and Planning A, 1986. **18**(4): p. 553-556.
296. Guagliardo, M.F., et al., *Physician accessibility: an urban case study of pediatric providers.* Health & Place, 2004. **10**(3): p. 273-283.
297. Knox, P.L., *The accessibility of primary care to urban patients: a geographical analysis.* J R Coll Gen Pract, 1979. **29**(200): p. 160-8.
298. de Oliveira, R.L.M., C.S.H.F. Garcia, and P.H.G. Pinto, *Accessibility to Food Retailers: The Case of Belo Horizonte, Brazil.* Sustainability, 2020. **12**(7).
299. Giavarina, D., *Understanding Bland Altman analysis.* Biochemia Medica, 2015. **25**(2): p. 141-151.
300. Bland, J.M. and D.G. Altman, *Statistical methods for assessing agreement between two methods of clinical measurement.* International Journal of Nursing Studies, 2010. **47**(8): p. 931-936.
301. Barnhart, H.X., M. Haber, and J.L. Song, *Overall concordance correlation coefficient for evaluating agreement among multiple observers.* Biometrics, 2002. **58**(4): p. 1020-1027.
302. McBride, G., *A proposal for strength-of-agreement criteria for Lins Concordance Correlation Coefficient*. 2005, National Institute of Water & Atmospheric Research Ltd: NIWA Client Report: HAM2005-062.

303. Seliske, L., et al., *The number and type of food retailers surrounding schools and their association with lunchtime eating behaviours in students.* International Journal of Behavioral Nutrition and Physical Activity, 2013. **10**.
304. Smoyer-Tomic, K.E., J.N. Hewko, and M.J. Hodgson, *Spatial accessibility and equity of playgrounds in Edmonton, Canada.* Canadian Geographer-Geographe Canadien, 2004. **48**(3): p. 287-302.
305. Shahid, R., et al., *Comparison of distance measures in spatial analytical modeling for health service planning.* Bmc Health Services Research, 2009. **9**.
306. Pearce, M., I. Bray, and M. Horswell, *Weight gain in mid-childhood and its relationship with the fast food environment.* Journal of Public Health, 2018. **40**(2): p. 237-244.
307. Oliver, L.N., N. Schuurman, and A.W. Hall, *Comparing circular and network buffers to examine the influence of land use on walking for leisure and errands.* International Journal of Health Geographics, 2007. **6**.
308. Mackenbach, J.D., et al., *Exploring the Relation of Spatial Access to Fast Food Outlets With Body Weight: A Mediation Analysis.* Environment and Behavior, 2019. **51**(4): p. 401-430.
309. Altman, D.G., *Practical Statistics for Medical Research*. 1st ed, ed. C.H.C.T.i.S. Science. 1990: Chapman and Hall/CRC. 624
310. Mhurchu, C.N., et al., *Monitoring the availability of healthy and unhealthy foods and non-alcoholic beverages in community and consumer retail food environments globally.* Obesity Reviews, 2013. **14**: p. 108-119.
311. Mahendra, A., et al., *Geographic retail food environment measures for use in public health.* Health Promotion and Chronic Disease Prevention in Canada-Research Policy and Practice, 2017. **37**(10): p. 357-362.
312. NHS. *Statistics on Obesity, Physical Activity and Diet: England, 2006*. 2006 [cited 2018 9 January]; Available from: https://digital.nhs.uk/catalogue/PUB00166.
313. Government Office for Science. *Tackling Obesities: Future Choices (2nd Edition)*. 2007 [cited 2018 21 June]; Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287937/07-1184x-tackling-obesities-future-choices-report.pdf.
314. Fraser, L.K., et al., *The Geography of Fast Food Outlets: A Review.* International Journal of Environmental Research and Public Health, 2010. **7**(5): p. 2290-2308.
315. Fraser, L.K. and K.L. Edwards, *The association between the geography of fast food outlets and childhood obesity rates in Leeds, UK.* Health Place, 2010. **16**.
316. Okuyama, K., et al., *Fast food outlets, physical activity facilities, and obesity among adults: a nationwide longitudinal study from Sweden.* Int J Obes (Lond), 2020. **44**(8): p. 1703-1711.
317. Hughes, A.R., et al., *Incidence of obesity during childhood and adolescence in a large contemporary cohort.* Preventive Medicine, 2011. **52**(5): p. 300-304.
318. ALSPAC study team, *THE ALSPAC STUDY: Address data*. 2014: University of Bristol.
319. Grossman, D.C., et al., *Screening for Obesity in Children and Adolescents US Preventive Services Task Force Recommendation Statement.* Jama-Journal of the American Medical Association, 2017. **317**(23): p. 2417-2426.
320. PHE. *Patterns and trends in child obesity: national and regional data*. 2020 [cited 2020 20 June]; Available from: https://www.gov.uk/government/publications/child-obesity-patterns-and-trends/patterns-and-trends-in-child-obesity-national-and-regional-data.
321. Mellor, J.M., C.B. Dolan, and R.B. Rapoport, *Child body mass index, obesity, and proximity to fast food restaurants.* International Journal of Pediatric Obesity, 2011. **6**(1): p. 60-68.
322. Grier, S. and B. Davis, *Are All Proximity Effects Created Equal? Fast Food Near Schools and Body Weight Among Diverse Adolescents.* Journal of Public Policy & Marketing, 2013. **32**(1): p. 116-128.

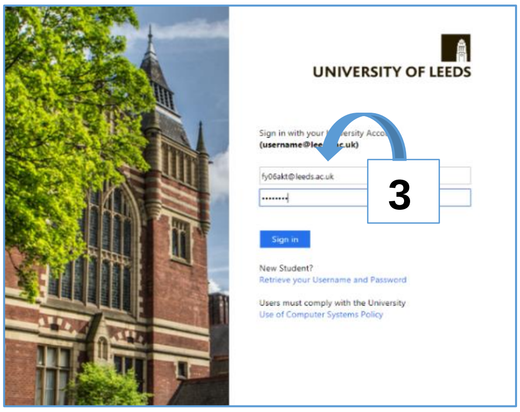
323. Sanchez, B.N., et al., *Differential Associations Between the Food Environment Near Schools and Childhood Overweight Across Race/Ethnicity, Gender, and Grade.* American Journal of Epidemiology, 2012. **175**(12): p. 1284-1293.
324. Baines, E. and P. Blatchford, *School break and lunch times and young people's social lives: A follow-up national study*, in *Final report*. 2019, UCL Institute of Education: Department of Psychology and Human Development.
325. Turbutt, C., J. Richardson, and C. Pettinger, *The impact of hot food takeaways near schools in the UK on childhood obesity: a systematic review of the evidence.* Journal of Public Health, 2019. **41**(2): p. 231-239.
326. Smith, K. *What Is a Non Linear Relationship?* 2020 [cited 2020 25 July]; Available from: https://sciencing.com/non-linear-relationship-10003107.html.
327. Gilliland, J.A., et al., *Linking Childhood Obesity to the Built Environment: A Multi-level Analysis of Home and School Neighbourhood Factors Associated With Body Mass Index.* Canadian Journal of Public Health-Revue Canadienne De Sante Publique, 2012. **103**(9): p. S15-S21.
328. University of Bristol. *Cohort profile* 2017 [cited 2017 6 November]; Available from: http://www.bristol.ac.uk/alspac/researchers/cohort-profile/.
329. UNICEF, *The State of the World's Children 2019. Children, food and nutrition: Growing well in a changing world*. 2019: New York.
330. Roberts, K.E., *An investigation of dietary patterns in UK adults as a method for developing a brief diet quality*, in *Faculty of Medicine, School of Health and Related Research (Sheffield)* 2017, University of Sheffield.
331. Clary, C.M., et al., *Should we use absolute or relative measures when assessing foodscape exposure in relation to fruit and vegetable intake? Evidence from a wide-scale Canadian study.* Preventive Medicine, 2015. **71**: p. 83-87.
332. Hobbs, M., et al., *Neighbourhood typologies and associations with body mass index and obesity: A cross-sectional study.* Preventive Medicine, 2018. **111**: p. 351-357.
333. ESRI. *ArcMap: Service area analysis*. 2018 [cited 2018 9 December]; Available from: http://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/service-area.htm.
334. Cole, J. and J.V. Freeman, *Body mass index reference curves for the UK, 1990.* Arch Dis Child, 1995. **73**.
335. Cole, T.J., et al., *What is the best measure of adiposity change in growing children: BMI, BMI %, BMI z-score or BMI centile? (vol 59, pg 419, 2005).* European Journal of Clinical Nutrition, 2005. **59**(6): p. 807-807.
336. Strain, T., et al., *How are we measuring physical activity and sedentary behaviour in the four home nations of the UK? A narrative review of current surveillance measures and future directions.* Br J Sports Med, 2019.
337. Sylvia, L.G., et al., *Practical guide to measuring physical activity.* J Acad Nutr Diet, 2014. **114**(2): p. 199-208.
338. WHO. *Global action plan on physical activity 2018–2030: more active people for a healthier world*. 2018 [cited 2019 6 December]; Available from: https://www.who.int/ncds/prevention/physical-activity/global-action-plan-2018-2030/en/.
339. Statista. *Number of employees in the United States fast food restaurant industry from 2004 to 2018**. 2020 [cited 2020 9 May]; Available from: https://www.statista.com/statistics/196630/number-of-employees-in-us-fast-food-restaurants-since-2002/.
340. Office for National Statistics. *Workers in restaurant and mobile food service activities, UK, 2009 to 2018*. 2020 [cited 2020 10 May]; Available from: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/adhocs/010313workersinrestaurantandmobilefoodserviceactivitiesuk2009to2018.

List of Appendices

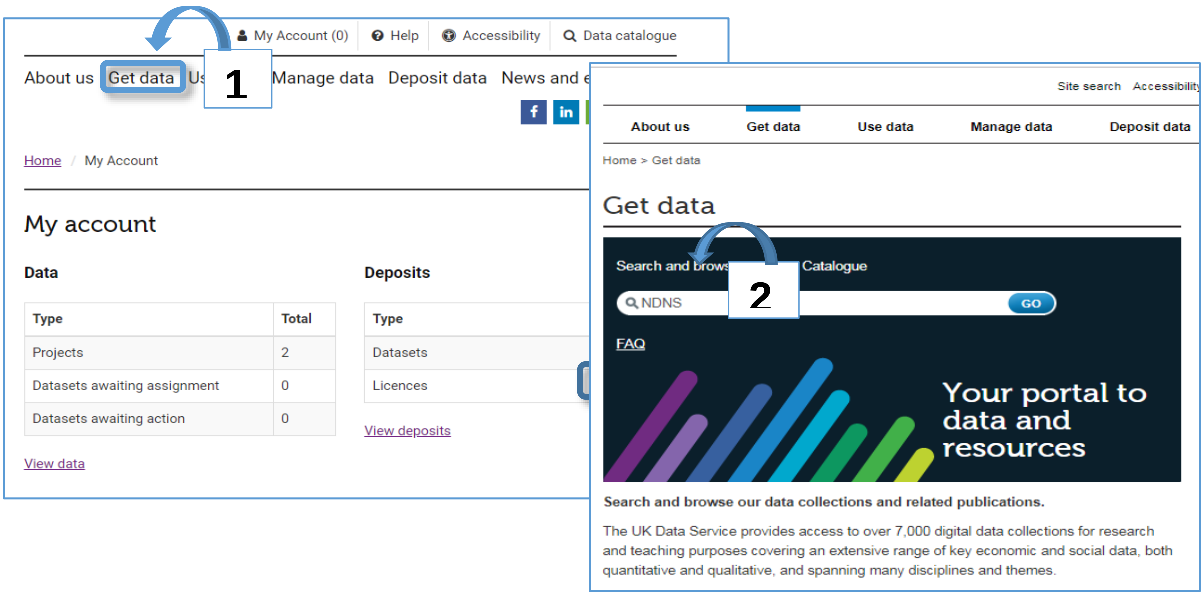
Appendix 1: Obtaining the NDNS Data



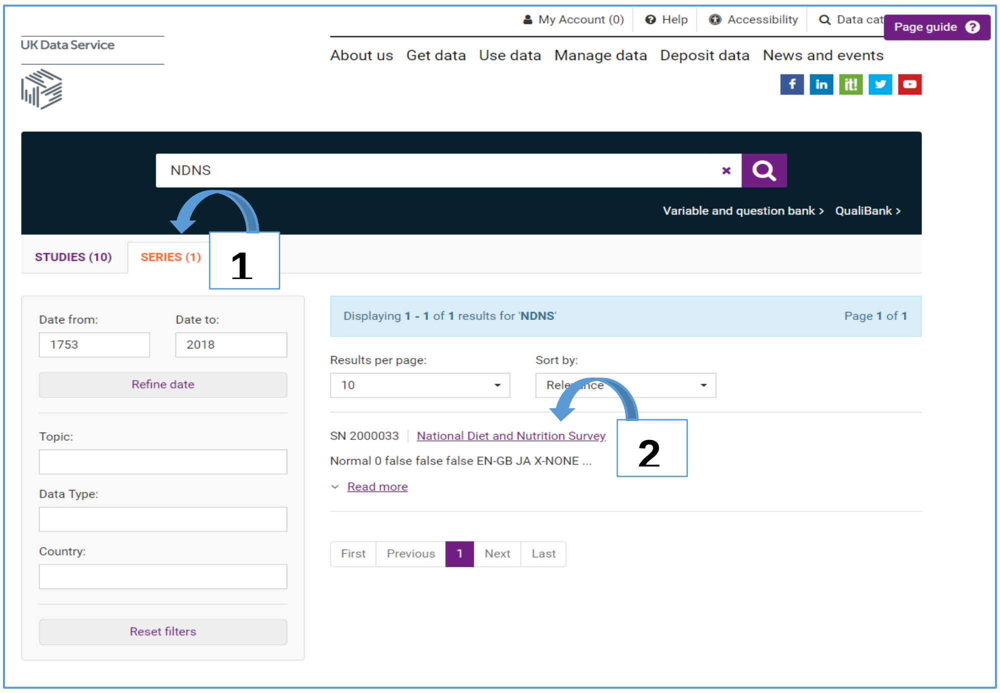
Step 1 Registration is required and then log in by using the University of Leeds email address.

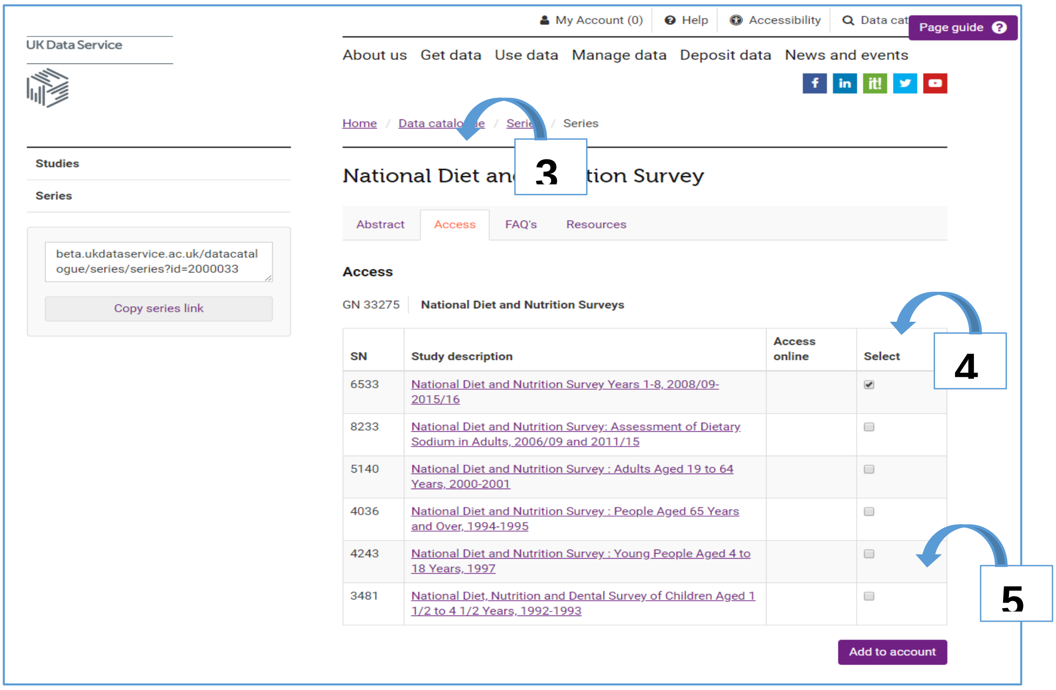


Step 2 Getting the data by searching for NDNS

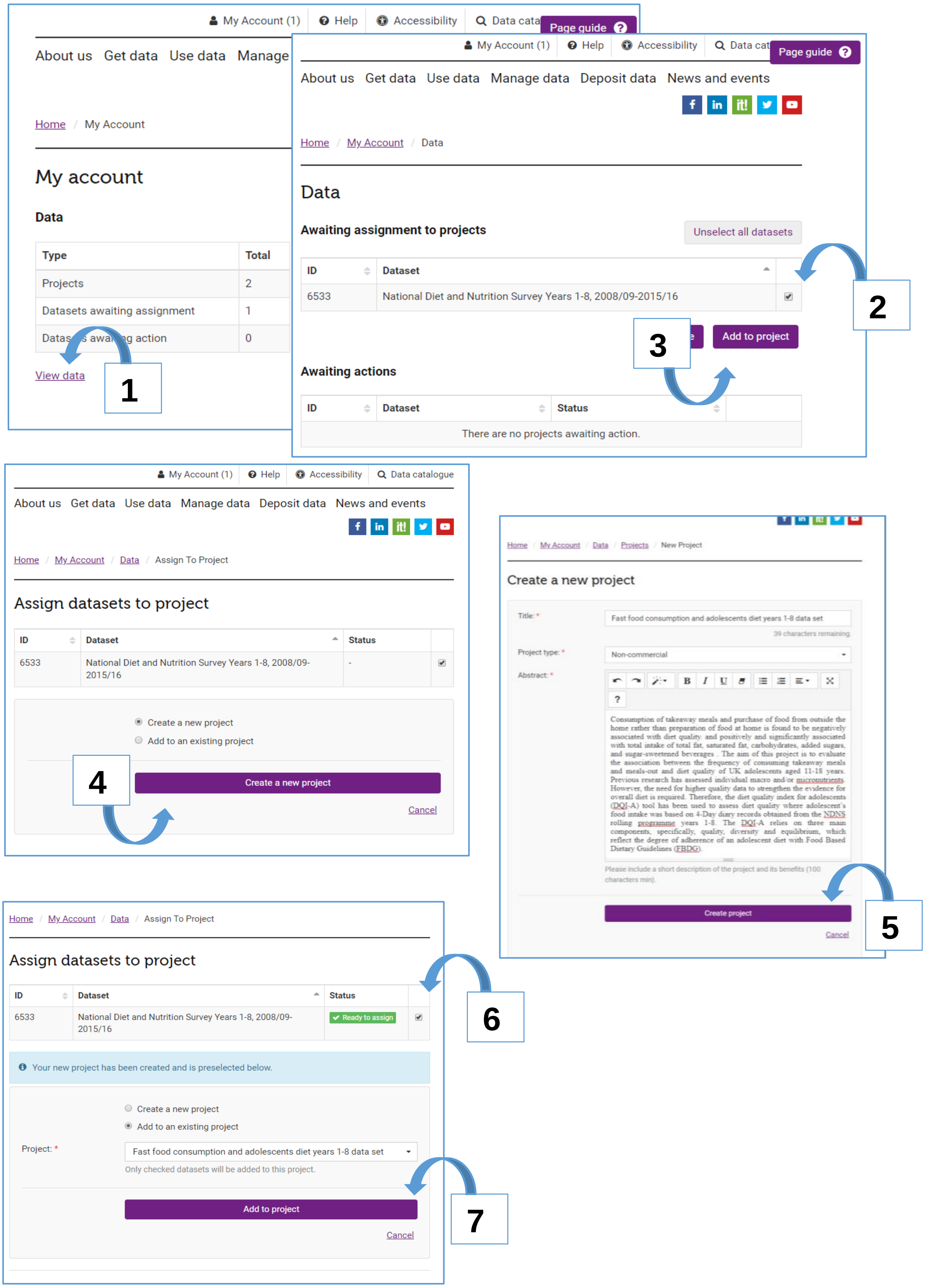


Step 3 accessing and adding the data to your account

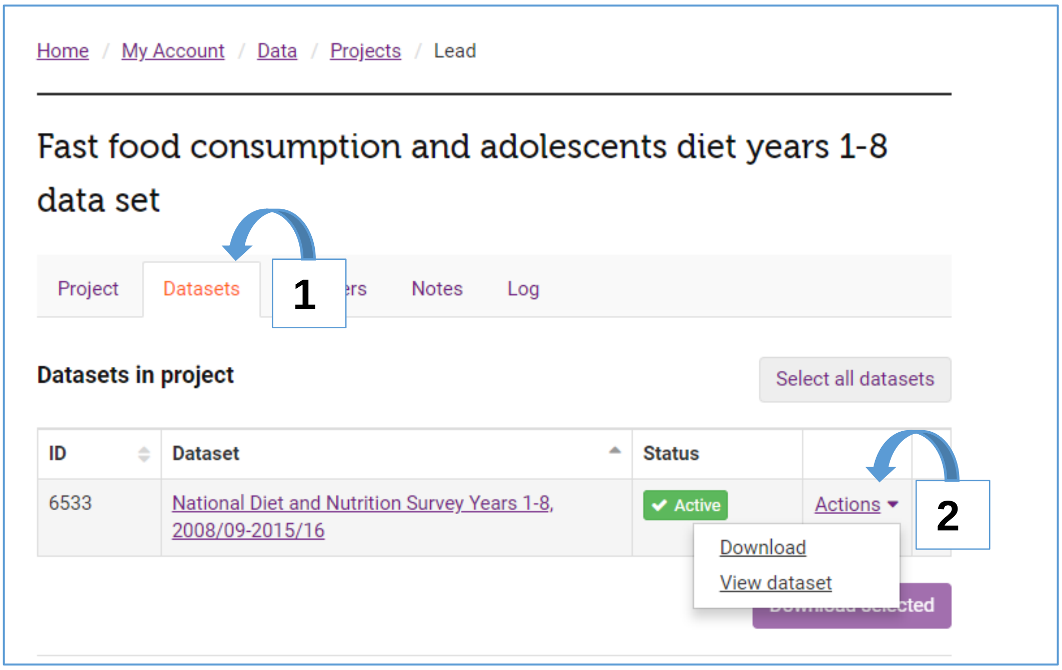


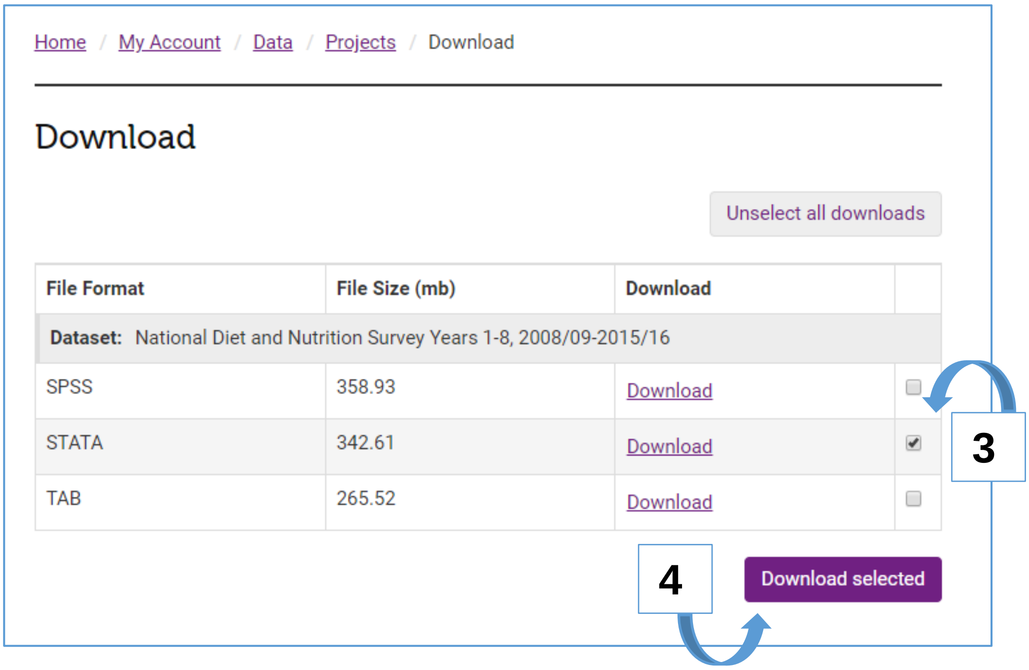


Step 4 Viewing the data and creating a project to add the data



Finally: Step 5 Download the data





Appendix 2: Weighting, Appending and Merging of NDNS dataset

Stata commands used in order to analyse NDNS dataset years 1-6 were as the following:

1. **Merging datasets**

In stata, following the order of these steps Data > Combine Datasets > Merge two datasets, the researcher will be able to merge two datasets of the NDNS data. For example in this project the dataset named '' ndns_rp_yr1-4a_indiv_uk.dta'' was merged with the dataset named '' ndns_rp_yr1-4a_personleveldietarydata_uk.dta''.

2. **Append datasets**

   In stata, following the order of these steps Data > Combine Datasets > Append datasets. Then brows for the wanted datasets namely ''ndns_rp_yr5-6a_indiv.dta'' to be appended with the other dataset namely ''ndns_rp_yr1-4a_indiv_uk.dta''

3. Weighting the data

A. For year 1-4 dataset, the command used was svyset area [pweight= wti_UKY1234], strata(cluster) singleunit(centered). For years 5-6 dataset, the command used was svyset area [pweight= wti wti_Y56], strata(cluster) singleunit(centered).

However, to make sure each of the datasets weighted in the correct proprtion, the following commands were used:

generate WTI_UKY1234r = wti_UKY1234 * (6828 + 2546) / 6828 * (2/3)

generate WTI_UKY56r = wti_Y56   * (6828 + 2546) / 2546 * (1/3)

generate WTI_UKY1to6 = sum(WTI_UKY1234r - WTI_UKY56r)

B. For Year 1-8 dataset, the commands used were as follows:

generate WTI_UKY1234r = wti_UKY1234 * (5964 + 2181 + 2157) / 5964 * (1/2)

generate WTI_UKY56r   = wti_Y56   * (5964 + 2181 + 2157) / 2181 * (1/4)

```
generate WTI_UKY78r = wti_Y78   * (5964 + 2181 + 2157) / 2157  * (1/4)

replace WTI_UKY1234r=0 if WTI_UKY1234r==.

replace WTI_UKY56r =0 if WTI_UKY56r ==.

replace WTI_UKY78r =0 if WTI_UKY78r ==.

generate WTI_UKY1to8 = WTI_UKY1234r + WTI_UKY56r + WTI_UKY78r

sum WTI_UKY1to8

generate WTI_UKY1to8C = WTI_UKY1to8 /.4520821

sum WTI_UKY1to8C
```

Appendix 3: The NDNS food group categorisation

Main Food group code and name	Subsidiary food group code and name	Subsidiary food group description
		Cereals and Cereal Products
1 Pasta, rice and other miscellaneous cereals	1C Pizza	All types - thin and crispy, deep pan, French bread, etc. Includes homemade pizza
	1D Pasta (manufactured products and ready meals)	All types of purchased/retail products or ready meals based on pasta or noodles; includes filled fresh pasta and canned pasta
	1E Pasta (other, including homemade dishes)	Dried and cooked plain pasta (including fresh pasta and gluten-free), egg noodles and recipes for homemade dishes (including macaroni cheese)
	1F Rice (manufactured products and ready meals)	All types of purchased/retail products or ready meals based on rice; includes ready meal risotto, ready cooked rice. Not purchased rice pudding. Not takeaway rice dishes
	1G Rice (other, including homemade dishes)	Raw and cooked plain rice, rice flour, rice flakes, rice noodles and recipes for homemade dishes, including fried rice, risotto. Rice dishes from a takeaway (eg egg fried or pilau rice). Not homemade rice pudding
	1R Other cereals	Includes flour (not rice flour), cous cous, bran, oats, semolina, papadums/poppadoms, dumplings, Yorkshire pudding
2 White bread	2R White bread (not high fibre, not multiseed bread)	Sliced, unsliced, toast, fried. Includes all types of bread and bread products made with white wheat flour: French stick, milk loaf, slimmers, pitta bread, rolls, chappatis, soda bread, brioche, panini, focaccia, ciabatta, plain bagels, plain naan, garlic bread, cheese garlic bread, English muffins (white only), crumpets/pikelets, wheat tortillas, puri. Not fruit loaf. Not high fibre. Not multiseed bread
3 Wholemeal bread	3R Wholemeal bread	Sliced, unsliced, toast, fried. Includes all types of

		bread and bread products made with wholewheat flour: chappatis, pitta bread, rolls, hi-bran bread, wholemeal soda bread, wholemeal multi-seeded, wholemeal puri and roti, paratha, wholemeal English muffins, wholewheat tortillas
59 Brown, granary and wheatgerm bread	59R Brown, granary and wheatgerm bread	Sliced, unsliced, toast, fried. Includes Vitbe, rolls, Hovis Best of Both, Kingsmill 50/50, softgrain, brown chappatis, high fibre white bread, multiseed white bread
4 Other breads	4R Other bread	Breads made with non-wheat flour; sliced, unsliced, toast, fried. Includes rye bread, gluten free, oatmeal bread, besan flour chappatis, soya and linseed bread.
5 High fibre breakfast cereals	5R High fibre breakfast cereals	All breakfast cereals with non-starch polysaccharide (Englyst fibre) of 4g/100g or more. Eg All Bran, muesli, Shredded Wheat. Includes porridge & Ready Brek
6 Other breakfast cereals	6R Other breakfast cereals (not high fibre)	All breakfast cereals with non-starch polysaccharide (Englyst fibre) of less than 4g/100g. Eg Cornflakes, Coco Pops, Sugar Puffs. Includes Pop Tarts
7 Biscuits	7A Biscuits (manufactured/retail)	All types of purchased/retail biscuits, sweet and savoury. Includes cream crackers, flapjacks, breadsticks, oatcakes, rice cakes, crispbread, cereal bars, ice cream cornet/wafers, gluten free biscuits. Not caramel shortcake
	7B Biscuits (homemade)	All types of homemade biscuit, sweet and savoury
8 Buns, cakes, pastries and fruit pies	8B Fruit pies (manufactured)	All types of purchased/retail fruit pies, one and two crusts; includes strudel, individual fruit pies from takeaways
	8C Fruit pies (homemade)	All types of homemade fruit pies, any fruit, any pastry
	8D Buns cakes and pastries (manufactured)	Includes any purchased/retail buns, cakes or pastries; danish pastries, currant bun, doughnuts, American muffins, eccles cakes, Bakewell tarts, jam tarts, scones (sweet and savoury), sponge cakes, fruit cakes, eclairs, fruit loaf, malt loaf, gateaux, pastry, mince pies, sponge fingers, scotch pancakes, croissants, custard tart, lemon meringue pie, egg custard, caramel shortcake

9 Puddings	9C Cereal based milk puddings (manufactured)	Includes any purchased/retail cereal based milk puddings; rice pudding (including canned), custard (not egg custard), Angel Delight, blancmange, confectioners custard, sweet white sauce. Includes sweet packet mixes and custard packet mix made up with milk or soya milk
	9D Cereal based milk puddings (homemade)	All types of homemade cereal based milk puddings. Not made up packet mixes
	9E Sponge puddings (manufactured)	All types of retail/purchased sponge puddings, includes steamed, canned, suet pudding, jam roly poly, sponge flan, upside down pudding, treacle sponge, spotted dick
	9F Sponge puddings (homemade)	Includes any other sponge puddings and those made from homemade recipes
	9G Other cereal based puddings (manufactured)	Any other types of pudding purchased/retail. Includes trifle, pancakes, crumble, bread pudding, summer pudding, cheesecakes, tiramisu, rum baba, Christmas pudding, jelly cubes
	9H Other cereal based puddings (homemade)	Includes any other type of pudding made from homemade recipes. Includes jelly made up with water
		Milk and Milk Products
10 Whole milk	10R Whole milk	All types of whole cow's milk including pasteurised, UHT, sterilised, Channel Island, milk with added fatty acids
11 Semi-skimmed milk	11R Semi-skimmed milk	All types of semi-skimmed cow's milk including pasteurised, UHT, sterilised, canned, milk with added vitamins or fatty acids
60 1% Milk	60R 1% Milk	Includes 1% and 0.75% fat milk
12 Skimmed milk	12R Skimmed milk	All types of skimmed cow's milk including pasteurised, UHT, sterilised, canned, milk with added vitamins or fatty acids, Flora Pro.Activ
13 Other milk and cream	13A Infant formula	Includes all types of infant formula and progress milks, dry powder or ready made; SMA, Cow and Gate, Milupa, Nanny, Farleys, Hipp

	13B Cream (including imitation cream)	All types, including; single, double, whipping, sour, imitation cream, aerosol, dream topping, Tip Top, creme fraiche
	13R Other milk1	Includes goats, sheeps, evaporated, condensed, dried milk, milkshake, milk with added fibre, coffee whitener, buttermilk, flavoured milk drinks, purchased hot chocolate, breast milk, and all milk alternatives including soya, rice, oat and lactose-free
14 Cheese	14A Cottage cheese	Includes diet and flavoured varieties
	14B Cheddar cheese	All types, including reduced fat cheddar cheese
	14R Other cheese2	All types except cottage and cheddar. Includes hard, soft, cream cheese, processed, reduced fat cheeses, vegetarian cheese, cheese spread, tofu and soya cheeses, sheep and goats cheeses, Benecol cheese. Not fromage frais or Quark
15 Yogurt, fromage frais and other dairy desserts	15B Yogurt	All types including soya, goats, sheeps, yogurt mousse, yogurt drink/smoothie, lassi, frozen yogurt, custard style yogurt, Greek yogurt, Yakult
	15C Fromage frais and other dairy desserts (manufactured)	All types of manufactured fromage frais or other dairy based desserts, includes chocolate and fruit cream desserts, mousse, milk jelly, junket, buttermilk desserts, fruit fools, creme caramel, panna cotta, chilled soya desserts, quark, egg custard
	15D Dairy desserts (homemade)	Includes any type of homemade fromage frais or dairy dessert
53 Ice cream	53R Ice cream	All types of ice cream, dairy and non-dairy, choc ices, ice cream desserts eg Arctic roll, ice cream containing lollies, milk ice lollies, low fat/low calorie ice cream, sorbet
	Eggs and Egg Dishes	
16 Eggs and egg dishes	16C Manufactured egg products including ready meals	Any type of manufactured/retail egg dishes including ready meals: quiches, flans, scotch eggs, meringue, pavlova, curried eggs, egg mayonaise sandwich filler
	16D Other eggs and egg dishes including homemade	Includes all types of egg (duck, hen, goose) boiled, fried, scrambled, poached, dried, omelettes (sweet or savoury), eggy bread. Includes any homemade egg recipe dish

	Fat Spreads	
17 Butter3	17R Butter	Salted and unsalted, butter ghee, spreadable butter. Not light spreadable butter, not half fat butter, not brandy butter
18 Polyunsaturated margarine and oils3	18A Polyunsaturated margarine	Margarine claiming to be high in polyunsaturated fatty acids
	18B Polyunsaturated oils	Includes corn oil, sunflower oil, solid sunflower oil
19 Low fat spread3	19A Polyunsaturated low fat spread	Spreads containing 40% or less fat, claiming to be high in polyunsaturated fatty acids. Includes cholesterol lowering spreads
	19R Low fat spread not polyunsaturated	Spreads containing 40% or less fat, not claiming to be high in polyunsaturated fatty acids. Includes cholesterol lowering spreads and half fat butter
20 Margarine and other cooking fats and oils NOT polyunsaturated	20A Block margarine	All hard margarine and block fats (75-90% fat)
	20B Soft margarine not polyunsaturated	Tub margarine not claiming to be high in polyunsaturated fatty acids
	20C Other cooking fats and oils not polyunsaturated	Includes blended vegetable oil, suet (animal and vegetable), lard, compound cooking fat, dripping, olive oil, rapeseed oil, ghee made from oil, animal fats
21 Reduced fat spread3	21A Reduced fat spread (polyunsaturated)	Spreads containing more than 40% and less than 80% fat, claiming to be high in polyunsaturated fatty acids. Includes cholesterol lowering spreads
	21B Reduced fat spread (not polyunsaturated)	Spreads containing more than 40% and less than 80% fat, not claiming to be high in polyunsaturated fatty acids; includes spreads made with olive oil or rapeseed oil and light spreadable butter. Includes cholesterol lowering spreads
	Meat and Meat Products	

22 Bacon and ham	22A Ready meals/meal centres based on bacon and ham	Any types of bacon and ham purchased/retail products including ready meals
	22B Other bacon and ham (including homemade dishes)	Includes bacon and gammon joints, steaks, chops and rashers, any ham except in ready meals
23 Beef, veal and dishes	23A Manufactured beef products (including ready meals)	Any types of beef and veal products purchased/retail, including ready meals, canned beef products and pastrami
	23B Other beef & veal (including homemade recipe dishes)	Includes beef and veal joints, steaks, mince, cooked beef slices and homemade recipes for stews, casseroles, meat balls, lasagne, chilli, beef curry, bolognese sauce, cottage pie. Includes beef based takeaway dishes
24 Lamb and dishes	24A Manufactured lamb products (including ready meals)	Any types of lamb product purchased/retail, including ready meals and canned products
	24B Other lamb (including homemade recipe dishes)	Includes lamb joints, chops, fillets and homemade recipes for Irish stew, shepherds pie, lamb curries and casseroles. Includes lamb based takeaway dishes
25 Pork and dishes	25A Manufactured pork products (including ready meals)	Any types of pork product (not ham or bacon) purchased/retail including ready meals and canned pork products
	25B Other pork (including homemade recipe dishes)	Includes pork joints, chops, steaks, belly rashers, crackling and homemade recipes for stews, casseroles, sweet and sour pork. Includes pork based takeaway dishes
26 Coated chicken and turkey manufactured	26A Manufactured coated chicken/turkey products	Any type of coated chicken or turkey products purchased/retail or takeaway. Includes Kentucky Fried Chicken, nuggets, drumsticks, chicken kievs, burgers (with/without bun)
27 Chicken and turkey dishes	27A Manufactured chicken products (including ready meals)	Any type of chicken or turkey products purchased/retail, including ready meals, sandwich fillings, canned chicken/turkey and dishes. Not chicken/turkey sausages. Not coated chicken/turkey

	27B Other chicken/turkey (including homemade recipe dishes)	Includes chicken and turkey roasts, barbecued, curries, stews, casseroles and any other homemade recipes, including coated chicken or turkey. Includes takeaway dishes. Not liver or giblets
28 Liver, products and dishes	28R Liver and dishes	Any type of liver (fried, stewed, braised, grilled) and liver dishes; liver casserole, liver sausage, liver pate. Includes liver-based ready meals
29 Burgers and kebabs	29R Burgers and kebabs purchased	Any type of purchased/retail or takeaway burger or kebab products including beefburgers, hamburgers, cheeseburgers, (with or without roll) doner/shish/kofte kebabs (with or without pitta bread and salad), grillsteaks, steaklets. Not homemade burgers or kebabs; not chicken
30 Sausages	30A Ready meals based on sausages	Any type of manufactured product/ready meal, eg toad in the hole, sausage and mash
	30B Other sausages (including homemade dishes)	All types of sausage and homemade sausage dishes, including takeaway. Beef, pork, chicken/turkey sausages, polony, sausage in batter, saveloy, frankfurters, sausage casseroles, toad in the hole, sausage meat stuffing, canned sausages. Not sausage rolls
31 Meat pies and pastries	31A Meat pies and pastries (manufactured)	Any type of purchased/retail meat pies and pastries: chicken, turkey, beef, ham, steak and kidney, pork pies, game pie, meat samosas, meat pancake rolls, Cornish pasties, sausage rolls
	31B Meat pies and pastries (homemade)	Includes any type of homemade meat pies or pastries
32 Other meat and meat products	32A Other meat products (manufactured including ready meals)	Any other type of purchased/retail meat products, canned meat or ready meal, including pepperami, corned beef, luncheon meat, meat paste, meat loaf, black/white pudding, faggots, haggis, salami, haslet, tongue, garlic sausage
	32B Other meat (including homemade recipe dishes)	Includes any other meat such as game (venison, grouse, rabbit, pheasant), duck, goose, pigeon, offal (not liver), giblets, oxtail and homemade recipe dishes
	Fish and Fish Dishes	

33 White fish coated or fried	33R White fish coated or fried	Any type of white fish or roe (cod, plaice, haddock etc) purchased/retail or homemade, coated and/or fried. Includes battered and fried takeaway white fish, fried, grilled or baked fish fingers, fish cakes, scampi, McDonalds Fillet o Fish
34 Other white fish, shellfish and fish dishes	34C Manufactured white fish products (including ready meals)	Any type of white fish (cod, plaice, haddock etc) product purchased/retail including ready meals, eg white fish in sauce. Not coated fish
	34D Other white fish (including homemade dishes)	Includes poached, steamed, grilled, baked, smoked, dried white fish, caviar, and homemade white fish dishes, eg kedgeree, fish curry
	34E Manufactured shellfish products (including ready meals)	Any type of shellfish purchased/retail product including shellfish based ready meals. Includes canned shellfish. Not takeaway shellfish products
	34F Other shellfish (including homemade dishes)	Includes any type of shellfish (mussels, prawns, crab etc) and homemade and takeaway shellfish dishes
	34G Manufactured canned tuna products (including ready meals)	Any purchased/retail product based on canned tuna, including tuna sandwich fillers and purchased tuna in sauce/dressing. Includes canned tuna (in brine, oil (any), spring water)
	34H Other canned tuna (including homemade dishes)	Includes homemade recipes based on canned tuna
35 Oily fish	35A Manufactured oily fish products (including ready meals)	Any type of oily fish purchased/retail product including canned in oil/brine/tomato, pickled, sushi, ready meals, taramasalata, pate, paste
	35B Other oily fish (including homemade dishes)	Includes any oily fish or roe such as herrings, kippers, mackerel, sprats, eels, salmon, tuna (not canned), sardines, trout (baked, fried, grilled). Also homemade recipes based on oily fish
		Vegetables, Potatoes
	36A Carrots (raw)	

36 Salad and other raw vegetables	36B Salad and other raw vegetables	All types of raw vegetables, including coleslaw, tzatziki, guacamole, fresh herbs. Purchased or homemade. Not salads made with cooked vegetables or potato salad
	36C Tomatoes raw	
37 Vegetables (not raw)	37A Peas not raw	Includes canned and pease pudding canned. Includes cooked dried, mushy, frozen and mange tout peas. Includes pea curry
	37B Green beans not raw	Includes cooked (fresh or frozen) or canned French, runner and green beans
	37C Baked beans	Canned baked beans in sauce. Includes baked beans with additions eg sausages, burgers, pasta
	37D Leafy green vegetables not raw	Includes cooked or canned broccoli, spinach, cabbage (all types), brussels sprouts, chard
	37E Carrots not raw	Includes boiled, fried, canned
	37F Tomatoes not raw	Includes fried, grilled, canned, sundried tomatoes and passata
	37I Beans and pulses (including ready meal & homemade dishes)	Any type of lentils, dried beans and pulses, and purchased/retail products, takeaway and homemade dishes based on these. Includes hummous, dahl, dosa, falafel, soya flour. Not baked beans. Not soup
	37K Meat alternatives (including ready meals and homemade dishes)	Any type of products based on meat alternatives such as textured vegetable protein (TVP), soya mince, Quorn and tofu. Includes ready meals and homemade dishes based on these
	37L Other manufactured vegetable products (including ready meals)	Any type of purchased/retail vegetable products, including ready meals
	37M Other vegetables (including homemade dishes)	Includes all other non-raw vegetables and homemade vegetable dishes such as vegetable curries, casseroles and stews, pies, vegetable lasagne, cauliflower cheese, vegieburgers (not soya/tofu), bubble and squeak, vegetable samosas,

		pancake rolls, ratatouille, vegetable fingers, vegetable stir-fries etc. Includes pickled vegetables. Includes vegetable based takeaway foods
38 Chips, fried and roast potatoes and potato products	38A Chips purchased including takeaway	Any type of purchased/retail or takeaway chips or French fries, including fresh and frozen, oven and microwave
	38C Other manufactured potato products fried/baked	Any other type of purchased/retail potato product (not chips) such as roast potato, sliced potato with or without batter, waffles, croquettes, crunchies, alphabites, fritters, hash browns, wedges. Fried, grilled or baked
	38D Other fried/roast potatoes (including homemade dishes)	Any homemade fried or roast potato products, including chips and potatoes roasted in fat
39 Other potatoes, potato salads and dishes	39A Other potato products and dishes (manufactured)	Any other type of potato product, purchased/retail. Including instant potato (Smash), canned potatoes, potato salad and potato based ready meals (cheese and potato pie, aloo curries)
	39B Other potatoes (including homemade dishes)	Includes all other types of potato such as boiled, mashed, baked and homemade potato salads and dishes
		Savoury Snacks
42 Crisps and savoury snacks	42R Crisps and savoury snacks	Includes all potato and cereal based snacks, popcorn (not sweet), twiglets, pretzels, pork scratchings
		Nuts and Seeds
56 Nuts and seeds	56R Nuts and seeds	Includes fruit and nut mixes, coconut, salted peanuts, nut butters, tahini, bombay mix
		Fruit
40 Fruit	40A Apples and pears not canned	Includes raw, baked, stewed (with or without sugar), dried, apple sauce. Includes Asian pears
	40B Citrus fruit not canned	Includes oranges, grapefruit, limes, tangerines, ortaniques etc
	40C Bananas	Includes baked bananas, banana chips

	40D Canned fruit in juice	Includes canned in water. Includes prunes
	40E Canned fruit in syrup	
	40R Other fruit not canned	Includes plums, grapes, apricots etc; raw and stewed. Fruit pie fillings, dried fruit, fruit salad
	Sugar, Preserves and Confectionery	
41 Sugars, preserves and sweet spreads	41A Sugar	Includes glucose, golden syrup, treacle, maple syrup
	41B Preserves	Includes jam, fruit spreads, marmalade, honey, lemon curd. Includes low sugar types
	41R Sweet spreads fillings and icing	Includes ice cream topping sauce, chocolate spread, mincemeat, glace cherries, mixed peel, icing, brandy/rum butter, marzipan
43 Sugar confectionery	43R Sugar confectionery	Includes boiled sweets, gums, pastilles, fudge, chews, mints, rock, liquorice, toffees, chewing gum, sweet popcorn, ice lollies (without ice cream), nougat, halva
44 Chocolate confectionery	44R Chocolate confectionery	Includes chocolate bars, filled bars, assortments, carob, diabetic and low calorie chocolate
	Non-Alcoholic Beverages	
45 Fruit juice	45R Fruit juice	Includes 100% single or mixed fruit juices/smoothies, sweetened or unsweetened, canned, bottled, cartons, carbonated, still, freshly squeezed, vegetable juice
	61R Smoothies	100% fruit and/or juice (not smoothies containing dairy)
57 Soft drinks, not diet	57A Soft drinks not low calorie concentrated1	All types including squashes and cordials and water used as a diluent
	57B Soft drinks not low calorie carbonated	All types, including tonic waterand carbonated energy drinks. Not carbonated mineral water; Not alcoholic lemonade
	57C Soft drinks not low calorie, ready to drink, still	All types of still soft drinks and energy drinks, not carbonated. Includes RTD Ribena and Sunny D

58 Soft drinks, diet	58A Soft drinks low calorie concentrated1	All low calorie, no added sugar, sugar free types and water used as a diluent
	58B Soft drinks low calorie carbonated	All low calorie, no added sugar, sugar free types; includes slimline tonic water and low calorie energy drinks. Not carbonated mineral water
	58C Soft drinks low calorie, ready to drink, still	All types of still soft drinks and energy drinks, not carbonated; low calorie, no added sugar, sugar free types
51 Tea, coffee and water	51B Tea (made up)	Infusion, instant, decaffeinated, vending machine with whitener and water used as a diluent. Includes green and instant fruit/herbal
	51C Herbal tea (made up)	
	51D Bottled water still or carbonated	Includes carbonated and still, herbal tonics. Not sweetened drinks or tonic water
	51R Tap water only	Includes water drunk alone, used in recipes, or used as diluent for powdered beverages only. Not water as diluent for concentrated soft drinks, instant coffee or instant tea
		Alcoholic Beverages
47 Spirits and liqueurs	47A Liqueurs	Includes cream liqueurs, Pernod, Southern Comfort, Tia Maria, cherry brandy, Pimms
	47B Spirits	70 % proof spirits (brandy, gin, rum, vodka, whisky)
48 Wine	48A Wine	White, red, rosé, champagne and sparkling wines
	48B Fortified wine	Port, sherry, vermouth, martini
	48C Low alcohol and alcohol free wine	Includes fruit juice and wine drinks
49 Beer lager cider and perry	49A Beers and lagers	Premium and non premium, stout, strong ale, low carbohydrate, homemade (bottled, draft and canned)

	49B Low alcohol & alcohol free beer & lager	Includes shandy
	49C Cider and perry	Includes Babycham
	49D Low alcohol & alcohol free cider & perry	
	49E Alcoholic soft drinks (Alcopops)	Includes fruit flavoured and spirit based alcoholic soft drinks, and low calorie versions, such as Bacardi Breezer
		Miscellaneous
50 Miscellaneous	50A Beverages dry weight4	Includes drinking chocolate, cocoa, Ovaltine, Horlicks, malted drinks, milk shake powder etc
	50C Soup1 (manufactured/retail)	Any type of purchased/retail soup products, includes dried, condensed, canned, fresh
	50D Soup (homemade)	All homemade soup recipes
	50E Nutrition powders and drinks	Includes Complan, Slimfast, Ensure, protein powders and meal replacement drinks
	50R Savoury sauces pickles gravies & condiments	Includes white sauces, cook in sauces, sauce mixes, tomato ketchup, Bovril/Marmite, pickles, chutney, stuffing, gravy, mayonnaise, salad cream and dressings, yeast, stock cubes, dried herbs and spices and tomato puree
		Commercial Toddlers Foods and Drinks
52 Commercial toddlers foods and drinks	52A Commercial toddlers drinks	Includes powdered, concentrated and ready to drink beverages specifically manufactured for young children
	52R Commercial toddlers foods	Includes instant and ready to eat foods specifically manufactured for young children

Categorisation and classification of main food group codes and names, subsidiary food group codes and names and subsidiary food group descriptions[266].

Appendix 4: Re-classifying of food groups using "Food Level dietary data" dataset.

''Food level dietary data'' dataset

This paragraph explains how a selected food group from the ''food level dietary data'' dataset can be manipulated and merged with other dataset to be used in the calculation of dietary quality component (DQc) score. In order to get a table list if all items in a certain food group (Fruit group in this example) with a certain characteristics the tab command need to be used as the following:

(1) tab FoodName if strpos(MainFoodGroupDesc, 'FRUIT') & strpos(FoodName, 'FRESH') | strpos(MainFoodGroupDesc, 'CANNED') & strpos(FoodName, 'JUICE').

<u>Then to generate variable for new groups of fruit items, the following command need to be used:</u>

(2) gen FruitGr=. , the new variable then labelled to be identified using this command: label variable FruitGr 'all Fruit group'.

<u>After that, the new variable '' FruitGr'' need to be recorded to categorise fruit group into fresh and canned fruits by using the following commands:</u>

(3) replace FruitGr =0 if MainFoodGroupDesc =='FRUIT' & SubFoodGroupDesc =='CANNED FRUIT IN JUICE'
(4) replace FruitGr =0 if MainFoodGroupDesc =='FRUIT' & SubFoodGroupDesc =='CANNED FRUIT IN SYRUP'
(5) replace FruitGr =1 if MainFoodGroupDesc =='FRUIT' & SubFoodGroupDesc =='APPLES AND PEARS NOT CANNED'
(6) replace FruitGr =1 if MainFoodGroupDesc =='FRUIT' & SubFoodGroupDesc =='BANANAS'
(7) replace FruitGr =1 if MainFoodGroupDesc =='FRUIT' & SubFoodGroupDesc =='CITRUS FRUIT NOT CANNED'
(8) replace FruitGr =1 if MainFoodGroupDesc =='FRUIT' & SubFoodGroupDesc =='OTHER FRUIT NOT CANNED'
(9) label define FruitGr 0 'canned fruit' 1 'fresh fruit'
(10) label values FruitGr FruitGr
(11) tab FoodName FruitGr if strpos(MainFoodGroupDesc, 'FRUIT')

Then, to produce and average amount for each individual for the Fruit group, the ‘’seriali’’ variable is the individual's id, and FruitGr is a new variable for the average amount of fruit for each fruit category for each individual and the variable ‘’TotalGrams’’ is the total amount for each food consumption occasion (stata commands: bysort FruitGr seriali : egen fruitmeansG = mean(TotalGrams) if FruitGr !=. , label variable fruitmeansG ‘individual's mean intake of fruit products’). This will generate the mean amount in grams for each fruit category for each individual.

Finally, to create dataset with the mean fruit amount (g) per person to merged into main dataset, these commands have to be used:

(1) keep seriali FruitG fruitmeansG
(2) duplicates drop
(3) gen Freshfruitg = fruitmeansG
(4) replace Freshfruitg =. if FruitGr==0
(5) gen cannedfruitg = fruitmeansG
(6) replace cannedfruitg =. if FruitGr ==1
(7) label variable Freshfruitg ‘ mean intake of fresh fruit in grams’
(8) label variable cannedfruitg ‘ mean intake of canned fruit in grams’
(9) drop if FruitGr ==.
(10) drop if cannedfruitg ==.

Then, to make the format so that the groups are along the horizontal (top) and one person (seriali) along the vertical using the following command: reshape wide cannedfruitg , i(seriali) j(FruitGr). Similarly reshape command need to be carried out with the fresh fruit group.

Appendix 5: Obtaining the ALSPAC data

1. **Data Management Plan**

Project title and brief description:

Adolescent diet and cardio-metabolic health (ALSPAC B2798)

Worldwide the number of children and adolescents with risk factors for cardiovascular disease such as obesity and high blood pressure is increasing. Prevention strategies to reduce blood pressure and obesity are a national and international public health priority.
The relationship between diet and obesity and cardiovascular risk factors such as high blood pressure have been studied in adult populations but there are fewer corresponding studies in adolescents.

This joint project will use datasets about children and adolescents from the Avon Longitudinal Study of Parents and Children (ALSPAC) to explore the relationships between diet, body size and adiposity, blood pressure and biomarkers for cardiovascular health and takeaway (fast) food consumption

The three main objectives are:

- To determine the longitudinal associations between diet, biomarkers (such as serum lipids and serum tocopherols) and blood pressure in UK adolescents.
- To determine the longitudinal association between diet and body size, and then to develop and test a simple dietary based risk tool to predict future obesity risk in young people
- To explore the association between density/proximity of takeaway (fast) food outlets around schools and BMI status of secondary school students.

An application was made to the University of Bristol in November 2016, requesting permission to use data from the Avon Longitudinal Study of Parents and Children for this project, ALSPAC project B number: B2798.
The ALSPAC executive (alspac-exec@bristol.ac.uk) approved the proposal and subsequent amendments, assigning a data buddy, Louise Jones (louise-rena.jones@bristol.ac.uk).

Four named researchers from the University of Leeds were granted permission to use the data:

- Dr Charlotte Evans, Principal applicant, Senior Lecturer in Nutritional Epidemiology
- Ziyi Li, Co-applicant 1, Research Postgraduate
- Catherine Rycroft, Co-applicant 2, Research Postgraduate
- Ayyoub Taher Co-applicant 3, Research Postgraduate

The required ALSPAC data was selected and purchased.
All four researchers signed and returned a Confidentiality Form: Agreement for Access to ALSPAC data, providing a web-link to the University of Leeds information security policy. Requested variables were made available during July – September 2017.

2. What data will be produced?

This project will use existing quantitative ALSPAC data provided by the University of Bristol as STATA dta files. No primary data collection is planned. However researchers will generate new variables for analysis, derived from the existing data.
E.g. Body Mass Index (BMI) from height and weight, BMIz scores from BMI, age and gender, Sleep duration from bedtimes and wake times.

The sequence of STATA commands used to generate new variables will be saved as STATA do files.
New variables will be saved in STATA dta file format.
A catalogue of new variables will be created in a Microsoft Excel spreadsheet.
Full descriptions of how new variables were derived will be saved as Microsoft Word Documents. During and at the end of the project copies of these Word documents will be saved as pdf files to be sent to the University of Bristol ALSPAC team.

3. How will data be documented and described?

Existing variables in the ALSPAC dataset are fully described in the ALSPAC Data dictionary (Guide to ALSPAC data, search instructions, search index, copies of questionnaires and built pdf files for each assessment type and time point). Variables are listed in the ALSPAC variable catalogues provided as a series of Excel spreadsheets, one for each assessment type. The variable catalogues show every single variable name (Var name) and label (Var label) with the source of the data (Filename) set out in columns, with separate worksheets for each assessment time point. All documentation can be downloaded as zip files from http://www.bristol.ac.uk/alspac/researchers.

Newly created variables will be logged in a shared Microsoft Excel spreadsheet with individual worksheets for each researcher. This will serve as an addition to the variable catalogue provided by ALSPAC and the spreadsheet/worksheets will be set out in the same way.

Each researcher will record a full description of their newly created variables in an individual, ongoing Microsoft WORD document. New variables should be tabulated in WORD showing the date when they were created, the variable name and descriptive label used in STATA, with a clear explanation of how the new variable was derived, describing both the data set and version and the variables used. A copy of and/or reference to the saved STATA do file should be included in the description so that this work is reproducible.

Researchers will follow a standard protocol for naming new variables; the initials of the researcher who created the new variable, the data source using the file name already set out by ALSPAC, then a unique short name or abbreviation.
E.g. crkuslpd9 = new variable created by CR, derived from data in the KU file (Questionnaire: Your Son/Daughter at 9 years, completed by mother), sleep duration at 9 years.

4. **How will data be structured and stored?**

Data from ALSPAC was downloaded as a STATA dta file on 5.9.2017. Using the access password provided.
This file is 41,457KB in size and contains 680 variables and 15,445 observations. Two copies are saved:

- A **master** copy saved as MASTER Evans_05Sep2017.dta in the restricted folder: \\ds.leeds.ac.uk\shared\MAPS\Research\PRC\NEG\NEG051 ALSPAC\G. Data\ MASTER copy Amended data Sept 2017.
- A **working** copy saved as Evans_05Sep2017.dta in the restricted folder: \\ds.leeds.ac.uk\shared\MAPS\Research\PRC\NEG\NEG051 ALSPAC\G. Data\WORKING copy Amended data Sept 2017.

Each research postgraduate will have a named a folder containing their personal working copy of the original dataset and will save additional versions as they proceed through their research analyses. Each subsequent version of the dataset should be named with the Researcher's name, version number, month and year when first saved.
E.g. Ziyi Vers1 Sept 2017….Ziyi Vers2 Oct 2017...Ziyi Vers3 Oct 2017….Ziyi Vers4 Nov 2017. Researchers will record which variables/observations have been dropped from and/or added to each version of their dataset in an ongoing Microsoft WORD document.

During the active phase of the project all research data will be stored on the University of Leeds N: drive in restricted access folders. N:\MAPS\Research\PRC\NEG\NEG051 ALSPAC\G. Data.

The University of Leeds N: drive is a (collaborative) storage service, which comprises enterprise level disk storage and file servers distributed across physically separate and secure data centres with appropriate fire suppression equipment. Data is synchronously replicated between the storage units in the two on-campus data centres. A further copy of this data is asynchronously replicated every 4 hours to a third off-campus storage unit. NAS (Network Attached Storage) layer snapshots, that are accessible by end users, are taken every day between 10pm-midnight and are retained for up to 64 days. Further system level snapshots, which are only accessible by system administrators, are taken and retained on the following schedule: Every 4 hours (retained for 25 hours), every 24 hours (retained for 28 days) and once each month (retained for 52 weeks). All snapshots are replicated using the same synchronous/asynchronous schedules and to the same storage locations as described for data storage. Both the storage and NAS layers are located behind the University's Institutional firewall to protect against external attacks.

Off-campus access to the restricted folders in the N: drive is via the Citrix portal and the Desk Top Anywhere app, using a University username and password.

As research will be desk-based rather than "in the field" it is not anticipated that data will need to be stored on portable electronic devices (such as University owned lap-top computers). If sensitive data (as defined by the Data Protection Act) is stored on portable electronic devices it will only be on a temporary basis and only if protected by encryption software to FIPS 140-2 standard, as set out by the University of Leeds information protection policy. The same policy directs that any sensitive data that is to be transmitted electronically must be encrypted to FIPS 140-2 beforehand.

ALSPAC's access policy stipulates that ALL data transferred electronically must be encrypted using AES-256 encryption (using compression tools such as WinZip or 7-Zip).

5. Are there any 'special' requirements for your data?

ALSPAC study participants gave information on the understanding that it will be treated confidentially and anonymously. The data provided by ALSPAC is already anonymised with no exact address, complete postcodes or complete dates of birth, but confidentiality is potentially an issue as ALSPAC is a regionally based study that recruited children born in a specific period. Researchers have agreed not to try to identify study participants.

Only the named researchers on the proposal form (CE, ZL, CR and AT) have permission to use this data. Under the terms of the agreement for access to ALSPAC data, data cannot be shared with any other researchers.
Through Faculty IT the NEG database manager, Neil Hancock, set up restricted folders in N:\MAPS\Research\PRC\NEG\NEG051 ALSPAC. The restricted folders in NEG051 ALSPAC can only be accessed by CE, ZL, CR or AT using their University username and password.

Any breaches of data security such as access by unauthorised persons or unencrypted data transfer, must be reported to the ALSPAC executive immediately.

Derived variables must be returned to the ALSPAC data buddy with appropriate documentation, whenever a manuscript is submitted for approval by the ALSPAC executive.

The approved project will run until 30th September 2020. Under the terms of the agreement for access to ALSPAC data, when the project ceases the ALSPAC datasets must be securely destroyed.

6. What are the plans for data sharing and access?

Data sharing and access are restricted under the terms of the agreement for access to ALSPAC data: Only named researchers can use the data and ALSPAC datasets must be securely destroyed at the end of the project. Derived variables must be returned to the ALSPAC data buddy, to be incorporated into the main resource and made available for all researchers.

Researchers intend to write papers and thesis chapters about this project.

Research output intended for the public domain (E.g. working papers, non-peer reviewed or peer-reviewed full papers), other than submissions to conferences, must be sent to the ALSPAC executive with a completed papers checklist for approval *before* journal submission. ALSPAC's data management policy does not permit ALSPAC datasets used in a publication to be deposited in publicly available resources.

ALSPAC request an electronic copy of any **reports or publications** that use ALSPAC data as soon as possible.

ALSPAC request an electronic copy of any **theses** that use ALSPAC data as soon as possible after graduation.

7. What are your main data challenges? Who can help?

NEG database manager, Neil Hancock, does not have authorised access to the ALSPAC data, but will provide IT guidance and support.

Named researchers have read and understood the following policies, which are relevant to the project:

- ALSPAC access policy Vers.7.0 September 2016. http://www.bristol.ac.uk/media-library/sites/alspac/documents/ALSPAC_access_policy.pdf

- University of Leeds Information Protection Policy version 1.2 March 2016 http://it.leeds.ac.uk/info/116/policies/249/information_protection_policy

- University of Leeds Policy on safeguarding data-storage, back-up and encryption http://it.leeds.ac.uk/info/116/policies/255/policy_on_safeguarding_data-storage_backup_and_encryption

8. Who is responsible for managing the data? What resources will you need?

The Principal applicant, Dr Charlotte Evans will direct the overall data management process. Dr Evans will ensure that the terms of the agreement for access to ALSPAC data are met and will report any security breach to the ALSPAC executive.

Together with the database manager, Neil Hancock, Dr Charlotte Evans will take responsibility for secure destruction of ALSPAC data at the project's end.

The three Co-applicants, Ziyi Li, Catherine Rycroft and Ayyoub Taher, will produce meta-data/documentation about the new variables they create and will carry out day-to-day cross-checks and quality control and ensure that back-up is maintained.

Appendix 6: Confidentiality Form: Agreement for Access to ALSPAC data

University of BRISTOL

ALSPAC
School of Social and Community Medicine
Oakfield House, Oakfield Grove
Bristol, BS8 2BN

www.alspac.bristol.ac.uk

Confidentiality Form: Agreement for Access to ALSPAC data

Please complete **all** of the following boxes:

Name:	AYYOUB TAHER	Institution:	University of Leeds
Email:	FY06AKT@leeds.ac.uk	ALSPAC Project B number:	B2798
Project title:	ADOLESCENT DIET AND CARDIOMETABOLIC HEALTH		
Project end date:	30.9.2020	Role within project:	CO. APPLICANT RESEARCH POSTGRADUATE

The information obtained in any study using ALSPAC data has been given by the study participants on the understanding that it will be treated confidentially and anonymously. Please tick each point and sign the form to indicate that you will abide by the following:

1) I will not try to identify study participants. ☑

2) I have read and understood the data security issues highlighted in the 'ALSPAC access policy v 7.0' (section 6 summary of researchers and responsibilities) and will adhere to them for the duration of this project. ☑

3) I will not share my dataset with any researchers, other than those named on the proposal form and approved by the ALSPAC executive for **this** particular project, and only if they also sign a copy of this form. I will not attempt to match my dataset with any other provided by ALSPAC for previous projects (See section 6 summary of researchers and responsibilities 'ALSPAC access policy v 7.0'). ☑

4) If your project involves potentially identifying data, the data will be released using our Split Stage Protocol. If you are involved in one of these projects please confirm you have read understood the procedures for this process stated in the 'ALSPAC access policy' and will adhere to them for the duration of this project ☑

5) Prior to submission of any papers for publication, I will complete a papers checklist (http://www.bristol.ac.uk/alspac/researchers/data-access/) and submit it, along with a manuscript of my paper, to the ALSPAC Executive for approval. ☑

6) When I submit a manuscript for approval, I will return any derived variables to my data buddy together with appropriate documentation. ☑

University of BRISTOL

ALSPAC
School of Social and Community Med
Oakfield House, Oakfield Grove
Bristol, BS8 2BN

7) I understand that I am required to securely destroy any ALSPAC datasets provided when my approved project ceases. ☑

8) I have provided a weblink to my institution's information security policy (written below; I understand ALSPAC *cannot* send data until this is done). ☑

http://www. http://it.leeds.ac.uk/info/116/Policies/249/information-Protection-Policy

Signature: .... أبرم .... **Date**: 6.7.2017

Failure to abide by these rules could result in exclusion of your institution from further access to ALSPAC data and you will be subject to all appropriate sanctions, where applicable.

Please return your completed form to your assigned data buddy

Appendix 7: Research Data Agreement with Ordnance Survey

Ordnance Survey

Research Data Agreement

This Agreement is made between:

(1) Ordnance Survey Limited, a company registered in England and Wales (company registration number 09121572) whose registered address is at Explorer House, Adanac Drive, SOUTHAMPTON, UK, SO16 0AS (**OS**); and

(2) Ayyoub Taher

University of Leeds, incorporated by Royal Charter in the United Kingdom (Royal Charter number RC000658), whose principal place of business is at Woodhouse Lane, Leeds LS2 9JT (the **Researcher**).

Background:

A OS is Britain's mapping agency.

B The Researcher wishes to carry out a study 'The relationship between density of takeaway (fast) food outlets and BMI status of UK secondary school aged adolescents' in relation to samples of the data products detailed in Schedule 1 (**OS Data**) in order to evaluate the relationship between BMI (weight) status of secondary school adolescents and both proximity and density of fast-food outlets in the Avon region (England) and to evaluate the association between the frequency of consuming fast food and location of fast food outlets around secondary schools (the **Purpose**).

C OS has agreed to provide the Researcher with a licence to use the OS Data for the Purpose on the terms set out in this Agreement.

Agreed Terms:

1 Definitions & interpretations

1.1 In this Agreement, the following terms shall have the following meanings:

Agreement	means this agreement (including Schedule 1).
Commencement Date	means 4/12/17.
Confidential Information	means the OS Data and any information or material of a confidential nature supplied by (or on behalf) of one party (the **Disclosing Party**) to the other (the **Receiving Party**) or otherwise obtained by the Receiving Party (including any information relating to the business or financial or other affairs of OS).
Intellectual Property Rights	all patents, copyrights, design rights, trade marks, service marks, trade secrets, know-how, database rights, domain names, moral rights and other rights in the nature of intellectual property rights (whether registered or unregistered) and all applications for the same, anywhere in the world.
OS Net Data	means OS Net Feed data derived from observations collected from the OS Net base stations.
OS Net Feed	means the national infrastructure of Global Navigation Satellite System (**GNSS**) base stations across Great Britain, developed by OS. This infrastructure is called OS Net. OS Net base stations collect real time GNSS observations. These observations are then made available in Leica Binary 2 (**LB2**), Radio Technical Commission for Maritime Services (**RTCM**) or some other format.

Points of Interest Data means any and all data relating to locations and descriptions of natural and man made points of interest in Great Britain held within a database owned, developed and maintained by PointX Limited, which OS is permitted to licence in accordance with the terms of the distribution agreement for Points of Interest Data between PointX Limited and OS, as amended and updated from time to time.

1.2 The Schedule and Recitals form part of this Agreement and shall have effect as if set out in the body of this Agreement and any reference to this Agreement includes the Schedule and Recitals.

2 Grant of Licence

2.1 In consideration of the payment of one pound sterling (£1) by the Researcher to OS (the receipt of which OS hereby acknowledges) and the mutual rights and obligations set out herein, OS hereby grants to the Researcher a non-exclusive, non transferable licence to use the OS Data for the Purpose in accordance with the terms of this Agreement (the **Licence**).

2.2 Subject to Clause 2.3 below, the term of this Agreement and the Licence shall be for a period of 34 months from the Commencement Date (the **Term**).

2.3 The term of the Licence in relation to any AddressBase®, AddressBase® Plus and/or AddressBase® Premium data contained in the OS Data shall be the earlier of the expiry of the Term or 3 months from the date of supply of the AddressBase®, AddressBase® Plus and/or AddressBase® Premium data to the Researcher (the **AddressBase® Term**).

2.4 Within 30 days of the expiry of

2.4.1 the AddressBase® Term, the Researcher shall destroy or delete all copies of AddressBase® data, AddressBase® Plus data and AddressBase® Premium data; and

2.4.2 the Term, the Researcher shall destroy or delete all copies of the OS Data; and

2.4.3 in each case within 7 days of the deletion or destruction of the data referred to in Clauses 2.4.1 and 2.4.2, the Researcher shall provide OS with a statement signed by the Researcher's duly authorised employee to confirm that neither Researcher nor any third party to which the Researcher has passed copies of such data continues to hold such data.

2.5 **OS Net Data**

2.5.1 Following signature of this Agreement by OS, OS shall inform its communications provider that the Researcher is entitled to access the OS Net Data.

2.5.2 The Researcher shall arrange (at its own cost and risk) a link with the communications provider for the purpose of accessing the OS Net Data.

2.5.3 The Researcher agrees and undertakes to keep the access to the OS Net Data in its exclusive possession and control and safeguard the OS Net Data from unauthorised access and unauthorised use.

2.5.4 OS reserves the right to modify, enhance or make additions to the OS Net Data in any way whatsoever as OS may in its sole discretion decide but shall not be obliged to do so. OS agrees to give the Researcher not less than three (3) months' notice of any change in the output format of the observations of the OS Net Data that OS deems will result in the Researcher being unable to access the OS Net Data pursuant to this Agreement.

2.5.5 Whilst the OS Net Data currently relies on GPS, OS reserves the right to use GPS and/or alternative GNSS at its sole discretion.

2.5.6 OS will provide the Researcher with a list of the coordinates of all OS Net base stations used to create the OS Net Data, which may be amended from time to time by OS at its sole discretion.CONTR@CT17

2.5.7 If OS discontinues access and use of OS Net, it will give the Researcher as much notice as reasonably practicable. OS will use its reasonable endeavours to inform the Researcher of any alternatives to the OS Net Data it is able to provide. OS reserves the right to discontinue OS Net at any time without penalty.

3 Ownership

3.1 All rights not expressly granted are reserved to OS and its licensors (including the Crown).

17 Contracts (Rights of Third Parties) Act 1999

17.1 A person who is not a party to this Agreement has no rights under the *Contracts (Rights of Third Parties) Act 1999* to enforce or enjoy the benefit of any term of this Agreement.

Signed for and on behalf of **Ordnance Survey Limited**		Signed for and on behalf of **University of Leeds**	
Signature		**Signature**	
Name	NICK GROOME	**Name**	Ayyoub Taher
Title	Externel Research Mgr	**Title**	Mr
Date	5/12/17	**Date**	04/12/2017

Appendix 8: Points of Interest data

1. **Response from OS team**

A. "I've had a look at the current data and Ayyoub is right in that we only supply eight codes within the Food Classification Codes (0102). However, we also subdivide the 01020043 Code further through use of the Qualifier_Type and Qualifier_Data field. While Qualifier_Type in this case will always be "Restaurant", the Qualifier_Data holds more information on the actual type of the restaurant. That said, having looked at the "Brand" field for some explanation it does appear that the majority of fast food related outlets are still contained within 0018, 0019 and 0020. I'll have to get onto our supplier to get a definitive answer on the way the classification was condensed down, as we can't seem to find any documentation on this in-house".

B. "With 0043 being subdivided by use of the Qualifier_Data field (Qualifier_Type as per previous email is "Restaurant Type" in all cases for this code. None of the other food codes are subdivided. There may have been some data quality assurance surrounding the food category around the time of the schema change or an effort to correctly reclassify as much as possible/practical, though this is purely a guess. I can conclude that, given there are 30 unique "Qualifier_Data" entries, we are providing the same 37 categories we provided previously though using a slightly more complex data structure".

2. Misclassification of some of the food outlets

All food outlets classified as missing in 2011 but exist in 2012 were cross-checked in all other classes within eating and drinking category. Highlighted food outlets were either cannot be found or found to be classified as restaurants or another type of outlet.

Checked and found to be classified as restaurants in 2011

Checked and **Not** found within all other classes including restaurants, cafes, interner cafes, pubs and bars in 2011

Checked and found to be classified as cafes or bars in 2011

2012		2011	
Palace Chinese Takeaway	1	Panda Chinese Takeaway	1
Panda Chinese Takeaway	1	Panda Takeaway	1
Panda Takeaway	1	Pang Fish & Chips	1
Pang Fish & Chips	1	Pangs Chinese Takeaway	1
Papas Pizza	2	Papas Pizza	1
Papas Traditional Fish Restaurant & T..	1	Papas Traditional Fish Restaurant & T..	1
Parky's Chippy	1	Pappadoms	1
Pasta Pizza	1	Patchway	1
Patchway	1	Patchway Fish Bar	1
Pearl City	1	Pearl City	1
Peking Chef	3	Peking Chef	1
Peking Dynasty	1	Pepes	1
Pepenero	1	Perfect Pizza Ltd	4
Pepes	1	Philpotts	1
Perfect Pizza Ltd	5	Pic Niks	1
Philpotts	1	Piccolo's Pizza	1
Pic Niks	1	Pick a Pizza	1
Piccante Pizza	1	Pill Village	1
Piccolo's Pizza	1	Pisces	1
Pick a Pizza	1	Pit Stop	1
Picton Take Away	1	Pizza & Real Italian Ice Cream	1
Pieminister	2	Pizza Casa	1
Pill Village	1	Pizza D Q	1
Pisces	1	Pizza Giant	1
Pit Stop	1	Pizza Magic	1
Pizza & Real Italian Ice Cream	1	Pizza Palace	1
Pizza Bella	1	Pizza Picante	1
Pizza Casa	1	Pizza Plus	1
Pizza Choice	1	Pizza2go	1
Pizza Fresca	1	Pizzarella	1
Pizza Hut	6	Portishead Fish Bar	1
Pizza King	1	Portishead Restaurant	1

Pizza Magic	2	Portland Cafe	1
Pizza Palace	1	Premier Curry	1
Pizza Picante	1	Presto	1
Pizza Plus	1	Prince's Traditional Fish & Chips	1
Pizza Top to Go	1	Pure Deer	1
Pizza2go	1		
Pizzarella	1		
Planet Pizza Ltd	1		
Polish Cukiernia	1		
Portishead Fish Bar	1		
Portishead Restaurant	1		
Portland Cafe	1		
Portuguese Taste	1		
Premier Curry	1		
Presto	1		
Pret A Manger	3		
Prince's Traditional Fish & Chips	1		
Princes Pantry	1		
Pure Deer	1		
Pure Taste	1		

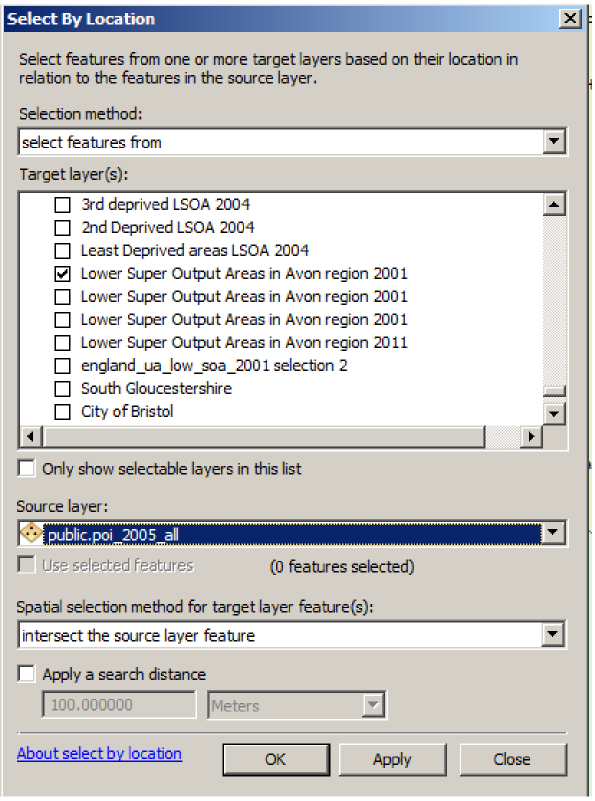
Example of a full list of fast food names stated with the letter “P” classified as HFTs within eating and drinking category as 0018, 0019 and 0020 classes in 2011 and 2012.

Appendix 9: Number of HFTS by IMD quintiles

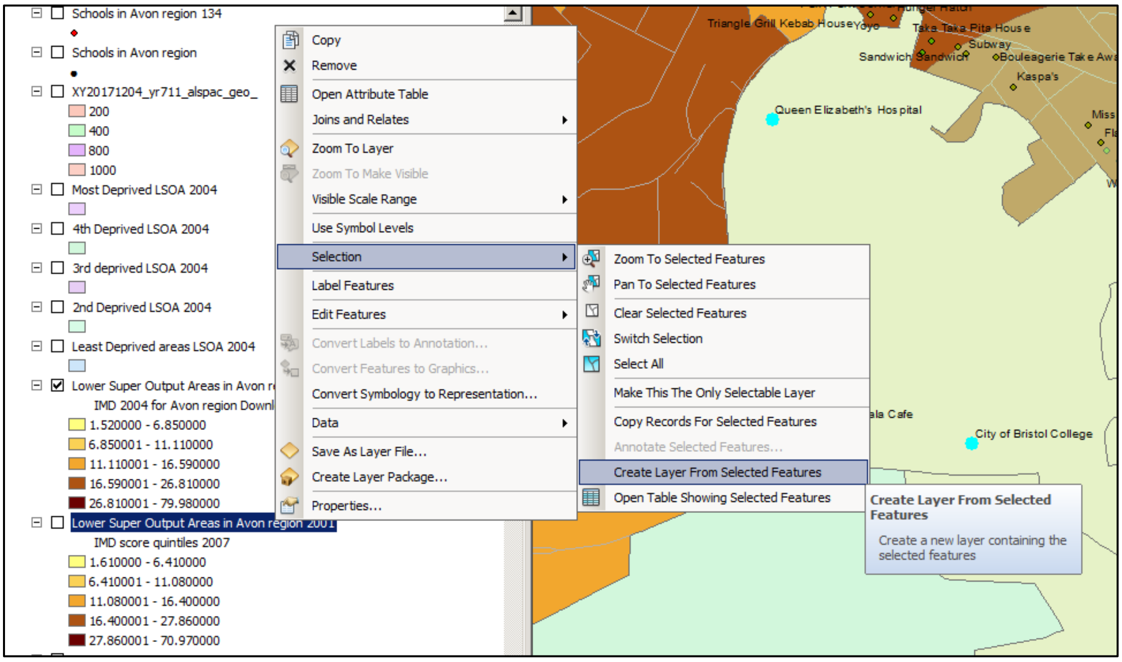
From the GIS software – navigate to the selection tab and then:

1. Click on Selection tab from the tool bar

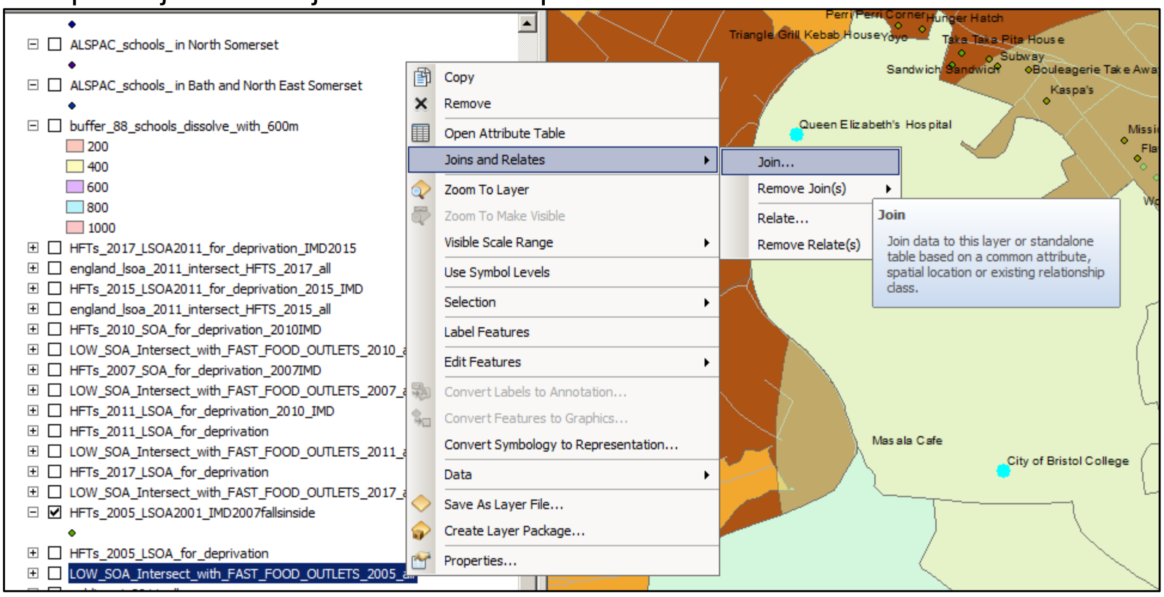
- Choose the option select by location and another window will appear; and you need to set:
    - **a.** target layer: LSOA with IMD scores
    - **b.** Source layer: HFTs for the specified year
    - **c.** Spatial selection method: Intersect the source layer feature
    - **d.** then Click OK



2. Right click on LSOA layer and choose selection and then click on "create layer from the selected feature"

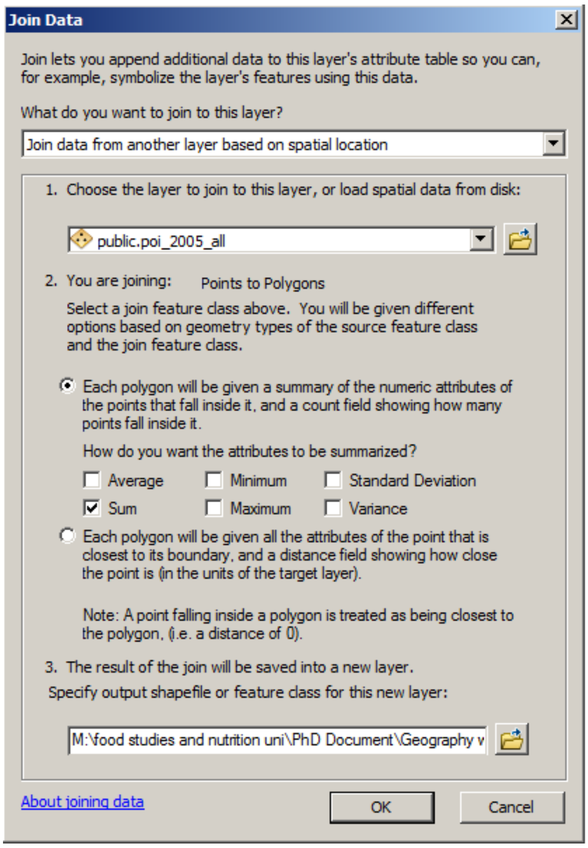


3. Right click on the created layer from the previous step and choose the option "join" from join and relate option



4. A window will open and you need to set:

a. The layer to join
b. Tick on each polygon gave a summary
c. Tick on Sum
d. Save where appropriate and click ok



Finally, open attribute table of the created LSOA layer after joining the layer with HFTs features. The sum of HFTs located within each LSOA has been calculated.

Appendix 10: Unadjusted and adjusted models for 1000 metres

Linear (clustered) regression analysis between availability of HFTs at baseline within 1000 metres road network school buffer and BMI z–score and body fat percentage at 15 and 17 years

Variable of interest	Unadjusted model								Adjusted model							
Mean age 15 years	**BMI Z-score**				**Body fat percentage**				**BMI Z-score**				**Body fat percentage**			
	Coeff	**CI**		**P**	**Coeff**	**CI**		**P**	**Coeff**	**CI**		**P**	**Coeff**	**CI**		**P**
Takeaway available	-1.13E-03	-0.05	0.04	0.96	0.22	-0.35	0.80	0.44	-0.02	-0.07	0.02	0.33	-0.13	-0.61	0.34	0.58
Mean age 17 years																
Takeaway available	-0.08	-0.17	-2.14E-03	0.045	-0.26	-1.37	0.84	0.63	-0.05	-0.14	0.04	0.24	-0.64	-1.68	0.40	0.22
Both models were adjusted for BMI z–score at baseline; Adjusted analysis for gender, ethnicity, individual deprivation level and physical activity level																

Logistic (clustered) regression between availability of HFTs at baseline within 1000 metres and risk of being obese at age 15 and 17 years.

Takeaway available	**Unadjusted analysis**				**Adjusted analysis**			
Risk of being obese	**OR**	**CI**		**P**	**OR**	**CI**		**P**
Mean age 15 years	0.78	0.45	1.35	0.38	0.65	0.34	1.25	0.20
Mean age 17 years	0.67	0.49	0.90	0.01	0.59	0.38	0.91	0.02
Both models were adjusted for being obese or not at baseline; Adjusted analysis for gender, ethnicity, individual deprivation level and physical activity level								

Appendix 11: Stratifying analysis for 1000 metres (by individual IMD level).

Linear (clustered) regression analysis between availability of HFTs at baseline within 1000 metres road network school buffer and BMI z–score and body fat percentage at 15 and 17 years, among students from the most deprived areas

Variable of interest	Unadjusted model								Adjusted model							
Mean age 15 years	**BMI Z-score**				**Body fat percentage**				**BMI Z-score**				**Body fat percentage**			
	Coeff	**CI**		**P**	**Coeff**	**CI**		**P**	**Coeff**	**CI**		**P**	**Coeff**	**CI**		**P**
Takeaway available	-0.03	-0.07	0.02	0.19	0.09	-0.51	0.69	0.77	-0.05	-0.10	5.13E-04	0.05	-0.28	-0.87	0.31	0.34
Mean age 17 years																
Takeaway available	-0.07	-0.16	0.02	0.12	-0.14	-1.08	0.79	0.76	-0.06	-0.16	0.04	0.24	-0.56	-1.49	0.38	0.23

Both Models were adjusted for BMI z–score at baseline; Adjusted analysis for gender, ethnicity, individual deprivation level and physical activity level

Linear (clustered) regression analysis between availability of HFTs at baseline within 1000 metres road network school buffer and BMI z–score and body fat percentage at 15 and 17 years, among students from the least deprived areas

Variable of interest	Unadjusted model								Adjusted model							
Mean age 15 years	**BMI Z-score**				**Body fat percentage**				**BMI Z-score**				**Body fat percentage**			
	Coeff	**CI**		**P**	**Coeff**	**CI**		**P**	**Coeff**	**CI**		**P**	**Coeff**	**CI**		**P**
Takeaway available	0.07	-0.03	0.17	0.17	0.52	-0.71	1.75	0.40	0.05	-0.06	0.15	0.39	0.24	-0.61	1.08	0.57
Mean age 17 years																
Takeaway available	-0.15	-0.36	0.06	0.16	-0.90	-4.05	2.25	0.56	0.02	-0.23	0.26	0.89	-0.40	-2.97	2.18	0.75

Both Models were adjusted for BMI z–score at baseline; Adjusted analysis for gender, ethnicity, individual deprivation level and physical activity level

Appendix 12: Agreement test

It is interesting to mention the fact that DQI-A percentage score has been calculated using 2 different methods. At first, the researcher (I) was interested in calculating the mean percentage score of DQI-A using the mean intake of consumed food pre-calculated by the NDNS team obtained from the personal dietary data dataset, with further categorisation done by the researcher himself (method 1). However, due to the fact than each of the participants has provided 3 and/or 4 day diary records, and according to previous research done [36], the DQI-A percentage score need to be calculated for each day independently. Therefore, the need to use level dietary data dataset from the NDNS databank was essential. This dataset provided information about daily consumption for each of the participants in each diary day. In the second method, the personal dietary data dataset was not used in calculation DQI-A components and sub-components percentage score, it was only used to gain an overview of how each of the 11 food groups may look like during the analysis.

Interestingly, after using the Bland & Altman method, the limits of agreements was found to range between -31.910 to 23.402 and with mean difference= -4.25 (CI -4.554 to -3.954). Although the limits of agreement was narrower compared to range of variables (-26.040 to 70.514) the mean difference (bias) was statistically significant ($p<0.01$), see Figure 1.

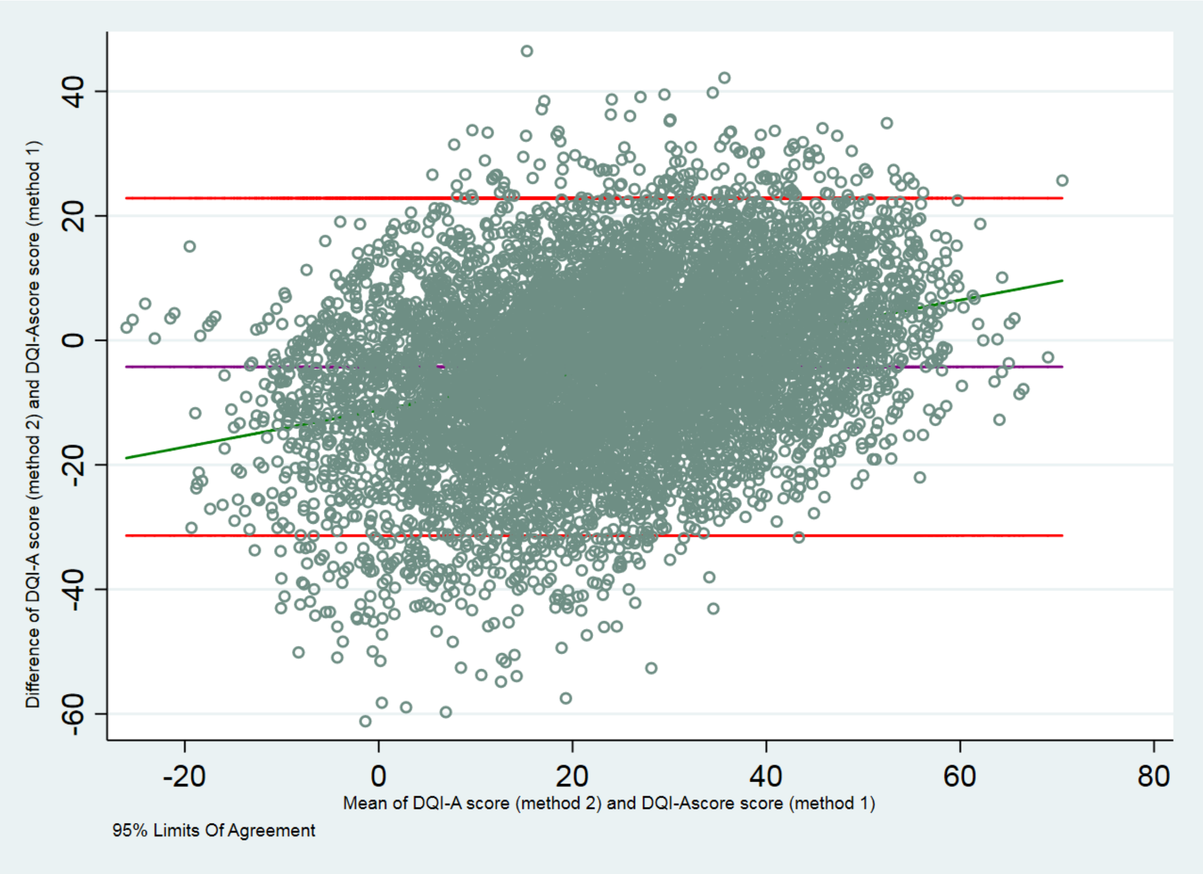


Figure 1 Plot of differences between method 1 and method 2, verses, and the mean of the two measurements. The bias of -4.25 percentage is represented by the gap between the X axis, corresponding to zero differences, and the parallel line to the X axis at -4.25 percentage.

Appendix 13: Number of HFTs and Deprivation level

- **Number of HFTs by IMD (2004, 2007, 2010 and 2015)**

All of the figures below (Figure 1, Figure 2 and Figure 3) represent the total number of Hot Food Takeaways (HFTs) by the Index of Multiple Deprivation Score quintiles. As can be seen in 2005, 2007 and 2011 the highest number of HFTs were located within the most deprived areas. Nevertheless, in 2010, 2015 and 2017 the highest number of HFTs were located within the 4th most deprived areas. In general, the lowest number of HFTs were located within the least and 2nd least deprived areas whereas the highest number of HFTs were observed among the 4th and 5th (highest) deprived areas.

Statistical differences in the number of hot food takeaways were not observed among all deprivation quintiles of Lower Super Output Areas (LSOAs). The number of HFTs was not found to be normally distributed by the IMD score quintiles. Therefore, the non-parametric test Kruskal-Wallis ANOVA followed by Mann-Whitney test were used. The first quintile of IMD score was always used as a reference group for all years. The star symbol (*) in each of the Figures 1, 2 and 3 illustrate that there were significant differences between the reference group (RG) and other IMD score quintiles. Nevertheless, in 2005, the differences between the numbers of HFTs among the IMD score quintiles were only observed between the reference group, 4th and 5th IMD quintiles.

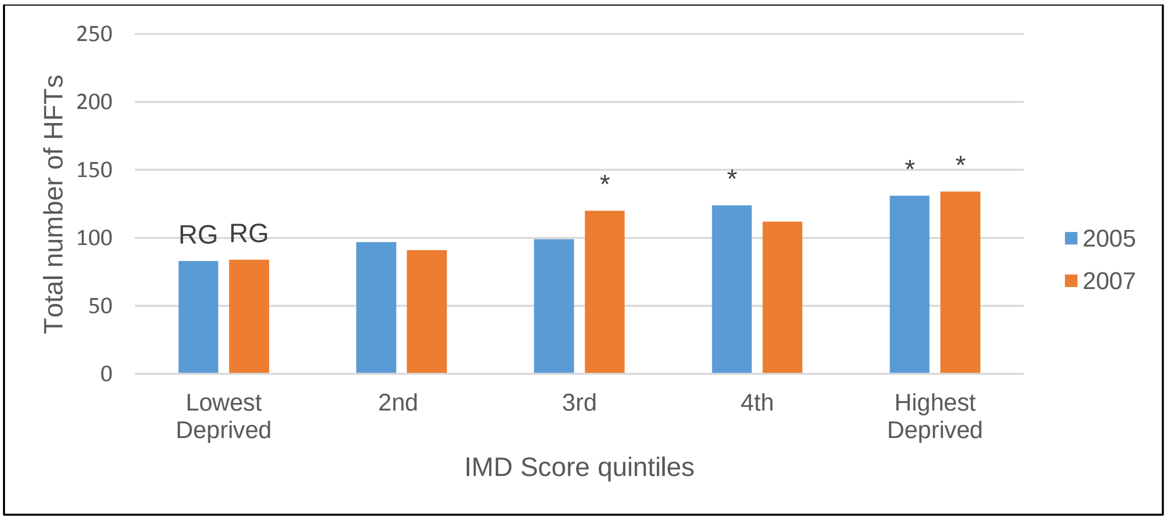


Figure 1 The total number of HFTS by IMD_2007 quintiles Score, in 2005 and 2007

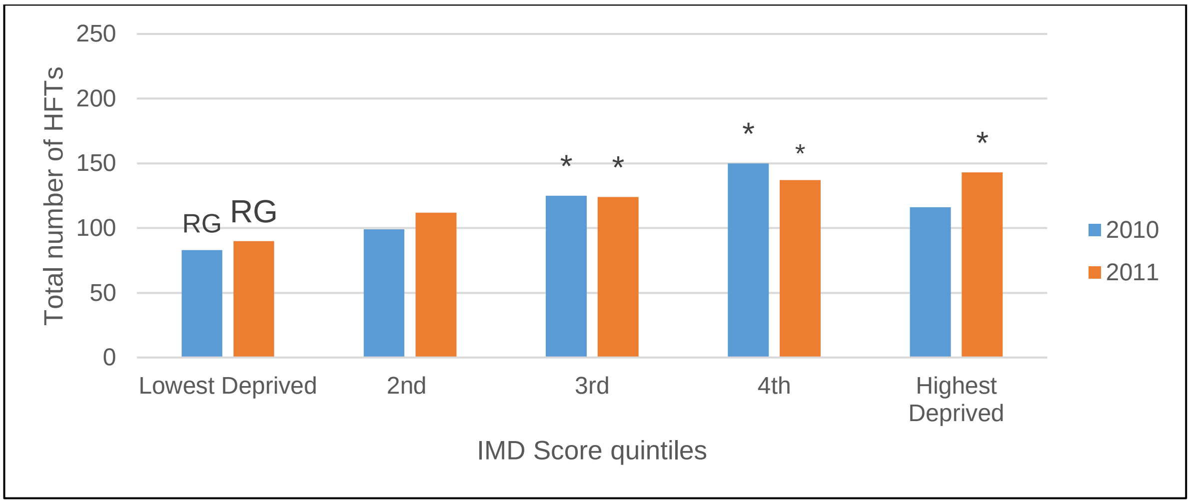


Figure 2 The total number of HFTS by IMD_2010 quintiles Score, in 2010 and 2011

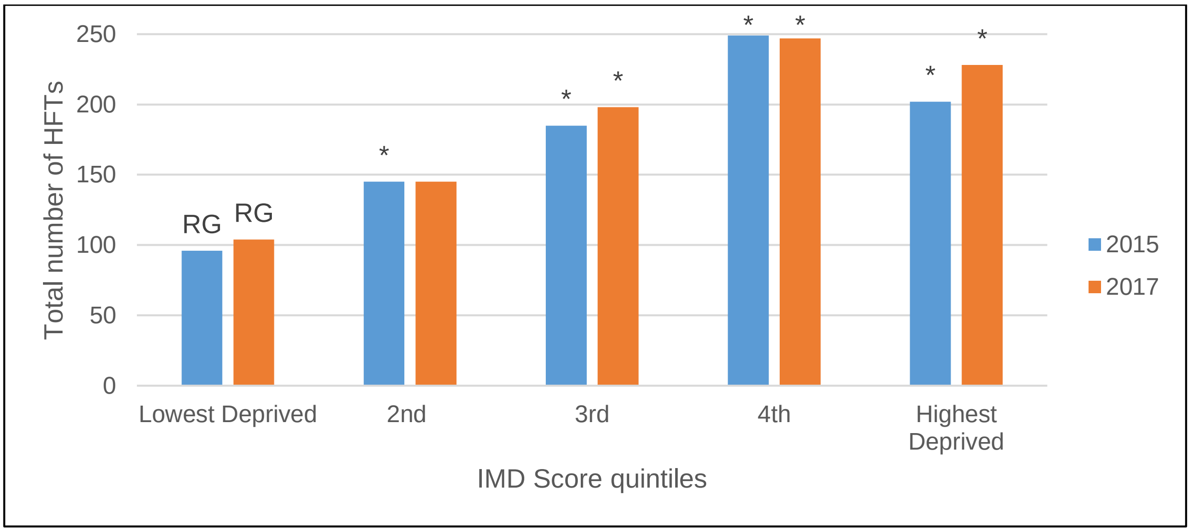


Figure 3 The total number of HFTS by IMD_2015 quintiles Score, in 2015 and 2017.

Appendix 14: Sample size calculation

```
. sampsi 0.8 0.6, n1(610) sd1(1.2) a(0.05) onesided

Estimated power for two-sample comparison of means

Test Ho: m1 = m2, where m1 is the mean in population 1
                    and m2 is the mean in population 2
Assumptions:

         alpha =   0.0500  (one-sided)
            m1 =       .8
            m2 =       .6
           sd1 =      1.2
           sd2 =      1.2
sample size n1 =      610
            n2 =      610
         n2/n1 =     1.00

Estimated power:

         power =   0.8972
```

```
.  power onemean 0 0.2, k(53) m(28) sd(1) rho(0.02)

Estimated power for a one-sample mean test
Cluster randomized design, z test
Ho: m = m0  versus  Ha: m != m0

Study parameters:

        alpha =    0.0500
        delta =    0.1612
           m0 =    0.0000
           ma =    0.2000
           sd =    1.0000

Cluster design:

            K =        53
            M =        28
            N =     1,484
          rho =    0.0200

Estimated power:

        power =    1.0000
```