Exploring the impact of school food policy on 11–12-year-olds diets in Northumberland in 2000, 2010 and 2022: a repeat cross-sectional study.

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Abstract

Introduction

In England, school food has undergone major changes from no standards in 2000, to food- and nutrient-based standards in 2008, to revised food-based standards in 2014. This thesis explores the impact of these changes on 11–12-year-olds diets.

Methods

Dietary data were collected using two three-day food diaries and entered into Intake24. Mean diet quality scores were calculated using the diet quality index for adolescents (DQI-A). Changes in mean nutrient intakes were examined. Level of deprivation was calculated using individual child-level postcodes. Linear regression analyses explored the effect of year, school lunch type, level of deprivation, and the interaction of year and school lunch type.

Results

In total, 371 children participated. While mean DQI-A improved across years, and was statistically significant, children's diet quality remains poor. There was no evidence of an effect by school lunch type or deprivation on mean DQI-A.

In children's total diet, several nutrients decreased across years, including per cent energy from non-milk extrinsic sugars (%E NMES). Lunch type had a statistically significant effect on some nutrient intakes studied, for example, school lunch (SL) consumers had lower sodium and NMES intakes than packed lunch (PL) consumers. There was no evidence of a year by school lunch type interaction or effect of deprivation on mean total diet nutrient intakes. At lunchtime, there were several year by school lunch type interactions, for example, %E NMES. In 2000, SL consumers had a lower intake than PL consumers, by 2022 this reversed, now SL consumers had a higher intake. There was no evidence that deprivation impacted total diet or lunchtime intakes.

Conclusion

Despite some improvements to children's diets, dietary intakes remain poor. Potential solutions could include updating the school food standards and modifying school food and drink availability. Additional policies are needed to address children's diet beyond school.

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List of Abbreviations

Abbreviation	Full Name
%E	Per cent energy
BMI	Body mass index
CHO	Carbohydrate
CI	Confidence Interval
COMA	Committee on Medical Aspects of Food and Nutrition Policy
COVID-19	Coronavirus disease 2019
DAx	Diet adequacy subcomponent
DDc	Diet diversity component
DEc	Diet equilibrium component
DEx	Diet excess subcomponent
DQc	Diet quality component
DQI-A	Diet Quality Index for Adolescents
DQI-I	Diet Quality Index – International
F	Female
FBDG	Food based dietary guidelines
g	Grams
HEI-2010	Healthy Eating Index-2010
HEI-C	Healthy Eating Index Canada
HHFKA	Healthy Hunger-Free Kids Act 2010
HNRC	Human Nutrition Research Centre
IMD	English Index of multiple deprivation
kcals	Kilocalories
M	Male
mg	Milligrams
ml	Millilitre
n/s	Not significant
NDNS	National Diet and Nutrition Survey

NHS	National health service
NMES	Non-milk extrinsic sugars
NSP	Non-starch polysaccharide
PL	Home-packed lunch
SACN	Scientific Advisory Committee on Nutrition
SES	Socioeconomic status
SL	School lunch
UK	United Kingdom
US or USA	United States of America

Chapter 1 Background

Chapter overview:

This chapter gives an overview of the current issues surrounding children's diets and contribution to overweight and obesity. Current UK dietary intakes and recommendations are outlined. Diet quality as a measure to summarise dietary intakes is introduced. The complex factors that influence children's food choices are also explored highlighting that policy and the food environment play a role in food choice. Recent government approaches to improve children's diet are also explored, with emphasis on school food policy and a brief history of school food policy implementation in England.

1.1 Childhood overweight and obesity

The prevalence of childhood overweight and obesity is a major public health concern in the UK, particularly following the COVID-19 pandemic [1, 2]. In 2021/22, the National Child Measurement Programme reported that 37.8% of children in year 6 (aged 10-11 years) were overweight or obese which decreased from 40.9% in 2020/21, however, this remains higher than the 35.2% of children reported overweight and/or obese in 2019/20 [3]. It was also indicated that rates of overweight and obesity were higher in lower socioeconomic groups. In 2021/2022, 46.0% of year 6 pupils in the most deprived decile in England were overweight and/or obese compared with 26.3% in the least deprived decile [3]. It is important to note that due to the COVID-19 pandemic, collection of data for the National Child Measurement Programme was delayed and as a result the 2020/21 data were collected from a 10% representative sample of children in local authorities [3].

The prevalence of non-communicable diseases associated with overweight and obesity have increased in recent years including type 2 diabetes in children and adolescents [4, 5]. Evidence suggests that being overweight or obese during childhood and adolescence increases the risk of obesity and associated non-communicable diseases such as cardiovascular disease in adulthood [5, 6].

Evidence shows that dietary habits formed in childhood have the potential to track into adulthood [7, 8], highlighting the importance of encouraging healthy eating from a young age.

Poor diets, particularly diets high in energy, saturated fat, and sugar, and low in fibre are associated with increased overweight and obesity [9-11]. There is evidence that children living with obesity consume less fruits and vegetables, more foods high in fat, salt and sugar including cakes, fast food, and soft drinks than non-obese children [11, 12]. While, for the most part parents or carers control what younger children eat, children begin to have more control over the food they consume during adolescence (between the ages of 10 and 19 years), including preparing meals for themselves, involvement in making packed lunches, choosing meals at restaurants and other food outlets especially with friends, and using pocket money to buy food and drinks [13]. Factors influencing children's dietary intakes are explored in section 1.4.

1.2 Children's dietary intakes and current recommendations

In 1991, the Committee on Medical Aspects of Food and Nutrition Policy (COMA) published recommendations for nutrient intakes [14]. In 2001, the Scientific Advisory Committee on Nutrition (SACN) was established and has since released several reports examining the relationships between nutrient intakes and health and has revised recommendations for specific nutrients. The recommendations published by SACN have formed the scientific basis of many recommendations [15]. In 2015, SACN recommended that intakes of free sugars should not exceed 5% total energy intake, this recommendation had previously been for no more than 11% total energy intake [14]. SACN also recommended the term 'non-milk extrinsic sugars (NMES)' to be replaced with 'free sugars' [14, 16]. The main difference between NMES and free sugars is that NMES include 50% of sugars from stewed, dried and canned fruit to account for food processing but free sugars are all monosaccharides and disaccharides added to foods and sugars found naturally in honey, syrups and fruit juice (unsweetened) [16]. There was no recommendation for fibre by COMA, however COMA recommended that intakes of non-starch polysaccharides (NSP) was at least 18 grams per day, SACN recommended AOAC fibre intakes of 25 grams per day [16]. The main difference between NSP and AOAC fibre is that NSP only includes fibre within plant cell walls but AOAC fibre includes NSP and non-digestible carbohydrates [16]. However, as this thesis reports findings for NSP and NMES the previous recommendations are used.

The National Diet and Nutrition Survey (NDNS) is used to monitor food and nutrient intakes in a representative sample of the UK population. The most recent NDNS, published in 2021, showed that free sugars intakes had fallen in recent years in the 11-18 years age group, and the consumption of soft drinks in boys had also reduced in comparison to previous years, however intakes remain above recommendations (see Table 1.1) [17]. Table 1.1 compares examples of specific nutrient intakes with their current recommendations as defined by COMA or SACN, whichever is the most recent, as NMES and NSP recommendations are used in this thesis, recommendations for these and the updated free sugars and AOAC fibre are included.

Table 1.1 Recommendations for selected nutrients and current mean daily intakes in 11–18-year-olds reported by the NDNS

Food/Nutrient	Recommendations		Intakes (11–18-year-olds) [5]	
	Males	Females	Males	Females
Energy (kcals)	2127 [1]	2032 [1]	1846	1511
Total Fat (%E)	≤35 [2]	≤35 [2]	34.7	43.3
Saturated Fat (%E)	≤11 [2]	≤11 [2]	13.3	12.7
NMES (%E)	≤11 [2]	≤11 [2]	No current NDNS data available	
Free Sugars (%E)	≤5 [3]	≤5 [3]	11.9*	12.1*
NSP (g)	18 [2]	18 [2]	No current NDNS data available	
AOAC Fibre (g)	25g (11-16y) [3] 30g (17y+) [3]	25g (11-16y) [3] 30g (17y+) [3]	17.4*	14.0*
Vitamin C (mg)	40 [2]	40 [2]	No NDNS data available	
Calcium (mg)	1000 [2]	800 [2]	797	717
Sodium (mg)	1600 [2]	1600 [2]	2075	1619
Iron (mg)	11.3 [2]	14.8 [2]	11.0	8.0
Fruit and Vegetable (portions/day)	≥5 [4]	≥5 [4]	2.8	2.9

[1]Scientific Advisory Committee on Nutrition, (2011) [18]; [2] Committee on Medical Aspects of Food and Nutrition Policy, (1991) [14]; [3]Scientific Advisory Committee on Nutrition, (2015) [16] [4]NHS, (2022) [19]; [5]Ashford *et al.* (2021) [17]; * current intakes reported for free sugars and AOAC fibre not NMES and NSP

1.3 Diet quality

Diet quality indicates how closely a diet aligns with dietary guidelines and is assessed using a scoring system [20]. Higher scores indicate better adherence to dietary recommendations and greater variation in diet [21]. These measures allow the overall quality of diets to be assessed and captured in a single value and can be used to monitor diet and risk of non-communicable diseases [21, 22]. Diet quality can be influenced by various factors including socioeconomic status (SES), food preferences, and food environment (including the school food environment and wider food environment) [23]. Zheng *et al.* (2023) used data from the National Health and Nutrition Examination Survey and found that higher diet quality scores were associated with lower risks of overweight and obesity in US children and adolescents aged 2-19 years [24]. This highlights the importance of consuming a good quality diet to reduce the risk of overweight and obesity. The impact of school food on diet quality and different measures used are detailed in section 2.5 in Chapter 2.

1.4 Factors influencing children's dietary intakes

Figure 1.1 displays the conceptual model illustrating the different factors which influences diets (adapted from Chen and Antonelli 2020). The factors impacting food choice included in this model are: food-internal factors, food-external factors, personal-state factors, cognitive factors and societal factors [25]. These are discussed below under relevant sub-headings. Coloured text indicates key factors for consideration in this PhD.

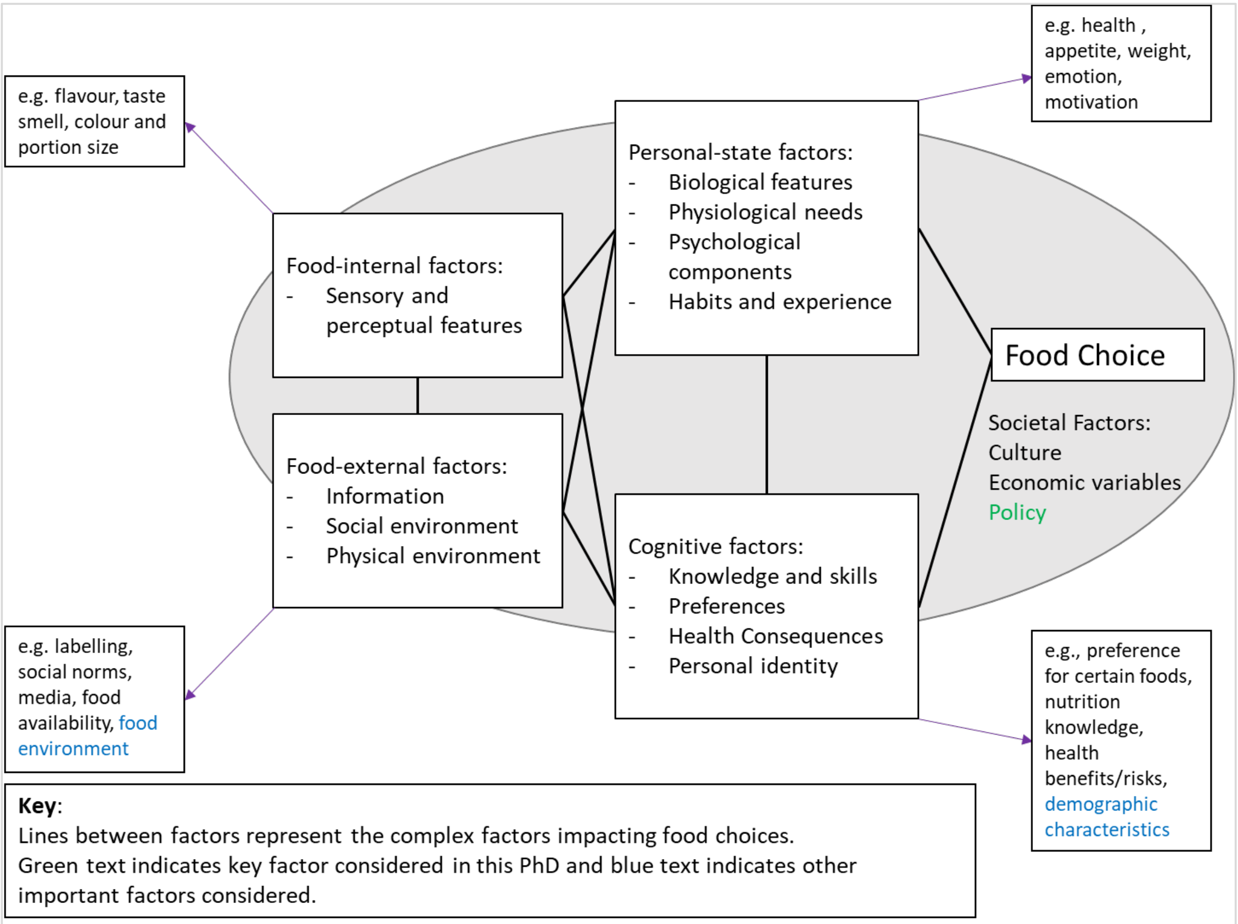


Figure 1.1 Examples of factors affecting food choices using a conceptual model (adapted from Chen and Antonelli 2020 [25]).

1.4.1 Food-internal factors

Food-internal factors refers to the impact of food itself on food choice and includes sensory and perceptual properties of food and drinks [25]. Sensory properties include flavour, taste, texture and smells of food/drink items. Perceptual features of food include colour, portion size and nutrition value [25]. A recent study by Bawajeeh *et al.* (2022), using NDNS data, demonstrated that for children aged between 10-19 years, sweet foods contributed most towards daily energy intakes. This study indicated that UK children's diets were predominately composed of sweet tasting (e.g., cakes and sweet pastries) and neutral tasting (no specific taste, e.g., potatoes, bread, and white fish) foods, each contribute to approximately 34% of children's energy intakes. Higher sweet food intakes was associated with higher intakes of energy, sugar, fibre and saturated fats; higher intakes of salty foods was associated with saturated fat and sodium intakes [26].

Canales and Hernández (2016) found sensory aspects of food including taste, texture, smell and appearance played a major role in food choice for Spanish children aged between 13-18 years (27). In contrast, Maulida *et al.* (2016) found sensory appeal was not an important factor determining food choice among Indonesian children aged 13-14 years (28). Similar findings regarding sensory appeal being a less important factor regarding food choice were reported by Share and Stewart-Knox (2012) among Irish children aged 14-17 years (29).

1.4.2 Food-external factors

Food-external factors includes information, social and physical environments (25). Information can refer to advertising, brands, labelling and packaging (25). A systematic review and meta-analysis of 39 studies by Russell *et al.* (2019) concluded food advertising increased food intake in children aged 2-18 years compared to non-food advertising, and exposure to food advertising increased calorie consumption (30). Evidence also suggests that children who are overweight or obese consume more calories when exposed to food advertising than children who are a healthy weight (30). Social media may also influence the diets of children as highlighted by Coates *et al.* (2019). They found the marketing of unhealthy foods by online influencers increased immediate food intake among UK children aged 9-11 years, whereas marketing of healthy foods had no effect (31). Similarly, Baldwin *et al.* (2018) found Australian children, aged 10-16 years, who had more exposure to food brands online, particularly through videos (e.g., YouTube) were more likely to consume unhealthy foods and drinks, such as soft drinks (32).

Social environments that have the potential to influence children's diets include family, friends, and peers. A systematic review of 60 studies by Pearson *et al.* (2009) showed that the availability of fruits and vegetables in the home, family rules, parental intake and encouragement from parent(s) to consume fruits and vegetables were associated with increased consumption in children aged between 6-18 years (33). Another study by Pearson *et al.* (2012) indicated that Australian children, aged 12-15 years, who observed their mother skip meals were more likely to skip breakfast and lunch (34). Further, Robson *et al.* (2016) captured dietary intakes among parents and children (aged 6-12 years) across three days. They found that parental and child energy intakes were similar, and that parental energy intakes significantly predicted child energy intakes (35).

Peer influence in adolescence has often been found to have a negative impact on diet including increased consumption of energy-dense, low-nutrient value foods. A systematic review of 29 studies, by Ragelienė *et al.* (2020) explored peer and sibling influences on children's diet, aged between 9-18 years old. Fear of not being accepted or being mocked by friends for eating healthier foods was found to impact the diets of children [(36)]. In contrast, seven studies included in Ragelienė's systematic review concluded that peer influence can encourage positive eating behaviours by copying friends' that consume healthier foods [(36)]. Pearson *et al.* (2012) also found that children who perceived that their best friend had skipped meals were more likely to skip lunch [(34)].

Physical environments that can influence children's diets include home, neighbourhoods, communities, restaurants, fast-food outlets, supermarkets, and schools. The home food environment has been widely linked to dietary intake and weight status in children. Healthy weight status has been associated with healthy home food environment, including increased family meal frequency, increased fruit and vegetable consumption and lower consumption of fast foods [(37-40)]. A systematic review and meta-analysis of 57 studies by Dallacker *et al.* (2018) concluded that higher frequency of family meals was associated with better diet quality, including higher intakes of healthy foods and lower intakes of unhealthy food items including fast foods [(38)]. Further, a cohort study by Couch *et al.* (2014), indicated that the availability of foods high in calories (including high calorie beverages, e.g., soft drinks, and sweet and savoury snacks, e.g., cakes, jam) in the home food environment was associated with poorer diet quality in US children aged 6-11 years [(41)].

The neighbourhood food environment also has the potential to have an impact on children's diets. Ziauddeen *et al.* (2018) using NDNS data for children aged 1.5-18 years, and Futrell Dunaway *et al.* (2017) in US children aged 4-14 years reported that easy access to poor-quality food, such as fast-food outlets has been associated with unhealthy diets, decreased vegetable consumption, and increased risk of overweight and obesity [(42, 43)]. Proximity of food outlets in the local neighbourhood (e.g., within a 10-minute walk) has been associated with increased consumption of soft drinks in US children aged 11-18 years as reported by Hearst *et al.* (2012) [(44)]. Additionally, Van Hulst *et al.* (2012) found that for Canadian children aged 8-10 years, a lack of fast-food outlets in children's neighbourhoods was associated higher diet quality, with children being less likely to eat at fast food outlets [(45)]. Barrett *et al.* (2017) reported greater access to more healthy outlets (e.g., supermarkets) was associated with better diet quality in six-year-old English children [46]. A qualitative study by Kelly *et al.* (2021) explored perception of the out-of-school food environment in Irish children aged 12-18 years. It was reported that food price and food outlets visited played a role in food choice, and low cost, high fat, salt and sugar foods were popular food choices [47]. Also, food outlets around schools, particularly secondary schools may allow easy access to energy dense foods that have the potential to have negative effects on the diets of children [48, 49].

The school food environment has also been widely associated as having an impact on children's diets. The school food environment can be defined as "all spaces, infrastructure and conditions inside and around schools premises where food is available, obtained and/or consumed" [50]. A systematic review of 18 studies, focussed on school food environment exclusively within schools, by Driessen *et al.* (2014) concluded that improving the school food environment, including reducing availability of high sugar beverages, increasing water availability and changes to canteen menus, has been found to increase healthy food behaviours (e.g., increased fruit and vegetable intakes, reduced consumption of soft drinks) and to decrease body mass index (BMI) in children aged 9-19 years [51]. The impact of school food on children's diets will be discussed more in section 1.6.

1.4.3 Personal-state factors

Personal-state factors include biological and physical factors such as health, weight, genetics and appetite, along with, psychological factors such as emotion and motivation [25]. Weight status is a key factor associated with children and adolescents' food choice and dietary behaviours. A review by Cox *et al.* (2016) of 25 studies concluded that individuals (children and adults) living with overweight and obesity generally have a higher preference for fatty and salty foods [52]. Preference for sweet tastes has been associated with overweight and obesity in children aged 8-15 years as reported by Sobek *et al.* (2022) and in children aged 15-19 years by de Andrade Previato and Behrens (2017) [53, 54].

Emotions may also play a role in children's food choices. Jalo *et al.* (2019) examined associations between emotional eating, BMI and diet in 8–11-year-olds across 12 countries with different cultural settings. They showed that eating in response to negative emotions was associated with an unhealthy dietary pattern containing high intakes of fast and fried foods, cakes, and soft drinks. However, this did not impact on weight status [55]. Michels *et al.* (2012)

indicated that stress was associated with emotional eating and increased intakes of unhealthy foods such as snacks, sweet and fatty foods in 5-12 year old children in Belgium [(56)].

1.4.4 Cognitive factors

There are various cognitive factors that may influence children's food choices including nutrition knowledge, food preferences, and personal identity which includes age, gender and ethnic identity [(25)]. Nutrition knowledge has the potential to have an impact on diets. However, a systematic review by Thakur and Mathur (2022) indicated that nutrition knowledge alone is not sufficient to encourage healthy eating [(57)]. Fitzgerald *et al.* (2010) reported that children preferred more unhealthy foods despite indicating some awareness of the importance of eating healthily [(58)].

Food preferences also play a role in food choices of children. A qualitative study by Fitzgerald *et al.* (2010) indicated that food preferences play a large role in food choice [(58)]. This is influenced by several other factors including sensory aspects mentioned previously. A study by Appleton *et al.* (2019) found that adolescents generally prefer vegetables that possess more appealing sensory aspects, including texture and taste and also that adolescents who consumed vegetables with both appealing and less appealing sensory properties had overall healthier diets [(59)].

Gender has also been linked to having a role in children's food choices. A study by Caine-Bish *et al.* (2009) reported that, in US children aged 8-18 years, girls generally preferred fruits and vegetables whereas boys preferred meat, fish and poultry [(60)]. Similarly, a study by Skårdal *et al.* (2014) in children aged 13-14 years in Norway, found that girls generally had a healthier diet than boys and consumed more fruit and vegetables and fewer soft drinks [(61)]. Skipping meals has been linked with food choice including consumption of snacks and overall poorer diet quality, with girls being more likely to skip meals than boys [(54, 62, 63)]. For example, a study by Medin *et al.* (2019) in children aged 12-14 years in Norway found that children had poorer diet quality (e.g., higher sugar intakes, lower fibre intakes) on days when breakfast or lunch was not consumed [(63)].

1.4.5 Societal Factors

Societal factors include cultural norms, food and agriculture policies and socioeconomic status (SES) [(25)]. Several studies have looked at the impact of SES and food choice on eating behaviours. A study by Fismen *et al.* (2021) in children aged 6-9 years across 23 countries, indicated that unhealthy food habits were associated with children from lower SES groups, including lower fruit and vegetable intakes, increased intakes of soft drinks [(64)]. Similarly, Skårdal *et al.* (2014) found lower intakes of soft drinks and fast foods, and higher vegetable and fish intakes among 13-14 year old children from high SES families [(61)]. A study by Ding *et al.* (2012) in US children aged 12-18 years reported that higher household income was associated with higher availability of more healthy foods (e.g., fruit and vegetables) in the home but not associated with availability of less healthy food items [(65)].

Food policy may also influence children's diets. Key policies aiming to improve children's diets are those relating to school food and the school food environment; these are discussed in more detail in section 1.6. Wider food policies also have the potential to impact children's dietary intakes, including the Soft Drinks Industry Levy [(66)] and is detailed in section 1.5.

1.5 Government strategies to address children's diets

The UK government has implemented several strategies and policies to improve children's diets, a timeline of these strategies from 2011 onwards is outlined in Table 1.2. Between 2000 and 2010 the government published several reports and strategies to improve children's diets. For example, "Choosing Health: Making healthier choices easier" published in 2004, outlined several priorities including encouraging exercise, improving diet and reducing obesity [(67)]. A second report "Choosing a Better Diet: A food and action plan" published in 2005, outlined plans to raise awareness of obesity-related health risks and included strategies to reduce obesity through diet and exercise, such as increasing the availability of healthier foods, the 5-a-day initiative to improve fruit and vegetable intakes, and improving nutrition in schools (including 2007 school food standards) [(68)]. The government published "Foresight: Tackling Obesities – Future Choices" in 2007 and highlighted issues surrounding the increase in rates of overweight and obesity in the UK, and the need for a system-wide approach to ensure change [(69)]. In 2008 the "Healthy Weight, Healthy Lives: A Cross-Government Strategy for England" report outlined plans to improve diets and weight, including increasing participation in school sporting activities (school-time and extracurricular) and encouraging schools to consider the school lunch environment (time period for lunch, stay-on-site policies) and healthy packed lunch policies [(70)].

In 2011, the UK government published "Healthy Lives, Healthy People: A call to action on obesity in England" which outlined aims to reduce obesity rates by 2020. Following this white paper a number of policies and initiatives were implemented including the public health responsibility deals which was non-legislative, encouraged reformulation of food items and improvements to voluntary labelling guidelines and a commitment to updating school food policy which was ultimately implemented in 2014 [(71)].

The report "Childhood Obesity: A Plan for Action" was published by the UK Government in 2016 and outlined plans to reduce the prevalence of childhood obesity within the next decade. Some aspects included: improving school food, clearer food labelling and the introduction of a soft drinks industry levy [(72)]. The Soft Drinks Industry Levy was implemented in April 2018, [(66, 72)]. The policy aimed to encourage manufacturers of soft drinks to reformulate high sugar drink products to reduce sugar content or reduce the portion size of these products [(66)]. A study by Rogers *et al.* (2023) explored obesity prevalence pre- and post-implementation of the Soft Drinks Industry Levy in English primary school children aged 4 to 5 and 10 to 11 years using data from National Child Measurement Programme [(73)]. The National Child Measurement Programme is an annual programme delivered by local authorities in England and involved the measurement of all children in reception (aged 4-5 years) and year 6 (aged 10-11 years) [(74)]. There was evidence of a significant decrease in obesity prevalence in 10- to 11-year-old girls post-implementation, with the largest change occurring in girls from the most deprived groups, there was no significant change in boys and younger children [(73)]. Another study by Pell *et al.* (2021), using UK household purchasing data, where households were asked to record all food and drink purchases found that although the volume of soft drinks purchased did not significantly change, the sugar content of drinks purchased was approximately 10% lower per household per week post-policy implementation [(75)].

"Childhood Obesity: A Plan for Action, Chapter 2" was published in 2018, and summarised what had been implemented from the initial report and gave areas for future focus, such as advertising and promotion rules for foods high in fat, sugar and/or salt and updated school food standards to take into consideration the new sugar recommendation from SACN [(76)]. However, despite inclusion in the plan in 2018, this update to school food standards has not yet taken place, explanations given include the COVID-19 pandemic and the governments focus shifted to ensuring that the current standards were being followed [(77)]. Children's continued high levels of consumption of sugar as outlined in the NDNS [(17)], highlights the need for these standards to be updated or for a more consistent monitoring system for school food to be implemented across England. In 2019, "Childhood Obesity: A Plan for Action, Chapter 3" was published as part of a larger report ("Advancing our health: prevention in the 2020s") [78]. This outlined what has been completed since the previous report and gave more areas for future focus, such as banning the sale of energy drinks to children and the potential expansion of the Soft Drinks Industry Levy to include high sugar milk-based drinks [78].

The Chief Medical Officer at the time, Professor Dame Sally Davies, published a report titled "Time to Solve Childhood Obesity" in 2019. This report outlined the current situation in relation to childhood obesity and included recommendations for next steps that may help achieve the government's goal to halve the prevalence of childhood obesity by 2030 [1]. Several recommendations were specifically related to school food provision including availability of food at an affordable price, review of current standards and increased value of the free school meal allowance to ensure all children receive a healthy meal [1].

In July 2020, in a policy paper titled "Tackling obesity: empowering adults and children to live healthier lives", the Government outlined plans to improve the diets of children and reduce childhood obesity. These plans included a 9pm watershed on advertisement of foods high in fat, sugar and salt to be implemented by the end of 2022, however this was subsequently delayed until July 2025 [79, 80]. Plans were also outlined to introduce legislation to ban the promotion of foods high in fat, sugar and salt in England for both online and in store for food retailers selling with 50 or more employees [79]. This came into force on the 1st October 2022 restricting the placement of foods high in fat salt and sugar in prominent locations, such as these foods cannot be displayed at checkouts or store entrances for physical stores and on online checkout pages [81]. However, a ban on volume promotions including buy one get one free or multi-buy offers was delayed until 2025 [82].

The "National Food Strategy: Part 1" was published in July 2020 and outlined various recommendations related to the UK leaving the European Union and the COVID-19 pandemic, particularly for disadvantaged families [83]. Examples of the recommendations include expansion of the free school meal scheme to include those whose families receive Universal Credit, extension of the Holiday Activities and Food Programme to all areas in England and increase the value of Healthy start vouchers. The "National Food Strategy: The Plan" published in July 2021, was a government-commissioned review into the UK's food system, and outlined several recommendations [84]. Examples included the implementation of a sugar and salt reformulation tax, extension of free school meal eligibility and an ‘Eat and Learn’ initiative in schools to encourage a whole school approach to healthy eating. This report also reflected on how the government responded to the “National Food Strategy: Part 1”, including the implementation of the Holiday Activities and Food programme to all areas in England in 2021. However, the recommendation to expand the eligibility criteria for free school meals to include all families who receive Universal Credit was not implemented [84].

The government published “Levelling up the United Kingdom” in February 2022 [85]. The white paper outlined several approaches that aimed to reduce socioeconomic inequalities across a range of areas. This included a plan to improve the curriculum to include practical cooking skills and teacher training to ensure children learn cooking skills. Further, plans were announced for a pilot project to ensure schools have support to improve compliance to school food standards and also encourage schools to produce information on their school websites to describe their whole school approach to food [85].

Table 1.2 A timeline of Government strategies/reports to improve the diets in England (focus on children's diets) from 2011-present.

Government Strategy	Year	Summary	Examples of related policies and initiatives (including outlined plans)	Implemented/ completed

Healthy Lives, Healthy People: A call to action on obesity in England [71]	2011	• Local government given power to determine appropriate approaches to improving health.
		• Main aim:
		  ○ Sustained downward trends in overweight and obesity in children by 2020.
			• Public health responsibility deal
			  ○ Non-legislative.
			  ○ Included collaboration with business for reformulation of food items and improvements to food labelling (e.g., voluntary calorie labelling).
			• Change4Life
			  ○ Was in place prior to report, plans announced to expand campaign.
			  ○ Encouraged and provided advice for families to develop healthy eating behaviours including 5 a day, and the "Great Swapathon" which provided vouchers to help towards healthier food and activities.
			• Support healthier food provision in schools.
			  ○ Outlined commitment to nutrient standards for school meal (ultimately became the 2014 school food standards outlined in section 1.6).
			• Calorie Reduction Challenge
			  ○ Improve the food environment to encourage healthier food choice.
				✓
				
				✓
				
				✓
				
				✓

Childhood Obesity: a plan for action [72]	2016	• Outlined the problems surrounding childhood obesity both health and economic issues.
		• Main aim:
			• Soft Drinks Industry Levy
			  ○ Introduced as a measure to target high consumption of soft drinks and sugar consumption.
			  ○ Aimed to reduce sugar content of soft drinks.
			  ○ Revenue planned to contribute to programmes designed to reduce prevalence of obesity.
				✓

Government Strategy	Year	Summary	Examples of related policies and initiatives (including outlined plans)	Implemented/ completed
		○ Significantly reduce obesity prevalence in English children within the next decade (by 2026).	• Product reformulation ○ Food industry encouraged to reduce the sugar content of products, commonly consumed by children to aid reduction of sugar intakes, also includes reducing portion sizes and encouragement of lower sugar alternatives. • Healthy rating scheme for primary schools ○ Voluntary. ○ Recognise contribution to encouraging children to make healthier food choices and increase physical activity. • Healthier school food ○ Outlined plan to update current school food policy (not yet completed) to consider updated sugar recommendations.	✓ ✓ ✗
Childhood Obesity: a plan for action, chapter 2 (76)	2018	• Outlined what has been implemented following the previous report. • Updated aim of previous report to: ○ Halve childhood obesity and reduce the socioeconomic gap in obesity by 2030.	• 9pm watershed on advertising foods high in fat, salt and sugar on TV and online (not yet implemented). • Restriction on price promotions including multi-buy offers for unhealthy foods and drinks (not yet implemented). • Age restrictions to target sale of energy drinks to children (not yet implemented). • Reiterated commitment to update school food policy as outlined in the previous report.	✗ ✗ ✗ ✗
Childhood Obesity: a plan for action, chapter 3 (78)	2019	• Included within a larger report targeting public health across several key health issues. • Outlined what has been implemented following the previous report. • Reiterated aim from previous report to halve childhood obesity and the socioeconomic gap in obesity by 2030.	• Banning the sale of energy drinks to children. • Plans for consultation on how to improve front of pack labelling post leaving the European Union. • Plan to explore the potential to extend the soft drinks industry levy to cover high sugar milk-based drinks. • Outlined aim to reduce salt consumption to 7g per day (voluntary approach).	✗ ✗ ✗ n/a

Government Strategy	Year	Summary	Examples of related policies and initiatives (including outlined plans)	Implemented/ completed
		• Focus on infant feeding, food labelling and individual support to achieve a healthy weight.		
Tackling obesity: empowering adults and children to live healthier lives [79]	2020	• Outlined issues associated with obesity, especially following COVID-19.	• Plans outlined: ○ Consultation to improve "traffic light" labelling. ○ Implement policy to introduce calorie labelling in food outlets employing more than 250 people. ○ Implement policy to restrict price promotions of foods high in fat, salt, and sugar both in person and online. ○ Restriction of advertising foods high in fat, salt and sugar before 9pm and a consultation to restrict online advertising.	 ✓ ✓ ✗ ✗
National Food Strategy: Part 1 [83]	2020	• Main aim: to present a plan to change and improve the UK's food system. • Part 1 focused on urgent recommendations provide support during the COVID-19 pandemic and the UK leaving the European Union. • Includes recommendations across a wide range of areas including disadvantaged children and trade deals.	• Recommendations included (child diet specific): ○ Expansion of free school meal eligibility criteria. ○ Extension of the Holiday Activity and Food Programme in England (extended for duration of 2021 following report). ○ Increase value of Healthy Start vouchers.	 ✗ ✓ ✓
National Food Strategy: The Plan [84]	2021	• Main aim: to present a plan to change and improve the UK's food system. • Included summary of government's actions after publication of part 1. ○ Holiday Activities and Food Programme extended.	• Recommendations included (child diet specific): ○ Introduction of a reformulation tax for sugar and salt and use a portion of that income to help fund healthy eating for disadvantaged families. ○ An "Eat and Learn" initiative in schools including changes to curriculum and inspections to improve food education.	 ✗ ✗

Government Strategy	Year	Summary	Examples of related policies and initiatives (including outlined plans)	Implemented/ completed
		○ Healthy Start voucher value increased.	○ Extension of free school meal eligibility (not implemented after part 1). ○ Extend funding for Holiday Activities and Food Programme (for next three years).	× ✓
Levelling up the United Kingdom [85]	2022	• This report is a long-term plan for the UK. • Targets several key areas of improvement to reduce socioeconomic inequalities across the UK. ○ Including education, health, wellbeing, and housing.	• Plans outlined (child diet specific): ○ New approach of monitoring compliance to school food policy and more support to ensure compliance (included announcement of pilot projects). ○ Improve the school curriculum surrounding food education and teacher training to support children learning to cook healthy recipes.	n/a n/a

1.6 School food policy

School food is a significant contributor to the diet of children, contributing approximately one third of children's daily dietary intake [86]. School food is regulated by school food standards which restrict the types of foods available in primary and secondary schools in the UK. Evidence shows that school meals tend to be healthier and higher in favourable nutrients such as vitamin C, iron and fibre compared to packed lunches [87]. Children who consume school meals have been found to have a healthier diet overall in comparison to children who consume packed lunches with higher fruit and vegetable intakes, and lower intakes of sodium and sugar [88, 89]. Although, it has been reported that children express preference for unhealthier options available for sale in schools for lunch, e.g., pizza and sandwiches, some children report feeling forced to consume healthier options and unable to decide for themselves what they want to eat [90, 91].

Unlike school meals, packed lunches are not regulated by nationwide policies, however individual schools may have their own policies in place [92, 93]. In 2015, The Children's Food Trust published a packed lunch policy template to aid schools with implementation which is now available on the School Food Plan website [94]. This may help to ensure packed lunches brought from home and consumed in school would be more consistent with the school food standards [94]. Also, there is evidence that parents involve children in choosing what goes into their packed lunches, children can select foods they want and will eat and parents felt that ensuring the content of packed lunches was healthy was their responsibility and not the schools' [92]. A repeat-cross sectional study by Evans *et al.* (2020) exploring changes in the diets of English primary schoolchildren consuming a home-packed lunch reported reductions in sugar content between 2006 and 2016 and fewer children taking a high sugar drink. However, overall sugar content in packed lunches remained above recommendations [95]. Further, vitamin and mineral content of packed lunches remained low and saturated fat is high, this may be due to less fresh food included in packed lunches e.g., vegetables or salad [95].

School food policy has a long history, a timeline of key school food policy changes in England since 1906 is shown in Figure 1.2. The Education (Provision of Meals) Act 1906 was introduced to ensure all children received a suitable meal in school and allowed local education authorities to provide free school meals to children from the most disadvantaged families [96]. Nutritional standards for school meals were introduced for specific nutrients including protein, fat and calories in 1941 [97]. However, nutritional standards for school meals were removed when deregulated in 1980 [98]. In 2001, food-based standards for school lunches were introduced, [99]. These standards were updated in 2007 to include both food and nutrient based standards [100].

Most recently 'The Requirements for School Food Regulations' was introduced in 2014. These were implemented following the recommendations outlined in the "The School Food Plan" published in 2013. [101]. Recommendations included encouraging uptake of school meals, extending free school meal entitlement and the introduction of food-based standards in all schools [101]. The report also highlighted issues surrounding nutrient-based aspect of the previous standards including challenges in the implementation and limiting the creativity of school cooks to alter recipes to be more appealing to children [101]. The Requirements for School Food Regulations were entirely food-based, with the nutrient-based standards of the previous policy being removed. Food-based standards included the removal of confectionery, chocolate and high sugar drinks such as soft drinks in schools, and the availability of at least one portion of fruit and one portion of vegetables (or salad as an accompaniment) every day [102]. In addition, a guidance document titled "School Food Standards: A practical guide for schools, their cooks and caterers". This provided advice on the implementation of the regulations, highlighted typical portion sizes of each food group and provided a checklist for headteachers and caterers to use to ensure standards were being met [103].

The Government has committed to updating school food standards in 2016 and again in 2018 [72, 76], however, this review has been delayed as a result of the COVID-19 pandemic, with government focus now shifting to improve compliance to current school food standards [77] with a pilot project (mentioned above) outlined in "Levelling Up the United Kingdom" white paper [85].

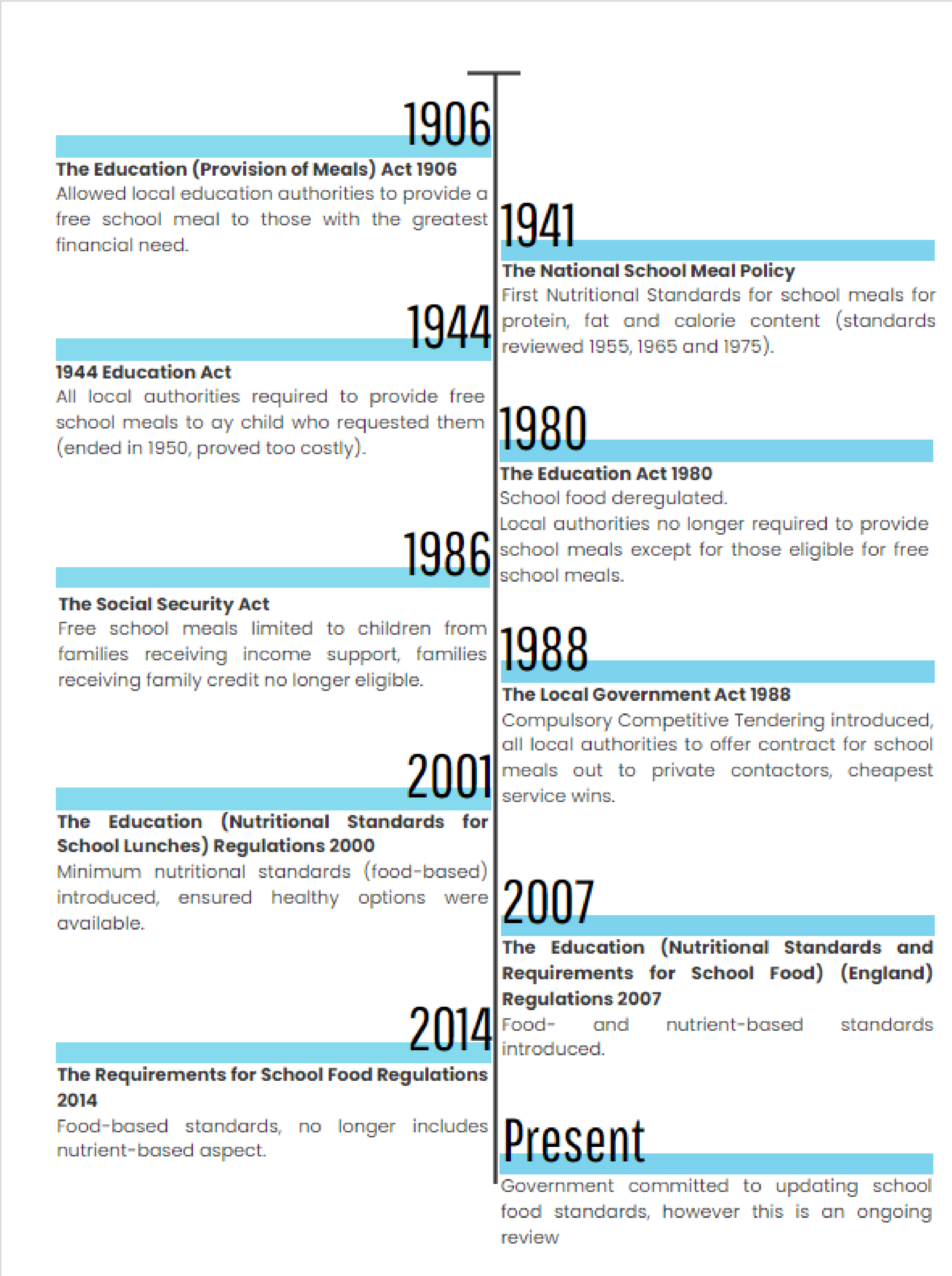


Figure 1.2 History of School Food Policy implemented since 1906 until present day in England

1.7 Summary

In summary, childhood overweight and obesity is a major public health problem in the UK. One key reason for this is poor quality diets that do not meet current UK government recommendations for several food groups and nutrients including fruit and vegetables, sugar, and saturated fat. Children's food choices and dietary intakes are influenced by a number of complex, interacting factors including demographic characteristics, food environment and food policy, thereby highlighting the complex and multi-faceted approaches required to improve children's diets. School food is an important contributor to children's diets and is therefore a crucial area for intervention implementation and policy development. There was no implemented school food policy in English schools in 2000, by 2007 food and nutrient based standards were introduced and 2014 school food policy was updated, and only food-based standards remain. A review of current literature regarding the impact of various worldwide school food policies on children's diets, specifically diet quality, food group and nutrient intakes, is provided in Chapter 2. The aims and objectives for this thesis are outlined in Section 2.7.6 at the end of Chapter 2.

Chapter 2 Literature Review

Chapter overview:

The aim of this chapter is to provide a review of the literature examining the impact of school food policies on children's total diet and lunchtime dietary intakes for:

- Food group intakes (soft drinks and fruit and vegetables)
- Diet quality
- Nutrient intakes

A brief introduction is provided followed by the objectives for the literature review and search strategy used. For each objective, a description of studies is provided, key findings are presented, and study limitations discussed. To conclude this chapter, key points are summarised, the rationale and objectives for the current study are presented.

2.1 Introduction

As mentioned in Chapter 1, school food policies have the potential to improve children's diets for those children consuming school food. Although each country has different school food policies in place, school food policies have the potential to improve the diets of children. This narrative literature review will focus on studies published from 2010 that explore the impact of food and drink policies implemented in middle or secondary schools worldwide on children's diets. This review will explore the impact of school food policies on food group intakes, with a focus on soft drinks and fruit and vegetables as these food groups are frequently highlighted as a public health concerns. For example, consumption of soft drinks is a major contributor to high sugar intakes in the UK (104). This review will also examine the current literature on impact of school food policies on children's diet quality which is an emerging approach for exploring children's diets and nutrient intakes.

For the purposes of this thesis, school food policies discussed relate to Government policies that restrict what food and drink is permitted to be sold in schools. Policies beyond the school gate at lunchtime are beyond the scope of this PhD.

Objective

The objective of this narrative literature review is to explore the literature on the impact of school food policies, pre- and post-policy implementation or between school lunch types on the dietary intakes (lunchtime and total diet) of children aged 11-18 years in relation to:

(i) Food group intakes (soft drinks and fruit and vegetables)
(ii) Diet quality
(iii) Nutrient intakes

2.2 Methods

The literature review was conducted using three frequently used electronic databases: Medline, PsycInfo and Embase. The keywords for the literature search included variations of "school food policy", "diet" and "children", full search criteria used can be found in Table 2.1. Additionally, a hand-search was conducted to identify studies that were not identified using the previously mentioned electronic databases.

Table 2.1 Search terms used for searching literature (Medline, Embase and PsycInfo)

Search Terms
Diet OR Food Intake OR Dietary Intake OR Nutrient Intake OR Food Group Intake OR Diet Quality OR Food Behaviour OR Diet* Behaviour
AND
Child* OR Adolescent OR Student OR Pupil OR Young People OR Teen* OR Middle school OR Secondary school
AND
School Food Policy OR School Food Regulations OR Menu Standards OR Food Based Standards OR Nutrient Based Standards OR School Food Standards OR Nutrition Policy* OR School Food Environment OR School food

2.2.1 Search Strategy

Inclusion and exclusion criteria for including studies in this narrative review can be found in Table 2.2. The inclusion criteria included primary, peer-reviewed research studies carried out worldwide in older children aged between 11-18 years, and articles published in English.

Further, this review only included studies published between 2010 and 2023, with the full text available. This date range was selected to include the most recently published studies, published since the previous ASH11 data collection in 2010 (see Chapter 3, section 3.2 for more information regarding the ASH11 studies). This review excludes articles with the following designs: reviews (all review types), study protocols, grey literature, editorials/commentaries, and unpublished articles. When studies also included age groups that did not meet the inclusion criteria, only results from relevant age groups were considered, when not possible this was noted as a limitation and results for all ages considered. Data was extracted from relevant studies including study author, location, participant number, participant age, study design, outcomes of interest and key findings. For nutrients, all nutrients explored in relevant papers are included in this review.

Table 2.2 Literature review inclusion and exclusion criteria

Inclusion Criteria	**Exclusion Criteria**
• Primary research studies. • Studies published from 2010 onwards. • Middle and secondary aged children (11-18 years). • Published in English. • Full text available. • Must be school food policy related. • Main outcome: diet (or diet-related outcomes). • Must include a comparison, including pre- and post-policy, school lunch type: packed and school lunches, policy type (e.g., voluntary or mandatory) or food group availability.	• Reviews, editorials, protocols and commentaries. • Grey literature. • Unpublished work. • Preschool and primary school aged children only. • Studies with focus only on education/behaviour/physical activity outcomes. • Focus only on purchasing behaviours or food availability. • Focused on free school meal provision only. • Studies focused only on children’s view of school meals/school food policy. • Studies looking at health outcomes only.

2.3 Overview of studies included

Each section of this literature review starts with a description of included studies (*n*=35), and tables detailing study design, participant characteristics and key findings are included at the end of each section (Table 2.5, Table 2.6, Table 2.7 and Table 2.8). As this review contains studies from different countries worldwide, the policies studied vary and therefore potentially have differing effects on children’s diets. The policies explored by studies included in this review are summarised in Table 2.3. Generally, these policies include food and/or nutrient based standards which state what can be provided or sold in schools, both at lunchtime and during the school day. Studies were categorised by dietary aspect studied: food group intakes, diet quality and nutrient intakes, then by total diet or lunchtime only. Some studies may examine more than one aspect and are therefore included in multiple sections.

Table 2.3 Policies explored by studies included in this literature review summary

Policy	Description/Summary
UK	
The Education (Nutritional Standards and Requirements for School Food) (England) Regulations 2007 [100]	Mandatory food and nutrient based standards for school food in England.
The Requirements for School Food Regulations 2014 [102]	Updated food-based standards, removed nutrient-based standards (mandatory).
USA	
Healthy Hunger-Free Kids Act 2010 (HHFKA) [105]	Mandatory nutritional standards for the National School Lunch Program (low/no cost meals).
Smart Snacks in School (2014/15) [106]	Mandatory nutrition standards for food and drinks sold in schools outside of the National School Lunch Program ('competitive foods').
Los Angeles Unified School District Healthy Beverage Motion and Los Angeles Unified School District Childhood Obesity Prevention Motion (2004) [107]	Mandatory food and nutrient-based standards for foods sold in schools.
Nutrition Standards for Competitive Foods (105 CMR 225.000) (2014) [108]	Sets out food- and nutrient-based requirements for all competitive foods sold in schools, similar to Smart Snacks in School (mandatory).
Texas Public School Nutrition Policy (2004) [109]	Mandatory food- and nutrient-based standards for competitive foods and school meals.
California Senate Bill 12 (2007) [110]	Provided nutrient-based standards for competitive foods sold in schools (mandatory).
District and school level policies (various years) [111-118]	Restricts the beverages that can be sold in schools (voluntary).
Canada	
Policy/Program Memorandum no. 150 (P/PM150) (2010) [119]	Mandatory food-based standards in public schools, voluntary for private schools (Ontario).
Alberta Nutrition Guidelines for Children and Youth (2012) [120]	Voluntary food-based guidelines for schools.
School and district level policies (various years) [121-123]	Restricts the beverages that can be sold in schools (voluntary).
South Korea	
The School Meals Act (2007) [124, 125]	Soft drink sales banned in schools and recommended the ban the sale of fried food and instant noodles (mandatory).
The Special Act on Safety Management of Children's Dietary Lifestyle (2009) [124, 125]	Banned sale of energy-dense, nutrient-poor foods in schools (mandatory).
Chile	
Law of Food Labelling and Advertising (2016) [126]	Includes regulations that restrict the provision of foods high in calories, fat, salt and sugar in schools (mandatory).

2.4 School food policies and the effect on children's food intakes

This review identified 22 studies that considered children's food intakes including soft drink consumption, and fruit and vegetable consumption.

2.4.1 Soft drinks

2.4.1.1 Summary of studies included

The review identified 17 studies that considered the impact of school food policies on intakes of soft drinks [87, 111-117, 122, 124, 125, 127-132]. Soft drinks generally include drinks with added sugar and include non-diet soft drinks, sports drinks and energy drinks [133], the type of soft drinks explored in the included studies is detailed in Table 2.4. The studies included in the current review are detailed in Table 2.5. The majority of the studies included (ten) were conducted in the USA [111-118, 128, 129], three studies in Canada [122, 131, 132], two studies in the UK [87, 127], and two in South Korea [124, 125]. Children's ages ranged from 10-18 years. Twelve of the included studies were cross-sectional [87, 112, 115-118, 122, 124, 125, 127-129], three were longitudinal [113, 114, 132] and two were observational [111, 131]. Various methods were utilised for dietary data collections including lunchtime observations [87, 127], 24-hour recalls [124, 128, 129] and food frequency questionnaires [111-118, 122, 125, 131, 132]. A variety of policies were studied, as indicated in Table 2.5, most of which limit the sale of soft drinks in schools. Nine studies used soft drinks availability and consumption as a method of comparison [112, 113, 115-118, 129, 131, 132], three studies used policy types, three used pre- and post-policy implementation [111, 114, 122] and two used school lunch type [87, 127]. Fifteen of the included studies looked at total diet intakes of soft drinks [111-118, 122, 124, 125, 128, 129, 131, 132] and two explored lunchtime intakes [87, 127].

Table 2.4 Definition of soft drinks for the studies included in the literature review

Study	Soft drinks studied
UK studies	
Pearce *et al.* (2013) (87)	Not explicitly defined, referred to as 'soft drinks'.
Stevens *et al.* (2013) (127)	Not explicitly defined, referred to as 'soft drinks'.
US studies	
Bauhoff (2014) (128)	Soda
Chriqui *et al.* (2021) (129)	Diet and non-diet soft drinks, other drinks above 10 kcal per 20 fluid ounces and 60 kcal per 20 fluid ounces.
Hoffman *et al.* (2016) (111)	Soda, sports drinks, energy drinks, other beverages with added sweeteners.
Miller *et al.* (2016) (112)	Soda.
Nanney *et al.* (2014) (114)	Soda and sports drinks.
Nanney *et al.* (2016) (113)	Soda and sports drinks.
Taber *et al.* (2012) (115)	Soda, sports drinks, and high calorie fruit drinks.
Taber *et al.* (2014) (116)	Soda.
Taber *et al.* (2015) (117)	Soda, diet soda, sports drinks, energy drinks, coffee/tea and less than 100% fruit juice, flavoured milk.
Terry-McElrath *et al.* (2015) (118)	Soda.
Canadian studies	
Godin *et al.* (2018) (132)	Soft drinks, fruit drinks, sports drinks, energy drinks, sweetened tea, and coffee.
Godin *et al.* (2019) (131)	Soft drinks, fruit drinks, sports drinks, energy drinks, flavoured milk drinks, sweetened coffee and tea.
Masse *et al.* (2014) (122)	Soda.
South Korean studies	
Choi *et al.* (2017) (124)	Not explicitly defined, referred to as 'soft drinks'.
Kim *et al.* (2013) (125)	Not explicitly defined, referred to as 'carbonated beverages'.

2.4.1.2 Impact of school food policies on total diet soft drink consumption

Most studies explored children's total dietary intake of soft drinks in relation to school food policies (111-118, 122, 124, 125, 128, 129, 131, 132). Studies conducted in the US reported varied findings regarding the impact of school food policies on soft drink intakes (Table 2.5). A study by Bauhoff (2014) reported that post-policy implementation (pre/post policy comparison) restricting sale of soft drinks in schools, children's (*n*=unclear, aged 12-15 years) consumption of soft drinks significantly decreased [128]. Similarly, Nanney *et al.* (2014) found that with implementation of each extra school nutrition and physical activity policies (including policies limiting the sale of soda in vending machines/school canteens) soft drink intakes decreased (*n*=18881, aged 11-18 years, policy type comparison) [114].

As many of these school food policies state what foods can be sold in schools, several studies looked at the associations between availability and children's consumption of soft drinks (Table 2.5). Nanney *et al.* (2016) reported that higher availability of soft drinks was associated with higher soft drink consumption in boys but not girls or in boys and girls combined (*n*=14028, aged 11-18 years, soft drink availability comparison) [113]. Chriqui *et al.* (2021) found that when more policy-compliant beverages were available in high schools, children were less likely to consume less healthy drinks (soft drinks), although this was not significant for middle school children (*n*=1024, aged 11-18 years, soft drink availability comparison) [129]. Similarly, Miller *et al.* (2016) found children were less likely to consume non-diet soft drinks when soft drink access was restricted, and healthier options were available (*n*=25241, aged 14-18 years, soft drink availability comparison) [112].

In contrast, Taber *et al.* (2012) found although availability and purchase of soft drinks was lower, children had higher soft drink consumption in USA states that regulate the availability of soft drinks, and consumption was not associated with state policies (*n*=6900, aged 13-14 years, soft drink availability comparison) [115]. Studies by Taber *et al.* (2014) and Taber *et al.* (2015) also found children with access to vending machines consumed less soft drinks than children with no access (*n*=8245, aged 14-18 years, soft drink availability comparison) [116] and consumed other soft drinks including energy and sports drinks (*n*=8696, aged 14-18 years, soft drink availability comparison) [117]. Also, children with no vending machine access but allowed soft drinks in schools consumed more diet alternatives, sports drinks, and tea/coffee [117]. Further, Terry-McElrath *et al.* (2015) reported that despite lower availability associated with state bans on sale of soft drinks, there was no significant difference in consumption (*n*=7877, aged 15-18 years, soft drink availability comparison) [118]. Hoffman *et al.* (2016) reported similar findings that daily soft drink intakes were not associated with policy strength (*n*=78854, aged 14-17 years, policy type comparison) [111], this is potentially a result of compensatory changes due to restricted in-school access to soft drinks resulting in increased intakes outside of school [134]. These mixed findings could be due to different policies being studied, including school-level and state level policies.

For the studies conducted in Canada, Godin *et al.* (2018) (*n*=7679, aged 12-18 years, soft drink availability comparison) and Godin *et al.* (2019) (*n*=41829, aged 14-17 years, soft drink availability comparison) found that areas with voluntary guidelines had higher soft drink intakes than those with mandatory and no guidelines [131, 132]. Despite this, Godin *et al.* (2018) found no significant association between soft drink availability in school vending machines and frequency of soft drink consumption [132]. Further, Masse *et al.* (2014) found the presence of school nutrition policies restricting soft drink availability was associated with children being less likely to be high consumers of soft drinks (*n*=11385, aged 12-18 years, policy type comparison) [122].

Both studies conducted in South Korea reported similar findings. Kim *et al.* (2013) found that following implementation of various school food policies that restrict the sale of soft drinks in schools, children's consumption of soft drinks significantly decreased (*n*=11386, aged 12-18 years, pre/post policy comparison) [125]. Similarly, Choi *et al.* (2017) reported that in-school consumption of softs decreased the year of policy implementation (sale of soft drinks banned in schools) however, intakes out-of-school and home increased significantly (*n*=4959, aged 12-19 years, pre/post policy comparison) [124], suggesting that children may compensate for these restrictions when not in school. No UK studies explored the impact of school food policies on soft drink consumption for total diet.

2.4.1.3 Impact of school food policies on lunchtime soft drink consumption

There were limited studies that explored the impact of school food policies on soft drink consumption at lunchtime. Both UK studies looked only at lunchtime intakes of soft drinks (Table 2.5). No studies were found that explore the impact of school food policies on lunchtime soft drink intakes in other countries. Both Stevens *et al.* (2013) (*n*=7730, aged 11-18 years, school lunch type comparison) and Pearce *et al.* (2013) found packed lunch consumers were more likely to consume soft drinks in comparison to children consuming school lunches (*n*=497, aged 11-16 years, school lunch type comparison) [87], this may be due to a lack of packed lunch policies in schools, the majority of school food policies in the UK restrict only what can and cannot be sold in schools, and many do not have restrictions on home-packed lunches.

2.4.1.4 Impact of socioeconomic status

Some of the studies included in this review also looked at differences between SES groups and reported mixed results for total diet soft drink intakes (Table 2.5) [111, 125, 129]. Chriqui *et al.* (2021) reported children from lower SES were less likely to consume diet (low or no sugar) alternatives than children from higher SES [129]. Hoffman *et al.* (2016) reported areas with lower levels of eligibility for free or reduced-price lunches had significantly lower intakes of soft drinks compared with medium and high-level areas [111]. However, Kim *et al.* (2013) found although intakes of soft drinks decreased across all SES groups following implementation of school nutrition policies, children from higher SES groups were more likely to consume soft drinks than other children [125]. These results indicate that there is mixed evidence relating to soft drink consumption across socioeconomic groups.

2.4.1.5 Study strengths and limitations

The studies included have several strengths. Most studies had large sample sizes [111, 112, 114, 116-118, 122, 125, 127, 131, 132, 135] which is beneficial as studies with larger sample sizes may be more representative of the general population (in this case children aged 11-18 years) than studies with smaller sample sizes [136, 137]. All studies contained a comparator to explore potential school food policy impacts [87, 111-117, 122, 124, 125, 127-132]. Many studies used national survey data (particularly the US and South Korean studies), which is beneficial as these studies may more representative of the general population of 11-18 year olds in that country [112, 115-118, 124, 125, 135, 138]. Several studies also obtained data using food frequency questionnaires [111-118, 122, 125, 131, 132] which may give a better indication of habitual diets of specific food groups than other methods obtaining one day only (e.g. 24-hour recall) [139]. The studies included have several limitations. Most studies included in this review obtain information on soft drink consumption using self-reported measures (food frequency questionnaire, 24-hour recall) and as a result, there is a chance of misreporting intakes [111-117, 122, 124, 125, 128-132]. The remaining two studies used lunchtime observations to determine food intakes in school at lunchtime, in these studies there is a risk of observer error or children may alter behaviours if aware of being watched [87, 127]. Most studies obtained information using self-report measures including questionnaires, due to this there is a risk of errors including reporting and social desirability bias [112, 114, 118, 122]. Two of the included studies only assessed lunchtime or in-school consumption and did not look at out-of-school consumption, therefore, it is not possible to consider the impact of policies on overall diet. In these studies, it is not possible to determine if soft drink consumption is compensated for outside of school [87, 127]. Four of the studies focused on soda (carbonated drink) consumption and not any other soft drinks, it is not clear in these studies if soda was substituted with other types of soft drinks [112, 116-118]. Godin *et al.* (2018) and Godin *et al.* (2019) did not measure sources of beverages consumed so comparisons could not be made between locations such as home and school, making it difficult to determine impacts of school food policies and whether children compensate limited soft drink access in school with increased consumption out-of-school [131, 132]. Godin *et al.* (2018), Godin *et al.* (2019) and Taber *et al.* (2015) also measured only purchase and consumption of soft drinks in school from vending machines and not school cafeteria, this does not give an accurate reflection for all soft drinks sold in schools and potential impacts of policies restricting sale of soft drinks [117, 131, 132]. Additionally, the studies included looked at different types of soft drinks, for example some studies only considered soda, but others include more drink items (see Table 2.4), this may account for the mixed findings.

2.4.1.6 Summary

In summary, the studies included reported mixed findings regarding the impact of school food policies on children's soft drink intakes. Most of the studies included reported that school food policies reduced children's consumption of soft drinks, particularly in school [87, 112, 114, 122, 124, 125, 127, 128, 131]. Some studies reported the positive impact of decreased soft drink availability and increased availability of healthier alternatives on children's intakes, either in school canteens or vending machines. However, other studies reported mixed findings [113, 129, 132], no association [111, 118] or increased consumption [115-117] when soft drink availability was limited. For studies that explored the effect of SES, there is mixed evidence regarding soft drink consumption across groups. More evidence is needed to explore the impact of school food policies on soft drink consumption by SES. These mixed findings highlight a need for more research on how school food policies may improve children's soft drink intakes both in and out of school. Further, as most of the research was carried out in the USA, the results cannot be generalised for other populations as policies potentially differ from those implemented in other countries. Additionally, the UK-based studies both looked at the impact of The Education (Nutritional Standards and Requirements for School Food) (England) Regulations 2007 which is not the current school food policy in England, this highlights a need for more research following implementation of the current policy. Although policies were implemented differently worldwide, the policies studied are generally similar as they either ban the sale of soda or other soft drinks, or they restrict where/when soft drinks can be sold.

2.4.2 Fruit and Vegetables

2.4.2.1 Summary of studies included

The review identified nine studies that considered the impact of school food policies on fruit and vegetable intakes [(87, 111, 114, 123, 127, 135, 138, 140, 141)]. The studies included are detailed in Table 2.5. The majority of the studies included (five) were conducted in the USA [(111, 114, 135, 138, 141)], three studies were conducted in the UK [(87, 127, 140)], one study was conducted in Canada [(123)]. Children's ages ranged from 4-19 years. Six of the studies included were cross-sectional [(87, 123, 127, 135, 138, 140)], one was longitudinal [(114)], one was a pilot study [(141)], and one was ecological [(111)]. Various methods were utilised for dietary data collection including lunchtime observations [(87, 127, 141)], 24-hour recalls [(123, 138)], food frequency questionnaires [(111, 114, 135)] and food diaries [(140)]. A variety of policies were studied, as indicated in Table 2.5, most of which encourage the provision of fruit and vegetables in school. Five studies used school lunch type (school lunch and packed lunch) as the comparator, two used pre- and post-policy implementation and one used policy type. Three of the included studies looked at total diet intakes of fruit and vegetables [(111, 114, 135)], four explored lunchtime intakes [(87, 127, 138, 140, 141)] and one study looked at both lunchtime and total diet [(123)].

2.4.2.2 Impact of school food policies on total diet fruit and vegetable consumption

Three studies in children from the USA, explored the impact of school food policies on total diet fruit and vegetable intakes and reported mixed findings (detailed in Table 2.5) [(111, 114, 135)]. Nanney *et al.* (2014) reported that with each additional school nutrition and physical activity policy, daily consumption of fruit and vegetables increased, these policies included increased fruit and vegetable availability and provision of 100% fruit juice [(114)]. Chriqui *et al.* (2020) reported that pre-implementation of Smart Snack in School, the presence of a state-level school food policy was associated with higher vegetables intakes, but only salad remained significantly higher in states with strong state-level policies post-implementation. There was no significant difference in fruit intakes (*n*=99785, aged 12-18 years, pre/post policy comparison) [(135)]. Hoffman *et al.* (2016) looked only at the impact of free or reduced-price lunches on associations between school food policy and fruit and vegetable intakes and therefore is included only in the impact of SES section below [111].

Only one study in Canada looked at the impact of school food policies on total diet intakes of fruit and vegetables (detailed in Table 2.5). Tugault-Lafleur *et al.* (2018) explored fruit and vegetables intakes for total diet on a school day. The study reported that there was no significant difference for the total diet fruit and vegetable intakes between packed and school lunch consumers (*n*=4589, aged 6-17 years, school lunch type comparison) [123].

2.4.2.3 Impact of school food policies on lunchtime fruit and vegetable consumption

The three UK studies looked at lunchtime intakes only and reported similar findings (Table 2.5) [87, 127, 140]. Haney *et al.* (2023) reported that packed lunch consumers had higher fruit intakes compared with school lunch consumers, however, school lunch consumers had higher vegetable intakes (*n*=1031, aged 12-16 years, school lunch type comparison) [140]. Pearce *et al.* (2013) found associations between children consuming school lunches and vegetable and vegetable dish intakes compared with packed lunch consumers not covered by school food policies. However, consuming packed lunches was associated with higher fruit, salad and raw vegetable intakes when compared to school lunches [87]. Similarly, Stevens *et al.* (2013) also found packed lunch consumers to be more likely to consume fruit as part of their lunch in comparison to school food consumers [127].

Two US studies explored lunchtime fruit and vegetable intakes (Table 2.5) [138, 141]. Cullen *et al.* (2015) found following implementation of the Healthy Hunger-Free Kids Act 2010 (HHFKA), for children aged 11-13 years, school meals contained more fruit, vegetables, and starchy vegetables and more were consumed at lunchtime when compared to children from schools adhering to previous policies (*n*=427, aged 11-13 years, pre/post policy comparison) [141]. However, Vernarelli and O'Brien (2017) reported that there were no significant differences in vegetable intakes between school lunch types for children aged 4-13 years. For older children aged 14-19 years, packed lunch consumers had higher vegetable intakes than school lunch consumers. Fruit intakes did not differ between school lunch types across all ages studied (*n*=2190, aged 4-19 years, school lunch type comparison) [138].

Only one study in Canada looked at the impact of school food policies on intakes of fruit and vegetables (Table 2.5) [123]. Tugault-Lafleur *et al.* (2018) explored fruit and vegetables intakes during school hours (includes lunchtime). The study reported that packed lunch consumers had significantly higher fruit and vegetable intakes compared with lunch from other sources (including school) during school hours (123).

2.4.2.4 Impact of socioeconomic status

From the studies included, only Hoffman *et al.* (2016) (Table 2.5) explored the impact of SES, in this case related to eligibility for free or reduced-price lunches (111). This study found positive associations between school food policies and fruit and vegetable consumption in areas with medium levels of eligibility for free or reduced-price meals. Areas with lower levels of eligibility had significantly higher fruit and vegetable intakes compared to areas with medium and high levels of eligibility (111). This study highlights that children from families in lower SES groups generally have a lower intake of fruits and vegetables than children from families in higher SES groups.

2.4.2.5 Study strengths and limitations

The studies included had several strengths. Many studies had relatively large sample sizes (111, 114, 123, 129) which, as mentioned previously, may be more representative of the general population than studies with smaller sample sizes (136, 137). All included studies contained a comparator to examine impacts of school food policies e.g., difference between school lunch and packed lunch consumers 87, 111, 114, 123, 127, 135, 138, 140, 141). Several included studies used national survey data (US, UK and Canada), the use of this data may give a more representative indication of the impact of school food policies on children aged 11-18 years fruit and vegetable intakes (114, 123, 135, 138, 140). Use of food frequency questionnaires and methods obtaining more than one day of dietary data may give an indication of the impact of school food policies on habitual intakes (114, 123, 135, 138-140). The studies included in this section of the review have several limitations. Cullen *et al.* (2015) is a pilot study and did not adjust for multiple comparisons due to the exploratory hypothesis which focused on fruit and vegetable consumption (141). For three studies the dietary data, in this case fruit and vegetable intakes, was obtained using lunchtime observation (87, 127, 141). Lunchtime observation, despite being an objective measurement of dietary intake, has several limitations, including that observation may alter individual's usual eating habits and there is a risk of observer errors (87, 127). The remaining studies used self-reported measures to assess dietary intakes, including food frequency questionnaires (111, 114, 135), 24-hour recalls (123, 138) and food diaries (140). Self-reported measures may result in misreporting by children, both intentional and unintentional [142].

2.4.2.6 Summary

In summary, the studies included found that school food policies generally had a positive impact on children's vegetable consumption for both total diet and lunchtime intakes, however, improvements were limited, especially for fruit intakes [87, 111, 114, 127, 135, 140, 141]. Only one study included in this review looked at the impact of school food policies on fruit and vegetable consumption by SES and reported that children from higher SES groups consumed more fruit and vegetables than children from lower SES groups [111]. Most of the research has been conducted in the USA, limiting generalisability of results. Further, two of the UK-based studies only looked at previously implemented policy, which has now been updated. The remaining UK-based study explores both the earlier policy and the current policy combined by comparing school lunch to packed lunch consumers lunchtime intakes, however changes to diets pre- and post-implementation are not studied. The lack of studies looking at potential different impacts of school food policies on fruit and vegetable consumption across SES groups highlights a need for further research.

Table 2.5 Characteristics and key findings of included studies exploring the impact of school food policies on children's food group intake

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
UK studies								
1	Haney *et al.* (2023) [140]	The Education (Nutritional Standards and Requirements for School Food) (England) Regulations 2007 The Requirements for School Food Regulations 2014	1031	12-16	• Cross-sectional • 4-day food diary • Data source: National Diet and Nutrition Survey (2008-2017)	School lunch type (packed and school lunches)	Lunchtime food intakes: • Fruit and vegetable	<u>Lunchtime</u> • Packed lunch consumers had significantly higher intakes of fruit compared with school lunch consumers ($p<0.001$). • School lunch consumers had significantly higher intakes of vegetables compared with packed lunch consumers ($p<0.001$).
2	Pearce *et al.* (2013) [87]	The Education (Nutritional Standards and Requirements for School Food) (England) Regulations 2007	497	11-16	• Cross sectional • School food available recorded, portions recorded • Subsample of lunches weighed before and after eating	School lunch type (school and packed lunches)	Lunchtime food intakes: • Fruit and vegetable • Soft drinks	<u>Lunchtime</u> • School lunch consumers more likely to have consumed vegetables (including veg dishes, $p=0.004$), fruit juice and baked beans (all $p<0.001$) compared with packed lunch consumers. • Packed lunch consumers more likely to consumed salad and raw veg ($p=0.008$), water ($p=0.013$), fruit and soft drinks (both $p<0.001$) than school lunch consumers.
3	Stevens *et al.* (2013) [127]	The Education (Nutritional Standards and Requirements for	7730	11-18	• Cross sectional	School lunch type (school	Lunchtime food intakes:	<u>Lunchtime</u> • More school lunch consumers consumed vegetables and

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
3 (cont.)	Stevens *et al.* (2013) [127] (cont.)	School Food) (England) Regulations 2007			• School food available recorded, portions recorded. • Subsample of lunches weighed before and after eating.	and packed lunches)	• Fruit and vegetable • Soft drinks	salad, and baked beans (both p<0.001) than packed lunch consumers. • More packed lunch consumers consumed fruit, water, and non-permitted drinks e.g., soft drinks (both p<0.001) than school lunch consumers. • There was no difference between packed and school lunches for per cent consuming fruit juice (p>0.05). • School lunch consumers had higher mean intakes of fruit, water, fruit juice and non-permitted drinks compared with packed lunch consumers (all p<0.001). No significant difference for mean intakes for vegetables and salad p>0.05).
USA Studies								
1	Bauhoff (2014) [128]	Los Angeles Unified School District Healthy Beverage Motion Los Angeles Unified School District Childhood Obesity Prevention Motion	unclear	12-15	• Cross sectional • 24-hour recall • Data source: California Health Kids Survey	Pre- and post-policy implementation	Total Diet foods intakes: • Soft drinks	<u>Total Diet</u> • Soft drink consumption in males decreased significantly in low end of consumption (p<0.05). • Soft drink consumption in females decreased in high end of consumption (3+ soft drinks) (p<0.05).

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
2	Chriqui *et al.* (2020) [135]	Smart Snacks in School	99785	12-18	• Cross-sectional • Food frequency questionnaire • Data source: CDC Youth Behavior Risk Survey (2005-2017)	Pre- and post-policy (and state policy strength)	Total Diet foods intakes: Vegetables	<u>Total diet</u> • Pre-implementation, children in states with weak and strong policies had significantly higher vegetable intakes (weak CI = 1.03; 1.24, strong CI = 1.04; 1.27) and salad (weak CI = 1.06; 1.30, strong CI = 1.09; 1.39) than states with no policy. • Pre-implementation, children in states with strong laws had higher intakes of carrots (CI = 1.02; 1.28) and states with weak laws had higher intakes of other vegetables (CI = 1.06; 1.23) compared with states with no policies. • Post-implementation only salad was significantly higher in states with strong laws compared with no laws (CI = 1.02; 1.35).
3	Chriqui *et al.* (2021) [129]	Smart Snacks in School	1024	11-18	• Cross-sectional • 1x 24-hour recall • Data source: School Nutrition and Meal Cost Study (2014-2015) and National	Soft drink availability and consumption	Total diet foods intakes: • Soft drinks (non-compliant beverages)	<u>Total Diet</u> • In middle school children there was no association between beverage availability and student consumption (p>0.05). • In high school higher availability of compliant

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
3 (cont.)	Chriqui *et al.* (2021) [129] (cont.)				Wellness Policy Study (2014-2015)			beverages was associated with higher consumption (p<0.01). • For SES differences in consumption (high school) children with a lower SES were less likely to consume diet beverages in school than students from higher SES (p<0.05).
4	Cullen *et al.* (2015) [141]	Healthy Hunger-free Kids Act of 2010	427	11-13	• Pilot Study • Lunchtime observation	Intervention (new policy) and control (old policy) Pre- and post-policy	Lunchtime food intakes: • Fruit and vegetables	Lunchtime • Children in intervention schools consumed more fruit (p<0.001), juice (p<0.01), total vegetables (p<0.01), starchy vegetables (p<0.05) and legumes (p<0.01) compared to control.
5	Hoffman *et al.* (2016) [111]	Minnesota local district policies	78854	14-17	• Ecological • Food frequency questionnaire • Policy assessment method: Wellness School Assessment Tool (WellSAT) – scores wellness policies • Data source: Minnesota Student Survey	Policy type	Total diet food intakes: • Fruit and vegetable • Soft drinks	Total Diet • No significant associations between WellSAT scores and daily soft drink consumption (p>0.05). • Districts with low free or reduced-price lunches eligibility (higher SES) had significantly lower daily soft drink intake and higher fruit and vegetable intake than medium and high eligibility districts (p<0.0001).

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
5 (cont.)	Hoffman *et al.* (2016) [111] (cont.)							• Higher WellSAT score in medium free or reduced-price lunches districts was associated with higher mean daily fruit and vegetable intakes (p<0.05).
6	Miller *et al.* (2016) [112]	District-level policies	25241	14-18	• Cross-sectional • Food frequency questionnaire • Data source: School Health Policies and Practices Study (2012), and Youth Risk Behaviour Surveillance System (2013)	Soft drink availability and consumption	Total diet food intakes: • Soft drinks	<u>Total Diet</u> • In districts restricting promotional products, students less likely to consume regular soda (CI = 0.71; 1.00). • Students less likely to consume regular soda in districts with restricted access to soft drinks (CI = 0.56; 0.93) and offered healthier beverages (CI = 0.63; 0.91).
7	Nanney *et al.* (2014) [114]	School-level policies	18881	11-18	• Longitudinal cohort • Food frequency questionnaire • Data source: CDC School Health Profiles Study and Minnesota Student Survey	Policy type	Total diet food intakes: • Fruit and vegetable • Soft drinks	<u>Total Diet</u> With each additional school nutrition and physical activity policy there was a significant decrease in soft drink intakes (p=0.04) and increased fruit and vegetables (p=0.01).
8	Nanney *et al.* (2016) [113]	School-level policies	14028	11-18	• Longitudinal cohort • Food frequency questionnaire	Soft drink availability and consumption	Total diet food intakes: • Soft drinks	<u>Total Diet</u> • Higher soda availability associated with increased intake in boys of soda relative to no soda availability (p<0.05),

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
8 (cont.)	Nanney *et al.* (2016) (113) (cont.)				• Data source: CDC School Health Profiles Study And Minnesota Student Survey			not significant in girls or all children combined (p>0.05).
9	Taber *et al.* (2012) (115)	State-level policies	6900	13-14	• Cross-sectional • Food frequency questionnaire • Data source: Early Childhood Longitudinal Study-Kindergarten Class	Soft drink availability and consumption	Total diet food intakes: • Soft drinks	Total Diet • Despite reduced access and purchase in schools, daily soft drink consumption was more prevalent in states that regulated soft drinks in school (p<0.05).
10	Taber *et al.* (2014) (116)	State-level policies	8245	14-18	• Cross-sectional • Food frequency questionnaire • Data source: National Youth Physical Activity and Nutrition Study (2010)	Soft drink availability and consumption	Total diet food intakes: • Soft drinks	Total Diet • Students with in-school access to vending machines consumed less soda daily than no access (p=0.02).
11	Taber *et al.* (2015) (117)	State-level policies	8696	14-18	• Cross-sectional • Food frequency questionnaire • Data source: National Youth Physical Activity and Nutrition Study (2010)	Soft drink availability and consumption	Total diet food intakes: • Soft drinks	Total Diet • Students with access to vending machines in states that ban soda in schools consumed more sports drinks (CI = 1.11; 1.42), energy drinks (CI = 1.03; 1.62), and other soft drinks (CI = 1.02; 1.32). • Students with no access to vending machines but allow

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
11 (cont.)	Taber *et al.* (2015) [117] (cont.)							soda in schools consumed more diet alternatives (CI = 1.00; 1.97) and sports drinks (CI = 1.03; 1.45).
12	Terry-McElrath *et al.* (2015) [118]	State-level policies	7877	15-18	• Cross-sectional • Food frequency questionnaire • Data source: Monitoring the Future (2010-2012), and Youth, Education and Society Study	Soft drink availability and consumption	Total diet food intakes: • Soft drinks	<u>Total Diet</u> • Associations between state school soda bans and lower soft drink availability in schools (p<0.05), no significant associations between state policies and student consumption in overall sample (p>0.05).
13	Vernarelli and O'Brien (2017) [138]	Healthy Hunger-free Kids Act of 2010	2190	4-19	• Cross-sectional • 24-hour recalls • Data source: NHANES (2009-2012)	School lunch type (school and packed lunches)	Lunchtime food intakes: • Fruit and vegetables	<u>Lunchtime</u> • No significant difference in lunchtime vegetable intakes between lunch type for children aged 4-13 (p>0.05). • Children aged 14-19, children consuming packed lunches had higher lunchtime vegetable intakes than school lunch consumers (p=0.007). • No significant differences in fruit intakes between lunch types across all age groups (p>0.05).
Canadian Studies								

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
1	Godin *et al.* (2018) [132]	Alberta – 2012 Alberta Nutrition Guidelines for Children and Youth (voluntary) Ontario – 2011 Policy/Program Memorandum no. 150 (P/PM150) (mandatory for public schools, voluntary for private schools)	7679	12-18	• Longitudinal • Food frequency questionnaire • Data source: COMPASS study (2013-2016)	Soft drink availability and consumption	Total diet food intakes: • Soft drinks	<u>Total Diet</u> • No significant association between beverage availability in school vending machines and frequency of soft drink intake ($p>0.05$). • Voluntary guidelines higher soft drink intake than no and mandatory guidelines ($p<0.05$).
2	Godin *et al.* (2019) [131]	Alberta – 2012 Alberta Nutrition Guidelines for Children and Youth (voluntary) Ontario – 2011 Policy/Program Memorandum no. 150 (P/PM150) (mandatory for public schools, voluntary for private schools)	41829	14-17	• Observational • Food frequency questionnaire • Data source: COMPASS study (2013-2014)	Soft drink availability and consumption	Total diet food intakes: • Soft drinks	<u>Total diet</u> • Voluntary guidelines higher soft drink intake (and availability) than mandatory guidelines ($p<0.05$).
3	Masse *et al.* (2014) [122]	District and school-level policies	11385	12-18	• Cross-sectional • Food frequency questionnaire • Data source: BC Adolescent Health	Policy type	Total diet food intakes: • Soft drinks	<u>Total Diet</u> • Students were less likely to be a moderate consumer in schools with healthier nutrition guidelines than those without

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
3 (cont.)	Masse *et al.* (2014) [122] (cont.)				Survey (2007-2008)			these guidelines (p<0.006), no effect for high consumers (p>0.05). • Soft drinks being available in schools was associated with moderate and high consumption of soft drinks (p=0.022 and p=0.003 respectively).
4	Tugault-Lafleur *et al.* (2018) [123]	District-level policies	4589	6-17	• Cross-sectional • 24-hour recall • Data source: 2004 Canadian Community Health Survey Cycle 2.2	School lunch type (school and packed lunches)	Lunchtime food intakes: • Fruit and vegetables	During school hours (including lunch) • Packed lunch consumers had higher intakes of fruit and vegetables compared to lunches obtained elsewhere (p<0.05). School day (total diet) • No significant difference between lunch types for total fruit and vegetable intakes (p>0.05).
South Korean studies								
1	Choi *et al.* (2017) [124]	2007 policy – ban on soft drinks, recommended ban on fried and fast foods 2009 policy – restriction of energy-dense, nutrient-poor foods	4959	12-19	• Cross-sectional • 1x 24-hour recall • Data source: KNHANES (1998-2012)	Pre- and post-policy implementation	Total diet food intakes: • Soft drinks	Total Diet • Consumption of soft drinks out of home and school increased significantly post-policy implementation (p=0.015). This was also consistently higher than intakes from other sources (including home and school).

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
1 (cont.)	Choi *et al.* (2017) [124] (cont.)							• In school soft drink consumption did not significantly change post-2009 policy implementation (p=0.491).
2	Kim *et al.* (2013) [125]	2007 policy – ban on soft drinks, recommended ban on fried and fast foods 2009 policy – restriction of energy-dense, nutrient-poor foods	11386	12-18	• Cross-sectional • Food frequency questionnaire • Data source: Korean Youth Risk Behavior Web-based Survey (2006-2011)	Pre- and post-policy implementation	Total diet food intakes: • Soft drinks	Total Diet • Mean soft drink consumption decrease over time post-implementation, regardless of SES and gender (p<0.0001). • High SES consumed more soft drinks compared with low SES between 2006-2009 (p<0.05), but no significant differences 2009-2011 (p>0.05).

2.5 School food policies and the effect on children's diet quality

2.5.1 Summary of studies included

The review identified nine studies that looked at the impact of school food policies on children's diet quality [121, 123, 143-149]. The studies included are detailed in Table 2.6. The majority of studies included (six) were conducted in the USA [143-147, 149], two studies in Canada [121, 123], and one in the UK [148]. Children's ages ranged from 4-19 years. All nine studies used a cross-sectional study design [121, 123, 143-149]. Various methods were utilised for dietary data collections including food diaries [148] and 24-hour recalls [121, 123, 143-147, 149]. A variety of policies were studied, as shown in Table 2.6. Four studies explored difference by school lunch type [123, 144, 145, 148], three explored diet quality pre- and post-policy implementation [121, 143, 149], and two explored both lunch type and pre- and post-policy [146, 147]. Five of the included studies consider diet quality for total diet [143, 144, 147-149], and four considered both lunchtime and total diet [121, 123, 145, 146].

2.5.2 Diet quality measures used by included studies

For the studies included, diet quality is measured by comparing how closely dietary intakes adhere to dietary guidelines. Higher diet quality scores indicate closer adherence to dietary guidelines, and lower scores indicate that diets have low adherence to guidelines [143-149]. Diet quality can be influenced by numerous factors including socioeconomic status, various food environments, dietary habits, and food preferences [21]. Six of these studies used the Healthy Eating Index-2010 (HEI-2010) to measure diet quality [143-147, 149]. The HEI-2010 measures how closely a diet adheres to the 2010 Dietary Guidelines for Americans and is composed of two components: adequacy and moderation [150]. One study conducted in Canada, used an adapted version of the HEI-2010, called Healthy Eating Index Canada (HEI-C) validated for a Canadian population and the School Healthy Eating Index, which is adapted version of HEI-C used by this study to look at diet quality during school hours only [123]. The only UK study used Diet Quality Index for Adolescents (DQI-A) to measure diet quality [148]. The DQI-A measures adherence to food-based dietary guidelines originally designed for Flemish adolescents, but was adapted for this study to measure adherence to guidelines set out by the UK Eatwell Guide [148]. The DQI-A is composed of three components: quality, diversity equilibrium (adequacy and excess) [22]. One study used the Diet Quality Index – International (DQI-I) [121]. This is composed of four components: variety adequacy, moderation and overall balance, and includes food group intakes and macronutrient intakes [121]. This differs from the DQI-A as it also takes into consideration macronutrient intakes while and the DQI-A score only considers intakes of food groups.

2.5.3 Impact of school food policies on diet quality

2.5.3.1 Impact of school food policies on diet quality for total diet

The only study conducted in the UK is by Taher *et al.* (2020) (*n*=2118, aged 11-18 years, school lunch type comparison) who reported that for children aged 15-18 years, packed lunch consumers had significantly higher DQI-A scores (i.e., a better diet) than school lunch consumers (Table 2.6) [148]. However, in children 11-14 years, there was no significant difference between school and packed lunch consumers [148]. Two Canadian studies reported the impact of school food policies on diet quality for total diet. Gaudin *et al.* (2023) reported that DQI-I score was not significantly different between children's dietary intake that attended schools with mandatory or voluntary policies (*n*=12142, aged 6-18 years, pre/post policy and policy type comparison) [121]. Similarly, Tugault-Lafleur *et al.* (2018) reported no significant differences in total diet quality scores between school lunch types [123]. Overall, studies conducted in the USA reported that school food policies had a positive impact on children's diet quality for total diet [143-147, 149]. Berger *et al.* (2020) found that following implementation of the Healthy Hunger-Free Kids Act 2010 (HHFKA) policy, diet quality improved by 4.3 HEI-2010 points when children consumed school food, and 1.3 HEI-2010 points for all children participating in the study (*n*=8525, aged 4-19 years, pre/post policy comparison) [143]. This is similar to findings reported by Valizadeh and Ng (2020) which reported that before HHFKA implementation school food improved children's total day diet quality by 2.4 HEI-2010 points, after implementation the effect of school food on diet quality increased (4.3 HEI-2010 points) (*n*=7341, aged 4-19 years, pre/post policy comparison) [149]. Smith *et al.* (2021) found post-policy implementation, consumption of school lunches increased diet quality compared with packed lunches (*n*=7350, aged 4-19 years, pre/post policy and school lunch type comparison) [147]. Forrestal *et al.* (2021) (*n*=1843, aged 6-19 years, school lunch type comparison), Gearan *et al.* (2020a) (*n*=6389, aged 5-18 years, school lunch type comparison) and Kinderknecht *et al.* (2020) focussed on the impact of SES on associations between school food policy and diet quality and therefore is included in the section on impact of SES section below (*n*=6389, aged 5-18 years, pre/post policy and school lunch type comparison) [144-146].

It was indicated by one Canadian and four US-based studies that diet quality scores were lower out-of-school in comparison to in-school diet quality scores (123, 144, 146, 149). Forrestal *et al.* (2021) also found that school foods generally had a higher diet quality score than foods obtained outside of school, for school meal participants, HEI-2010 score for lunchtime diet quality was 80% and for total diet was 56.5% (144). This suggests that foods consumed outside of school which are not regulated by school food policy, can have a negative impact on overall diet quality.

2.5.3.2 Impact of school food policies on diet quality for lunchtime

Similar to studies on total diet, studies of lunchtime food conducted in the USA reported that school food policies had a positive impact on children's lunchtime diet quality (Table 2.6) (145, 146). Gearan *et al.* (2020a) found that school lunch consumers had higher diet quality than children consuming packed lunches (151). Further, Kinderknecht *et al.* (2020) reported that post-policy implementation, lunchtime diet quality improved for children consuming school lunches and was limited for children not consuming school lunches (146).

Two Canadian studies reported impacts of school food policy on lunchtime diet quality (121, 123). During school hours, Gaudin *et al.* (2023) reported that children in provinces with mandatory school food policies had higher diet quality than voluntary policy provinces (121). Conversely, Tugault-Lafleur *et al.* (2018) found that packed lunch consumers had higher lunchtime diet quality than school lunch consumers and children consuming lunch from other sources (123).

2.5.4 Impact of socioeconomic status

Although school food policies were found to have a positive impact on diet quality across SES groups at lunchtime (146), some studies found variations in impact on total diet and lunchtime diet quality (Table 2.6) (121, 144-147). Kinderknecht *et al.* (2020) found for all SES groups there were improvements in lunchtime diet quality post-implementation, however, the greatest improvement to lunchtime diet quality score was found in lower income groups consuming school lunch (146). Conversely, Gaudin *et al.* (2023) reported that diet quality did not significantly change for children in lower income children, but did increase for higher income children (121).

In terms of total diet, diet quality, Gearan *et al.* (2020a) found children from families of higher income consuming school lunches had significantly higher overall diet quality than non-consumers, but that this was not significant for children from families of lower income [(145)]. Further, Smith *et al.* (2021) found that post-policy implementation, school food significantly improved diet quality compared with packed lunches, however, the change in diet quality following policy implementation when children consumed school meals was only significant in children from higher income families [(147)]. However, Kinderknecht *et al.* (2020) found overall diet quality significantly increased post-policy implementation in both low and low-middle income children, with improvements in higher income children not significant [(146)]. These results indicate that school food policies generally improved diet quality in all SES groups, and children in lower SES groups may have a greater improvement, although despite this, children in higher SES groups had a higher overall diet quality [(144, 145)]. Forrestal *et al.* (2021) found that despite more food insecure and moderately insecure children than food secure children participating in the national school lunch program, full day diet quality did not significantly differ between food security groups [(144)]. Similarly, Gaudin *et al.* (2023) reported full day diet quality did not change post-implementation of policy across income groups [(121)].

Other studies, have stated that children from higher SES groups tend to have better diet quality than children from families in lower SES groups [(152)]. This is potentially due to lower income families consuming low-cost, energy-dense diets which are also less nutrient dense [(152, 153)]. A study by Sabinsky *et al.* (2019) found that providing free school meals improved diet quality in children aged between 7 and 13 years in Denmark compared with paid meals and packed lunches [(154)].

2.5.5 Study strengths and limitations

The studies included had several strengths. Many included studies had relatively large sample sizes [(121, 123, 143, 145-147, 149)], as mentioned previously, this is beneficial as these studies may be more representative of the general population than studies with smaller sample sizes [(136, 137)]. All studies included in this review contained a comparison to examine the potential impacts of school food policies on children's diet quality e.g., diet quality pre- and post-implementation of school food policies [(121, 123, 143-149)]. All included studies used national survey data (US, UK and Canada), which is beneficial as the results from these studies may be more representative of the general population of 11-18 year olds in that country [(121, 123, 143-149)]. All included studies used a validated measure of diet quality (or an adapted version of a validated measure) [121, 123, 143-149], which may be beneficial as these have been assessed to ensure that the give an accurate representation of diet quality [21]. Several limitations were highlighted in the studies included in the review. A key limitation is that some studies included children between the ages of 4-19 years which is a broader age range than the inclusion criteria for this review [123, 143-147, 149]. For some studies, it was possible to only include results from older children (middle and high school), however, this was not possible for all studies. As a result, it is difficult to know the extent to which school food policies had an impact on diet quality of children aged between 11-18 years. Dietary information obtained was self-reported, consequently there is a chance of misreporting by the children. In several of the studies carried out in the USA, data were gathered nationwide and did not distinguish between federal, state, and local school food policy changes [143-147, 149]. Additionally, other policies targeting food and drinks sold in schools were introduced during the study period of many of the studies included. These other policies may have had an impact on the diets of children in the USA and may have resulted in the impact of the HHFKA policy being overestimated in these studies [146].

There are two main limitations surrounding the measure of diet quality used. Most studies included in this review used the HEI-2010 measure of diet quality allowing for comparisons to be made [143-147, 149]. However, different measures of diet quality used in different countries may result in issues around comparisons of diet quality scores. Additionally, the Canadian study using DQI-I as a measure of diet quality highlighted that this measure does not use Canada-specific dietary guidelines [123].

2.5.6 Summary

In summary, all studies exploring the impact of school food policies on children's diet quality in this review have been published since 2018, suggesting that this is a topical and emerging approach to studying dietary intake. Most of the studies included in this review found that school food policies had a positive impact on children's diet quality both at lunchtime and overall [123, 143, 145, 147-149]. However, food consumed outside of school appeared to have a negative impact on diet quality, which reduces the impact of school food policies over the full day [145, 146, 149]. In terms of SES, although children from higher SES groups tended to have a higher diet quality over the full day, there were mixed findings regarding which SES groups saw the greatest improvement in diet quality score following policy implementation [144, 146].

Some studies included a wide range of age groups across school stages and do not separate results by age group, therefore, studies are needed to explore impact on diet quality at specific age groups to help determine areas of improvement for school food policies. The review did highlight several gaps. Most of the research on diet quality and school food has been carried out in the USA, so more studies are needed in other countries as results cannot be generalised for other populations due to different policies, and populations. Additionally, there is only one other UK-based study that has explored the impact of school food policies on children's diet quality, this study does not explore differences pre- and post-policy implementation, so more research is needed to explore this.

Table 2.6 Characteristics and key findings of included studies exploring the impact of school food policies on diet quality

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
					UK studies			
1	Taher *et al.* (2020) [148]	The Education (Nutritional Standards and Requirements for School Food) (England) Regulations 2007 The Requirements for School Food Regulations 2014	2118	11-18	• Cross sectional. • 4-day food diary • Data source: NDNS (2008-2016)	School lunch type (packed, school, other)	Diet Quality Index for Adolescents (DQI-A)	<u>Total Diet</u> • Overall, mean DQI-A score was low at 21.1%. • For children aged 11-14 consuming school meals had a high diet quality score compared with children buying lunch at a shop or café (p<0.01). • For children aged 15-18 packed lunch consumers had a higher diet quality score than school meal consumers (p<0.01), however, school meal consumers had a higher diet quality score then shop or café bought lunch consumers (p<0.01). • No significant differences in diet quality between hot and cold school meal consumers, children who had lunch at home or did not have lunch.
					USA studies			
1	Berger *et al.* (2020) [143]	Healthy Hunger-free Kids Act of 2010	8525	4-19	• Cross-sectional. • 2x 24-hour recall	Pre- and post-policy implementation	Healthy Eating Index 2010 (HEI)	<u>Total diet</u> • Post-implementation, improved diet quality by 4.3

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
1 (cont.)	Berger *et al.* (2020) [143] (cont.)				• Data source: NHANES (2007-2016)			HEI-2010 points when school food consumed (CI = 2.5; 6.1) and 1.3 points overall (CI = 0.73; 1.8) in all school aged children. • Post-implementation, improved total diet quality by 5.3 points when school food consumed (CI = 0.86; 9.8) and 1.2 points overall (CI = 0.18; 2.2) in high school children.
2	Forrestal *et al.* (2021) [144]	Healthy Hunger-free Kids Act of 2010	1843	6-19	• Cross-sectional • 1x 24-hour recall • Data source: School Nutrition and Meal Cost Survey (2014-2015)	School lunch type (consumers vs non-consumers)	Healthy Eating Index 2010 (HEI) • Total diet	<u>Total Diet</u> • More food insecure and marginally insecure children participated in the National School Lunch program. • Diet quality was not significantly different between food insecure, marginally secure and food secure groups for children participating in the school lunch program (p>0.05). • Across food security status groups, food consumed from school was of higher diet quality than food obtained elsewhere.
3	Gearan *et al.* (2020a) [145]	Healthy Hunger-free Kids Act of 2010	6389	5-18	• Cross-sectional • 1x 24-hour recall • Data source: School Nutrition	School lunch type (consumers vs non-consumers)	Healthy Eating Index 2010 (HEI) • Lunchtime • Total diet	<u>Lunchtime</u> • For both lower and higher income children, school lunch consumers had significantly

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
3 (cont.)	Gearan *et al.* (2020a) [145] (cont.)				and Meal Cost Survey (2014-2015)			higher diet quality score than non-consumers (p<0.05). <u>Total Diet</u> • In both low- and high-income students, school lunch consumers had higher HEI-2010 scores than non-consumers at lunch (p<0.05). • In higher income students, school lunch consumers had a significantly higher HEI-2010 score than non-consumers (p<0.05) for total diet, not significant in lower income students (p>0.05). <u>Difference between lunch and total diet</u> • Total HEI-2010 scores for school lunch consumers decreased from lunch to 24 hours by 13-17 percentage points across all income subgroups.
4	Kinderknecht *et al.* (2020) [146]	Healthy Hunger-free Kids Act of 2010	6389	5-18	• Cross-sectional. • 2x 24-hour recall • Data source: NHANES (2007-2010, 2013-2016)	Pre- and post-policy implementation School lunch type	Healthy Eating Index 2010 (HEI) • Lunchtime • Total diet	<u>Lunchtime</u> • Post-implementation HEI-2010 lunch score for school lunch consumers improved by 11.9 points (CI = 9.4; 14.3) for low-income children, by 14.3 for low-middle income children (CI

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
4 (cont.)	Kinderknecht *et al.* (2020) [146] (cont.)					(consumers vs non-consumers)		= 9.4; 19.1), 12.8 for middle-high income children (CI = 9.8; 15.8). • Post-implementation for non-consumers HEI-2010 lunch score was not significant for low, low-middle income but was significant for middle-high income increasing by 4.7 (CI = 2.3; 7.0). <u>Total Diet</u> • Total daily HEI-2010 difference in difference mean score increased by 3.4 (CI = 0.5; 6.3) for low-income school lunch consumers, 4.7 (CI = 0.8; 8.7) low middle income, no significant association for total day HEI score for middle-high income.
5	Smith *et al.* (2021) [147]	Healthy Hunger-free Kids Act of 2010	7350	4-19	• Cross-sectional. • 2x 24-hour recall • Data source: NHANES (2009-2016)	Pre- and post-policy implementation School lunch type (packed, school, other)	Healthy Eating Index 2010 (HEI) • Total diet	<u>Total Diet</u> • Post-policy implementation, school meals increased diet quality by 3.96 HEI-2010 points in middle and high school students, compared with packed lunches. The difference between school food and food from home was significant ($p<0.01$).

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
5 (cont.)	Smith *et al.* (2021) (147) (cont.)							• For lower income children, compared with packed lunches school meals had a beneficial impact on diet quality both pre- and post-policy implementation ($p<0.05$), however, the impact of schools on diet quality did not significantly change over time. • For higher income children, no significant difference pre-implementation for diet quality between lunch types, however, for school food significant difference post-implementation ($p<0.01$). The impact of school meals on diet quality significantly increased over time ($p<0.05$).

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
6	Valizadeh and Ng (2020) [149]	Healthy Hunger-free Kids Act of 2010	7341	4-19	• Cross-sectional. • 2x 24-hour recall • Data source: NHANES (2009-2010, 2015-2016)	Pre- and post-policy implementation	Healthy Eating Index 2010 (HEI) • Total diet	<u>Total Diet</u> • Pre-implementation, consuming school food improved diet quality by 2.10 HEI-2010 points. Post-implementation this effect increased to 4.28 HEI-2010 point increase ($p<0.01$). • Post-implementation, away from school diet quality decreased ($p<0.01$) despite overall improvement in diet quality.
Canadian studies								
1	Gaudin *et al.* (2023) [121]	Provincial mandatory and voluntary school food policies	12142	6-18	• Cross-sectional • 1x 24-hour recall • Data source: Canadian Community Health Survey (2004, 2015)	Pre- and post-policy implementation Policy type (Mandatory v voluntary policy)	Diet Quality Index International (DQI-I) • Total Diet • During school hours (lunchtime, break etc.) • Out of school	<u>During school hours (including lunch)</u> • DQI-I score increased by 3.44 points during school hours in mandatory policy provinces relative to voluntary ($p=0.004$). • For low-income children, school hours DQI-I score did not significantly change ($p>0.05$). • For higher income children, DQI-I score increased by 3.0 points during school hours ($p=0.041$). <u>Total diet</u>

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
1 (cont.)	Gaudin *et al.* (2023) [121] (cont.)							• DQI-I score did not significantly change for total diet in mandatory policy provinces relative to voluntary (p>0.05). • For low income and higher income children, DQI-I score did not significantly change (p>0.05). <u>Out of school</u> • DQI-I did not significantly change for out of school in mandatory policy provinces relative to voluntary (p>0.05). • For low- and higher-income children, out of school DQI-I did not significantly change (p>0.05).
2	Tugault-Lafleur *et al.* (2018) [123]	District-level policies	4589	6-17	• Cross-sectional • 1x 24-hour recall • Data source: Canadian Community Health Survey (2004)	School lunch type (packed, school, other)	School - Healthy Eating Index • During school hours (lunchtime, break etc.) Healthy Eating index Canada	<u>During school hours (including lunch)</u> • For children aged 9-13, children consuming packed lunches had significantly higher school HEI-C than children consuming school lunches and other lunches (p<0.05). <u>Total diet</u> • No significant difference between school lunch type (p>0.05).

2.6 School food policies and the effect on children's nutrients intakes

2.6.1 Summary of studies included

Of the studies included in this review eleven studies explored the impact of school food policies on nutrient intakes of children [87, 123, 127, 138, 140, 141, 155-159]. The studies included are detailed in Table 2.7 and results are summarised in Table 2.8. The majority of the included studies (five) were conducted in the UK [87, 127, 140, 158, 159], four were conducted in the USA [138, 141, 155, 157], one was conducted in Canada [123] and one was conducted in Chile [156]. Children's ages ranged from 4-19 years. Eight of the included studies were cross-sectional [87, 123, 127, 138, 140, 157-159], one was longitudinal [156], one was observational [155], and one was a pilot study [141]. Various methods were utilised for dietary data collection including lunchtime observations [87, 127, 141, 157, 158], food diaries [140, 159], and 24-hour recalls [123, 138, 155, 156]. A variety of policies were studied, as shown in Table 2.7. Five of the included studies used pre- and post-implementation of policy [141, 155-158], five used school lunch types [87, 123, 127, 138, 140] and one used both pre- and post-implementation and school lunch types for comparisons [159].

2.6.2 Total diet

2.6.2.1 Energy intakes

Studies reported varied findings regarding the impact of school food policies on children's energy intakes (Table 2.8) [123, 155, 159]. For total diet, a UK study by Spence *et al.* (2014) reported that post-implementation of the school food policy, children's mean energy intake decreased (*n*=513, aged 11-12 years, pre/post policy and policy type and school lunch type comparison) [159]. However, a USA study by Cohen *et al.* (2018) did not find a significant difference in energy intake throughout the day following implementation of school food policies (*n*=160, aged 9-17 years, pre/post policy comparison) [155]. Additionally, a Canadian study by Tugault-Lafleur *et al.* (2018) reported no significant differences in energy intakes between school lunch types [123].

2.6.2.2 Fat intakes

The studies included in this review reported mixed effects of school food policies on children's total diet fat intakes (Table 2.8) [123, 155, 159]. A study conducted in the UK by Spence *et al.* (2014) found that mean per cent energy from fat decreased following implementation of school food policy regardless of lunch type, however, there was a greater decrease observed in school lunch consumers [159]. However, a Canadian study by Tugault-Lafleur *et al.* (2018) reported that school lunch consumers had higher fat intakes than packed lunch consumers [123]. Further, a study conducted in the USA by Cohen *et al.* (2018) did not find a significant difference in fat intakes following policy implementation, regardless of school lunch type [155].

2.6.2.3 Saturated fat intakes

The studies included in this review reported no significant impact of school food policies on children's total diet saturated fat intakes (Table 2.8) [123, 155, 156, 159]. Four studies included in this review reported on the impacts of school food policies on saturated fat intakes. Tugault-Lafleur *et al.* (2018) reported no significant differences in saturated fat intakes between school lunch types in Canadian children [123]. Additionally, Spence *et al.* (2014) (UK children), Cohen *et al.* (2018) (USA children) and Fretes *et al.* (2023) (Chilean children) (*n*=294, aged 12-14 years, pre/post policy comparison) reported no significant differences in saturated fat intakes pre- and post-policy implementation regardless of school lunch type [155, 156, 159].

2.6.2.4 Carbohydrate intakes

Only one study in this review explored the impact of school food policies on carbohydrate intakes (Table 2.8), Tugault-Lafleur *et al.* (2018) reported that, in Canadian children, school lunch consumers had lower carbohydrate intakes compared with packed lunch consumers [123].

2.6.2.5 Sugar intakes

Generally, the studies included in this review reported no significant impact of school food policies on sugar intakes (Table 2.8) [123, 155, 156, 159]. A study by Tugault-Lafleur *et al.* (2018) including Canadian children reported no significant differences in sugar intake between school lunch types for total diet [123]. Spence *et al.* (2014) which explored effects in UK children and Fretes *et al.* (2023) in Chilean children reported no significant differences in sugar intakes post-policy implementation [156, 159]. However, Cohen *et al.* (2018) reported that, in USA children, sugar intakes decreased following implementation of school food policies [155].

2.6.2.6 Fibre intakes

Three studies explored the impact of school food policies on children's fibre intakes for total diet (Table 2.8) (123, 155, 159). Spence *et al.* (2014) (UK children) and Cohen *et al.* (2018) (USA children) reported no significant difference for fibre intake post-policy implementation (155, 159). However, Tugault-Lafleur *et al.* (2018) reported that, in Canadian children, school lunch consumers had lower fibre intakes than packed lunch consumers (123).

2.6.2.7 Protein intakes

Only one study, conducted in Canadian children, looked at impact of school food policies on total diet protein intakes (Table 2.8) (123). Tugault-Lafleur *et al.* (2018) reported no evidence of significant differences in protein intakes between school lunch types (123).

2.6.2.8 Vitamin A intakes

Only one study, included in this review conducted in Canadian children, looked at impact of school food policies on total diet vitamin A intakes (Table 2.8) (123). Tugault-Lafleur *et al.* (2018) reported that there was no evidence of significant differences in vitamin A intakes between school lunch types (123).

2.6.2.9 Vitamin C intakes

Two studies included in the review looked at the impact of school food policies on total diet vitamin C intakes (Table 2.8) (123, 159). A study conducted in the UK by Spence *et al.* (2014) found that vitamin C intakes increased post-policy implementation regardless of school lunch type (159). However, Tugault-Lafleur *et al.* (2018) reported no significant difference between school lunch types regarding vitamin C intakes in Canadian children (123).

2.6.2.10 Folate intakes

None of the studies included in this review explored the impact of school food policies on total diet folate intakes.

2.6.2.11 Sodium intakes

Studies reported varied findings regarding the impact of school food polices on total diet sodium intakes (Table 2.8) (123, 155, 156, 159). A UK study by Spence *et al.* (2014) reported that post-implementation of school food policy, children's sodium intakes decreased in all children regardless of school lunch type [159]. However, a study conducted in Chile by Fretes *et al.* (2023) reported increased sodium intakes post-policy implementation [156]. Additionally, a study conducted in the USA reported no significant differences post-policy implementation and a Canadian study by Tugault-Lafleur *et al.* (2018) reported no significant difference between school lunch types [123].

2.6.2.12 Calcium intakes

Three studies included in this review reported varied findings regarding the impact of school food policies on children's total diet calcium intakes (Table 2.8) [123, 156, 159]. A study by Spence *et al.* (2014) reported that calcium intakes increased post-implementation of school food policy in all children regardless of school lunch type [159]. The Canadian study by Tugault-Lafleur *et al.* (2018) reported no significant differences in total diet calcium intakes between school lunch types [123].

2.6.2.13 Iron intakes

Two studies included in the review explored the impact of school food policies on children's total diet iron intakes (Table 2.8) [123, 159]. A UK study by Spence *et al.* (2014) reported decreased iron intake post-policy implementation [159]. Similarly, a Canadian study by Tugault-Lafleur *et al.* (2018) reported school lunch consumers had lower iron intakes compared to packed lunch consumers [123].

2.6.2.14 Zinc intakes

Only one study included in this review, conducted in Canadian children, looked at impact of school food policies on total diet zinc intakes (Table 2.8) [123]. Tugault-Lafleur *et al.* (2018) reported that there was no evidence of significant differences in zinc intakes between school lunch types [123].

2.6.3 Lunchtime

2.6.3.1 Energy intakes

For lunchtime energy intakes, the studies included in this review reported mixed findings (Table 2.8) [87, 123, 127, 138, 141, 157-159]. A USA study by Mendoza *et al.* (2010) found after policy implementation, children's energy density from all foods and beverages foods at lunchtime decreased, though this study did not look at overall energy intakes (*n*=12788, aged 11-14 years, pre/post policy comparison) [157]. Similarly, another USA study by Vernarelli and O'Brien (2017) found school lunch consumers reported lower lunch meal energy density compared with non-consumers. Children aged 9-13 years consuming school meals reported lower lunchtime energy intakes, this was not significant for older children [138]. Both Cullen *et al.* (2015) (USA) and Nicholas *et al.* (2013) (UK, school lunch consumers) (*n*=5969, aged 10-19 years, pre/post policy comparison) reported decreased lunchtime energy intakes following implementation of school food policies [141, 158]. The UK study by Spence *et al.* (2014) reported that following implementation of school food policies, school lunch consumers had lower energy intakes at lunchtime, although the difference between school lunch types was not significant for total diet [159]. Pearce *et al.* (2013) and Stevens *et al.* (2013), both conducted in the UK, found that compared with packed lunch consumers, children consuming school meals had a higher energy intake [87, 158].

2.6.3.2 Fat Intakes

The studies included in this review reported generally positive effects of school food policies on children's lunchtime fat intakes (Table 2.8) [87, 123, 127, 138, 158, 159]. Four UK studies reported on lunchtime fat intakes. Nicholas *et al.* (2013) reported that, lunchtime intakes of fat in school lunch consumers decreased following implementation of policy [158]. Pearce *et al.* (2013) found that compared with packed lunches, school lunch consumers had lower per cent energy intake from fat at lunch [87]. Additionally, Spence *et al.* (2014) reported that, for children aged 11-12 years, mean lunchtime per cent energy intake from fat decreased following implementation of school food policy for school lunch consumers [159]. A USA study by Vernarelli and O'Brien (2017) found school lunch consumers 9-13 years had lower per cent energy from fat compared with non-consumers, however, there was no significant difference between lunch types for children aged over 14 years [138]. Conversely, another UK study by Stevens *et al.* (2013) found school lunch consumers had higher fat intakes than packed lunch consumers [127]. Similarly, a Canadian study by Tugault-Lafleur *et al.* (2018) reported that school lunch consumers reported higher fat intakes than packed lunch consumers [123].

2.6.3.3 Saturated fat intakes

For lunchtime saturated fat intakes, most of the included studies reported positive effects of school food policies (Table 2.8) [87, 123, 127, 138, 156, 158, 159]. Two UK studies by Spence *et al.* (2014)

and Nicholas *et al.* (2013) reported that lunchtime intakes of saturated fat (per cent energy) decreased following implementation of policy [158, 159]. Another UK study by Pearce *et al.* (2013) found that compared with packed lunches, school lunch consumers had lower per cent energy intake saturated fat at lunch [87]. Further, a study conducted in Chile reported that following policy implementation, per cent energy from saturated fat at lunchtime decreased [156]. A study conducted in the USA by Vernarelli and O'Brien (2017) found school lunch consumers aged 9-13 years had lower per cent energy from saturated fat compared with non-consumers, however, there was no significant difference for older children aged over 14 years [138]. Two other studies reported no significant effect of school food policy on lunchtime saturated fat intakes. Haney *et al.* (2023) and Stevens *et al.* (2013) reported that there was no significant difference between school lunch types for lunchtime per cent energy saturated fat in UK children [127, 140] and Tugault-Lafleur *et al.* (2018) reported no significant differences in saturated fat (grams) intakes between school lunch types in Canadian children [123].

2.6.3.4 Carbohydrate intakes

Mixed findings were reported in the studies included in this review regarding lunchtime carbohydrate intakes (Table 2.8) [87, 123, 127, 138, 156, 158]. Both Pearce *et al.* (2013) and Stevens *et al.* (2013) found, in UK children, school lunch consumers had higher carbohydrate (grams) intakes than packed lunch consumers, not significant for per cent energy from carbohydrates [87, 127]. However, Nicholas *et al.* (2013) found, following policy implementation, carbohydrate intakes (grams and per cent energy) decreased in UK children consuming school lunches [158]. Further, Tugault-Lafleur *et al.* (2018) reported that, in Canadian children, school lunch consumers had lower lunchtime carbohydrate intakes (grams) compared with packed lunch consumers [123]. Vernarelli and O'Brien (2017) reported that there were no significant differences in carbohydrate intakes (grams) between school lunch types in US children [138].

2.6.3.5 Sugar intakes

Four studies included in the literature review found a positive impact of school food policies on children's mean sugar intakes at lunch (Table 2.8) [87, 123, 127, 138, 156, 158, 159]. Nicholas *et al.* (2013) reported that following implementation of policy in the UK, for children consuming school lunches, intakes of sugar decreased [158]. Further, a study conducted in Chile by Fretes *et al.* (2023) reported decreased mean lunchtime sugar intakes post-implementation of policy [156]. Similarly, Pearce *et al.* (2013) found that UK children consuming school food consumed a lower per cent energy from sugar compared with packed lunch consumers [87] and Vernarelli and O'Brien (2017) conducted in the USA reported that in children aged 9-13 years school lunch consumers had lower sugar intakes [138]. Spence *et al.* (2014) found no significant change in per cent energy from sugar at lunchtime [159]. Similarly, Haney *et al.* (2023) and Stevens *et al.* (2013) reported no significant differences between school lunch types for UK children's sugar intakes and Tugault-Lafleur *et al.* (2018) reported no significant differences between school lunch types in Canadian children [123, 127, 140].

2.6.3.6 Fibre intakes

Studies included in this review report varied findings regarding impacts of school food policies on children's mean lunchtime fibre intakes (Table 2.8) [87, 123, 127, 138, 140, 158, 159]. Studies by Stevens *et al.* (2013) and Pearce *et al.* (2013), both conducted in the UK, found children consuming school lunches had higher lunchtime intakes of fibre than packed lunches [87, 127]. Similarly, another UK study by Nicholas *et al.* (2013), reported that fibre intakes in school lunch consumers increased post-implementation of school food policy [158]. However, Spence *et al.* (2014) (UK children) found that school lunch consumers had lower lunchtime intakes of fibre compared with intakes before policy implementation, intakes increased for packed lunch consumers [159]. Further, studies carried out in the USA by Vernarelli and O'Brien (2017) and Tugault-Lafleur *et al.* (2018) in Canada, reported that school lunch consumers had lower fibre intakes compared with packed lunch consumers [123, 138]. Haney *et al.* (2023) found that in UK children, there was no evidence of a statistically significant difference in fibre intakes between school lunch types [140].

2.6.3.7 Protein intakes

Varied findings were reported for lunchtime protein intakes in the studies included (Table 2.8) [87, 123, 127, 138, 156, 158]. For the studies conducted in the UK, Pearce *et al.* (2013) and Stevens *et al.* (2013) reported school lunch consumers had higher protein intakes at lunchtime compared with packed lunch consumers [87, 127]. Additionally, Nicholas *et al.* (2013), also conducted in the UK, reported that lunchtime protein intakes increased in school lunch consumers post-implementation of school food policy [158]. However, a study conducted in the USA by Vernarelli and O'Brien (2017), reported school lunch consumers had lower protein intakes than packed lunch consumers [138]. Another study in Canadian children by Tugault-Lafleur *et* *al.* (2018) reported that there was no evidence of significant differences in lunchtime protein intakes between school lunch types [123].

2.6.3.8 Vitamin A intakes

Only three studies included in this review explore the impacts of school food policies on vitamin A intakes at lunchtime and these studies report consistent findings [123, 127, 158]. Nicholas *et al.* (2013), in UK children consuming school lunches, found that vitamin A intakes increased post-implementation of school food policy [158]. Both Stevens *et al.* (2013) (UK children) and Tugault-Lafleur *et al.* (2018) (Canadian children) reported that school lunch consumers had higher intakes of vitamin A than packed lunch consumers [123, 127].

2.6.3.9 Vitamin C intakes

Mixed findings were reported on the impact of school food policies on lunchtime vitamin C intakes (Table 2.8) [87, 123, 127, 158, 159]. A UK study by Nicholas *et al.* (2013) reported decreased lunchtime vitamin C intakes in school lunch consumers post-policy implementation [158]. Similarly, a Canadian study by Tugault-Lafleur *et al.* (2018) reported that school lunch consumers had lower vitamin C intakes compared with packed lunch consumers [123]. However, Pearce *et al.* (2013) (UK children) reported that school lunch consumers had higher intakes [87]. Other UK-based studies reported different findings, Spence *et al.* (2014) reported that vitamin C intake did not significantly change post-policy implementation for school lunch consumers but increased for packed lunch consumers [159]. Haney *et al.* (2023) and Stevens *et al.* (2013) reported no significant differences in intakes between school lunch types [127, 140].

2.6.3.10 Folate intakes

Three studies included in this review explored the impact of school food policies on children's lunchtime folate intakes (Table 2.8) [87, 127, 158]. A study by Nicholas *et al.* (2013), conducted in UK children, found that folate intakes in school lunch consumers significantly decreased following policy implementation [158]. However, two other UK studies by Pearce *et al.* (2013) and Stevens *et al.* (2013) explored the impact of school food policies on folate intakes and reported that school lunch consumers had higher intakes than packed lunch consumers [87, 127].

2.6.3.11 Sodium intakes

Six studies included in this review reported varied findings regarding impacts of school food policies on lunchtime sodium intakes (Table 2.8) [123, 138, 140, 156, 158, 159]. A study conducted in the UK by Haney *et al.* (2023) found that school lunch consumers had lower intakes of sodium than packed lunch consumers [140]. Further, two other UK studies by Nicholas *et al.* (2013) and Spence *et al.* (2014) (school lunch consumers only) reported decreased lunchtime sodium intakes post-implementation of school food policy [158, 159]. Similarly, Vernarelli and O'Brien (2017) reported that school lunch consumers had lower sodium intakes at lunchtime compared with packed lunch consumers [138]. However, a Canadian study by Tugault-Lafleur *et al.* (2018) reported no significant differences between school lunch types [123] and a Chilean study by Fretes *et al.* (2023) reported no significant change post-policy implementation for lunchtime sodium intakes [156].

2.6.3.12 Calcium intakes

The studies included in this review also reported mixed findings on the impact of school food policies on lunchtime calcium intakes (Table 2.8) [123, 127, 140, 158, 159]. A UK study by Haney *et al.* (2023) reported that school lunch consumers had lower calcium intakes than packed lunch consumers [140]. Another UK study by Nicholas *et al.* (2013) reported that calcium intakes significantly increased in school lunch consumers post-policy implementation [158]. However, a UK study by Spence *et al.* (2014) reported that for school lunch consumers calcium intakes decreased post-policy implementation, though intakes in packed lunch consumers increased [159]. Another UK study by Stevens *et al.* (2013) found no significant differences in lunchtime calcium intakes between school lunch types [127]. Additionally, a Canadian study by Tugault-Lafleur *et al.* (2018) reported no significant differences in lunchtime calcium intakes between school lunch types [123].

2.6.3.13 Iron intakes

Varied findings were reported regarding impact of school lunch policies on lunchtime iron intakes (Table 2.8) [87, 123, 127, 159]. Two UK studies by Pearce *et al.* (2013) and Stevens *et al.* (2013) reported that school lunch consumer had higher iron intakes compared with packed lunch consumers [87, 127]. However, Spence *et al.* (2014) reported decreased lunchtime iron intake for school lunch consumers post-policy implementation [159]. Further, a Canadian study by Tugault-Lafleur *et al.* (2018) reported school lunch consumers had lower iron intakes compared with packed lunch consumers [123]. However, a UK study by Haney *et al.* (2023) reported no significant differences in iron intakes between school lunch types [140].

2.6.3.14 Zinc intakes

Three studies explored the impact of school food policies on children's lunchtime zinc intakes (Table 2.8) [87, 123, 127]. Two UK-based studies by Pearce *et al.* (2013) and Stevens *et al.* (2013) reported that school lunch consumers had higher lunchtime zinc intakes compared with packed lunch consumers [87, 127]. However, a Canadian study by Tugault-Lafleur *et al.* (2018) reported that lunchtime zinc intakes did not differ between school lunch types [123].

2.6.4 Impact of socioeconomic status

Several studies included explored the effects of school food policy on SES groups (Table 2.8) [138, 157, 159]. Vernarelli and O'Brien (2017) found no significant differences between school lunch consumers eligible for reduced price lunches compared with non-participants, but differences were found for children eligible for free lunches [138]. Mendoza *et al.* (2010) found energy density decreased across socioeconomic groups, however, the greatest effect was observed for children from less deprived groups [157]. This could be a result of those children potentially having more money to spend on energy dense foods like snacks, leading to higher energy density and the restriction of these items due to policy resulting in a larger reduction [157]. This is potentially a result of more energy dense food items being cheaper than healthier more nutrient dense foods. Spence *et al.* (2014) found vitamin C intakes were lower in children from more deprived areas, with some evidence of calcium and iron also being lower in more deprived areas [159]. Vernarelli and O'Brien (2017) reported children consuming school food and that were eligible for free school lunches had significantly better lunchtime nutrient intakes compared with eligible non-consumers, though this was not significant for children eligible for reduced price lunches [138].

2.6.5 Study strengths and limitations

The studies included have several strengths. Many studies had relatively large sample sizes, as mentioned previously, may be more representative than studies with smaller sample size of the general population [136, 137]. All included studies contained a comparator which allowed impacts school food policies to be examined [87, 123, 127, 138, 140, 141, 155-159]. Three studies included in this review contained national survey data (US, UK and Canada) [123, 138, 140], which is beneficial as the results from these studies may be more representative of the general population of children in that country. The studies included in this review had several limitations. Six of the studies collected dietary data using self-reported measures which are at risk of errors such as misreporting [123, 138, 140, 155, 156, 159]. Two of the studies included in this section of the review, Cohen *et al.* (2018) and Vernarelli and O'Brien (2017), included data from children younger than the target age groups as this data could not be separated to only include children aged 11-18 years, so it is difficult to know the extent to which this may have had on the results reported [138, 155]. Further, as previously mentioned, these studies explore the impact of policies from different countries so policies will differ, and within the USA studies looked at a combination of state and national policy which may result in differences in impact of school food policies within the US. Six of the included studies only looked at lunchtime intakes [87, 127, 140, 141, 157, 158, 160], meaning that these studies do not give an indication on how school food policies may impact on nutrient intake over the full day and whether children may compensate for restricted availability of desired foods and drinks in school with increased intakes out-of-school.

2.6.6 Summary

In summary, this review found mixed evidence for the impact of school food policies on dietary intakes including micronutrient intakes, however, the impact on fat, saturated fat was generally positive. In terms of impact of SES groups, children from families in lower SES groups generally had a poorer diet, which may be a result of higher consumption of energy dense, nutrient poor foods. The studies included in this section only included studies from the USA, UK, Canada, and Chile, as no studies from other countries were identified which limits the generalisability of results for other populations. Further, most UK-based studies only looked at the previously introduced policy and not the policy most recently implemented from 2014.

Table 2.7 Characteristics and key findings of included studies exploring the impact of school food policies on nutrient intakes

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
UK studies								
1	Haney *et al.* (2023) [140]	The Education (Nutritional Standards and Requirements for School Food) (England) Regulations 2007 The Requirements for School Food Regulations 2014	3001	12-16	• Cross-sectional • 4-day food diary • Data source: National Diet and Nutrition Survey (2008-2017)	School lunch type (packed and school lunches)	• Lunchtime nutrient intakes	Lunchtime • For children aged 12-14, packed lunch consumers had significantly higher intakes of calcium (p=0.01) and salt (p<0.01) compared with school lunch consumers. No significant differences between lunch types for fibre, vitamin C, iron, NMES and saturated fat (p>0.05). • For children aged 14-16, no significant differences between lunch types for fibre, vitamin C, iron, calcium, salt, NMES and saturated fat (p>0.05).
2	Nicholas *et al.* (2013) [158]	The Education (Nutritional Standards and Requirements for School Food) (England) Regulations 2007	5969	10-19	• Cross sectional • School food available recorded, portions recorded • Subsample of lunches weighed before and after eating	Pre- and post-policy implementation	• Lunchtime nutrient intakes	Lunchtime • For school lunch consumers, post-implementation decreased intakes of energy, carbohydrates, NMES, fat, saturated fat, sodium, vitamin C and folate and increased intakes of protein, fibre, vitamin A and calcium (p<0.001).

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
3	Pearce *et al.* (2013) [87]	The Education (Nutritional Standards and Requirements for School Food) (England) Regulations 2007	497	11-16	• Cross sectional • School food available recorded, portions recorded • Subsample of lunches weighed before and after eating	School lunch type (school and packed lunches)	• Lunchtime nutrient intakes	<u>Lunchtime</u> • School lunch consumers had higher intakes of energy (p= 0·03), protein (p < 0·001), carbohydrate (p= 0·008), NSP (p< 0·001), vitamin C (p= 0·009), folate (p < 0·001), iron (p= 0·005) and zinc (p< 0·001) than packed lunch consumers, and a significantly lower per cent energy from fat (p= 0·035), saturated fat (p= 0·014) and NMES (p=0.029).
4	Spence *et al.* (2014) [159]	The Education (Nutritional Standards and Requirements for School Food) (England) Regulations 2007	513	11-12	• Cross-sectional • 2x 3-day food diary	Pre- and post-implementation School lunch type (school and packed lunches)	• Lunchtime and total diet nutrient intakes	<u>Lunchtime</u> • Post-implementation school lunch consumers demonstrated decreased energy intake, per cent energy from fat, per cent energy from saturated fat, sodium, NSP and iron (all p<0.001). No evidence for change per cent energy from NMES (p>0.05). <u>Total diet</u> • Post-implementation, energy, NSP, sodium and iron intakes decreased (NSP p=0.002, rest p<0.001), calcium and vitamin C intakes increased (p<0.001). • Post-implementation, school lunch consumers had a lower

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
4 (cont.)	Spence *et al.* (2014) (159) (cont.)							per cent energy from saturated fat, intake of sodium (both p<0.02) and calcium (p=0.001) than packed lunch consumers. No difference was found between school lunch and packed lunch consumers for energy, NSP, vitamin C and iron intakes. • Per cent energy from fat decreased post-implementation regardless of lunch type, greater decrease in school lunch consumers (p<0.001) Children from the most deprived areas consumed less vitamin C compared with less deprived areas (p<0.001). No evidence for intakes of energy, sodium, NSP per cent energy from fat, saturated fat and NMES.
5	Stevens *et al.* (2013) (127)	The Education (Nutritional Standards and Requirements for School Food) (England) Regulations 2008	7730	11-18	• Cross sectional • School food available recorded, portions recorded. • Subsample of lunches weighed	School lunch type (school and packed lunches)	Lunchtime nutrient intakes	<u>Lunchtime</u> • School lunch consumers had significantly higher intakes of energy, carbohydrate, protein, fibre, vitamin A, folate, iron and zinc than packed lunches (all p<0.001).

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
5 (cont.)	Stevens *et al.* (2013) [127] (cont.)				before and after eating			• No significant difference between lunch types for fat, saturated fat, sugar, vitamin C and calcium intakes (p>0.05).
				USA Studies				
1	Cohen *et al.* (2018) [155]	Massachusetts competitive food law (105 CR 225.00)	160	9-17	• Observational cohort • 2x 24-hour recall • Data source: NOURISH study	Pre- and post-policy implementation	• Total diet nutrient intakes	<u>Total diet</u> • No significant difference in energy, total fat, saturated fat, fibre or sodium consumed throughout day after implementation (p>0.05 for all). • Children consumed 22g less sugar daily after implementation (p<0.002). • Children consumed 10g less sugar after school after implementation (p<0.01).
2	Cullen *et al.* (2015) [141]	Healthy Hunger-free Kids Act of 2010	427	11-13	• Pilot Study • Lunchtime observation	Intervention (new school food policy) and control (old school food policy)	Lunchtime nutrient intakes	<u>Lunchtime</u> • Intervention school students consumed significantly less energy (p<0.01) than control.
3	Mendoza *et al.* (2010) [157]	Texas School Nutrition Policy	12788	11-14	• Cross-sectional • Lunch food record	Pre- and post-policy implementation	Lunchtime nutrient intakes	<u>Lunchtime</u> • Post-implementation, energy density significantly decreased from food only, and food and beverages (both p<0.0001).
4	Vernarelli and O'Brien (2017) [138]	Healthy Hunger-free Kids Act of 2010	2190	4-19	• Cross-sectional • 24-hour recalls	School lunch type (school and packed lunches)	Lunchtime nutrient intakes	<u>Lunchtime</u> • Children over 14 years only difference school lunch

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
4 (cont.)	Vernarelli and O'Brien (2017) [138] (cont.)				• Data source: NHANES (2009-2012)			consumers reported lower meal energy density compared with non-consumers (p=0.01). • School lunch consumers (aged 9-13) reported lower energy (p<0.0001), meal energy density (p=0.007), total fat (p=0.0003), saturated fat (p=0.0068), sodium (p=0.0004) and added sugars (p=0.003). • No significant difference in nutrient intake for school lunch consumers receiving reduced price lunches compared to non-consumers. • Significant differences in school lunch consumers (vs non-consumers) eligible for free meals including lower energy density, carbohydrates, total fat, saturated fat, sodium and added sugar (p<0.0001).
Canadian Studies								
1	Tugault-Lafleur *et al.* (2018) [123]	District-level policies	4589	6-17	• Cross-sectional • 24-hour recall • Data source: 2004 Canadian Community Health Survey Cycle 2.2	School lunch type (school, packed lunches and other lunches)	Total diet and lunchtime nutrient intakes	<u>During school hours (including lunch)</u> • School lunch consumers had higher intakes of energy compared with (home) packed lunch consumers, but lower intakes than other lunches (p<0.05 for both).

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
1 (cont.)	Tugault-Lafleur *et al.* (2018) [123] (cont.)							• School lunch consumers had higher intakes of fat and vitamin A compared with (home) packed lunch consumers ($p<0.05$). • School lunch consumers had lower intakes of carbohydrates, fibre (not significant for other lunches, $p>0.05$), vitamin C (other lunches significantly lower intakes, $p>0.05$) and iron (all $p<0.05$). • No significant differences between lunch types for intakes of sugar, saturated fat, protein, calcium, zinc and sodium ($p>0.05$). <u>School day (total diet)</u> • School lunch consumers had higher fat intakes than children consuming packed and other lunches ($p<0.05$). • School lunch consumers had lower carbohydrate ($p<0.05$), fibre ($p<0.05$, not significant for other lunches, $p>0.05$), and iron intakes ($p<0.05$, not significant for other lunches) compared with packed lunches.

No	Study	Policy Studied	Children (n)	Age (years)	Design/method	Data used	Outcomes of interest	Key findings
1 (cont.)	Tugault-Lafleur *et al.* (2018) [123] (cont.)							• No significant differences between lunch types for intakes of energy, sugar, saturated fat, protein, vitamin A, vitamin C, calcium, zinc and sodium ($p>0.05$).
Chile studies								
1	Fretes *et al.* (2023) [156]	Law of Food Labelling and Advertising	294	12-14	• Longitudinal cohort • 1x 24-hour recall • Data source: Growth and Obesity Cohort Study	Pre- and post-policy implementation	Total diet and during school nutrient intakes	<u>Total diet</u> • No significant difference in sugar and saturated fat consumption post-policy implementation ($p>0.05$). • Sodium intakes significantly increased post-policy implementation ($p<0.05$). <u>In-school diet</u> • Sugar and saturated fat intakes in school significantly decreased post-policy implementation ($p<0.05$). • No significant difference in sodium intake post-policy implementation ($p>0.05$).

Table 2.8 Summary of nutrients studied at lunchtime and in total diet

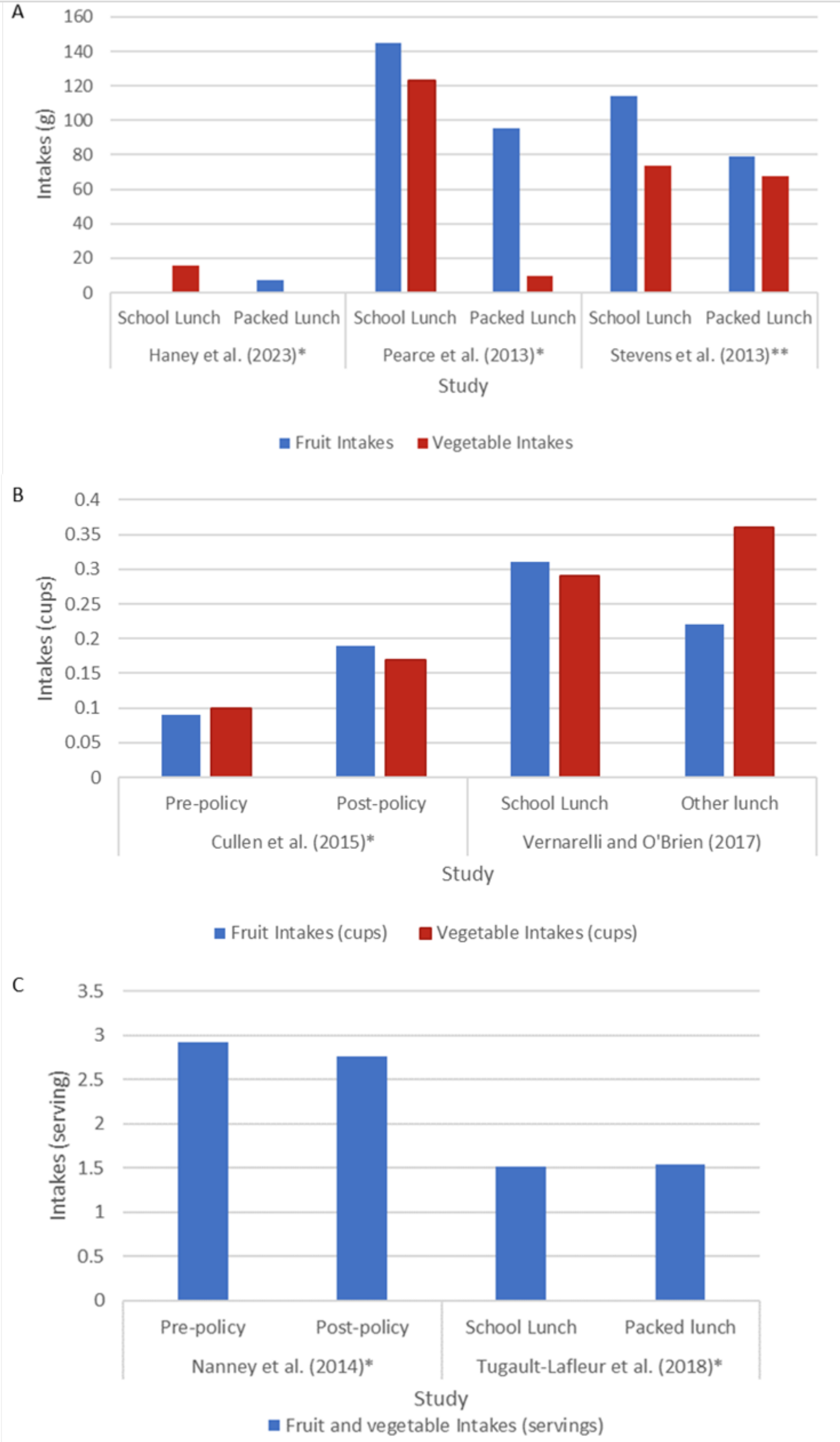
Author	Nutrient Studied													
	Energy	Total Fat	Saturated fat	CHO	Sugar	Fibre	Protein	Vitamin A	Vitamin C	Folate	Sodium	Calcium	Iron	Zinc
Total Diet														
Spence *et al*. (2014) [159]	↓	↓	n/s	-	n/s	↓	-	-	↑	-	↓	↑	↓	-
Cohen *et al*. (2018) [155]	n/s	n/s	n/s	-	↓	n/s	-	-	-	-	n/s	-	-	-
Tugault-Lafleur *et al*. (2018) [123]	n/s	SL↑	n/s	SL↓	n/s	SL↓	n/s	n/s	n/s	-	n/s	n/s	SL↓	n/s
Fretes *et al*. (2023) [156]	-	-	n/s	-	n/s	-	-	-	-	-	↑	-	-	-
Lunchtime														
Haney *et al*. (2023)* [140]	-	-	n/s	-	n/s	n/s	-	-	n/s	-	SL↓	SL↓	n/s	-
Nicholas *et al*. (2013) [158]	↓	↓	↓	↓	↓	↑	↑	↑	↓	↓	↓	↑	-	-
Pearce *et al*. (2013) [87]	SL↑	SL↓	SL↓	SL↑	SL↓	SL↑	SL↑	-	SL↑	SL↑	-	-	SL↑	SL↑
Spence *et al*. (2014)† [159]	↓	↓	↓	-	n/s	↓	-	-	n/s	-	↓	↓	↓	-
Stevens *et al*. (2013) [127]	SL↑	n/s	n/s	SL↑	n/s	SL↑	SL↑	SL↑	n/s	SL↑	-	n/s	SL↑	SL↑
Cullen *et al*. (2015) [141]	↓	-	-	-	-	-	-	-	-	-	-	-	-	-
Mendoza *et al*. (2010) [157]	↓	-	-	-	-	-	-	-	-	-	-	-	-	-
Vernarelli and O'Brien (2017)‡ [138]	SL↓	SL↓	SL↓	n/s	SL↓	SL↓	SL↓	-	-	-	SL↓	-	-	-
Tugault-Lafleur *et al*. (2018) [123]	SL↑	SL↑	n/s	SL↓	n/s	SL↓	n/s	SL↑	SL↓	-	n/s	n/s	SL↓	n/s
Fretes *et al*. (2023) [156]	-	-	↓	-	↓	-	-	-	-	-	n/s	-	-	-

n/s = not significant, ↑= increased/higher intakes, ↓=decreased/lower intakes, note: *Haney only significant for 12-14; †Results for changes in school lunch consumers, ‡results for 9-13y shown, §CHO = carbohydrate

2.7 Discussion

2.7.1 Summary of included studies

In summary, school food policies generally have a positive impact on diets of children aged between 11-18 years, particularly at lunchtime across different socioeconomic groups. Studies looking at the effect of school food policies on food groups report varied findings on soft drink intakes. For soft drinks, most studies reported a positive impact of school food policies on soft drink consumption (e.g., a decrease in consumption) [87, 112, 114, 122, 124, 125, 127, 128, 131], however, some studies reported mixed findings [113, 129, 132], no significant association [111, 118] or increased intakes [115-117]. For fruit and vegetable intakes, significant positive associations were identified by most of the included studies, although this was not observed in all studies, therefore impact on fruit and vegetable intakes seems to be limited, these differences are displayed in Figure 2.1 [87, 111, 114, 123, 127, 135, 138, 140, 141]. Most of the included studies exploring the effect on diet quality reported that school food policies had a positive impact on diet quality score [123, 143, 145, 147-149]. It was also reported that improvements were greater for in-school diet quality as food consumed out-of-school was reported to have a negative impact on diet quality [145, 146, 149]. Studies that considered nutrient intakes post-implementation of school food policies, reported mixed findings although, overall findings were positive impact [87, 123, 127, 138, 140, 141, 155-159].



Key: studies split by unit used to measure fruit and vegetable intakes, * indicates that p<0.05 for the differences between either school lunch and packed lunch or pre- and post-policy implementation, ** indicates significant difference for fruit intakes only

Figure 2.1 Changes to fruit and vegetable intakes found in the studies included in the literature review, majority studies indicate lunchtime intakes[87, 123, 127, 138, 140, 141], Nanney *et al.* (2014) displays total diet intakes[114]

2.7.2 Impact of school food policies

Mixed findings regarding impacts of school food policies on soft drink intakes were also reported in the wider literature. A study by Whatley Blum *et al.* (2008) which looked at changes in soft drink consumption in US children aged 14-17 years when availability of soft drinks is reduced and reported there was no decrease in soft drink consumption when soft drink availability is limited [161]. Similarly, van de Gaar *et al.* (2017) explored associations between home and school environment factors and soft drink consumption. The study found that Dutch primary school-aged children had lower intakes of soft drinks when they are available in the school environment [162]. In contrast, Johnson *et al.* (2009) found higher soft drink availability was associated with higher soft drink consumption in US children aged 12-18 years [163] and Grimm *et al.* (2004) identified soft drink availability in schools as a factor that significantly impacts consumption for US children aged 8-13 years [164]. Further, a study by Alston *et al.* (2019) indicated Australian children aged 7-12 years attending schools with a high food environment score, which includes strong school food policy, school garden and cooking classes, were less likely to consume soft drinks than children attending schools with lower scores [165]. This all continues to highlight that current research that school food policies that alter the availability of soft drinks in schools has reported mixed findings, further emphasising the need for more research in this area.

Generally, school food policies displayed a positive impact on fruit and vegetable consumption in the studies included in this review. This is similar to the findings of a scoping review by Graziose *et al.* (2018) in younger children (aged 5-11 years) which found, following the implementation of updated school food policies in the USA, was associated with children's increased consumption of fruit and vegetables [166]. A systematic review of 91 studies worldwide by Micha *et al.* (2018) reported that policies that impact and improve the school food environment including direct provision and increased availability of fruit and vegetables in canteens have the potential to improve children's intakes, particularly school food standards and direct provision policies that specifically target fruit and vegetable consumption [134].

This positive effect of school food policies on diet quality has also been found in the wider literature. Johnson *et al.* (2016) explored the changes to the nutritional quality of foods chosen by US children aged 11-18 years in school after implementation of school food policy, and found foods chosen after implementation had a significantly higher diet quality score [167].

Similarly, a study by Au *et al.* (2016) looked at differences in diet quality in younger US children aged 9-11 years between school lunch and packed lunch consumers and indicated that children consuming school lunches had a higher diet quality score for total diet compared with children consuming packed lunches [168]. Further, Gearan *et al.* (2020b), looked at the impact of US school food policies on meals sold in schools and found that the diet quality score for school food significantly improved following policy implementation [151]. A study by Liu *et al.* (2021) found that between 2003 and 2018 the largest improvements in diet quality for children aged 5-19 years occurred in schools which had the highest diet quality of any other location of consumption [169]. These improvements seen in schools are potentially a result of school food policy implementation, however findings also demonstrate the potentially limited impact of these policies on children's overall diets.

The studies included in this review found varied findings regarding the impact of policies on nutrient intakes of children. Generally, school food policies had a positive impact on energy, fat, saturated fat, sugar intakes, although impact on micronutrient intakes are mixed. A UK study by Wickramasinghe *et al.* (2017) looked at potential impacts of implementation of the most updated school food standards (2014) on nutritional quality of school lunches in primary schools. The study reported some improvements for micronutrients such as vitamin C, iron and calcium in school lunches but did not improve salt, saturated fat, and free sugars of school meals. However, this is a modelling study, so it only explored expected changes to school meals and lunchtime intakes, not actual intakes [170]. Another UK study in primary school children looking at previously introduced policy found that after policy implementation, children's lunchtime intakes of total fat, saturated fat and sugar intakes decreased. Also, for total diet, school consumers had lower per cent energy intakes from fat and saturated fat, and higher intakes of protein, fibre, folate and vitamin C in comparison to packed lunch consumers [171]. Additionally, a US study in middle school children found following policy implementation, children consumed lower per cent energy from fat and higher intakes of fibre, vitamin A, vitamin C, and calcium, although sodium intakes were also higher [109]. Generally, the impact of school food policies on micronutrient intakes is mixed and requires more research, although policies seem to have an overall positive impact on children's diets.

2.7.3 Impact of socioeconomic status

Several studies included in this review explored differences between different SES groups. Three studies reported mixed findings for soft drink intakes though children from families in lower SES groups generally had higher intakes than children from families in other SES groups [111, 125, 129]. Only one study by Hoffman *et al.* (2016) looked at the impact of SES and reported that though improvements were found across SES groups following policy implementation, children from families in higher SES groups had higher intakes of fruit and vegetables [111]. This is similar to a study by Zarnowiecki *et al.* (2014) which reported that lower SES is associated with a poorer overall diet for Australian children aged 9-13 years, including lower consumption of fruits and vegetables regardless of school food policy [172]. For diet quality, four of the included studies looked at the impact of SES groups and reported mixed findings, however, most studies reported children from families in higher SES groups have a higher diet quality score than children from families in lower SES groups [144-147]. Other studies, have stated that children from higher SES groups tend to have better diet quality than children from families in lower SES groups [152]. This is potentially due to lower income families consuming low-cost, energy-dense diets which are also less nutrient dense [152, 153]. A study by Sabinsky *et al.* (2019) found that providing free school meals improved diet quality in children aged between 7 and 13 years in Denmark compared with paid meals and packed lunches [154]. Three studies looked at the impact of SES on nutrient intakes and found that higher SES groups generally had more favourable nutrient intakes than children from families in lower SES groups [138, 157, 159].

2.7.4 Issues with comparisons used in studies included

Although the various policies worldwide were implemented differently, the policies studied are generally similar as they limit which food and drink products can be sold in schools for example, through food and/or nutrient-based regulations and ban of the sale of soda or other soft drinks.

Also, this review included studies from several different countries which could potentially have influenced the inconsistent findings of the review and also means that the results cannot be generalised for one specific population (e.g., children in the UK). There are limited studies looking at impact of school food policies in the UK, most studies included in this review were based in the USA. Different types of policies implemented at different levels including national, district-level, state level or national policies were included, although these generally state what can and cannot be sold in the school cafeteria or other school settings (e.g., vending machines). In addition, individual schools may have differing levels of compliance to school food policies making it difficult to measure and compare the impact of these policies within countries.

Several of the studies included in this review do not compare children's dietary intakes pre- and post-policy implementation, instead comparing school lunch consumers and non-consumers (including packed lunches and out-of-school) [87, 127, 138, 145, 148]. This may not allow for accurate comparisons for impact of policies and changes over time. Another limitation is that some studies in this review looked only at lunchtime intakes and therefore did not give an indication on whether the effects shown would continue throughout the day or were only limited to lunchtime [87, 127, 141, 157, 158, 160]. Further, most studies used methods to collect dietary data that are reliant on self-reporting and consequently, there is a risk of misreporting or changing of behaviours due to social desirability bias. Additionally, most studies included in this review are cross-sectional meaning that the findings reported are associations from which it is not possible to attribute causation.

2.7.5 Gaps in the research and rationale

Most studies conducted in the UK explore the impacts of earlier school food policy pre- and post-implementation on children's diets. This highlights a need for updated research in the UK exploring the impact of The Requirements for School Food Regulations 2014 pre- and post-implementation. It is important to explore the impacts of changes to school food policies on children's dietary intakes as children consume approximately a third of their daily dietary intakes in school [86].

Many of the studies included in this review explore the impact of school food policies at lunchtime only, especially for nutrient intakes. Additionally, several studies only look at either lunchtime or total dietary intakes. Considering both lunchtime and total dietary intakes allows for the impact of school food policies to be explored when directly regulating food available in schools at lunchtime and any further impacts that potentially has occurred outside of school.

Only a small number of studies explored the role of SES on the impact of school food policies on children's dietary intakes regarding food groups, diet quality and nutrient intakes.

Various methods were used to obtain dietary data, most studies included in this review use 24 hour recalls over one or two days, or food frequency questionnaires. As a result, variations in diets may not be considered, for example, weekday and weekend or seasonal variations. The use of three-day food diaries carried out at two time points during the school year used in the ASH11 studies such as that employed by Spence *et al.* (2014) help account for these variations [159].

Most studies included in this review explore the impact of school food policies on diet quality used the HEI-2010 or a variation of this measure. However, as stated by Gaudin *et al.* (2023) DQI-I (Diet Quality Index-International) is a more comprehensive measure than HEI-2010 as it takes into account more dietary components [121]. DQI-A (Diet Quality Index for Adolescents) is a similar measure to DQI-I which also takes more dietary components into account that HEI-2010. HEI-2010 only looks at adequacy and moderation, while DQI-I looks at variety, adequacy, moderation, and overall balance in the diet [121, 173]. Similarly, the DQI-A looks at quality of food choices, variation in the diet, and dietary equilibrium (adequacy and excess) using food group intakes and food based dietary guidelines [22, 173].

Dietary data has been collected from the same schools in Northumberland every 10 years since 1980 with data being collected from 11-12-year-old children in 1980, 1990, 2000 and 2010, referred to as the ASH11 studies. These dietary data have previously been used to compare changes in food and nutrient intakes over time including sugar and fibre intakes [159, 174-176]. Using these unique dietary data will allow for comparisons to be made to dietary intakes before the implementation of the current school food standards and post-implementation (using the 2022 data collected in this thesis).

This study will address these gaps by exploring the impact of school food policies on children's dietary intakes in terms of food groups, diet quality and nutrient intakes. Children's total diet and lunch time diets will be considered to explore the impact of changes to school food policy on total dietary intake and lunchtime (one of the main targets of school food policy). The impact of SES will also be considered.

Chapter 3 details the methods used in this PhD, starting with the use of previous ASH11 data, dietary data collection and methodological changes from the previous study, data cleaning and manipulation, calculation of DQI-A scores and data analysis.

2.7.6 Aims and objectives

The main aim of this project is to explore the impact of changes to school food policy on the diets of 11–12-year-olds in Northumberland (pre- to post-policy).

The key objectives for this project are:

1. To examine mean food group intakes (soft drinks and fruit and vegetables) and diet quality of 11-12-year-olds in Northumberland at three time points: 2000, 2010 and 2022 to consider the impact of changes to school food policy.
2. To explore changes to the mean nutrient intakes (total diet) of 11–12-year-olds in 2022 to the previous ASH11 studies (2000 and 2010) and with current recommendations.
3. To explore mean nutrient intakes at lunchtime of 11–12-year-olds in 2022 to the previous ASH11 studies (2000 and 2010).

Figure 2.1 below displays the thesis structure by chapter which includes seven chapters in total.

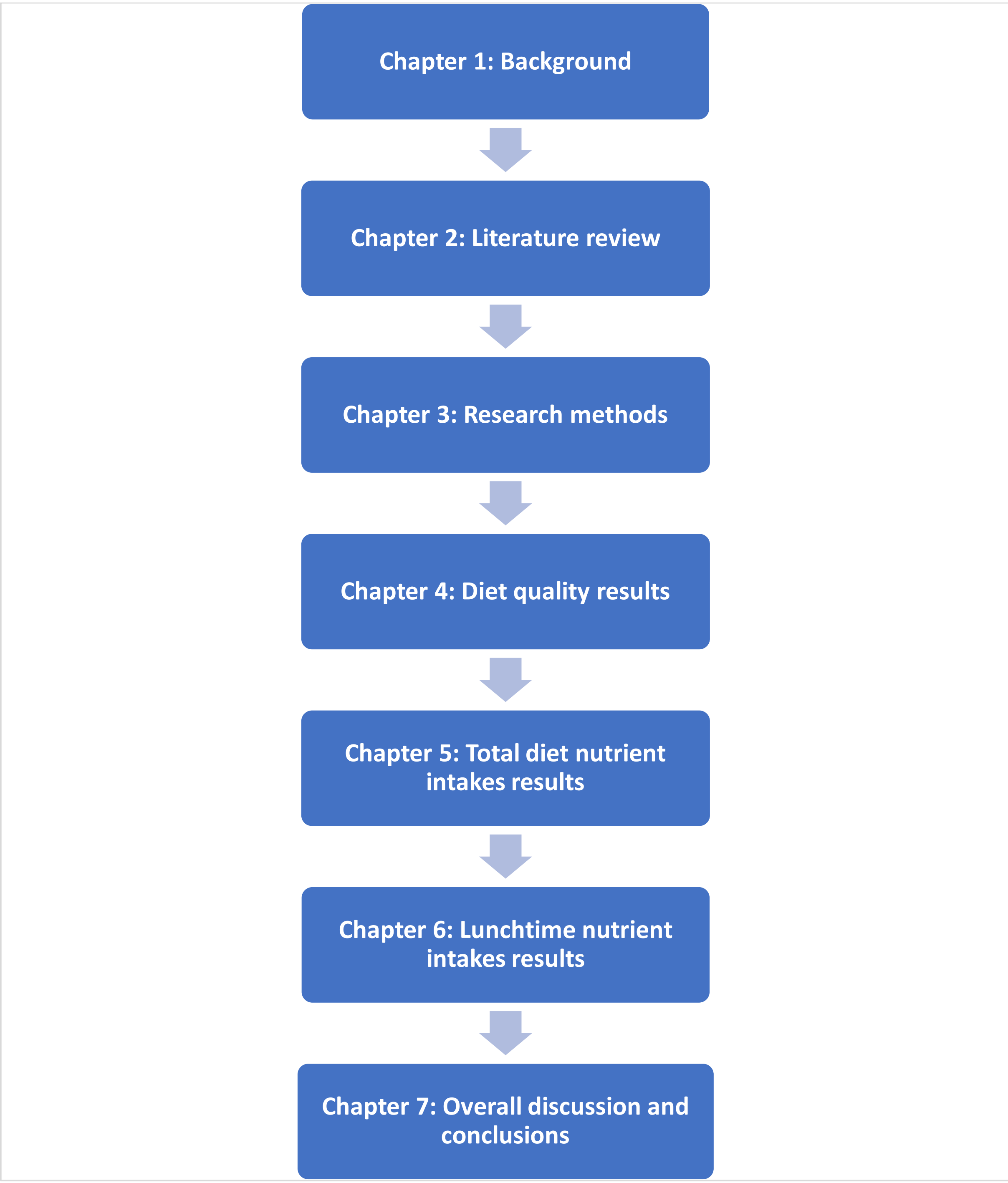


Figure 2.2 Overall thesis structure breakdown

Chapter 3 Research Methods

Chapter overview:

The aim of this chapter is to provide an overview of the methods used. First, details of ethical approval are provided. Then the study design and setting are described including an overview of previous studies in the same area of Northumberland. School and child recruitment is also outlined, with a description of study incentives provided and the method used for dietary data collection and dietary data handling is described. The use of the Diet Quality Index of Adolescents (DQI-A) to calculate children's diet quality is described including the coding and calculation of scores. Additionally, details and reasoning for food and nutrient intakes explored are provided. The participant characteristics obtained are outlined. Finally, the statistical analysis methods utilised are detailed.

3.1 Ethical approval

This study was approved by the Faculty of Medical Sciences Research Ethics Committee, Newcastle University (reference number 1861/695/2019). An amendment to the ethical approval was obtained for changes to the study incentives. This included a change from a school gift voucher to a contribution of funding to enable the school to purchase slow cookers for a healthy eating initiative as requested by the School Head. A copy of the ethical approval letter can be found in Appendix A.

3.2 Study design & setting

This is a repeat cross-sectional study with comparisons being made to existing dietary data collected in 11–12-year-old children in the same area of Northumberland. Northumberland is a county located in North-East England. As of 2021, Northumberland had a population of 320,600 which is an increase from 316,000 in 2011 [177]. From 2011, there was a 2% decrease in children aged 10 to 14 years in Northumberland [177]. According to the 2021 Census, 96.1% of people living in Northumberland identified as white (English, Scottish, Northern Irish or British) [178]. Free school meal eligibility in Northumberland was 22.2% in 2022/23 which is an increase from 11.9% in 2015/16 for all schools (nursery, primary and secondary). For state-funded secondary schools in Northumberland free school meal eligibility increased from 11.0% in 2015/16 to 20.6% in 2022/23 [179].

Previous studies were carried out in schools in Ashington, Morpeth and Newbiggin-by-the-sea, Northumberland, every ten years since 1980 [159, 174-176]. These studies (collectively known as the ASH11 studies) have been used to explore changes in children's food and mean nutrient intakes over time. The most recent data, collected in 2010, considered the effect of the school food policy implemented in England in 2007 (The Education (Nutritional Standards and Requirements for School Food) (England) Regulations 2007) on children's dietary intakes [159]. In addition to the data collected during the 2022 ASH11 study (current study), the existing datasets from the previous ASH11 studies in 2000 and 2010 were used to compare children's dietary intakes pre- and post-current school food policy implementation in 2014. Figure 3.1 below provides an overview of the data collected over the last 42 years known as the ASH11 data and the key aims of each of these studies. Figure 3.2 displays the areas where schools involved with the 2000 ASH11 studies were located and how this has changed by the current study (2022).

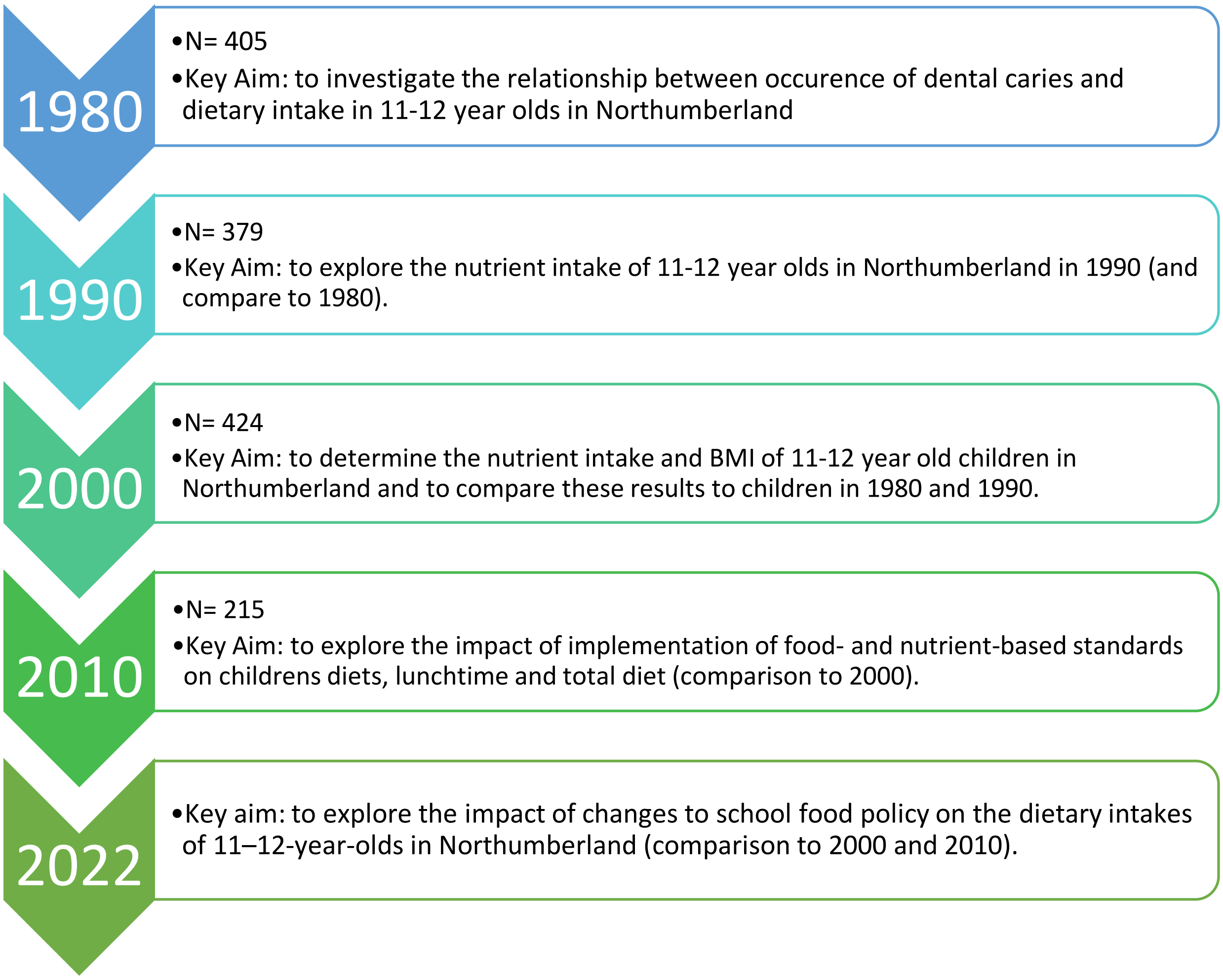


Figure 3.1 Timeline of previous studies, number of participants and the main aim of each study

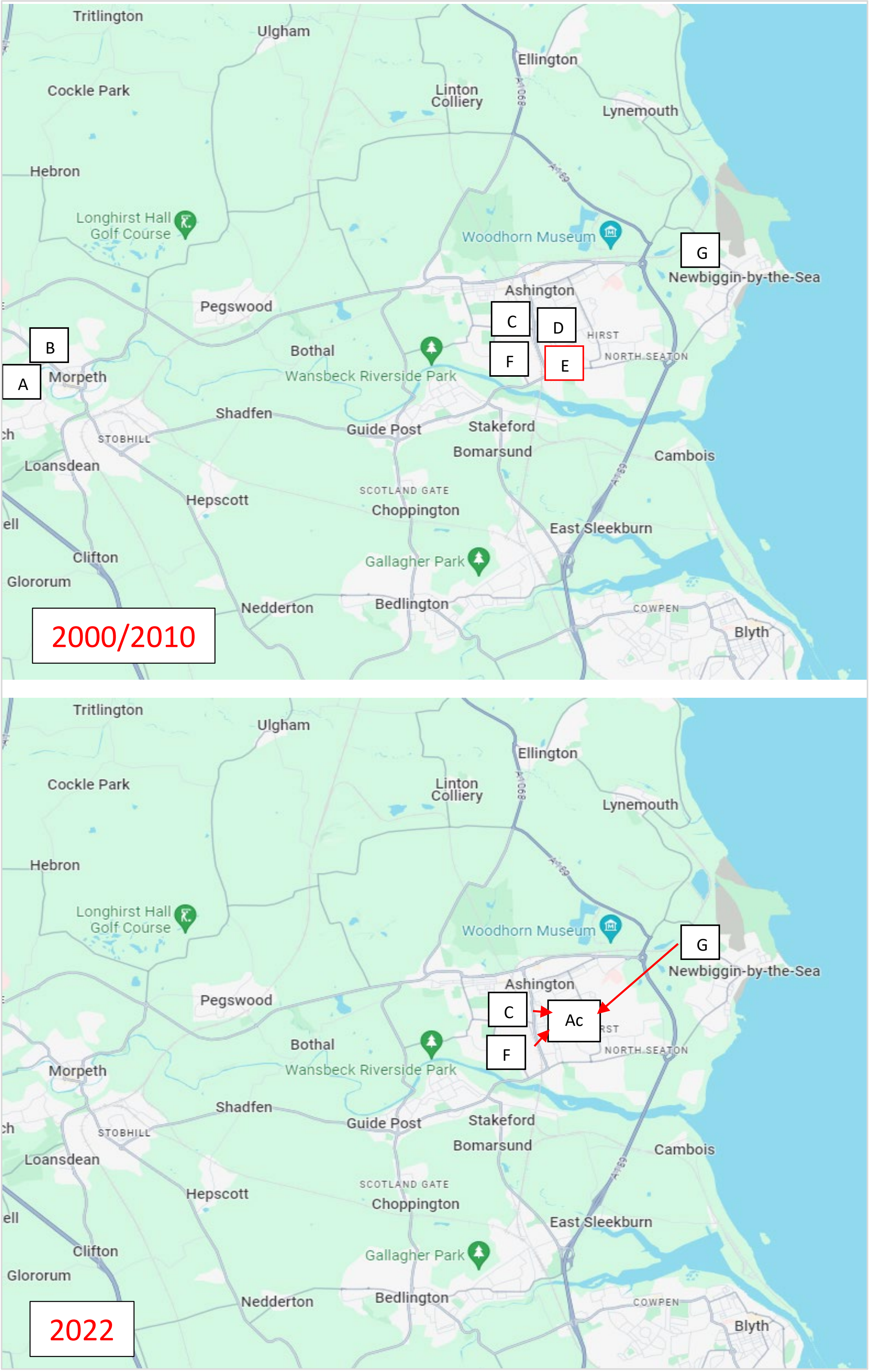


Figure 3.2 Areas where schools were located in 2000 and changes to schools involved by 2022, map obtained via google maps [180]. Box in red indicates the school that participated in 2000 only

3.3 Study recruitment

3.3.1 Recruitment

Northumberland schools involved in the previous ASH11 studies were invited to take part in 2022. In 2000, seven schools participated, in 2010 six schools participated and in 2022 three of the original schools had merged to form an academy and agreed to participate; one school closed; one school declined to participate, and one school did not respond. Using Figure 3.2 above, in 2000 all schools A-G were involved in the study, by 2010 one school closed (school E) and all other schools participated and finally in 2022 two schools elected not to participate (schools A and B), school D closed and three schools merged (schools C, F and G) to form an academy (school Ac).

The school involved in the current study was an academy including over 1000 children aged 11-19 years and mixed gender [(181)]. The catchment area for the school included Ashington, Newbiggin-by-the-Sea and Lynemouth [(182)]. The IMD score (English Index of Multiple Deprivation 2019) for the school (using postcode [(181)]) was 0.9061, and was within the 20-30% least deprived neighbourhoods in the UK [(183)]. No data on ethnicity was obtained during the study. The eligibility for free school meals in the participating school was high at 44.2% [(181)], though it is important to note eligibility may not reflect participation in free school meals.

Initial contact with schools was made via email to headteachers, this was followed up by personal contact via phone. The information sheets sent to headteachers can be found in Appendix B. In the participating school, online Zoom meetings were arranged with the Head of year 7 to discuss plans for the study, logistics of data collection, and to answer any questions.

All children in year 7 were eligible to participate. A suitable time was arranged with the school to talk to year 7 children during “tutor time”. During this time children were given an overview of the study. This included information on why we were doing the study and what they would be asked to do. Children were also shown an example of the food diary they would use to record everything they consumed if they chose to participate. Children and teachers were given the opportunity to ask any questions.

Following the talk, information packs were distributed to children and delivered to parents using “pupil post”. The information pack contained study details, researcher contact information and an opt-out consent form (participant information sheet and consent form). Children were informed they could withdraw from the study at any point without having to provide a reason. An example of the participant information sheet and consent form can be found in Appendix C and participant debrief sheet in Appendix D. Children were asked to return the opt-out consent forms to their teacher only if they did not wish to participate in the study. The forms were then collected from the school. A participant debrief sheet was provided once data collection was completed, and distributed alongside study incentive vouchers.

In 2010, the method of consent was changed to opt-out consent as requested by school headteachers and agreed with school governors. This was because school headteachers stated that by using opt-in consent, children whose parent or guardian did not return forms to school were actively being excluded, whereas parent or guardian who did not want their child to participate would likely return the form to school [(184)]. This method of opt-out consent was used in 2022 for the reasons detailed above.

3.3.2 Study Incentives

As a thank you for their time, children were offered a £10 Love2Shop voucher on completion of the study. As mentioned in Section 3.1, following an amendment to ethical approval, a sum of £500 was given to the school towards purchasing slow cookers for a school healthy eating initiative. The research team also assisted with the organisation of a healthy eating cooking event in the school after data collection (more detail is provided in Section 7.9 in Chapter 7)

3.4 Protocol for study team in school

Prior to the start of data collection, an enhanced DBS check was obtained for all researchers who would be working in the school, and a risk assessment was completed. When in school, a university ID badge and an ID badge provided by the school was worn at all times. All child interviews were conducted in an open space situated just outside the Year 7 school contacts office.

3.5 Dietary data collection

Several steps were involved in collecting individual level dietary information. This section will discuss each and included training in dietary data collection, use of three-day food diaries, portion size estimation. Additionally, the change in methods for portion size estimation is outlined.

3.5.1 Training in dietary data collection

To ensure consistency with previous data collection and to maximise the accuracy of the data collected I received training in the dietary data collection methods. Practice asking relevant questions was completed to ensure as much dietary information as possible was obtained during the interviews. One example of this was for toast, probing questions were asked to find out what type of bread (e.g., white/wholemeal), if any butter or margarine was used, and finally if there were any jams or spreads (e.g., Nutella). Another example was for tea, the following probing questions were asked: whether there was any milk added, what type of milk (e.g., semi-skimmed milk/soya milk) and if there was any sugar or sweetener added. If curry was consumed, children were asked what type of curry (e.g., chicken tikka masala), if they had any rice as an accompaniment and if they consumed any naan bread. This was completed using a combination of adults (both researchers and lay members of the public) and children (all aged between 10-16 years).

3.5.2 Three-day food diary

All children participating in the ASH11 studies (2000, 2010 and 2022) completed three-day food diaries at two time points during the school year. This method was used to account for both seasonal and habitual variations in children's dietary intakes. The food diaries were designed to be easy for children to carry and write in throughout the day. An example of the food diary cover page is shown in Figure 3.3 and an example of a completed day is displayed in Figure 3.4. Each child was assigned a unique ID number on their food diary. Instructions explaining how to complete food diaries were given in both a written and verbal format. Written instructions were provided in the first two pages of the food diary and included an example of how much detail should be given. When distributing diet diaries, verbal instructions and examples were given to children explaining how to complete the diet diaries and children were invited to ask questions. Children were asked to give as much detail as possible, for example, if they consumed a sandwich, they were asked to note down what type of bread they had, if they had butter or any other type of spread and what other sandwich fillings they had. Another example given was that if children consumed a "Sunday lunch", they were asked to list what individual food items were included, cooking methods, and portion sizes.

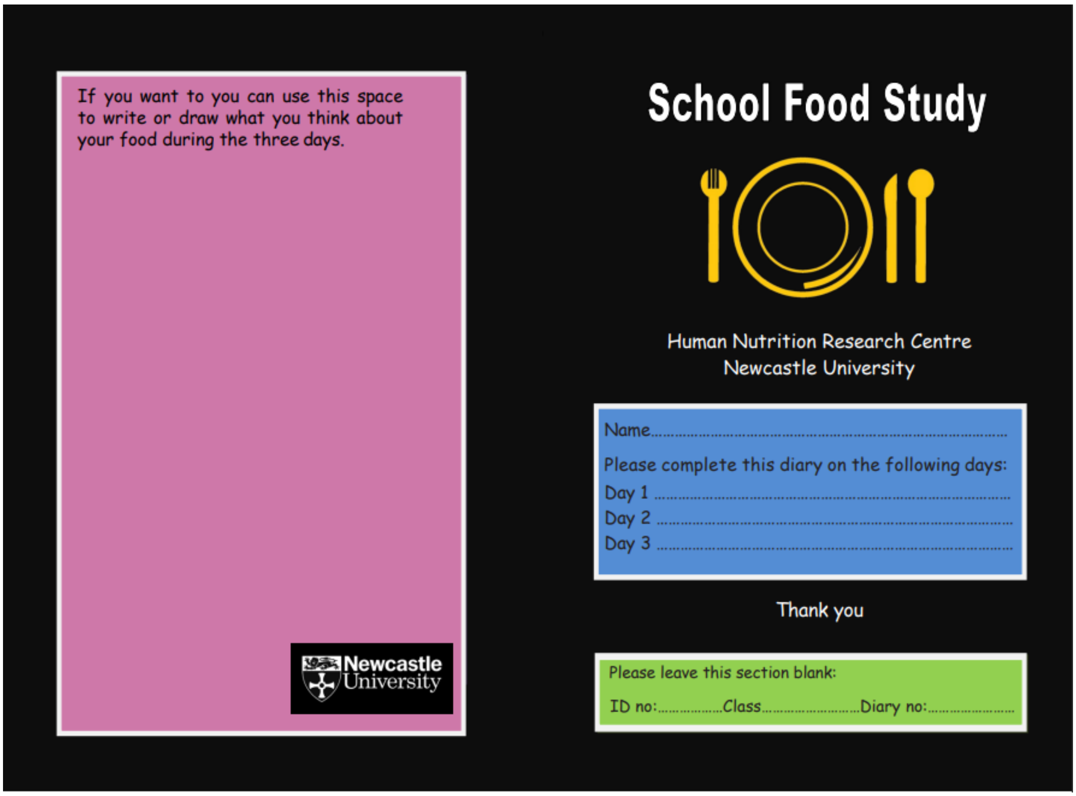
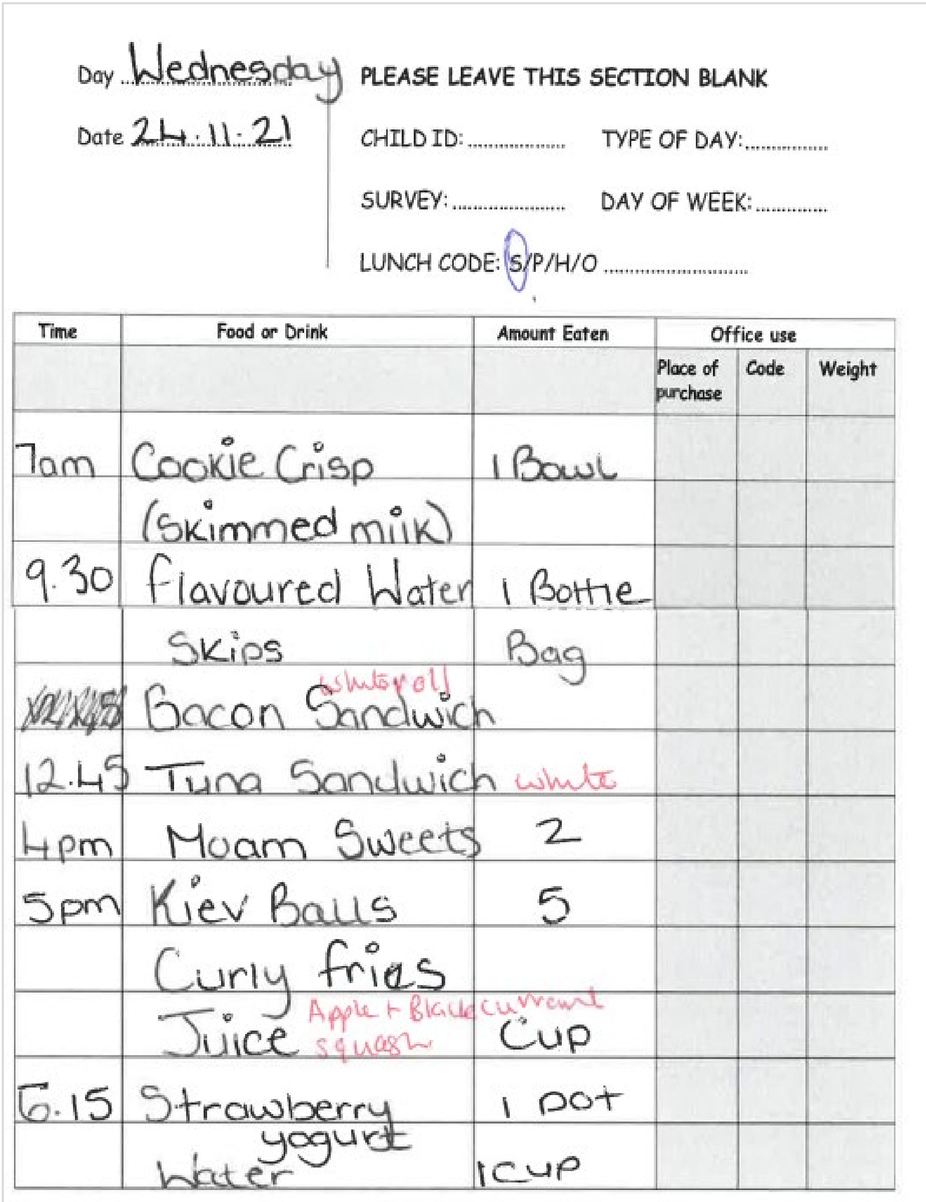


Figure 3.3 Front and back cover page for three-day food diaries



Day Wednesday PLEASE LEAVE THIS SECTION BLANK

Date 24.11.21

CHILD ID: .... TYPE OF DAY: ....

SURVEY: .... DAY OF WEEK: ....

LUNCH CODE: S/P/H/O ....

Time	Food or Drink	Amount Eaten	Office use: Place of purchase	Code	Weight
7am	Cookie Crisp (skimmed milk)	1 Bowl			
9.30	Flavoured Water	1 Bottle			
	Skips	Bag			
	Bacon Sandwich (white roll)				
12.45	Tuna Sandwich white				
4pm	Moam Sweets	2			
5pm	Kiev Balls	5			
	Curly fries				
	Juice Apple + Blackcurrant squash	Cup			
6.15	Strawberry yogurt	1 pot			
	Water	1cup			

Figure 3.4 An example of a completed day dietary intake

In total, six days of dietary data were obtained for each child. Each child completed four weekdays and two weekend days over the two time points. For example, during time point one, children recorded their food and drink intakes Monday to Wednesday, then had a discussion on the fourth day (Thursday) with myself or a research assistant to clarify dietary information and to estimate portion sizes. Using Figure 3.4 above as an example, this child indicated they consumed a bacon sandwich, during the discussion further questions with the child clarified how the bacon was cooked (e.g., grilled or fried), what kind of bread was consumed, and if they had butter or condiments with the bacon roll.

During the discussion, it was noted for each weekday what type of lunch the child consumed: packed lunch or school lunch. Children were given a suitable date and time for the discussion with a researcher (myself or a research assistant). This was agreed with the school and teachers were aware of study days to assist with reminding children to complete food diaries and attend their allocated discussion time. This process is summarised in Figure 3.5.

Figure 3.5 Data collection process for each child, from delivery of food diary to collection of the diary and dietary discussion

3.5.3 Use of Intake24 to estimate portion sizes

Intake24 (intake24.co.uk) is an online dietary recall tool developed by researchers at Newcastle University[185]. The tool contains a database of foods linked to UK food composition data and uses portion size images from the Young Persons Food Atlas to aid portion estimation. This was developed as a self-report tool for use in the Scottish Health Survey and is currently used in the NDNS [186, 187]. However, Intake24 in this study was completed by myself or a research assistant and used to estimate portion size using a food diary as an aid, the process used is outlined below.

3.5.3.1 Use of the food diary as a prompt

The items recorded in the food diary were entered into Intake24 by myself or a research assistant. Children specified the meal type (e.g., breakfast, morning snack or lunch) and were asked to provide further information including cooking methods where required. These were noted in the food diary and added to Intake24.

3.5.3.2 Selecting relevant foods

For each item entered into Intake24, I selected and clarified with the child the exact or closest match from the drop-down food list in the Intake24 database. This list contained generic foods items and brand names; an example is shown in . For sandwiches, Intake24 includes prompts to enter bread type, spreads, meat or fish, cheese, salad, and any sauces used, this was used to help prompt children to detail exactly what was included in sandwiches and allow myself or a research assistant to enter this information into Intake24. Salads have a similar feature which includes prompts to list ingredients and any sauces or dressings used. Each food and drink included in the food list is linked to a food composition code. Estimated portion sizes allow nutrient intakes to be calculated [188]. The process for portion size estimation is outlined below.

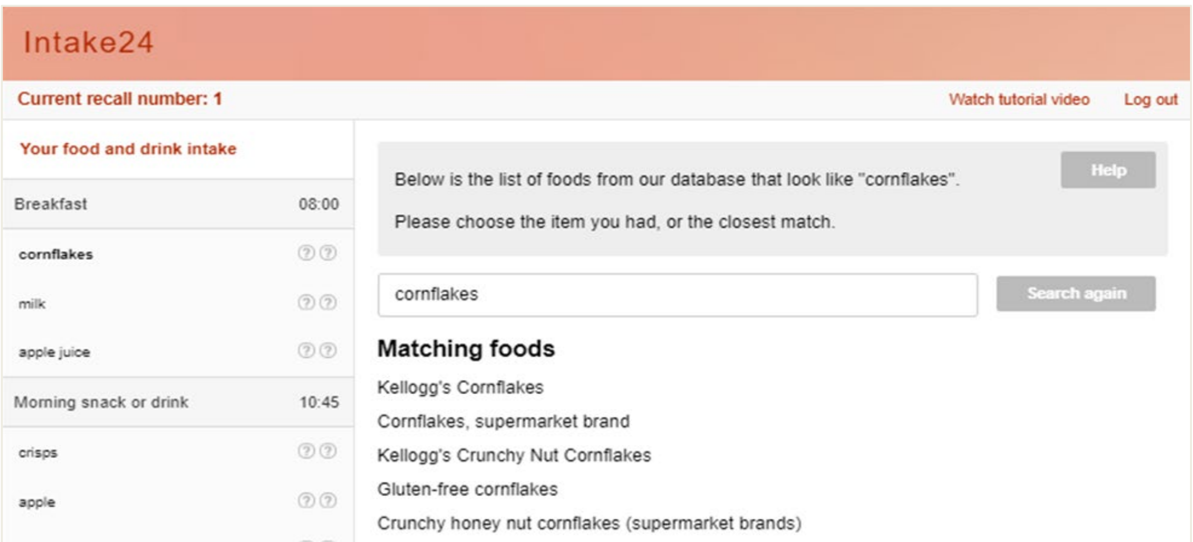


Figure 3.6 Example of food lists from Intake24 database

This stage also allowed children to identify if the food or drink they consumed was not listed, if this occurred, then a missing food form was completed. This contains information on name of food, brand, food description, cooking methods, amount consumed using household measures, Figure 3.7.

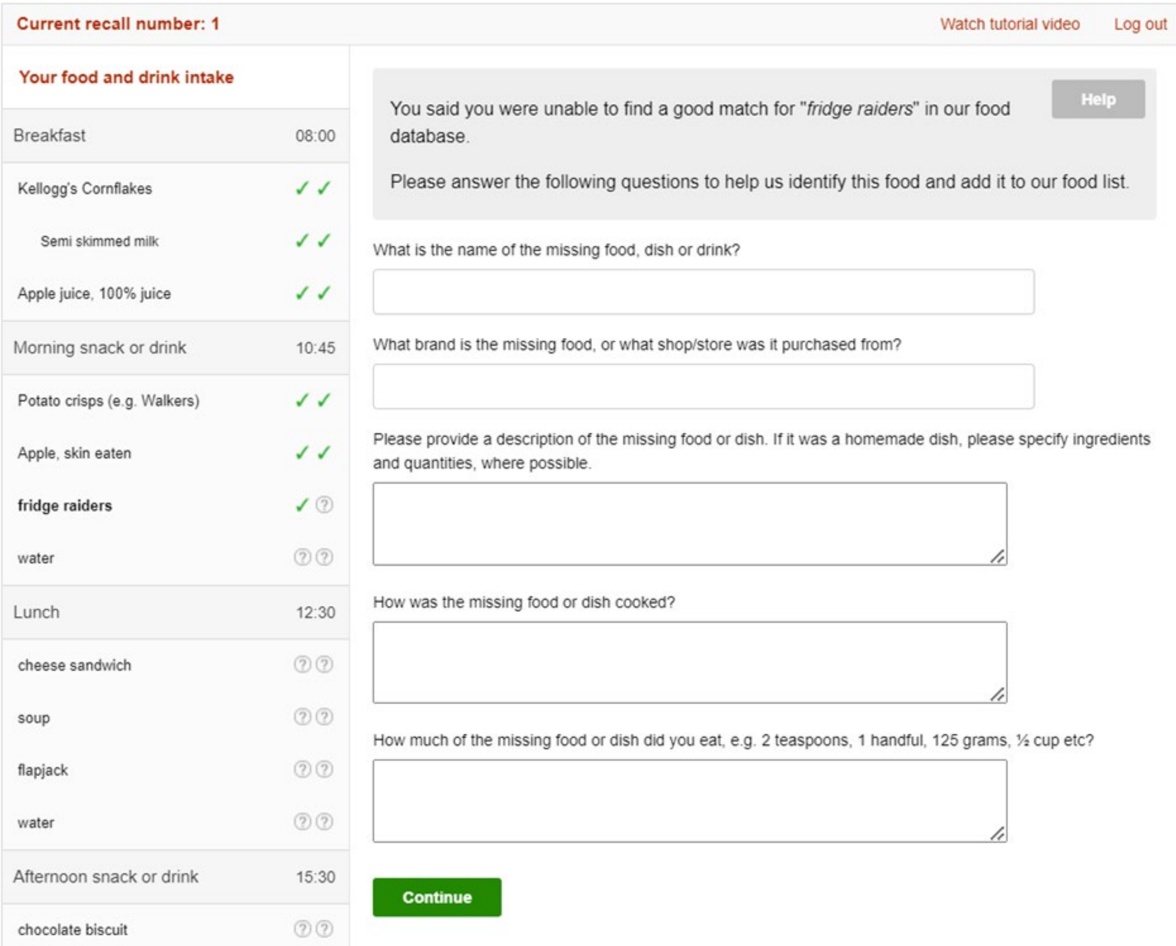


Figure 3.7 Example of a missing food form

3.5.3.3 Estimating portion size

Children were asked to estimate the portion size of each food and drink item entered. There are four portion size estimation methods in Intake24, depending on the item [189].

- Guide images show a range of items that are in pre-determined sizes, for example biscuits, sweets, slices of bread. Children can select the closest size to the item consumed

- As served images display increasing portion sizes of foods. These pictures depict how food items may be served in a usual setting, for example, chopped fruit or slices of pizza
- Standard portion descriptions, for example, number of teaspoons of sugar, number of pieces of fruit (e.g., 1 apple)
- Sliding scale for drinks allowed children to select how full a cup/mug/glass was for served and leftover amounts

During portion estimation, children were asked if they had any leftovers and if yes, they were asked to indicate how much food or drink was left. Once portion sizes were entered, Intake24 would prompt for any food combinations that were potentially missed. This included common side dishes like naan bread with curries or garlic bread with pasta; or missing associated foods such as milk and sugar in cereal or tea/coffee. If no drinks had been entered for a meal or snack occasion Intake24 flagged this and the researcher would ask the child to clarify if a drink had been consumed.

3.5.3.4 Location of consumption

After each meal or eating occasion was entered, children were asked where they consumed that food or drink. There were four options to choose from: in school, at home, on the journey to/from school or another location. If another location was selected children were asked to provide further details, for example, in a restaurant or at a friend's house.

3.5.3.5 Forgotten foods and final review

Children were prompted by myself or a research assistant for the most frequently forgotten foods, using a list provided by Intake24 as an aid (Figure 3.8) and then asked if the amount consumed was usual, less than usual or more than usual and if any supplements were consumed. Finally, all foods and drinks entered were reviewed and checked for any errors or missing foods before submitting. The whole process was repeated for each day.

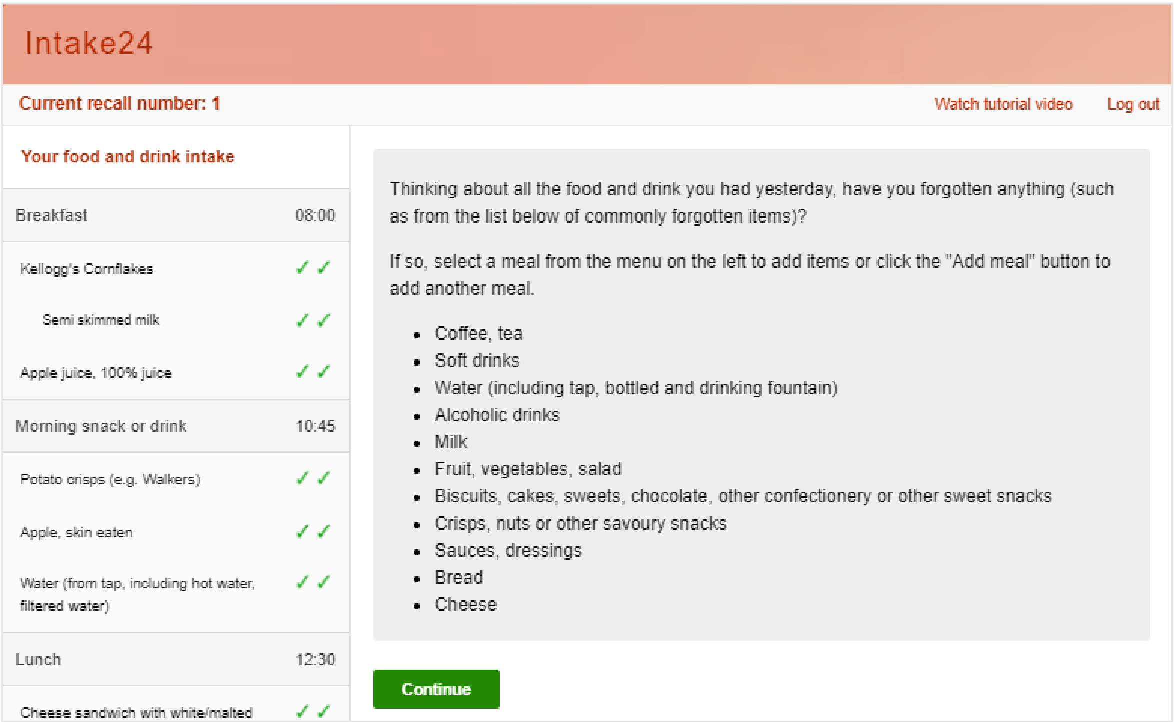


Figure 3.8 Example of a forgotten foods list

3.5.4 Change in methods from use of food models to use of Intake24

In 2000 and 2010, a combination of food models and food atlas (portion size photos) were used to estimate portion sizes. The use of food models was burdensome regarding transportation and preparation for interviews. The method also required manual coding and data entry into a database, which was time consuming for researchers. For the 2022 data collection, Intake24 was used, as described above. Intake24 only requires use of a laptop to access the website, and includes a large range of portion size pictures, greater than the food atlas and food models used in the previous studies. Additionally, entering the dietary data into intake24 removes the requirement for manual data coding and entry, reducing researcher burden.

Intake24 has been previously validated for use in children and adolescents to estimate dietary intakes using portion size pictures [186, 190]. Bradley *et al.* (2016) conducted a study comparing the use of Intake24 with an interviewer led 24hr diet recall in 11-24 year-olds [186]. This study reported that estimated intakes using Intake24 were comparable with estimated intakes from interviewer led 24-hour recalls. Prior to ASH11 2022, Bradley *et al.* (2021) compared the use of Intake24 portion size photos with 3D food models to estimate portion size in 11–12-year-olds. This was to identify any potential impact of a change in portion estimation method. This study was carried out in Newcastle with children in the same age group as the current study. Findings showed there was good agreement in portion size estimations to ensure the differences were not due to change in methods [190].

3.6 Dietary data

3.6.1 Exporting from Intake24

Dietary data from Intake24 was exported into a Microsoft Excel file for data cleaning. Intake24 output contained: (i) survey information (e.g., date/time, participant ID, time to complete), (ii) each individual food item along with serving size (amount of food before eating), (iii) portion size (amount of food consumed), (iv) location of consumption, (v) time of consumption, (vi) nutrient information and (vii) food group information including HNRC food groups which were used for food group coding.

All data were stored according to Newcastle University policy and a data management plan was created. The data management plan provided information on the data produced, data structure and storage, and how the data will be shared during and after the project. Additional intake data, which was not used in the current study, for example protein and zinc intakes, were kept and stored according to policy for potential future research and analysis.

3.6.2 Data cleaning

Data from 2000 and 2010 had already undergone the process of data cleaning and used in publications. Therefore, no further cleaning was required aside from excluding the two schools that declined to participate in the 2022 study from analysis. This section therefore focusses on the 2022 data.

3.6.2.1 Data entries and completion

First, data output was checked for duplicate entries and duplicated days were removed, there were two cases of this in the 2022 dataset. Data from children that did not complete both rounds of data collection were removed (*n*=7). Figure 3.9 details the reasons for removal from the 2022 dataset.

3.6.2.2 Gender

Once data were obtained and cleaned, children who selected "other" or "prefer not to say" for gender were removed from analysis; four children selected this option.

3.6.2.3 Mixed lunches

The majority of children consumed either school lunches or home-packed lunches in the full dataset (2000, 2010 and 2022). In 2022, only 12 children consumed mixed lunches in school (school and home-packed lunches). Of these 12 children, ten children consumed a different school lunch type on one day (e.g., three days school lunch and one day home-packed lunch). It was decided that the day that the different lunch type was consumed would be removed and five days of dietary intake would be used for analysis. Children who had mixed lunches where they consumed home-packed lunches on two days and school lunches on two days, were removed from analysis (*n*=2).

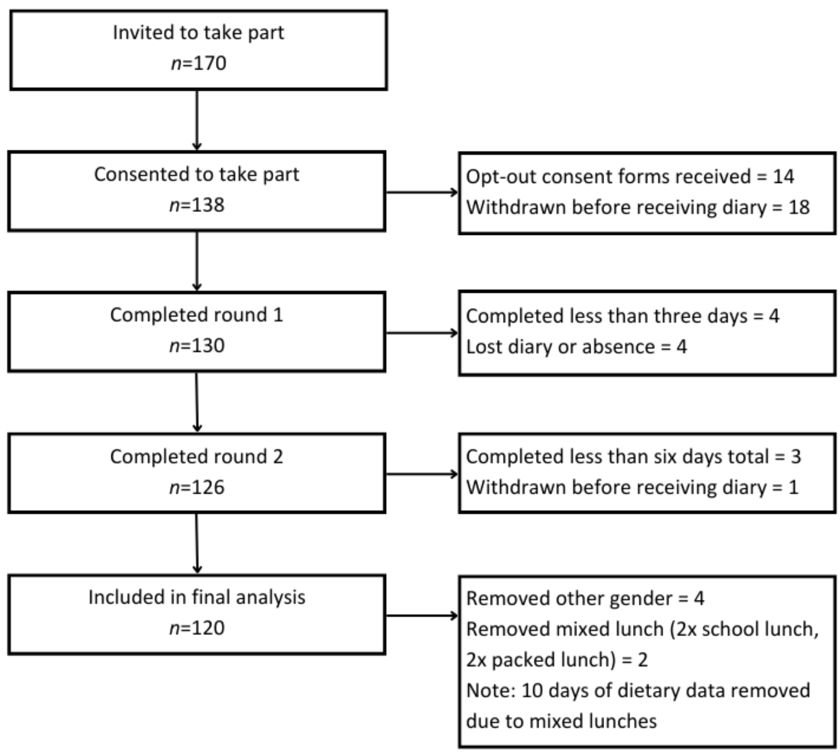


Figure 3.9 Reasons for excluding children and final numbers of children participating in 2022

3.6.3 Missing foods

Some of the food items consumed by the children were not included in Intake24, the food was therefore entered as a “missing food”. A total of 45 missing foods were recorded, many of these were repeated food items (e.g., Fridge Raiders). After missing foods were identified, the most appropriate alternative match was selected based on nearest nutrient information (see Table 3.1). Nutrient information was entered using the Vlookup function in excel, linked to a nutrient database. Portion size information was obtained from a combination of missing food information provided by children and information from online retailers.

Table 3.1 Missing foods from 2022 dataset and closest matches used for data analysis

Missing food	**Alternative match**	**Number of occurrences**
Fridge raiders	Roast chicken, meat only	21
Cheese and bacon pastry	Ham and mozzarella pastry	2
Sweet chilli chicken ready meal (with rice)	Sweet and sour chicken with rice ready meal	1
Mochi	Flavoured ice cream	1
Onion ring crisps	Maize and potato snacks with artificial sweeteners	1
Toasting waffle	Sweet waffles, grilled	3
Jawbreakers	Boiled sweets, soft centre	1
Pasta n sauce	Pasta and sauce mixes, tomato based cooked	2
Gummy worms	Pick n mix sweets unspecified	1
Mix milk cake	Sponge cake made with butter	2
Caramel apple	Entered separately as “apple” and “caramel sauce”	1
Pizza roll	Pizza baguette	1
Cocktail sausages	Pork sausages, grilled	1
Cabanossi	Salami	1
Biscoff spread	Chocolate spread	2
Fortune cookie	Ice cream wafer	2
Bonbons	Boiled sweets soft centre	1
Bruschetta	Individual ingredients entered – “garlic bread”, “cherry tomatoes, raw” and “cheese mozzarella”	1

3.6.4 Portion size

Data were also checked for 'unreasonable amounts'. Intake24 flags any portion sizes greater than 1000g, as 'reasonable' if under 1000g and 'unreasonable' if above to allow this to be checked. If any foods are flagged as unreasonable amounts, portion size would be changed to an average portion size, however, no portion sizes were flagged as unreasonable.

3.6.5 Under and over-reporting

Dietary data were checked for over and under reporters with low or high energy intakes. Similar to the NDNS protocol, if daily energy intakes were below 400 kcal or above 4000 kcal and the child had not indicated that their intake was less or more than usual, children were removed [(187)]. There were no energy intakes in the data above or below these values.

3.7 Diet Quality Index for Adolescents

The Diet Quality Index for Adolescents (DQI-A) assesses adolescents' dietary adherence to food-based dietary guidelines. DQI-A is based on food group intakes as opposed to nutrient intakes [(22, 173)]. DQI-A is based on a validated measure used for preschool children, which was adapted for an adolescent population, originally for a European population [(22)]. DQI-A includes three main components: diet quality, diet diversity and diet equilibrium. Each of these three components and the overall DQI-A score are presented as percentages, the score ranges for -33 to 100%. A higher DQI-A score (closer to 100%) indicates a better diet quality [(22)]. Table 3.2 provides a summary on how DQI-A score is calculated.

Table 3.2 Summary of the calculation of Diet Quality Index for Adolescents score (DQI-A) (from Vyncke *et al.* 2013 [22])

FBDG		DQI-A Components				
Food group*	**Recommended daily intake**	**Diet quality component (DQc)**	**Diet diversity component (DDc)**	**Diet adequacy component (DAx)**	**Diet excess component (DEx)**	**Diet equilibrium component (DEc)**
Recommended foods						
Water	1500-2250 ml	DQc= amount consumed (m) x weighting factor	DDc = 1 point for each food group if at least one portion consumed	DAx= Food group intake/ minimum recommended FG intake	DEx= (food group intake-maximum recommended FG intake)/maximum recommended FG intake	
Bread and cereal	150-360 g					
Potatoes and grains	210-350 g					
Vegetables	300-450 g					
Fruits	250-375 g	Weighting factor: '+1' preference foods '0' intermediate foods '-1' low-nutrient energy-dense foods		Values >1 truncated to 1	Values >1 truncated to 1 Values<0 truncated to 0	DEc= DAx=DEx
Milk products	450-600 ml					
Cheese	20-40 g					
Meat, fish and substitutes	75-100 g					
Fats and oils	10-15 g					
Non-recommended foods	<50g					
Non-recommended drinks	<300 ml					
Component scores		∑(DQc)/∑m x 100%	∑(DDc)/9 x 100%	∑(DAx)/9 x 100%	∑(DEx)/11 x 100%	∑(DEc)/11 x 100%
DQI-A score		(Diet quality + diet diversity + diet equilibrium)/3				

*** details of food group allocation are detailed in Section 3.7.2 and Table 3.5**

3.7.1 Diet Quality Coding

Permission to explore the Stata do-files by Taher *et al.* [148, 173] at Leeds University was sought and used as a basis for the calculation of diet quality scores. The do-files contained coding to categorise foods into the relevant food groups of DQI-A calculation and coding to calculate DQI-A scores. This method originally categorised foods using NDNS food codes, however, as data from 2000 and 2010 ASH11 studies only involved HNRC food groups (included in Appendix E), the decision was made to adapt this method to use HNRC food groups. HNRC food groups are a method of food group categorisation used by the Human Nutrition Research Centre at Newcastle University (now Human Nutrition and Exercise Research Centre). To ensure consistency across time points, food group coding was checked. All years used HNRC food groups to classify food items into groups. However, the 2000 data used an older, earlier version of HNRC food groups. The food groups for the 2000 study were therefore recoded to match 2010 and 2022. HNRC food groups were then matched to one of nine food groups included in DQI-A calculation, using Taher *et al.* coding of NDNS food groups as a guide.

3.7.1.1 Changes to coding

The miscellaneous HNRC food group was not used in calculation of DQI-A, foods included in this group are detailed in Table 3.3 and included multivitamins which are not covered in the DQI-A score.

Table 3.3 Miscellaneous foods included in 2000, 2010 and 2022 dataset but not considered in the calculation of DQI-A and component scores

Miscellaneous food items	Number of occurrences		
	2000	2010	2022
Chip shop batter	8	1	0
Meat spread	4	1	0
Stuffing	10	12	14
Yeast extract	7	26	0
Multivitamins	0	26	69
Olives in brine	0	2	0
Vegetable pate	0	1	0
White ham salad sandwich	0	7	0
Cheese rolls	0	10	0
Tuna Baguette	0	6	0
Tuna mayonnaise sandwich	0	8	0
Instant potato powder (made up with water)	0	5	1
White chicken salad sandwich	0	6	0
White bacon, lettuce tomato sandwich	0	1	0
Dairylea dunkers	0	0	4
Dairylea Lunchables	0	0	3
Sweeteners	0	0	14

Additionally, decisions were made on where to categorise several food items/food groups due to differences between NDNS and HNRC food group coding. Decisions for those food items are detailed in Table 3.4. Appendix F provides further details about the allocation of HNRC food groups and individual food items to DQI-A food groups. Additionally, the non-recommended foods outlined by Taher *et al.* (2020) [(173)] differs slightly from those outlined by Vyncke *et al.* 2013 [(22)], the decision was made to keep non-recommended food groups consistent with Taher *et al.* (2020) [(173)].

Table 3.4 Issues surrounding DQI-A coding and decisions made for food group categorisation

Food item	Issue	Food group categorisation
Gravy	Unclear where best to categorise	Other meat and meat products
Herbs, spices and vegetable-based sauces	Unclear where best to categorise	Vegetables (Herbs, spices, and vegetable-based sauces)
Other sauces (not vegetable-based)	Unclear where best to categorise	Oils and fat
Salt	Unclear where best to categorise	Vegetables (Herbs, spices, and vegetable-based sauces)
High fibre breakfast cereals	Not separate from other cereals in HNRC food group coding	Other breakfast cereals
Non-dairy ice cream	Not separated by HNRC food groups	Ice cream
Tap/bottled water	Both categorised as "Water" using HNRC code, separated in Leeds coding	Water (tap and plain bottled)
Wholegrains	Not separated by HNRC food groups	Other grains

3.7.1.2 DQI-A calculation checking

For each year, a sub-sample of child DQI-A scores from each year were calculated manually using excel to check for any errors in coding. To do this, for each child (included in the sub-sample) foods consumed on each day were manually categorised into one of the DQI-A food groups and allocated as a preference food, intermediate food or low-nutrient energy dense food (described in detail in Section 3.7.2.1). The steps outlined for the calculation of DQI-A and component scores outlined in Section 3.7.2 below were followed. This was completed by myself and two supervisors, and once DQI-A scores were calculated, results obtained were compared allowing for any mistakes in coding.

3.7.2 Diet Quality Calculation

3.7.2.1 Diet Quality Component

The diet quality component (DQc) assesses the quality of food choices consumed within food groups (e.g., white bread vs wholemeal bread). The nine food groups used for the DQI-A score are based on the Flemish food-based dietary guidelines and used by Vyncke *et al.* 2013 [(22)] are:

1. water,
2. breads and cereals,
3. potatoes and grains,
4. vegetables,
5. fruit,
6. milk products,
7. cheese,
8. meat and fish (and alternatives),
9. fats and oils.

To calculate diet quality, the total daily weight of food consumed for each of the nine food groups is required. The foods in each food group are further categorised into three groups based on the quality of food consumed:

- preference or healthy food,
- intermediate or moderation foods, and
- low-nutrient energy-dense foods.

Preference group

The preference group indicates the optimal food choices within that food group, for example, skimmed or semi skimmed milk for milk products and oily fish from the meat and fish group. Only one food group (cheese) does not have any food items categorised into the preference group.

Intermediate group

The intermediate group indicates foods that should be consumed in moderation, for example, cheddar cheese from the cheese food group, and whole milk from the milk products group.

Low-nutrient energy dense foods

The low-nutrient energy dense group refers to food items that should be avoided, for example, soft drinks and high sugar breakfast cereals. Also, it is important to note that fruit juice is the only food and drink item that falls into two of the categories, intermediate and low-nutrient energy-dense, in relation to weighting factors.:

- Fruit juice intakes less than 150ml are categorised as 'intermediate' and intakes above 150ml are categorised in the 'low-nutrient energy-dense' group.

Weighting factor

For each food group, foods must be classified into the groups mentioned above. Table 3.5 summarises the categorisation of foods into the relevant food groups and weighting factor groups. The weighting factors assigned to each quality group are: preference or healthy food (+1), intermediate or moderation foods (0) and low-nutrient energy-dense foods (-1). The DQc is calculated individually for each food group by multiplying the amount of food consumed by the weighting factor. Examples of this are:

- **Preference foods:** if a child consumed 150g of wholemeal bread, this will be multiplied by +1 to give a DQc score of 150 for that specific food item.
- **Intermediate foods:** if a child consumed 75g of cheddar cheese, this will be multiplied by 0 to give a DQc score of 0 for that food item.
- **Low-nutrient energy-dense foods:** if a child consumed 50g of bacon, this will be multiplied by -1 to give a DQc score of -50 for that food item.

To calculate the DQc score for all food groups, the sum of diet quality score for all components is divided by the total amount of food consumed in grams (m). This is then multiplied by 100 to calculate total component score. The equation used to calculate this is: $\sum(DQ)/\sum m \times 100\%$. The range for this component score is -100 to 100%, -100% refers to very poor-quality diets and 100% would represent the optimal quality of diet.

Table 3.5 Categorisation of foods into weighting factor groups (preference, intermediate and low-nutrient energy-dense)

Food Group	Preference foods (+1)	Intermediate foods (0)	Low-nutrient energy-dense foods (-1)
Water	• Water	• Tea and coffee • Soup	• Soft drinks (diet and non-diet) • Alcohol • Dry weight beverages
Bread and cereals	• Brown and wholemeal bread	• White bread • Other breakfast cereals	• High sugar breakfast cereals • Buns, cakes, pastries, and fruit pies • Non-milk-based puddings • Biscuits • Sugar confectionery
Potatoes and grains	• Nuts and seeds	• Potatoes and potato dishes • All grains and cereals (pasta, rice etc)	• Chips, fries and roasted potatoes • Crisps and savoury snacks
Vegetables	• Salad and raw vegetables • Other vegetables (not raw)	• Herbs, spices, and vegetable-based sauces	• No items categorised here
Fruits	• Fresh fruit	• Dried and canned fruit • Fruit juice less than or equal to 150ml per day	• Fruit juice more than 150ml • Sugars, preserves and sweet spreads
Milk products	• Skimmed and one per cent milk • Semi-skimmed milk • Low-fat yoghurt • Nutrition powders and drinks	• Whole milk • Other yoghurt and dairy desserts	• Other milk and cream • Milk-based puddings • Ice cream
Cheese	• No items categorised here	• Cottage cheese • Cheddar cheese • Other cheese	• No items categorised here
Meat and fish	• Beef, veal, and dishes • Lamb and dishes • Chicken and turkey dishes • Oily fish • White fish, shellfish, and fish dishes	• Pork and dishes • Liver and dishes • Other meat and meat products • Eggs and egg dishes • Meat pies and pastries	• Bacon and ham • Coated chicken and turkey dishes • Sausages • Burgers and kebabs • Coated or fried white fish
Fats and oils	• Polyunsaturated fatty acid vegetable oils	• Polyunsaturated fatty acid margarine • Reduced and low-fat spread • Other margarine, fats and oils	• Butter • Chocolate confectionery

3.7.2.2 Diet Diversity Component

Diet diversity (DDc) refers to the extent of variation within a child's diet, for example, children with more diverse diets consume at least one food item from each of the nine food groups mentioned above. The scoring range for this component is 0 to 9 points. This component only uses intakes from the preference and intermediate food groups, intakes from the low-nutrient energy-dense groups are not considered. One point is awarded if at least one portion is consumed for each food group identified above, excluding foods from the low-nutrient energy dense group. For this component, the minimum portion sizes used are those recommended by the British Dietetic Association as the Eatwell Guide does not provide portion size recommendations for all the nine food groups used to calculate the DDc [191, 192]. The portion sizes are detailed in Table 3.6. An example of DDc scoring is:

- If a child consumed more than 175g from the potatoes and grains food group, one point is awarded for that group.
- No food from that group or any intakes less than the minimum portion size when excluding low-nutrient energy dense foods will be awarded 0 points.

The final score for this component is calculated using the sum of DD points for all nine food groups for each child divided by nine and multiplied by 100. The equation for the calculation of this component is: **$\sum(DD)/9 \times 100\%$**. The range for this component score is 0 to 100%, with 0% representing a very poor diet diversity and 100% representing optimal diet diversity.

Table 3.6 Minimum portion sizes for each food group used to calculate DDc

Food group	Minimum portion sizes for DDc*
Water	200ml
Bread and cereals	35g
Potatoes and grains	175g
Vegetables	80g
Fruit	80g
Milk products	200ml
Cheese	30g
Meat and fish	100g
Fats and oils	4g

***one point is awarded if minimum portion size is met for each food group, obtained from the British Dietetic Association [(191)]**

3.7.2.3 Diet Equilibrium Component

Diet equilibrium (DEc) is made up of two sub-components: diet adequacy (DAx) and diet excess (DEx) which indicate how much a child's diet adheres to minimum and maximum dietary guidelines for each of the nine food groups [(22, 173)]. This component considers both over- and under-consumption of food groups. These maximum and minimum recommendations are obtained from the Flemish food-based dietary guidelines and are detailed in Table 3.7 as the UK Eatwell Guide does not provide similar recommendations [(22, 173, 193)]. This component also includes non-recommended food groups for the calculation and are shown in Table 3.8. The non-recommended food and drinks used were identified Vyncke *et al*. (2013) [(22)] and by Taher (2020) using the Eatwell Guide [(173)] and also includes foods categorised as low nutrient-energy dense.

Table 3.7 Minimum and maximum intakes for the calculation of DEc components

DQI-A Food group	Minimum portion sizes (DAx)*	Maximum portion sizes (DEx)†
Water	1500ml	2250ml
Bread and cereals	150g	360g
Potatoes and grains	210g	350g
Vegetables	300g	450g
Fruit	250g	375g
Milk products	450ml	600ml
Cheese	20g	40g
Meat and fish	75g	100g
Fats and oils	10g	15g
Non-recommended foods	n/a	50g
Non-recommended drinks	n/a	300ml

****minimum values utilised for DAx and* †*minimum values utilised for DEx***

Table 3.8 Categorisation of non-recommended food groups

Non recommended food group	Food items
Foods	Non-milk-based puddings Biscuits Sugar confectionery Chips, fried and roasted potatoes Crisps and savoury snacks Sugar, preserves and sweet spreads Other milk and cream Milk based puddings Ice cream Coated chicken and turkey Bacon and ham Sausages Burgers and kebabs Butter Chocolate confectionery
Drinks	Soft drinks (diet and non-diet) Alcohol Dry weight beverages Fruit juice more than 150mls per day

Diet Adequacy Sub-component

Diet adequacy sub-component (DAx) indicates the percentage of the minimum recommendation for each of the nine food groups, when the value is above '1' this is truncated to '1'. An example of this is:

- **Below minimum recommendation:** If a child consumed a total of 250g of foods categorised in the vegetable group, this was divided by the minimum recommendation, in this case 300g to give a score of 0.83 for this food groups DAx score.
- **Above minimum recommendation:** If a child consumed 300g of food and drink from the fruit food group, this was divided by the minimum recommendation of 250g to give a score of 1.2. As this value is greater than 1, the DAx score for this food group would be truncated to 1.

To calculate the score for this subcomponent, the sum of the DAx scores divided by nine (number of food groups) and then multiplied by 100%. The equation for this is: **$\sum(DAx)/9 \times 100\%$**. A higher score for this sub-component, indicates food group intakes that align more closely to minimum dietary guidelines.

Diet Excess Sub-component

Diet excess sub-component (DEx) indicates the percentage of intake exceeding maximum recommendations the nine food groups mentioned previously and for two additional food groups: non-recommended foods and non-recommended drinks; 11 groups in total. For each food group, when the value for DEx is over '1', this is truncated to '1'; when value is below '0' this is truncated to '0'. Examples of this are:

- **Below maximum recommendation:** If a child had an intake of 320g of foods from the bread and cereals group, the maximum intake of 360g is subtracted from the intake value and then this is divided by 360g (maximum intake value) to give a value of -0.11. As this is below 0, the DEx score for this food group would be truncated to 0.
    - Calculation: (320-360)/360 = -0.11 → value truncated to 0
- **Above maximum recommendation:** If a child had an intake of 2550ml of foods from the water group, the maximum intake of 2250ml is subtracted from the intake value

and then this is divided by 2250ml (maximum intake value) to give a DEx score of 0.13 for the water food group.

  - Calculation: (2550-2250)/2250 = 0.13

- **Non-recommended food and drink:** If a child had an intake of 125g of foods from the non-recommended food group, the maximum intake of 50g is subtracted from the intake value and then this is divided by 50g (maximum intake value) to give a DEx score of 1.5 for the water food group, which would be truncated to 1.
  - Calculation: (125-50)/50 = 1.5 → value truncated to 1

To calculate the score for this subcomponent, the sum of DEx scores is divided by 11 (number of food groups) and multiplied by 100%. The equation for this is: **∑(DEx)/11 x100%**. A higher score for this sub-component, unlike the other components, indicates poorer diets, as this component highlights excess intakes from food groups.

For calculating the diet equilibrium for each of the 11 food groups, DEx is subtracted from DAx; **DEc = DAx – DEx**. DAx for non-recommended food groups is '0', as this is only considered in the DEx component. The overall component score is calculated by calculating the sum of DEc scores, dividing by 11 and then multiplying by 100%. The equation for this is: **∑ (DE)/11 x100%**. The range for this component score is 0 to 100%, with 0% representing poor dietary equilibrium and 100% representing optimal or perfect diet equilibrium.

3.7.2.4 Overall DQI-A score

The overall DQI-A score is presented as a percentage and ranges between -33-100%. As mentioned above the ranges for the individual components are -100 to 100% for DQc and 0 to 100% for both DDc and DEc. The overall score is calculated by dividing the sum of the three main components by three. The equation for this is: **(DQc + DDc + DEc)/3**. A higher score reflects better adherence to dietary guidelines and greater variation in diet.

3.8 Food group intakes

The selected food groups explored in this thesis are: water, soft drinks and fruit and vegetables. Food group intakes were explored using HNRC food groups. Similarly, to DQI-A coding, data were manipulated across the three years to ensure food group coding was consistent and allow for analysis.

Fruit and vegetable intakes were considered both by weight (grams) and portions consumed. The current UK recommendation for fruit and vegetable consumption is that at least 5 portions should be consumed each day [194]. To calculate fruit and vegetable portions the following aspects were taken into consideration [19]:

- 80g of fresh, canned or frozen fruit and vegetables contributes one portion.
- 30g of dried fruit contributes one portion.
- Fruit juice and smoothie intakes were limited to one portion, which consists of 150ml/day. Intakes greater than this were counted only as one portion in total.
- Beans and pulses were limited to one portion, which consists of 80g/day. Intakes higher than this were counted only as one portion.

For beverage-related food groups, intakes of water and soft drinks were explored. For soft drink intakes, intakes of total soft drinks (diet and non-diet combined), diet soft drinks and non-diet soft drinks were explored separately, intakes were reported as volume (millilitres) consumed. Non-diet soft drinks included non-diet carbonated beverages, fruit juice drinks, full sugar cordials and squashes. Diet soft drinks included diet carbonated drinks and low/reduced sugar cordials and squashes. Soft drinks were chosen as a food group of interest due to the implementation of the Soft Drinks Industry Levy in 2018 [66]. Also, the NDNS has previously reported that soft drinks are a major contributor to children's NMES intakes in the UK [104].

3.9 Nutrient intakes

Nutrient intakes are explored both for total diet and lunchtime intakes. The nutrients explored were energy (kcals), total fat (per cent energy and grams), saturated fat (per cent energy and grams), NMES (per cent energy and grams), NSP, vitamin C, calcium, sodium (does not include discretionary salt), and iron. Non milk extrinsic sugars (NMES) were used instead of the more recent Free Sugars to ensure consistency and allow comparison to previous years. Similarly, NSP was used instead of AOAC fibre for the same reason.

Per cent energy (%E) from fat, saturated fat and NMES were calculated to compare intakes with current recommendations. Per cent energy from fat and saturated fat was calculated by multiplying the grams of fat/saturated fat consumed by 9 kcal (fat contains 9 kcal per gram of fat), dividing by the number of kilocalories consumed and multiplying by 100. Per cent energy from NMEs is calculated the same way, however grams of NMES consumed was multiplied by 4 kcal (sugars contain 4 kcal per gram of sugar).

3.10 Participant characteristics

3.10.1 Postcode

Child level postcodes were provided as a paper copy from the school. This information was transferred to an excel spreadsheet (password protected) and linked to child IDs and paper copies of child data were shredded. Socioeconomic status was estimated using the English Index of Multiple Deprivation (IMD) 2019. IMD is a measure of relative deprivation in England. This is made up of seven components (which are types of deprivation), including income, employment, education, health, crime, housing and living environment [(183)]. The IMD scores were categorised into tertiles due to distribution of the study sample. Tertile 1 was comprised of children in the 40% least deprived areas (least deprived group), tertile 2 contained children in the remaining 40% of areas (mid-deprived group) and tertile 3 was comprised of children from the 20% most deprived areas (most deprived group).

3.10.2 Gender

Gender information was collected using a short questionnaire with four options: male, females, other or prefer not to say. This was completed during the first round of data collection.

3.10.3 Lunch Type

Lunch type information was obtained by asking the participant what type of lunch they consumed that day (on weekdays), home-packed lunch (PL) or school lunch (SL). Weekday lunch source from other sources (e.g., restaurant or café) were not considered in the current study (both for lunchtime and total diet analysis).

3.10.4 Anthropometry

Initial plans included collection of anthropometric data from participants. However, due to COVID-19 restrictions and social distancing regulations, anthropometric data were not collected.

3.11 Statistical Analysis

Statistical analysis was completed using Stata Version 17 [195]. Statistical significance was a p-value of < 0.05, exact p-values and confidence intervals (CIs) are presented where relevant. All variables were checked for distribution prior to any statistical analysis being carried out using histograms, to determine which statistical tests (normal or non-normal) were required. For the regression analyses, Q-Q plots were used to check distribution of the residuals, normal distribution indicates that the assumption of normality of residuals for regression are met. This was completed for all variables included in analysis:

- **Food groups: water,** total soft drinks, diet soft drinks, non-diet soft drinks, fruit and vegetable intakes.
- **Diet quality:** DQI-A, DQc, DDc, DEc, DAx and DEx scores.
- **Nutrient intakes (both total diet and lunchtime)**: energy (kcals), total fat (per cent energy and grams), saturated fat (per cent energy and grams), NMES (per cent energy and grams), NSP (grams), vitamin C (milligrams), calcium (milligrams), sodium (milligrams), and iron (milligrams).

3.11.1 Food groups intakes

All food group intakes were calculated as a six-day average intake for each child. As food group data were not normally distributed, nonparametric tests were used. Kruskal Wallis tests were used to explore change over time. Mann Whitney tests were used to explore differences in food group intakes between genders and between school lunch types. Descriptive statistics are presented as median and interquartile range. Results from analysis of food group intakes are presented in Chapter 4.

3.11.2 DQI-A scores

DQI-A score was calculated at a daily level. For the analysis a six-day average DQI-A score was obtained. First, DQI-A and component scores were explored using descriptive statistics by year, presented as mean and standard deviation.

Next, more complex analysis was completed using multiple linear regression to explore changes to DQI-A scores. Linear regression was used to assess the effect of year (i.e., 2000, 2010 and 2022), school lunch type (i.e., school lunch or packed lunch) and IMD tertile on DQI-A scores. Analyses adjusted for gender. The interaction between year and school lunch type was also included. Results from diet quality analyses are presented in Chapter 4.

3.11.3 Nutrient intakes (lunchtime and total diet)

Children's nutrients intakes were explored using six-day average intakes for total diet and four-day average intakes for weekday lunchtime intakes. First, nutrient intakes were explored using descriptive statistics by year, presented as mean and standard deviations for normally distributed data. Geometric means and ratios are used for vitamin C intakes which was skewed and log-transformed before analysis. Linear regression was used to explore the effect of year (i.e., 2000, 2010 and 2022), school lunch type (i.e., school lunch consumers and packed lunch) and IMD tertile on nutrient intakes. All analyses adjusted for gender. The interaction between year and school lunch was also explored. Chapter 5 and Chapter 6 present the findings on nutrient intakes from total diet and lunchtime respectively.

Chapter 4 Food group intake and diet quality of 11–12-year-olds in Northumberland

Chapter overview:

This chapter describes the sample characteristics of the participants across the three years (2000, 2010 and 2020). The aim of this chapter was to explore intakes of key food groups, diet quality (total diet) of 11–12-year-olds and compare to the previous ASH11 studies (2000 and 2010) to consider the effect of pre- and post-implementation of school food policies in England on children's dietary intakes. The objectives were to:

1. To describe the study sample characteristics, for example, gender, school lunch type and IMD across the three years.
2. To explore children's median intakes of water, soft drinks and fruits and vegetables.
3. To describe children's mean DQI-A and component scores by year.
4. To explore the effect of year, school lunch type and IMD on children's mean DQI-A and component scores.

4.1 Study sample characteristics: 2000, 2010 and 2022

This section provides a description of the number of children participating by year, gender, school lunch type and index of multiple deprivation (IMD) tertile (level of deprivation). A total of 371 children aged 11-12 years participated across years; *n*=166 in 2000, *n*=85 in 2010 and *n*=120 in 2022 (see Table 4.1).

4.1.1 Gender

In 2000, more females (F) than males (M) participated in the study (M=46%; F=54%). A similar percentage of males and females participated in 2010 (M=51%; F = 49%) and 2022 (M=50%; F=50%).

4.1.2 School lunch type

In both 2000 and 2022, there was a higher percentage of school lunch (SL) consumers compared with packed lunch (PL) consumers. In 2000, 80% of children consumed school lunches and 20% consumed packed lunches; in 2022 76% consumed school lunches and 24% consumed packed lunches. In 2010, the percentage of SL and PL consumers were similar, 48% and 52% respectively.

4.1.3 Socioeconomic status/IMD distribution in 2000, 2010 and 2022

In 2000, the mean IMD score was 35.0, in 2010 mean IMD was 40.2 and in 2022 it was 38.8. Most children were categorised in the more deprived tertile (see Table 4.1). A higher IMD score indicates a higher level of deprivation, IMD scores in England range from 0.5 to 92.7 [183]. The mean IMD score for the participants in each year was higher than the mean IMD score for England (21.7) and Northumberland (22.1) [183].

Table 4.1 Number of participants by year, gender, school lunch type and level of deprivation (%)

	Year		
	2000 (*n*=166)	**2010 (*n*=85)**	**2022 (*n*=120)**
Gender			
Male	76 (46%)	43 (51%)	60 (50%)
Female	90 (54%)	42 (49%)	60 (50%)
School Lunch Types			
School Lunch	132 (80%)	41 (48%)	91 (76%)
Packed Lunch	34 (20%)	44 (52%)	29 (24%)
Level of deprivation			
Tertile 1 (least deprived)	19 (11%)	10 (12%)	22 (18%)
Tertile 2 (mid)	64 (39%)	22 (26%)	25 (21%)
Tertile 3 (most deprived)	83 (50%)	53 (62%)	73 (62%)

4.2 Total diet: children's median intake of water, soft drinks, fruit and vegetables in 2000, 2010 and 2022

Children completed four weekdays and two weekend days of dietary data across the three years. Median intakes are presented for all children and for consumers only (see Table 4.2) for the following food groups: water, soft drinks (total soft drinks and split by diet and non-diet soft drinks, fruit and vegetable intakes (grams and portions). Details on the calculation of fruit and vegetable portions are detailed in Chapter 3, Section 3.8.

4.2.1 All children

4.2.1.1 Water and soft drink intakes

Figure 4.1 displays children's median intakes of water and soft drinks. Children's median water intakes increased across years. Children consumed 79 ml/day in 2000, 108 ml/day in 2010 and 506 ml/day in 2022 ($p<0.001$). There was no evidence of a difference in total intake of soft drinks between years ($p=0.17$). There was evidence of an increase in children's median consumption of diet soft drinks across years: 0 ml/day in 2000; 50 ml/day in 2010 and 144 ml/day in 2022 ($p<0.001$). Children's median intakes of non-diet soft drinks initially increased (2000 to 2010) but decreased overall between 2000 and 2022 from 271 ml/day in 2000 to 318 ml/day in 2010 and decreased to 151 ml/day in 2022 ($p<0.001$).

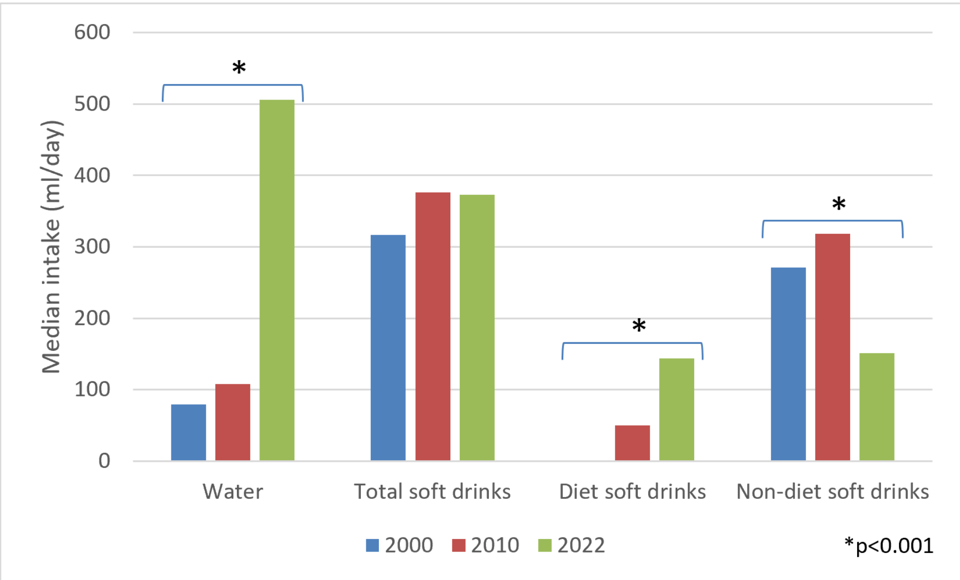


Figure 4.1 Median intakes of water (ml/day) and soft drinks (ml/day): total, diet and non-diet, by year in all children (consumers and non-consumers)

4.2.1.2 Fruit and vegetable intakes

Fruit and vegetable intakes are presented as: total grams fruit and vegetables (including fruit juice), total grams fruit (including fruit juice), total grams fruit (excluding juice), and total vegetables. Median intakes (g) are presented first, followed by median number of portions. Figure 4.2 displays children's median portions of fruit and vegetables per day.

There was no evidence of a difference between years for children's median fruit and vegetable intakes (p=0.49) or fruit intakes (excluding fruit juice, p=0.84). However, median fruit intake (including fruit juice) was found to increase across years, from 67 g/day in 2000 to 92 g/day in 2010 and 100 g/day in 2022 (p=0.02). Whilst mean fruit intakes (including fruit juice) increased, mean vegetable intakes (g) decreased from 61 g/day in 2000 to 38 g/day in 2022 (p<0.001). There was no evidence of a difference in median portions of total fruit and vegetable consumed, and fruit consumed (p=0.19 and p=0.16 respectively). There was a decrease in median number of portions of vegetables consumed, from 0.8 portions/day in 2000 to 0.4 portions/day in 2010 and 0.5 portions/day in 2022 (p<0.001).

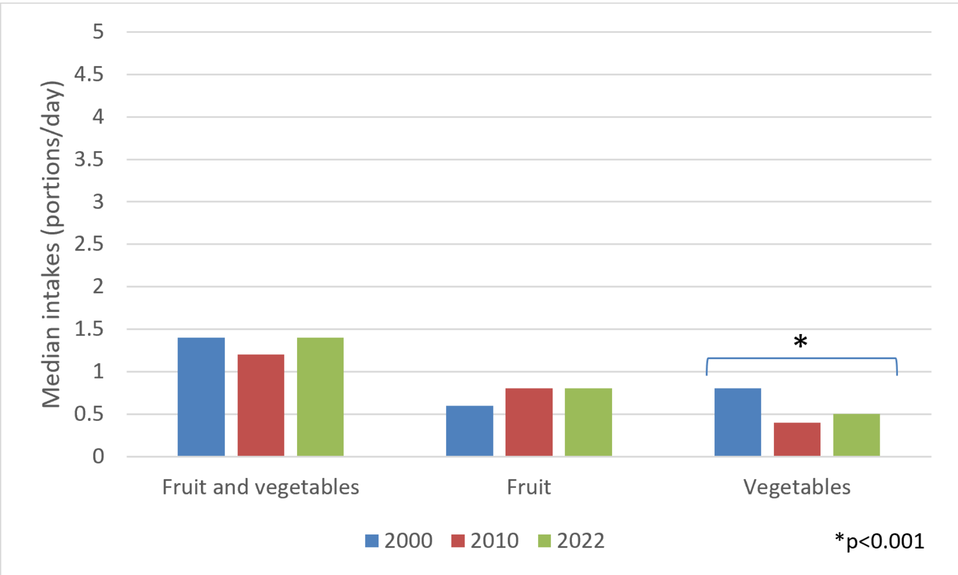


Figure 4.2 Median intakes of fruit and vegetables (portions/day), by year in all children (consumers and non-consumers)

4.2.2 Consumers only

4.2.2.1 Water and soft drink intakes

Figure 4.3 displays children's median intakes of water and soft drinks for consumers only. In 2000, 79% of participants consumed water, this increased to 81% in 2010 and 97% in 2022.

Median water intakes significantly increased across years from 108 ml/day in 2000 to 162 ml/day in 2010 and 534 ml/day in 2022 (p<0.001). The proportion of participants consuming soft drinks (diet and non-diet combined), was similar in 2000 and 2010; 99% and 100% respectively. This decreased slightly to 93% in 2022. There was no evidence of a difference in total soft drink consumption (ml/day) across years (p=0.10). For diet soft drinks, 36% of participants in 2000, 58% in 2010 and 81% of participants in 2022 consumed diet soft drinks. Diet soft drink intakes increased across years from 83 ml/day in 2000, 100 ml/day in 2010 and 188 ml/day in 2022 (p<0.001). For non-diet soft drinks, 98% of participants in 2000 and 2010, 84.2% of participants in 2022 consumed non-diet soft drinks. Intakes of non-diet soft drinks decreased from 280 ml/day in 2000 to 167 ml/day in 2022 (p<0.001).

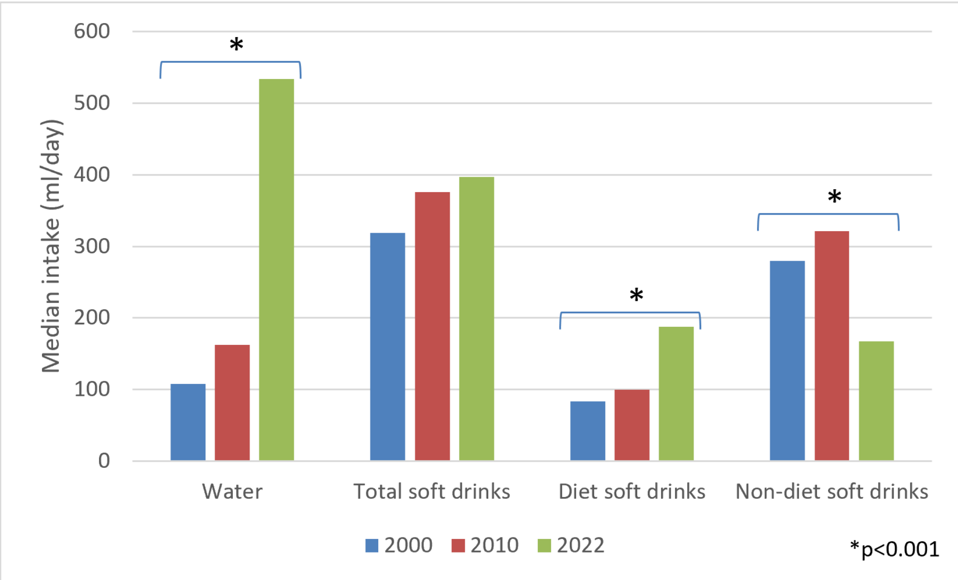


Figure 4.3 Median intakes of water (ml/day) and soft drinks (ml/day): total, diet and non-diet, by year in consumers only

4.2.2.2 Fruit and Vegetable intakes

Figure 4.4 displays children's median intakes of fruit and vegetables regarding median portions consumed for consumers only. There was no evidence of a difference in median fruit and vegetable intakes, both in grams and portions, across years (p=0.44 and p=0.24 respectively). For total fruit, excluding fruit juice consumption, 61% of participants consumed fruit in 2000 and 61% in 2010 and this increased to 68% in 2022. There was no evidence of a difference in fruit intakes excluding fruit juice across years (p=0.09). For fruit intakes, including fruit juice, 86%, 84% and 88% of participants in 2000, 2010 and 2022 consumed fruit and fruit juice respectively. Fruit intakes, including fruit juice, significantly increased across years, increasing from 79 g/day in 2000 to 112 g/day in 2022 (p=0.008). There was no evidence of a difference between years for fruit portions consumed (p=0.10). For vegetable intakes, 95%, 94% and 91% of participants consumed vegetables in 2000, 2010 and 2022 respectively. Vegetable intakes decreased in both grams and portions, across years from 64 g/day in 2000 to 41 g/day in 2022, and 0.8 portions/day in 2000 to 0.5 portions/day in 2022 (p<0.001 for both).

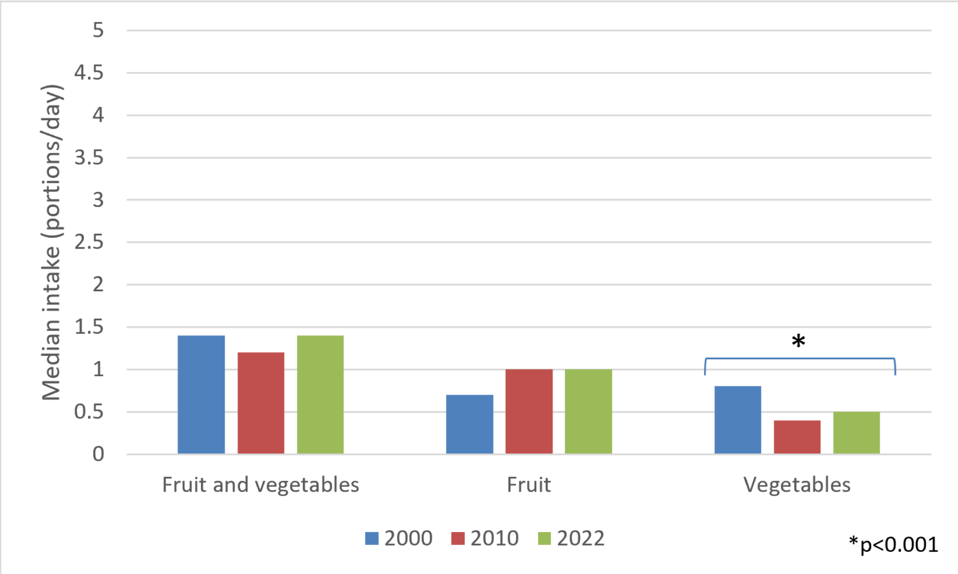


Figure 4.4 Median intakes of fruit and vegetables (portions/day), by year in consumers only

Table 4.2 Total diet: median intakes for water, soft drinks and fruit and vegetables in 2000, 2010 and 2022 by all children and consumers only

	All children				Consumers only			
Food group	**Year** *n*=371			**p-value**[†]	**Year**			**p-value**[†]
	2000 (*n*=166)	**2010** (*n*=85)	**2022** (*n*=120)		**2000**	**2010**	**2022**	
	Median (IQR[*])	**Median (IQR)**	**Median (IQR)**		**Median (IQR)**	**Median (IQR)**	**Median (IQR)**	
6-day average intakes (ml/d)								
Water	79 (150)	108 (227)	506 (423)	<0.001	108 (150)	162 (226)	534 (419)	<0.001
Total soft drinks[*]	317 (282)	376 (336)	373 (367)	0.17	319 (283)	376 (336)	397 (372)	0.10
Diet soft drinks	0 (55)	50 (120)	144 (232)	<0.001	83 (95)	100 (133)	188 (235)	<0.001
Non-diet soft drinks	271 (238)	318 (315)	151 (241)	<0.001	280 (229)	321 (316)	167 (218)	<0.001
6-day average intakes (g/d)								
Total fruit and vegetables	130 (116)	122 (154)	134 (139)	0.49	130 (118)	124 (144)	140 (226)	0.44
Total fruit (excl. juice)	22 (64)	29 (78)	23 (60)	0.84	52 (72)	64 (71)	45 (54)	0.09
Total fruit (incl. juice)	67 (115)	92 (147)	100 (126)	0.02	79 (180)	115 (129)	112 (117)	0.008
Total vegetables	61 (68)	31 (36)	38 (54)	<0.001	64 (63)	32 (32)	41 (53)	<0.001
6-day average intakes (portions/d)								
Fruit and vegetables	1.4 (1.2)	1.2 (1.3)	1.4 (1.2)	0.19	1.4 (1.2)	1.2 (1.3)	1.4 (1.1)	0.24
Fruit	0.6 (1.0)	0.8 (1.1)	0.8 (1.0)	0.16	0.7 (1.0)	1.0 (1.3)	1.0 (0.8)	0.10
Vegetables	0.8 (0.8)	0.4 (0.4)	0.5 (0.7)	<0.001	0.8 (0.8)	0.4 (0.4)	0.5 (0.7)	<0.001

[*]**IQR = interquartile range; [†]due to non-normal distribution, Kruskal-Wallis tests used to calculate p-value**

4.3 Total diet: mean DQI-A score and diet quality components by year in 2000, 2010 and 2022

4.3.1 Summary of DQI-A calculation

A summary of the calculation for Diet Quality Index for Adolescents (DQI-A) score and related components is detailed in Table 4.3, adapted from Vyncke *et al* (2013) [22] as a reminder as this is a complex calculation. Further details on the calculation of the DQI-A score can be found in Section 3.7.2 of Chapter 3 including: (i) categorisation of foods into weighting factor groups for calculation of the Diet Quality Component (DQc) score, (ii) portion size values for Diet Diversity Component (DDc) scoring and (iii) minimum and maximum food group recommendations for Diet Equilibrium Component (DEc) calculation. Figure 4.5 depicts the DQI-A score range from -33 to 100%, -33% is the lowest possible score illustrating a poor diet and 100% is the best possible score illustrating a very good diet.

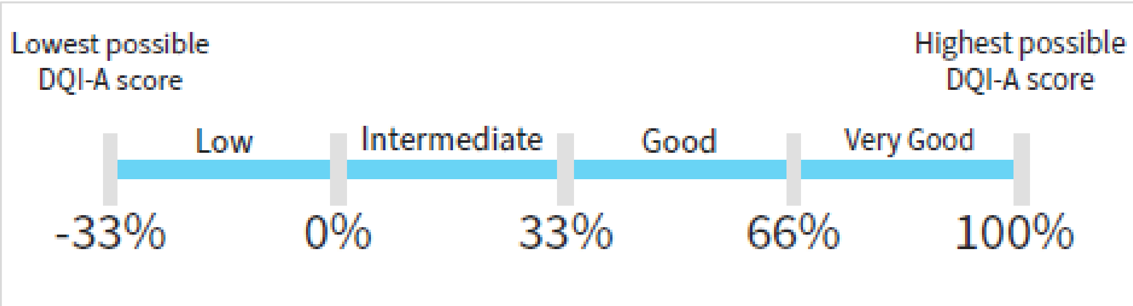


Figure 4.5 DQI-A score range, lowest possible score is -33%, highest possible score is 100%

The first part of these analyses provides an overall description of DQI-A scores and year. The second, more detailed analyses considers the effect of year, school lunch type and index of multiple deprivation (IMD) tertile (level of deprivation) on DQI-A scores using linear regression, adjusting for gender. Further, interactions between year and school lunch type were explored.

Table 4.3 Calculation of Diet Quality Index for Adolescents (DQI-A) score (adapted from Vyncke *et al*. 2013 [22]

FBDG*		DQI-A Components				
Food Group	**Recommended daily intake**	**Diet quality component (DQc)**	**Diet diversity component (DDc)**	**Diet adequacy component (DAx)**	**Diet excess component (DEx)**	**Diet equilibrium component (DEc)**
Recommended foods						
Water	1500-2250 ml	DQc= amount consumed (m) x weighting factor	DDc = 1 point for each food group if at least one portion consumed	DAx= Food group intake/minimum recommended FG intake	DEx= (food group intake-maximum recommended FG intake)/maximum recommended FG intake	
Bread and cereal	150-360 g					
Potatoes and grains	210-350 g					
Vegetables	300-450 g					
Fruits	250-375 g					
Milk products	450-600 ml					DEc= DAx=DEx
Cheese	20-40 g	Weighting factor: ‘+1’ preference foods ‘0’ intermediate foods ‘-1’ low-nutrient energy-dense foods		Values >1 truncated to 1	Values >1 truncated to 1 Values <0 truncated to 0	
Meat, fish and substitutes	75-100 g					
Fats and oils	10-15 g					
Non-recommended foods	<50 g					
Non-recommended drinks	<300 ml					
Component scores		∑(DQc)/∑m x 100%	∑(DDc)/9 x 100%	∑(DAx)/9 x 100%	∑(DEx)/11 x 100%	∑(DEc)/11 x 100%
DQI-A score		(Diet quality + diet diversity + diet equilibrium)/3				

***FBDG = Food based dietary guidelines**

4.3.2 Mean DQI-A score and diet quality sub-components by year

Children's mean DQI-A and component scores for each year are detailed in Table 4.4. Overall, mean DQI-A score increased across years: 10.9% in 2000, 11.4% in 2010 and 19.6% in 2022. In 2022, compared to 2010 and 2000, children had a higher mean DQc, DDc and DAx score which is a positive change and reflected in overall DQI-A score (see Appendix G for a breakdown of DQc score by food group and year). There was little difference in mean DEc and DEx across years.

Table 4.4 Mean DQI-A and component scores of 11-12yr old children (expressed as percentages) in 2000, 2010 and 2022

Diet Quality Component	**Year *n*=371**		
	2000 (*n*=166) Mean (SD)**	**2010 (*n*=85) Mean (SD)**	**2022 (*n*=120) Mean (SD)**
DQI-A*	**10.9 (10.3)**	**11.4 (11.8)**	**19.6 (13.4)**
DQc†	-25.0 (20.5)	-21.9 (26.5)	0.2 (31.0)
DDc‡	37.2 (10.2)	36.1 (10.30)	38.1 (9.6)
DEc§	20.6 (5.5)	20.1 (5.5)	20.6 (5.8)
DAx¶	51.1 (8.2)	49.8 (7.8)	52.3 (7.9)
DEx#	21.3 (5.1)	20.6 (5.4)	22.2 (5.2)

***DQI-A = Diet quality index for adolescents (overall diet quality score); †DQc = Diet Quality component; ‡DDc = Diet Diversity component; §DE = Diet Equilibrium component; ¶DAx = Diet Adequacy subcomponent; #DEx = Diet Excess subcomponent; **SD = standard deviation**

4.4 Total diet: the effect of year, gender, IMD and school lunch type on children's mean DQI-A score and diet quality components

4.4.1 The effect of year on children's mean DQI-A and diet quality components

Results exploring the effect of year on DQI-A and component scores are detailed in Table 4.5, means were adjusted for gender, school lunch type and IMD. The year 2000 was used as a baseline. The key finding is that there was evidence of an effect of year on children's mean DQI-A scores. In 2000 mean DQI-A score was 11.0%, in 2010 mean DQI-A score was 11.0% and in 2022 mean DQI-A score was 19.8%, with the significant change between 2000 and 2022 (mean difference 2010-2000 = 0, 2022-2000 = 8.8, p<0.001).

For the diet quality component (DQc), year had an effect: in 2000 mean DQc score was -24.9%, in 2010 mean DQc score was -21.9% and in 2022 mean DQc score was 0.2%, with the significant change between 2000 and 2022 (mean difference 2010-2000 = 3.0, 2022-2000 = 25.1, p<0.001).

For the diet adequacy subcomponent (DAx), year had an effect: in 2000 mean DAx score was 51.2%, in 2010 mean DAx score was 49.1% and in 2022 mean DAx score was 52.6% (mean difference 2010-2000 = -2.2, 2022-2000 = 1.4, p=0.01). The significant change in this case was between 2000 and 2010.

For the diet excess subcomponent (DEx), there was evidence that year had an effect: in 2000 mean DEx score was 21.2%, in 2010 mean DEx score was 20.3% and in 2022 mean DEx score was 22.6%, with a significant change between 2000 and 2022 (mean difference 2010-2000 = -0.9, 2022-2000 = 1.4, p=0.01).

For both the diet diversity component (DDc) and diet equilibrium component (DEc) scores, there was no evidence that year had an effect (see Table 4.5).

4.4.2 The effect of school lunch type on children's mean DQI-A and diet quality components

The effect of school lunch type on children's mean DQI-A and diet quality components is displayed in Table 4.6, using school lunch as a baseline. Overall, there was no evidence that school lunch type had an effect on children's mean DQI-A scores, for school lunch (SL) consumers mean DQI-A was 13.3% and for home-packed lunch (PL) consumers it was 15.1% (mean difference = 1.8, p=0.21).

However, there was some evidence that school lunch type had an effect on DQI-A component and subcomponent scores.

For DDc scores, there was evidence that school lunch type had an effect: for SL consumers mean DDc was 36.0% and for PL consumers it was 40.2% (mean difference = 4.2, p<0.001).

For DAx scores, there was evidence that school lunch type had an effect: for SL and PL consumers mean DAx was 50.3% and 53.4% respectively (mean difference = 3.1, p=0.001).

For DEx scores, there was evidence that school lunch type had an effect: for SL consumers mean DEx was 21.0% and for PL consumers it was 22.5% (mean difference = 1.5, p=0.02).

For both DQc and DEc scores, there was no evidence that school lunch type had an effect (see Table 4.6).

4.4.3 The effect of IMD on children's mean DQI-A and diet quality components

Results exploring the impact of IMD tertile on DQI-A and component scores are detailed in Table 4.7, using the least deprived tertile as a baseline. There was no evidence found that IMD had a statistically significant effect on children's mean DQI-A scores. In the least deprived tertile, the mean DQI-A score was 13.3%, in the mid deprived tertile mean DQI-A was 14.0% and in the most deprived tertile mean DQI-A score was 13.9% (see Table 4.7). For diet quality component scores (i.e., DQc), there was no evidence of a statistically significant effect of IMD.

4.4.4 Two-way interactions between year and school lunch type

Two-way interactions were explored between year and school lunch type. For overall mean DQI-A score, there was no evidence of an interaction between year and school lunch type (p=0.21).

Table 4.5 The effect of year on mean (adjusted) DQI-A score and diet quality component scores (expressed as percentages) of 11-12yr old children in 2000, 2010 and 2022

Diet quality component	Mean[*] *n*=371			Mean difference						p-value[‡]
	2000 (*n*=166)	2010 (*n*=85)	2022 (*n*=120)	2010-2000	95% CI for difference[†]	2022-2000	95% CI for difference[†]	2022-2010	95% CI for difference[†]	
%DQI-A[§]	**11.0**	**11.0**	**19.8**	**0**	**-3.2; 3.2**	**8.8**	**6.0; 11.6**	8.8	5.4; 12.2	**<0.001***
%DQc[¶]	-24.9	-21.9	0.2	3.0	-4.1; 10.1	25.1	18.9; 31.3	22.2	14.7; 29.6	<0.001*
%DDc[#]	37.3	35.1	38.6	-2.1	-4.8; 0.6	1.4	-1.0; 3.8	3.5	0.7; 6.4	0.06
%DEc**	20.7	19.8	20.4	-0.9	-2.4; 0.7	-0.2	-1.6; 1.1	0.6	-1.0; 2.2	0.54
%DAx[††]	51.2	49.1	52.6	-2.2	-4.3; -0.1	1.4	-0.5; 3.3	3.5	1.3; 5.8	0.01*
%DEx[‡‡]	21.2	20.3	22.6	-0.9	-2.3; 0.5	1.4	0.1; 2.6	2.3	0.8; 3.7	0.01*

[*]Mean adjusted for gender, school lunch type and IMD; [†]95% CI = 95% Confidence interval; [‡]95% CI and p-value derived for linear regression analysis; [§]DQI-A = Diet quality index for adolescents (overall diet quality score); [¶]DQc = Diet Quality component; [#]DDc = Diet Diversity component; **DE = Diet Equilibrium component; [††]DAx = Diet Adequacy component; [‡‡]DEx = Diet Excess component

Table 4.6 The effect of school lunch type (school and home-packed lunch) on mean DQI-A and diet quality component scores (expressed as percentages) of 11-12yr old children

Diet quality component	Mean[*] *n*=371		Mean difference	95% CI for difference[†]	p-value[‡]
	School Lunch (*n*=264)	Home-packed Lunch (*n*=107)			
%DQI-A[§]	**13.3**	**15.1**	**1.8**	**-1.0; 4.6**	**0.21**
%DQc[¶]	-16.1	-16.0	0.2	-6.6; 7.0	0.96
%DDc[#]	36.0	40.2	4.2	1.8; 6.6	<0.001*
%DEc**	20.1	21.1	1.0	-0.3; 2.4	0.13
%DAx[††]	50.3	53.4	3.1	1.2; 5.0	0.001*
%DEx[‡‡]	21.0	22.5	1.5	0.3; 2.7	0.02*

[*]Mean adjusted for year, gender and IMD; [†]95% CI = 95% Confidence interval; [‡]95% CI and p-value derived for linear regression analysis; [§]DQI-A = Diet quality index for adolescents (overall diet quality score); [¶]DQc = Diet Quality component; [#]DDc = Diet Diversity component; **DE = Diet Equilibrium component; [††]DAx = Diet Adequacy component; [‡‡]DEx = Diet Excess component

Table 4.7 The effect of IMD on mean DQI-A and diet quality component scores (expressed as percentages) of 11-12yr old children

Diet quality component	**Mean*** *n*=371			**Mean difference**				**p-value‡**
	T1§§ (*n*=51)	**T2 (*n*=111)**	**T3 (*n*=209)**	**T2-T1**	**95% CI for difference†**	**T3-T1**	**95% CI for difference†**	
%DQI-A§	**13.3**	**14.0**	**13.9**	**0.7**	**-3.3, 4.7**	**0.6**	**-3.1, 4.3**	**0.93**
%DQc¶	-16.5	-15.3	-16.4	1.2	-7.6, 10.1	0.2	-8.0, 8.3	0.93
%DDc#	36.6	37.0	37.5	0.3	-3.0, 3.7	0.9	-2.2, 4.0	0.80
%DEc**	19.7	20.3	20.6	0.6	-1.3, 2.5	0.9	-0.9, 2.6	0.63
%DAx††	52.2	51.2	50.9	-1.0	-3.7, 1.7	-1.3	-3.7, 1.2	0.61
%DEx‡‡	22.9	21.6	21.1	-1.4	-3.1, 0.4	-1.9	-3.5, -0.3	0.07

***Mean adjusted for year, gender and school lunch type; †95% CI = 95% Confidence interval; ‡95% CI and p-value derived for linear regression analysis; §DQI-A = Diet quality index for adolescents (overall diet quality score); ¶DQc = Diet Quality component; #DDc = Diet Diversity component; **DE = Diet Equilibrium component; ††DAx = Diet Adequacy component; ‡‡DEx = Diet Excess component; §§T1 = least deprived, T2 = mid deprived and T3 = most deprived tertile**

Chapter 5 Total diet nutrient intakes of 11–12-year-olds in Northumberland

Chapter overview:

The aim of this chapter was to explore the total diet nutrient intakes of 11–12-year-olds and compare with current UK recommendations to previous ASH11 studies (2000 and 2010) to consider the effect of pre- and post-implementation of school food policies in England on children's dietary intakes. The objectives were to:

1. To describe mean intakes of total diet nutrient intakes (energy (kcal), fat (%E and g), saturated fat (%E, g), NMES (%E, g), NSP (g), vitamin C (mg), calcium (mg), sodium (mg), and iron (mg) in 2000, 2010 and 2022.
2. To compare nutrient intakes for total diet to current UK recommendations.
3. To explore the effect of year, gender, school lunch type and level of deprivation on children's mean total diet nutrient intakes.

5.1 Total diet: mean nutrient intakes by year in 2000, 2010 and 2022

The first part of these analyses provides an overall description of nutrient intakes and year, and comparison to current recommendations. The second, more detailed analyses, considers the effect of year, school lunch type and index of multiple deprivation (IMD) tertile (level of deprivation) on children's mean nutrient intakes using linear regression, adjusting for gender. Further, interactions between year and school lunch types were explored for all nutrients.

Children's mean nutrient intakes for selected nutrients across each year and current nutrient recommendations are detailed in Table 5.1. Children's mean intakes of energy (kcal) were highest in 2000 (1893 kcal/day) compared with 2010 (1600 kcal/day) and 2022 (1641 kcal/day). Across years, mean intakes were below current UK recommendations of 2127 kcal/day for males and 2032 kcal/day for females aged 11 years [(18)].

Mean fat intakes (per cent energy (%E)) were highest in 2000 (35.7 %E) compared with 2010 (32.5 %E) and 2022 (34.9 %E). Mean fat intakes (grams (g)) were highest in 2000 (76.1 g/day) compared with 2010 (58.6 g/day) and 2022 (64.1 g/day). Children's %E from fat in 2010 and 2022 meets the current UK recommendation of no more than 35 %E, however, children's intakes in 2000 were above current recommendations [14]. Mean saturated fat intakes (%E) were lowest in 2000 (12.8 %E) compared with 2010 (13.1 %E) and 2022 (12.9 %E), however, there is very little difference across years. Mean saturated fat intakes (g) were highest in 2000 (27.3 g/day) compared 2010 (23.5 g/day) and 2022 (23.8 g/day). Children's mean %E from saturated fat across years were above the current UK recommendation of no more than 11 %E [14]. Mean non-milk extrinsic sugars (NMES) intakes (%E) were lower in 2000 (16.0 %E) compared with 2010 (17.0 %E) and higher compared with 2022 (13.9 %E). Mean NMES intakes (g) were highest in 2000 (81.7 g/day) compared with 2010 (72.7 g/day) and 2022 (58.7 g/day). Children's mean %E from NMES across years were above the UK recommendation of no more than 11 %E from NMES [14].

Mean non-starch polysaccharide (NSP) intakes were highest in 2000 (10.6 g/day) compared with 2010 (8.8 g/day) and 2022 (10.1 g/day). Children's mean NSP intakes across years were below the UK recommendation for NSP of 18 g/day [14].

Children's mean vitamin C intakes were lowest in 2000 (63.2 mg/day) compared with 2010 (70.7 mg/day) and 2022 (82.3 mg/day), though mean intakes met and exceeded current UK recommendations of 35 mg/day [14] across the years. Mean calcium intakes were lowest in 2000 (636.2 mg/day) compared with 2010 (772.2 mg/day) and 2022 (698.5 mg/day). Children's intakes of calcium intakes across years were below current UK recommendations of 1000 mg/day for males and 800 mg/day for females aged 11-14 years [14]. Children's mean sodium intakes were highest in 2000 (2534 mg/day) compared with 2010 (2121 mg/day) and 2022 (1741 mg/day). Children's mean sodium intakes across years are above current UK recommendations of 1600 mg/day [14]. Children's mean iron intakes were highest in 2000 (9.1 mg/day) and lowest in 2010 (8.1 mg/day) compared with 2022 (8.5 mg/day). Children's iron intakes were below the current UK recommendations of 11.3 mg/day for males and 14.8 mg/day aged 11-14 years [14].

Table 5.1 Total diet: current UK nutrient recommendations and mean nutrient intakes of 11-12yr old children by year: 2000, 2010 and 2022

Nutrient	Current UK recommendation	Year *n*=371					
		2000 (*n*=166)		2010 (*n*=85)		2022 (*n*=120)	
		Mean (SD)	Per cent meeting recommendation	Mean (SD)	Per cent meeting recommendation	Mean (SD)	Per cent meeting recommendation
Energy (kcal)		1893 (403)	34.3%	1600 (316)	8.2%	1641 (435)	15.8%
	M=2127; F=2032	M=1954 (475)	M=40.8%	M=1604 (317)	M=9.3%	M=1719 (492)	M=23.3%
		F=1842 (325)	F=28.9%	F=1595 (319)	F 7.1%	F=1561 (357)	F=8.3%
%E Fat	≤35 %E	35.7 (3.6)	37.4%	32.5 (3.7)	72.9%	34.9 (4.2)	49.2%
Fat (g)	-	76.1 (18.6)	-	58.6 (14.3)	-	64.1 (20.1)	-
%E Saturated Fat	≤11 %E	12.8 (1.7)	13.3%	13.1 (2.2)	16.5%	12.9 (2.3)	20.0%
Saturated fat (g)	-	27.3 (7.6)	-	23.5 (6.6)	-	23.8 (8.3)	-
%E NMES	≤11 %E	16.0 (4.3)	10.8%	17.0 (5.3)	12.9%	13.9 (4.9)	29.2%
NMES (g)	-	81.7 (32.1)	-	72.7 (28.6)	-	58.7 (31.1)	-
NSP (g)	18	10.6 (2.8)	1.2%	8.8 (2.4)	0%	10.1 (2.7)	1.7%
Vitamin C (mg)*	35	63.2 (1.6)	90.4%	70.7 (1.7)	91.8%	82.3 (1.9)	91.7%
Calcium (mg)		636.2 (186.7)	14.5%	772.2 (246.0)	42.4%	698.5 (246.7)	27.5%
	M=1000; F=800	M=682.4 (204.3)	M=19.7%	M=801.4 (251.2)	M=48.8%	M=750.8 (270.2)	M=33.3%
		F=597.2 (161.5)	F=10%	F=742.3 (240)	F=35.7%	F=646.2 (210.1)	F=21.7%
Sodium (mg)	1600	2534 (685)	4.8%	2121 (479)	14.1%	1741 (512)	43.3%
Iron (mg)		9.1 (2.3)	15.1%	8.1 (2.0)	7.1%	8.5 (2.9)	15.8%
	M=11.3; F=14.8	M=9.8 (2.7)	M=21.1%	M=8.1 (1.9)	M=4.7%	M=9.2 (3.1)	M=28.3%
		F=8.6 (3.0)	F=10.0%	F=8.0 (2.2)	F=9.5%	F=7.8 (2.6)	F=3.3%

***data log transformed, geometric mean presented**

5.2 Total diet: the effect of year, school lunch type and IMD on children's mean nutrient intakes

5.2.1 The effect of year on children's mean nutrient intakes

Results exploring the effect of year (2000, 2010 and 2022) on children's mean nutrient intakes are detailed in Table 5.2, using 2000 as baseline, means were adjusted for gender, school lunch type and IMD. Year was found to have a statistically significant effect on children's mean intakes of energy (kcal), fat (g), saturated fat (g), NMES (%E and g), NSP (g), sodium (mg) and iron (mg), with an overall decrease across years (p<0.001 for all; see Table 5.2).

For mean energy intakes (kcal) year had a significant effect and decreased across years, mean intakes in 2000 were 1902 kcal/day, in 2010 were 1583 kcal/day and in 2022 were 1640 kcal/day (mean difference 2010-2000 = -320, 2022-2000 = -262, p<0.001). For NMES intakes (%E) mean intakes in 2000 were 16.1 %E, in 2010 were 16.9 %E, and in 2022 were 13.8 %E (mean difference 2010-2000 = 0.8, 2022-2000 = -2.3, p<0.001). For sodium (mg) intakes year had a significant effect and decreased across years, mean intakes in 2000 were 2562 mg/day, in 2010 were 2055 mg/day and in 2022 were 1750 mg/day (mean difference 2010-2000 = -507, 2022-2000 = -812, p<0.001).

Year also had an effect on children's mean vitamin C (mg, p<0.001) and calcium (mg, p=0.004) intakes, with an overall increase across years. For mean vitamin C intakes (mg) increased across years, mean intakes in 2000 were 63.4 mg/day, in 2010 were 70.2 mg/day and in 2022 were 82.3 g/day (mean difference (ratio) 2010-2000 = 1.1, 2022-2000 = 1.3, p<0.001). Similarly, mean calcium (mg) intakes increased across years, mean intakes in 2000 were 647.6 mg/day, in 2010 were 741.2 mg/day and in 2022 were 704.7 mg/day (mean difference 2010-2000 = 93.7, 2022-2000 = 57.1, p=0.004).

There was no evidence found of a statistically significant effect of year on children's mean intake for %E saturated fat (see Table 5.2).

5.2.2 The effect of school lunch type on children's mean nutrient intakes

Results exploring the impact of school lunch type (school and home-packed lunch) on nutrient intakes are detailed in Table 5.3, using school lunch as a baseline. School lunch type had a statistically significant effect on mean intakes of fat (%E, p=0.02), saturated fat (%E and g, p=0.002 and p=0.006 respectively), calcium (p<0.001) sodium (p<0.001) and iron (p=0.003) intakes. For children consuming a school lunch and packed lunch, mean fat intakes (%E), mean intakes were 35.0 %E and 33.9 %E respectively (mean difference = -1.1, p=0.02). For mean saturated fat intakes (%E), mean intake for SL consumers were 12.7 %E and for PL consumers were 13.4 %E (mean difference = 0.8, p=0.002). For children consuming a school lunch and home-packed lunch, mean sodium intakes were 2101 mg/day and 2384 mg/day respectively (mean difference = 283, p<0.001). For mean iron intakes, SL consumers had lower intakes, mean intake in SL consumers was 8.4 mg/day and in PL consumers was 9.4 mg/day (mean difference = 1.0, p=0.003).

There was no evidence of a statistically significant effect of school lunch type on mean nutrient intakes for energy, fat (g), NMES (%E and g), NSP and vitamin C (see Table 5.3).

5.2.3 The effect of IMD on children's mean nutrient intakes

There was no evidence found that IMD had a statistically significant effect on children's mean nutrient intakes for total diet (see Table 5.4).

5.2.4 Two-way interactions between year and school lunch type

The interaction between year and school lunch type for each nutrient, was explored. There was no evidence of a year by school lunch type interaction for children's mean intakes of energy (p=0.35), fat (%E and g, p=0.05 and p=0.19 respectively), saturated fat (%E and g, p=0.96 and p=0.63 respectively), NMES (%E and g, p=0.83 and p=0.91 respectively). NSP (p=0.20), vitamin C (p=0.38), calcium (p=0.24), sodium (p=0.42) and iron (p=0.23).

Table 5.2 Total diet: the effect of year on mean nutrient intakes of 11-12yr old children in 2000, 2010 and 2022

Nutrient	**Mean***			**Mean difference**						**p-value‡**
		***n*=371**								
	2000 (*n*=166)	**2010 (*n*=85)**	**2022 (*n*=120)**	**2010-2000**	**95% CI for difference†**	**2022-2000**	**95% CI for difference†**	**2022-2010**	**95% CI for difference†**	
Energy (kcal)	1902	1583	1640	-320	-428; -212	-262	-356; -168	57.8	-55.6; 171.3	<0.001
%E Fat	35.6	32.8	34.8	-2.8	-3.9; -1.8	-0.8	-1.7; 0.1	2.0	1.0; 3.1	<0.001
Fat (g)	76.4	58.3	64.0	-18.1	-23.1; -13.0	-12.4	-16.8; -8.0	5.6	0.4; 11.0	<0.001
%E Saturated Fat	12.8	12.9	13.0	0.1	-0.5; 0.6	0.1	-0.3; 0.6	0.1	-0.5; 0.7	0.85
Saturated Fat (g)	27.5	22.9	23.9	-4.6	-6.7; -2.5	-3.6	-5.4; -1.8	1.0	-1.2; 3.1	<0.001
%E NMES§	16.1	16.9	13.8	0.8	-0.5; 2.1	-2.3	-3.4; -1.1	-3.0	-4.3; -1.7	<0.001
NMES (g)	82.5	71.6	58.4	-11.0	-19.4; -2.5	-24.1	-31.5; -16.8	-13.2	-22.0; -4.3	<0.001
NSP (g)¶	10.6	8.8	10.1	-1.8	-2.6; -1.1	-0.5	-1.1; 0.2	1.3	0.6; 2.1	<0.001
Vitamin C (mg) #	63.4	70.2	82.3	1.1	0.7; 1.3	1.3	1.1; 2.4	1.2	1.0; 1.4	<0.001
Calcium (mg)	647.6	741.2	704.7	93.7	35.6; 151.8	57.1	6.4; 107.8	-36.6	-97.6; 24.4	0.004
Sodium (mg)	2562	2055	1750	-507	-661; -352	-812	-947; -677	-305.2	-467.7; -142.8	<0.001
Iron (mg)	9.9	7.8	8.5	-1.4	-2.2; -0.7	-0.7	-1.4; -0.1	0.7	-0.1; 1.5	<0.001

***Mean adjusted for gender, school lunch type and IMD; †95% CI = 95% Confidence interval; ‡95% CI and p-value derived for linear regression analysis; §NMES = non milk extrinsic sugars; ¶NSP = non-starch polysaccharide; #data log transformed, geometric mean and ratio presented**

Table 5.3 Total diet: the effect or school lunch type (school lunch and home-packed) on mean nutrient intakes of 11-12yr old children

Nutrient	Mean* *n*=371		Mean difference	95% CI for difference†	p-values‡
	School Lunch (*n*=264)	Packed Lunch (*n*=107)			
Energy (kcal)	1725	1792	67	-28; 162	0.17
%E Fat	35.0	33.9	-1.1	-2.0; -0.1	0.02
Fat (g)	67.9	68.9	1.0	-3.4; 5.4	0.67
%E Saturated Fat	12.7	13.4	0.8	0.3; 1.3	0.002
Saturated Fat (g)	24.6	27.1	2.6	0.7; 4.4	0.006
%E NMES§	15.4	15.9	0.5	-0.6; 1.7	0.34
NMES (g)	70.7	75.9	5.2	-2.2; 12.7	0.16
NSP (g)¶	10.0	10.1	0.1	-0.6; 0.7	0.80
Vitamin C (mg)#	69.5	73.4	1.0	0.9; 1.2	0.40
Calcium (mg)	650.8	778.2	127.4	76.4; 178.4	<0.001
Sodium (mg)	2101	2384	283	147; 419	<0.001
Iron (mg)	8.4	9.4	1.0	0.3; 1.6	0.003

***Mean adjusted for year, gender and IMD; †95% CI = 95% Confidence interval; ‡95% CI and p-value derived for linear regression analysis; §NMES = non milk extrinsic sugars; ¶ NSP = non-starch polysaccharide; #data log transformed, geometric mean and ratio presented**

Table 5.4 Total diet: the effect of IMD on mean nutrient intakes of 11-12yr old children

Nutrient	Mean* *n*=371			Mean difference				p-value‡
	T1** (*n*=51)	T2 (*n*=111)	T3 (*n*=209)	T2-T1	95% CI for difference†	T3-T1	95% CI for difference†	
Energy (kcal)	1770	1738	1742	-32	-167; 102	-28	-153; 96	0.89
%E Fat	34.3	34.4	35.0	0.1	-1.2; 1.4	0.7	-0.5; 1.9	0.31
Fat (g)	68.5	67.5	68.5	-1.0	-7.2; 5.3	0.1	-5.7; 5.8	0.89
%E Saturated Fat	12.8	12.9	12.9	0.1	-0.5; 0.8	0.1	-0.6; 0.7	0.91
Saturated Fat (g)	25.5	25.4	25.2	-0.1	-2.7; 2.5	-0.2	-2.6; 2.2	0.98
%E NMES§	16.9	15.4	15.2	-1.5	-3.1; 0.1	-1.6	-3.2; -0.2	0.08
NMES (g)	81.1	70.7	70.9	-10.4	-20.9; 0.1	-10.2	-19.9; -0.5	0.10
NSP (g)¶	9.9	10.2	10.0	0.3	-0.6; 1.3	0.1	-0.8; 0.09	0.67
Vitamin C (mg)#	78.8	70.9	68.5	0.9	0.8; 1.1	0.9	0.7; 1.0	0.26
Calcium (mg)	670.2	695.4	687.5	25.2	-47.0; 97.4	17.3	-49.4; 84.1	0.79
Sodium (mg)	2250	2199	2158	-51	-243; 142	-92	-270; 85	0.55
Iron (mg)	8.7	8.7	8.6	0	-0.9; 1.0	-0.1	-0.9; 0.8	0.95

***Mean adjusted for year, gender and school lunch type; †95% CI = 95% Confidence interval; ‡95% CI and p-value derived for linear regression analysis; §NMES = non milk extrinsic sugars; ¶ NSP = non-starch polysaccharide; #data log transformed, geometric mean and ratio presented; **T1 = least deprived, T2 = mid deprived and T3 = most deprived tertile**

Chapter 6 Lunchtime nutrient intakes of 11–12-year-olds in Northumberland

Chapter overview:

The main aim of this chapter was to explore lunchtime nutrient intakes and compare to the previous ASH11 studies (2000 and 2010) to consider the effect of pre- and post-implementation of school food policies in England on children's dietary intakes, The objectives were to:

1. To describe mean intakes of lunchtime nutrient intakes (energy, fat, saturated fat, NMES, NSP, vitamin C, calcium, sodium, and iron) in 2000, 2010 and 2022.
2. To explore the effect of year, gender, school lunch type and level of deprivation on children's mean lunchtime nutrient intakes.

6.1 Lunchtime intakes: mean nutrient intakes by year in 2000, 2010 and 2022

The first part of these analyses provides an overall description of children's mean nutrient intakes at lunchtime by year and lunch type only to provide context. The second, more detailed analyses (section 6.2) considers the effect of year, school lunch type and index of multiple deprivation (IMD) (level of deprivation) on children's mean nutrient intakes using linear regression, adjusting for gender. Further, interactions between year and school lunch types were explored as these are key findings and are presented in Section 6.2.

Children's mean lunchtime nutrient intakes by year are detailed in Table 6.1. Children's mean intakes of energy (kcal) were highest in 2000 (712 kcal/day) compared with 2010 (520 kcal/day) and 2022 (434 kcal/day). Mean fat intakes (per cent energy (%E)) were highest in 2000 (39.2 %E) compared with 2010 (32.4 %E) and 2022 (32.8 %E). Mean fat intakes (grams (g)) were highest in 2000 (31.9 g/day) compared with 2010 (19.1 g/day) and 2022 (17.0 g/day). Mean saturated fat intakes (%E) were highest in 2000 (12.4%E) compared with 2010 (12.2%E) and 2022 (11.9 %E). Mean saturated fat intakes (g) were highest in 2000 (9.9 g/day) compared with 2010 (7.3 g/day) and 2022 (6.2 g/day). Mean non-milk extrinsic sugar (NMES) intakes (%E) were lowest in 2000 (12.2 %E) compared with 2010 (15.7 %E) and 2022 (14.5 %E). Mean

NMES intakes (g) were highest in 2000 (21.2 g/day) compared with 2010 (20.3 g/day) and 2022 (14.2 g/day). Mean non-starch polysaccharide (NSP) intakes (grams) was highest in 2000 (3.9 g/day) compared with 2010 (3.0 g/day) and 2022 (2.7 g/day).

Mean calcium intakes (mg) were lower in 2000 (208.8 mg/day) compared with 2010 (219.1 mg/day) and higher compared with 2022 (166.6 mg/day). Children's mean vitamin C, sodium and iron intakes decreased by year, see Table 6.1.

Table 6.1 Lunchtime: mean nutrient intakes of 11-12yr old children by year (2000, 2010 and 2022)

Nutrient	**Year** *n*=371		
	2000 (*n*=166) **Mean (SD*)**	**2010 (*n*=85)** **Mean (SD)**	**2022 (*n*=120)** **Mean (SD)**
Energy (kcal)	712 (189)	520 (146)	434 (157)
%E Fat	39.2 (5.8)	32.4 (8.2)	32.8 (9.4)
Fat (g)	31.9 (10.5)	19.1 (7.6)	17.0 (8.6)
%E Saturated Fat	12.4 (3.1)	12.2 (4.2)	11.9 (4.8)
Saturated Fat (g)	9.9 (3.7)	7.3 (3.6)	6.2 (3.4)
%E NMES†	12.2 (6.2)	15.7 (9.1)	14.5 (12.8)
NMES (g)	21.2 (11.3)	20.3 (13.2)	14.2 (11.1)
NSP (g) ‡	3.9 (1.5)	3.0 (1.1)	2.7 (1.1)
Vitamin C (mg)#	21.0 (2.5)	20.9 (3.3)	18.0 (3.8)
Calcium (mg)	208.8 (96.2)	219.1 (119.7)	166.6 (94.9)
Sodium (mg)	894 (315)	706 (338)	437 (245)
Iron (mg)	2.8 (0.8)	2.0 (0.8)	1.9 (0.8)

***SD = standard deviation; †NMES = non milk extrinsic sugars; ‡NSP = non-starch polysaccharide; #data log transformed, geometric mean presented**

6.2 Lunchtime: children's mean nutrient intakes and the effect of year, school lunch type and IMD

6.2.1 Two-way interactions between year and school lunch type

Table 6.2 shows the effect of the year by school lunch type interaction on children's mean nutrient intakes. There was no evidence of a year by school lunch type interaction for children's mean intakes of saturated fat (%E, p=0.15).

6.2.1.1 Energy (kcal), fat (g) and iron (g) intakes

From 2000 to 2022, there was an overall decrease in mean energy (kcal) intakes, regardless of school lunch type, however, the greatest decrease was observed in children consuming a SL (Figure 6.1 (A) and Table 6.2). In 2000, SL consumers had higher energy intakes than PL consumers (733 kcal/day v 641 kcal/day). By 2022 this was reversed; SL consumers now had lower mean energy intakes than PL consumers (411 kcal/day v 499 kcal/day). In 2000, the difference in mean energy intakes between SL and PL consumers was greater than in 2022, this change was found to be significant (2022-2000: mean difference of difference 180, 95% CI 86; 273, overall p-value for interaction p<0.001).

Similar to what was observed with children's mean energy intakes, from 2000-2022, there was an overall decrease in mean fat (g) intakes regardless of school lunch type consumed. The greatest decrease was observed in SL consumers (Figure 6.1 (B) and Table 6.2). In 2000, SL consumers had higher fat intakes than PL consumers (33.6 g/day v 26.0 g/day). By 2022 this was reversed; SL consumers now had lower intakes than PL consumers (15.8 g/day v 20.0 g/day). In 2000, the difference in mean fat intakes between SL and PL consumers was greater than in 2022, this change between 2000 and 2022 was found to be significant (2022-2000: mean difference of difference 11.8, 95% CI 6.6; 16.8, overall p-value for interaction p<0.001).

From 2000 to 2022, children's mean iron (mg) intakes decreased overall, regardless of school lunch type consumed and the greatest decrease was found in SL consumers (Figure 6.1 (C) and Table 6.2). In 2000, SL consumers had higher mean iron intakes than PL consumers (2.8 mg/day v 2.6 mg/day). By 2022 this was reversed; SL consumers now had lower mean iron intakes than PL consumers (1.9 mg/day v 2.2 mg/day) this change between 2000 and 2022 was found to be significant (2022-2000: mean difference of difference 0.5, 95% CI 0.1; 1.0, overall p-value for interaction p=0.02).

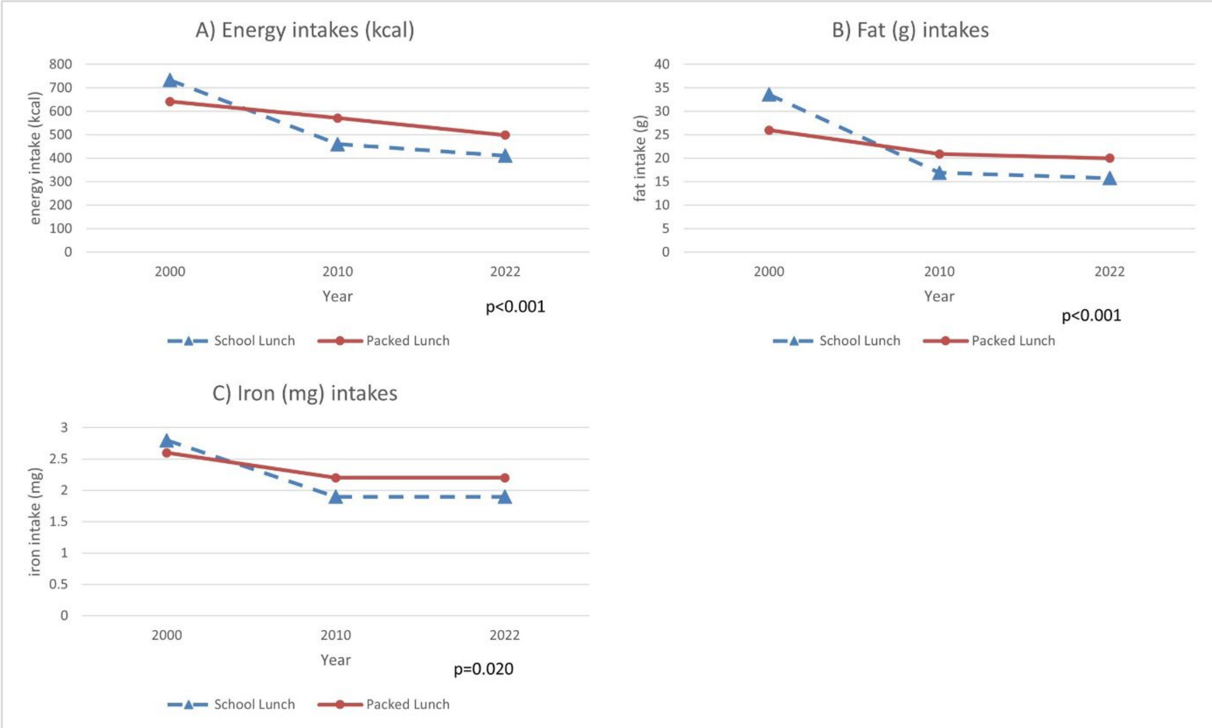


Figure 6.1 The effect of year by school lunch type on children's mean energy (kcal), fat (grams) and iron (mg) intakes (adjusted for gender and IMD)

6.2.1.2 Per cent energy fat and NSP (g) intakes

From 2000 to 2022, mean intakes of %E fat decreased in SL consumers and did not change overall in PL consumers (Figure 6.2 (A) and Table 6.2). In 2000, SL consumers had higher %E fat intakes than PL consumers (40.4 %E v 35.1 %E). By 2022 this was reversed; SL consumers had lower mean intakes than PL consumers (32.0 %E v 35.0 %E). In 2000, the difference in mean %E fat between SL and PL consumers was greater than in 2022, this change was found to be significant (2022-2000: mean difference of difference = 8.3, 95% CI = 3.9; 12.5, overall p-value for interaction p=0.007).

From 2000 to 2022, mean NSP (g) intakes decreased in SL consumers and did not change overall in PL consumers (Figure 6.2 (B) and Table 6.2). In 2000, SL consumers had higher mean intakes compared with PL consumers (4.2 g/day v 3.0 g/day). By 2022, this was reversed, and SL consumers had lower intakes than PL consumers (2.6 g/day v 3.1 g/day). In 2000, the difference in mean NSP intakes between SL and PL consumers was greater than in 2022, this change between 2000 and 2022 was found to be significant (2022-2000: mean difference of difference = 1.7, 95% CI = 1.0; 2.4, overall p-value for interaction p<0.001).

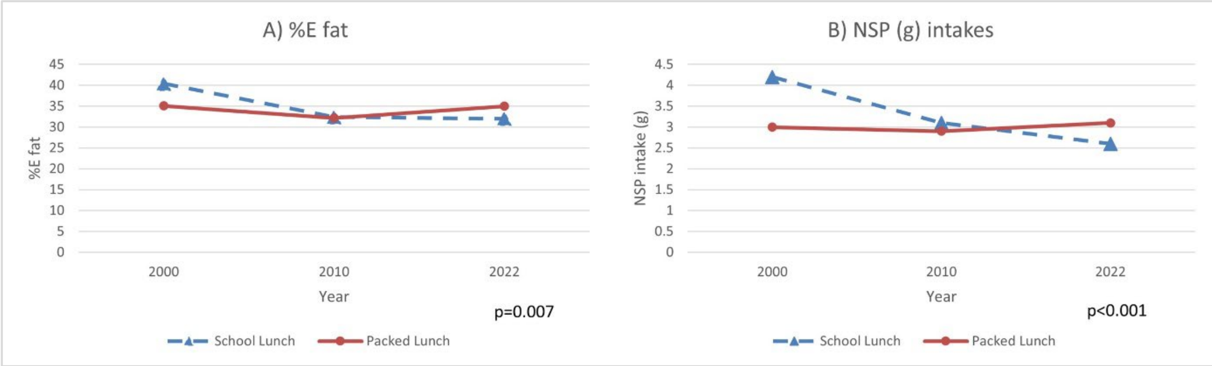


Figure 6.2 The effect of year by school lunch type on children's mean per cent energy (%E) from fat and NSP (g) intakes (adjusted for gender and IMD)

6.2.1.3 Saturated fat (g), NMES (g) and sodium intakes (mg)

From 2000 to 2022, there was an overall decrease in mean saturated fat (g) intakes, regardless of school lunch type (Figure 6.3 (A) and Table 6.2). In 2000, SL consumers had lower intakes compared with PL consumers (9.7 g/day v 10.8 g/day). By 2022, SL consumers mean intakes decreased overall and remained lower than PL consumers mean intakes (5.9 g/day v 7.1 g/day). This change between 2000 and 2022 was found to be significant (2022-2000: mean difference of difference = 0.1, 95% CI = -1.8; 2.1, overall p-value for interaction p=0.02).

From 2000 to 2022, there was an overall decrease in mean NMES (g) intakes, regardless of school lunch type, however, the greatest decrease was observed in children consuming a PL (Figure 6.3 (B) and Table 6.2). In 2000, SL consumers had lower mean NMES (g) intakes compared with PL consumers (19.6 g/day v 27.9 g/day). By 2022, this was reversed, and SL consumers had slightly higher intakes than PL consumers (14.3 g/day v 13.3 g/day). For children consuming a PL there was a greater decrease and means intakes between lunch types were now similar. This change was found to be significant (2022-2000: mean difference of difference = -9.3, 95% CI = -15.6; -3.2, overall p-value for interaction p<0.001).

From 2000 to 2022, there was an overall decrease in mean sodium (mg) intakes, regardless of school lunch type, however, the greatest decrease was observed in children consuming a SL (Figure 6.3 (C) and Table 6.2). In 2000, SL consumers had lower sodium intakes compared with PL consumers (868 mg/day v 1006 mg/day). By 2022, mean sodium intakes in both groups decreased with SL consumers having lower mean intakes than PL consumers (361 mg/day v 668 mg/day). This change was found to be significant (2022-2000: mean difference of difference = 169, 95% CI = 16; 322, overall p-value for interaction p=0.004).

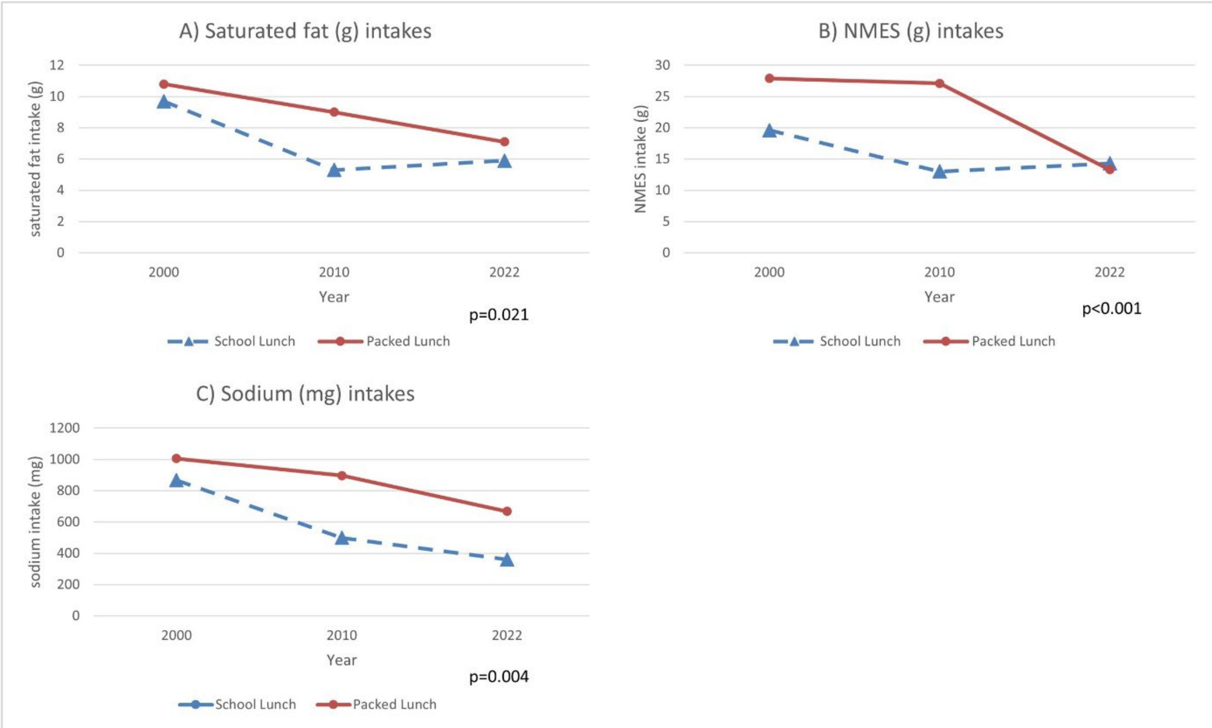


Figure 6.3 The effect of year by school lunch type on children's mean saturated fat (grams), NMES (grams) and sodium (mg) intakes (adjusted for gender and IMD)

6.2.1.4 Per cent energy NMES

Figure 6.4 shows that between 2000 and 2022 mean %E NMES increased for SL consumers and decreased for PL consumers; the difference between SL and PL consumers had narrowed. In 2000, SL consumers had lower mean intakes compared with PL consumers (10.8 %E v 17.8 %E). By 2022, this reversed, SL consumers now had higher intakes of %E NMES than PL consumers (15.6 %E v 10.4 %E). This change was found to be significant (2022-2000: mean difference of difference = -12.2, 95% CI = -17.1; -7.0, overall p-value for interaction $p<0.001$).

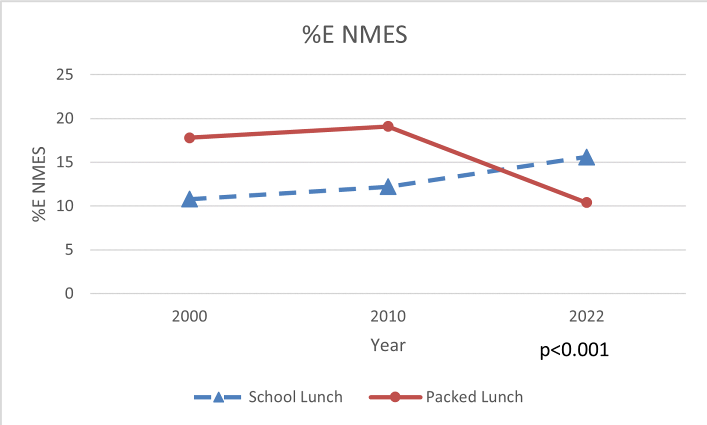


Figure 6.4 The effect of year by school lunch type on children's mean per cent energy from NMES (adjusted for gender and IMD)

6.2.1.5 Vitamin C (mg) intakes

For vitamin C intakes, geometric means are reported. Figure 6.5 shows that between 2000 and 2022 for mean vitamin C (mg) intakes there was no change for SL consumers; and a l decrease for PL consumers. In 2000, SL consumers had higher mean vitamin C intakes compared with PL consumers (21.7 mg/day v 18.3 mg/day). By 2022, mean intakes in SL consumers did not change but for those consuming a PL, intakes had decreased; this difference between SL and PL consumers had now increased (20.7 mg/day v 12.1 mg/day) and was found to be significant (2022-2000: mean difference of difference (ratio) = 0.7, 95% CI = 0.4; 1.3, overall p-value for interaction p=0.004).

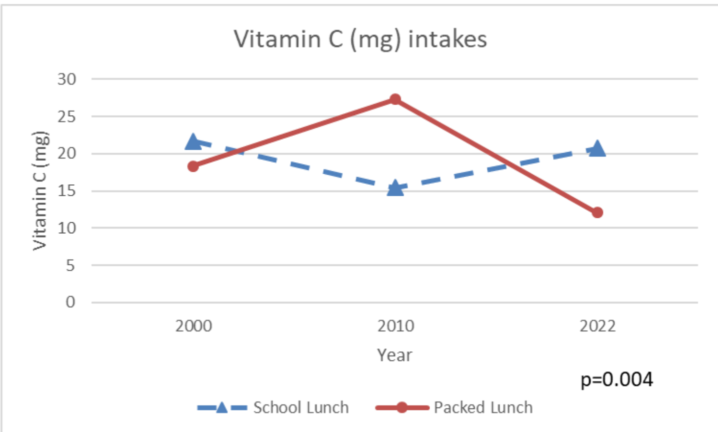


Figure 6.5 The effect of year by school lunch type on children's mean vitamin C (mg) intakes (adjusted for gender and IMD)

6.2.1.6 Calcium (mg) intakes

Figure 6.6 shows that between 2000 and 2022 there was an overall decrease in mean calcium intakes for SL consumers and overall increase for PL consumers. In 2000, mean intakes for both SL and PL consumers were similar (210.3 mg/day v 210.7 mg/day). By 2022, mean intakes in SL consumers decreased and PL consumers increased; SL consumers continued to have lower intakes and the difference between means increased (146.8 mg/day v 224.3 mg/day). This change was found to be significant (2022-2000: mean difference of difference = 77.1, 95% CI = 23.2; 131.0, overall p-value for interaction p<0.001).

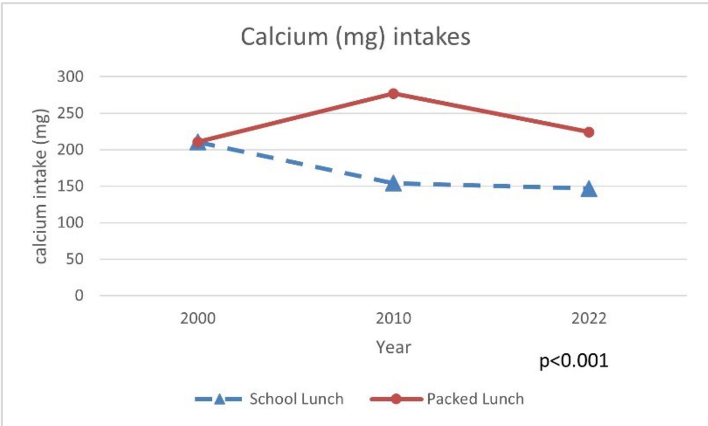


Figure 6.6 The effect of year by school lunch type on children's mean calcium (mg) intakes (adjusted for gender and IMD)

Table 6.2 Lunchtime: the effect of year and school lunch type on mean nutrient intakes of 11-12yr old children

Nutrient	Mean*						Mean difference between lunch types			Difference of difference†		Overall p-value
	2000		2010		2022		2000	2010	2022			
	SL	PL	SL	PL	SL	PL	PL-SL (A)	PL-SL (B)	PL-SL (C)	B-A (95% CI‡)	C-A (95% CI)	
Energy (kcal/day)	733	641	461	571	411	499	-92	111	88	202 (108; 297)	180 (86; 273)	<0.001
%E Fat	40.4	35.1	32.4	32.2	32.0	35.0	-5.3	-0.2	3.0	5.1 (0.8; 9.4)	8.3 (3.9; 12.5)	0.007
Fat (g)	33.6	26.0	16.9	20.9	15.8	20.0	-7.6	4.0	4.2	11.6 (6.4; 16.7)	11.8 (6.6; 16.8)	<0.001
%E Saturated Fat	11.9	14.5	10.5	13.8	11.5	12.6	2.6	3.3	1.1	0.7 (-1.5; 2.9)	-2.2 (-3.6; 0.7)	0.15
Saturated Fat (g)	9.7	10.8	5.3	9.0	5.9	7.1	1.1	3.7	1.2	2.6 (0.6; 4.6)	0.1 (-1.8; 2.1)	0.02
%E NMES§	10.8	17.8	12.2	19.1	15.6	10.4	7.0	6.9	-5.2	-0.1 (-5.2; 5.1)	-12.2 (-17.1; -7.0)	<0.001
NMES (g)	19.6	27.9	13.0	27.1	14.3	13.3	8.3	14.1	-1	5.8 (-0.5; 12.0)	-9.3 (-15.6; 3.2)	<0.001
NSP (g) ¶	4.2	3.0	3.1	2.9	2.6	3.1	-1.2	-0.21.8	0.6	1.0 (0.3; 1.7)	1.7 (1.0; 2.4)	<0.001
Vitamin C (mg) #	21.7	18.3	15.4	27.3	20.7	12.0	0.8	1.8	0.6	2.1 (1.1; 4.0)	0.7 (0.4; 1.3)	0.004
Calcium (mg)	210.3	210.7	154.0	277.0	146.8	224.3	0.4	123.0	77.5	122.6 (68.0; 177.2)	77.1 (23.2; 131.0)	<0.001
Sodium (mg)	868	1006	500	897	361	668	138	397	307	259 (103; 414)	169 (16; 322)	0.004
Iron (mg)	2.8	2.6	1.9	2.2	1.9	2.2	-0.2	0.3	0.3	0.5 (0.1; 1.0)	0.5 (0.1; 1.0)	0.02

***Mean adjusted for gender and IMD; †Difference of difference = mean difference 2010-2000, 2022-2000; ‡95% CI = 95% Confidence interval; §NMES = non milk extrinsic sugars; ¶NSP = non-starch polysaccharide; #data log transformed, geometric mean and ratio presented**

6.2.2 The effect of year on children's mean nutrient intakes

There was no evidence found of a statistically significant effect of year on children's mean intakes of %E saturated fat. Mean intakes (adjusted for gender, school lunch type and IMD) were: 12.7 %E in 2000, 11.6 %E in 2010 and 11.9 %E in 2022 (mean difference 2010-2000 = -1.0, 2022-2000 = -0.8; $p=0.07$). Only %E saturated fat is presented here and in Section 6.2.3 as this was the only nutrient which did not display a year by school lunch type interaction.

6.2.3 The effect of school lunch type on children's mean nutrient intakes

School lunch type was found to have statistically significant effect on children's mean saturated fat intakes (%E). For children consuming a school lunch (SL), mean %E from saturated fat was lower than for children consuming a home-packed lunch (11.5 %E and 13.9 %E respectively mean difference = 2.4, $p<0.001$).

6.2.4 The effect of IMD on children's mean nutrient intakes

There was no evidence found that IMD had a statistically significant effect on children's mean nutrient intakes at lunchtime (see Table 6.3).

Table 6.3 Lunchtime: the effect of IMD on mean lunchtime nutrient intakes of 11-12yr old children

Nutrient	Mean* *n*=371			Mean difference				p-value‡
	T1** (*n*=51)	T2 (*n*=111)	T3 (*n*=209)	T2-T1	95% CI for difference†	T3-T1	95% CI for difference†	
Energy (kcal)	557	565	591	8	-56; 72	34	-24; 92	0.27
%E Fat	34.9	34.8	36.1	-0.1	-3.0; 2.7	1.2	-1.5; 3.9	0.27
Fat (g)	23.1	23.1	24.9	0	-3.5; 3.4	1.8	-1.3; 5.0	0.17
%E Saturated Fat	12.4	11.8	12.4	-0.6	-2.1; 0.9	0	-1.5; 1.4	0.34
Saturated Fat (g)	8.0	7.7	8.3	-0.3	-1.7; 1.1	0.3	-1.0; 1.6	0.30
%E NMES§	15.8	13.5	13.3	-2.2	-5.8; 1.3	-2.4	-5.9; 1.0	0.38
NMES (g)	19.6	18.3	18.7	-1.4	-5.7; 2.9	-0.9	-5.0; 3.3	0.81
NSP (g)¶	3.0	3.4	3.4	0.4	0; 0.8	0.3	-0.1; 0.7	0.16
Vitamin C (mg)#	14.8	19.5	22.7	1.2	0.2; 1.8	1.4	1.0; 2.0	0.09
Calcium (mg)	186.6	189.7	204.3	3.2	-33.0; 39.3	17.7	-16.3; 51.8	0.31
Sodium (mg)	722	702	700	-20	-134; 93	-22	-125; 81	0.92
Iron (mg)	2.3	2.4	2.3	0.1	-0.2; 0.4	0.1	-0.2; 0.3	0.83

***Mean adjusted for year, gender and school lunch type; †95% CI = 95% Confidence interval; ‡95% CI and p-value derived for linear regression analysis; §NMES = non milk extrinsic sugars; ¶NSP = non-starch polysaccharide; #data log transformed, geometric mean and ratio presented; **T1 = least deprived, T2 = mid deprived and T3 = most deprived tertile**

Chapter 7 Discussion

Chapter overview:

This chapter summarises and brings together the key findings from this thesis and considers how the findings reported relate to other published studies. This chapter considers how children's diets in Northumberland have changed post-implementation of the current school food policy in England. Additionally, challenges and opportunities working with schools and around school food policies are explored. Further strengths and limitations of this study, what this study adds to the current evidence base, engagement and dissemination with the participating school and implications for practice and policy are discussed. Recommendations for future research are outlined. This chapter ends with an overall summary and conclusion.

7.1 Summary of key findings

This is the first UK study to explore the impacts of 'The Requirements for School Food Regulations 2014' on children's diet quality and nutrient intakes and has been completed using dietary data obtained from children attending schools in the same area of Northumberland in 2000, 2010, and 2022 (ASH11 studies). The findings outlined in Chapters 4, 5, and 6 provide some evidence that school food policy implementation in England has the potential to improve children's diets for lunchtime and total dietary intakes.

From 2000 to 2022, children's median water intakes increased, and although median intakes of total soft drinks remained similar, intakes of not-diet soft drinks decreased, and diet soft drinks increased (Chapter 4). These positive changes (i.e., an increased water intake and decreased non-diet soft drink intake) may potentially be explained by the implementation and update of school food policies in England. For example, the drinks available in schools must meet specific criteria to be compliant with food standards, free drinking water should be available at all times, fruit juice is limited to 150ml, and combination drinks (i.e., fruit juice, milk or alternatives) are limited to 330ml [102]. Children's median (total diet) intakes of total fruit and vegetables did not change post-implementation of school food policy in England.

Despite the lack of change in fruit and vegetable intakes combined, fruit intakes including fruit juice increased, but vegetable intakes decreased between 2000 and 2022 (Chapter 4). This lack of change in total fruit and vegetable consumption is despite efforts by school food policy to improve intakes. The school food policy stipulates at least one portion each of fruits and vegetables must be available every day, and at least three different types of fruit and vegetables must be available each week [102].

Despite some evidence of an improvement in children's mean diet quality index (DQI-A) score post-implementation of the most recent school food policy in England, children's diet quality remains poor (Chapter 4). Although some differences were found for DQI-A component scores, children's mean overall DQI-A scores were not impacted by school lunch type (school lunch or home-packed lunch), and there was no evidence found of a year by school lunch type interaction.

Children's total diet nutrient intakes did not meet current recommendations for most nutrients except for per cent energy (%E) from fat and vitamin C (Chapter 5). From 2000 to 2022, there were some positive dietary changes including increased mean calcium (mg) intakes, and decreased intakes from fat (%E and g) and non-milk extrinsic sugar (NMES, %E and g). However, there were also some negative changes, including decreased intakes of non-starch polysaccharide (NSP, g) and iron (mg). Additionally, for all years (2000, 2010 and 2022) children consuming a school lunch (SL) had lower saturated fat (%E and grams) and sodium (mg) intakes than home-packed lunch (PL) consumers, these are positive dietary findings. However, SL consumers also had lower calcium and iron intakes. There was no evidence of a year by school lunch type interaction for total diet nutrient intakes, potentially indicating that the impact of school food policies on children's total dietary intakes are more limited.

For children's lunchtime nutrient intakes, there was evidence of a year by school lunch type interaction for most nutrients, highlighting the impact of school lunch type on nutrient intakes and associated changes post-implementation of the current school food policy (Chapter 6). For some there were positive changes post-implementation of school food policies in England, including %E fat and sodium (mg). In 2000, SL consumers had a higher mean %E fat intake than PL consumers, by 2022 this reversed; now SL consumers had a lower intake and PL consumers intakes did not change. This may be explained as school food policy restricts the sale of foods high in fat, salt and sugar, for example, no more than two portions of foods that include pastry should be available each week [102]. Also, in 2000 SL consumers had lower mean sodium (mg) intakes than PL consumers, by 2022 SL consumers had a greater decrease in intakes and continued to have lower mean intakes. This may be explained by the fact school food policy restricts salt from being added to foods after cooking, limits condiments available to 10 grams and restricts the sale of snacks high in salt [102]. However, there were also some negative changes to some nutrient intakes post-policy implementation, for example, %E NMES and NSP (g). In 2000, SL consumers had a lower mean %E NMES than PL consumers, by 2022 this reversed, now SL consumers had a higher intake. This may potentially be a result of higher availability of drinks that comply with school food policy (noted above), however, these compliant drinks still contain NMES (e.g., combination drinks including fruit juice [102]) which may contribute to NMES intakes at lunchtime. Also, in 2000 SL consumers had a higher mean NSP (g) intakes than PL consumers, by 2022 this reversed and now SL consumers had a lower intake whilst PL consumers intakes did not change. School food policy restricts snack products (e.g., cakes and biscuits) from containing confectionery at lunchtime, and limits drinks available as mentioned previously [102]. This indicates that although there have been some positive changes in children's dietary intakes associated with school food policy in England, improving children's nutrient intakes while in school remains a priority. The use of food-based standards only may not be sufficient to improve children's nutrient intakes.

7.2 Relationship to other studies

7.2.1 Impact of year on children's dietary intakes

7.2.1.1 Food group intakes

Children's median water intakes increased from 2000-2022. One potential influence on children's water intakes is that as part of the school food policy in England, free drinking water should be available for all children during the school day, this would allow children to refill water bottles to consume in school [102]. Water intakes in 2000 and 2010 were lower than those reported in a study by Vieux *et al.* (2017) which used National Diet and Nutrition Survey (NDNS) data from a similar time period (2008-2011) as the 2010 study. For children aged 9-13 years, mean water intake was 273.7ml/day (current study 2000 = 79 ml/day, 2010 = 108 ml/day) [196]. Vieux *et al.* (2017) also highlighted that water intakes were higher in less deprived groups (least deprived = 318.9 ml/day, most deprived = 177.1 ml/day), which may be a potential explanation for the lower intakes in the current study (for 2000 and 2010) as the children participating in were more deprived than the UK average, however, in 2022 water intakes were higher despite high deprivation [196]. Findings from the current study (2000 and 2010 only) are similar to those reported by Coppinger *et al.* (2011), which looked at intakes in 11-13 year old children in London (males = 66ml/day; females = 75 ml/day) [197], however, for the current study intakes in 2022 were higher. This potentially aligns with the findings in this study as Coppinger *et al.* gathered this data in 2007 and 2008 and changes to children's water intakes may have occurred after this point. There are limited studies looking at older children's water intakes in more recent years in the UK.

The NDNS has reported that intakes of sugar sweetened soft drinks (not including diet soft drinks) have decreased over time in children aged 11-18 years [17], this is similar to the findings in this study. Studies have suggested that lower intakes of water are associated with higher intakes of soft drinks [198, 199]. For the current study, there was no change in total soft drink consumption, though there was a small decrease in the number of children consuming soft drinks. The current study also reported an increase in diet soft drinks but a reduction in non-diet soft drink consumption. One reason for this could be the implementation of the Soft Drinks Industry Levy which is described in Chapter 1. The higher consumption of diet soft drinks compared with non-diet was also observed in a study by O'Leary *et al.* (2021) which looked at the consumption of soft drinks in both children and adults using UK survey data from Kantar Fast Moving Goods panel of households [200]. This change is potentially a result of the Soft Drinks Industry Levy as diet varieties of soft drinks are not be taxed and as a result may be a cheaper, more attractive alternative to non-diet varieties [66].

No significant change to fruit and vegetable consumption was observed in the current study and children's median portions consumed still do not meet the 5-a-day recommendation [19]. This is comparable with the most recent NDNS report (2021). However, the average number of portions consumed (2.8 portions/day for children aged 11-18 years) was higher in the NDNS than the median intakes observed in the current study which was 1.4 portions /day in 2022[17]. Studies have suggested associations between socioeconomic status and fruit and vegetable intakes, with children from more deprived backgrounds being more likely to have lower fruit and vegetable intakes [201, 202]. Therefore, the higher proportion of children from more deprived IMD tertiles in this study sample may be a potential explanation for the lower intakes of fruit and vegetables compared with the NDNS. Additionally, the average number of portions reported by the NDNS was related to a wider age range (children aged 11-18 years) than the current study, which may explain some of the differences observed.

7.2.1.2 Diet quality

Children's mean DQI-A improved from 2000 to 2022, however, children's diet quality remains poor. Other studies that have examined changes in diet quality over time, using different measures (e.g., healthy eating index (HEI)), have also indicated that diet quality has improved in recent years. As noted in Chapter 2, several studies found that diet quality improved over time post-implementation of school food policies. For example, Gaudin *et al.* (2023) found that increased diet quality score over time was observed in Canadian children aged 6-18 years, using two different measures of diet quality (HEI and DQI) by 7.2 points and 3.6 points respectively [121]. This study used data from two Canadian Community Health Surveys (2004 and 2015) and collected dietary data using a 24-hour recall [121]. Another study by Liu *et al.* 2020 using NHANES data (intake data obtained using two 24-hour recalls) indicated that although US children's diets are poor, there have been some improvements in recent years [169]. This method differs from the six days of dietary data obtained for the current ASH11 study which account for day-to-day variations in children's diets. Additionally, the diet quality of foods consumed from school significantly increased post-school food policy implementation, and the diet quality of foods consumed or obtained from school was higher than food consumed from any other source [169].

Other UK-based studies have used the DQI-A to explore children's diet quality. Taher *et al.* (2020), reported a slight increase in DQI-A scores in UK children aged 11-18 years (using NDNS data), between 2008 and 2016 [148]. Taher *et al.* (2020) also reported a mean overall DQI-A score (for all years combined) of 21.0% which is similar to the 2022 mean DQI-A score observed in the current study (19.8%, mean for all years combined = 13.9%) [148]. Another study by Taher *et al.* (2019), also using NDNS data, explored the impact of takeaway foods and foods eaten out of the home on children aged 11-18 years and reported an average DQI-A score of 20.4% [173]. However, other UK-based studies, not looking specifically at school food, by Llauradó *et al.* (2016) and Thomas *et al.* (2023), reported a higher mean DQI-A score of 31.1% and 38.7% (females only) for children aged 11-18 years using NDNS data (2008-2012 and 2014-2016 respectively) [203, 204]. These studies reported different results in comparison to the current ASH11 study and that of Taher *et al.* (2019) and Taher *et al.* (2020), this is potentially due to Llauradó *et al.* (2016), using a slightly different method of categorising food for the calculation of the DQI-A and Thomas *et al.* (2023) only looking at DQI-A in females. All the studies using NDNS data mentioned above use three or four days of dietary data obtained using food diaries, differing from the six days used in the current study.

Vyncke *et al.* (2013) as part of the validation of the DQI-A score, compared diet quality to food and nutrient intakes [22]. For food intakes, Vyncke *et al.* (2013) found that higher DQI-A scores were linked to higher intakes of water, fruit, and vegetables. Whereas lower DQI-A scores were associated with higher intakes of soft drinks, fruit juices, snacks, and confectionery [22]. Tomiya *et al.* (2021) found that lower diet quality scores (calculated using an amended version of DQI-A), were associated with high intakes of non-recommended food and drinks including soft drinks and confectionery [205]. Tomiya *et al.* (2021) also reported intakes of grains, fruit, and vegetables were associated with higher diet quality scores [205]. A study by Leung *et al.* (2018) in US children aged 2-18 years reported that children with higher intakes of water were associated with a higher diet quality, using the HEI-2010 [199], this is a potential reason for the improvements seen in the current study, as water intakes increased from 2000 to 2022. Further, it was also reported that higher intakes of sugar sweetened beverages were associated with lower diet quality scores [199], which could be a potential explanation for the generally low DQI-A scores observed in the current ASH11 study between 2000 and 2022.

For nutrient intakes, Vyncke *et al.* (2013) reported that energy intakes were negatively associated with DQI-A score, children with higher energy intakes generally did not have higher DQI-A scores. [22]. Higher DQI-A scores were associated with children having higher intakes of fibre and most micronutrients including calcium, however, DQI-A score was not associated with iron or vitamin C intakes [22]. Thomas *et al.* (2023), using NDNS data (2014-2016) for female children aged 11-18 years, found that iron and zinc intakes were higher in children who had higher diet quality scores [204]. Wong *et al.* (2013) used a New Zealand-specific diet quality measure in children aged 14-18 years and found that higher diet quality was associated with higher iron intakes and lower total fat and saturated fat intakes [(206)]. A different New Zealand-specific diet quality measure was used by Wong *et al.* (2014) and found that higher diet quality scores were associated with higher intakes of several nutrients including fibre, calcium, iron, and vitamin C, and lower sugar intakes [(207)]. The associations outlined by these studies may potentially help explain the diet quality scores observed in the current study. For example, as mentioned above Vynkce *et al.* (2013) reported higher intakes of fibre were associated with higher DQI-A scores, the low fibre intakes (NSP) in the current study, in part, may help to explain the overall low DQI-A scores observed in the current study.

7.2.1.3 Nutrient intakes

For the current ASH11 study, year had a significant effect on children's nutrient intakes. Intakes of most nutrients decreased across years excluding %E from saturated fat (no change), vitamin C, and calcium (both increased). A systematic review of 91 studies by Micha *et al.* (2018), including both primary and secondary school-aged children, reported similar findings regarding fat and sodium intakes, however, the review also reported no change in energy intake and a significant decrease in saturated fat consumption (%E), which was not found in the current study [(134)]. These findings were reported by Fung *et al.* (2013), using a food frequency questionnaire including decreased fat (both %E and grams), sodium, and fibre intakes in 10-year-old Canadian children [(208)]. However, Fung *et al.* (2013) also reported increased iron intakes, and decreased vitamin C and calcium intakes which are different from the findings reported in this study [(208)]. A study by Perrar *et al.* (2020) including 1312 German children and adolescents reported a significant decrease in sugar intakes (%E) between 2010 and 2016 in children ages 3-18 years using three-day weighed food diaries [(209)]. In contrast, Cohen *et al.* (2018), explored nutrient intakes of US children aged 9-17 years pre- and post-implementation of school food policy using two 24-hour recalls and found no significant changes in nutrient intakes. Although they did find a reduction in sugar intake, which is similar to this study [(155)]. This highlights the inconsistent findings related to the impacts of school food policies on children's total diet intakes for many nutrients (e.g., fat). This is potentially due to differing dietary assessment methods, different numbers of dietary intake days collected or as a result of different types of policies implemented across different countries, making comparisons difficult. However, one consistent finding is a reduction in children's NMES intakes. It is important to note that the reduction in NMES observed in the current study may also be potentially a result of the Soft Drinks Industry Levy [(66)].

Unlike for total diet, year by school lunch type interactions were found for lunchtime nutrient intakes for most nutrients studied. This potentially indicates that although school food policies may impact diets at lunchtime when policy is restricting what can be provided in schools, the impact on total diet is limited. Post-implementation of the 2014 school food policy (2022), SL consumers had lower intakes of energy, fat (%E and g), saturated fat (g), NSP, calcium, sodium, and iron, but higher intakes of NMES (%E and g) and vitamin C. Pre-policy implementation, SL consumers generally had healthier lunchtime nutrient intakes compared to PL consumers. This was also the case post-policy implementation, SL consumers had healthier lunchtime nutrient intakes than PL consumers for most nutrients studied except for NMES, NSP, calcium, and iron intakes, iron intakes in SL consumers decreased post-policy implementation. However, the change to NMES, NSP, and calcium intakes is potentially a negative impact of changes to school food policy implementation. Other studies have reported similar findings. A study by Cullen *et al.* (2015) in 427 US children aged between 11-14 years, using schools following old and new school food policies as a proxy for pre- and post-implementation, reported that energy intakes decreased following policy implementation, using lunchtime observation [(141)]. Further, a UK study by Nicholas *et al.* (2013) explored the impact of school food policy pre- and post-implementation, using lunchtime observation, and reported similar findings to the current study for decreased energy, fat, saturated fat, NMES, and sodium intakes [(158)]. However, Nicholas *et al.* (2013) also reported increased NSP, calcium, and no significant change in iron intakes which is in contrast to the current study's findings [(158)]. The differences in findings may be again due to different methods being used in the current study and different school food policies being implemented in the US and only exploring earlier policy in the UK. The reduction in energy intakes across years reported by the current study is a potential reason for the reduction in nutrient intakes for most nutrients studied. This can also help explain the increase in %E from NMES despite the reduction in total amount (grams) consumed.

7.2.2 Impact of school lunch type on children's dietary intakes

The current study explored the impact of school lunch type on dietary intakes, the current school food policy was implemented in England in 2014. However, despite an overall improved mean DQI-A score in 2022, there was no statistically significant difference between mean DQI-A scores in children consuming a school and home-packed lunch. This may indicate that the impact of school food policy on total diets is limited and that other policies and strategies are also required to improve children's overall total dietary intakes. This finding is similar to results presented by Taher *et al.* (2020) in 11-14 year olds which reported no significant difference in DQI-A score between packed and school lunch consumers using NDNS data [(148)]. In contrast, Smith *et al.* (2021) reported that SL consumers in the US had higher diet quality scores (HEI) than PL consumers [(147)]. As with many of the other US-based studies exploring the impact of school food on diet quality, Smith *et al.* (2021) used NHANES data which obtained dietary data using two 24-hour recalls for children aged 4-19 years [(147)]. A reason for this difference is the location of the study and different age groups studied, as the study by Smith *et al.* (2021) is a US-based study and explores diet quality in a wider age group. However, as increased consumption of water may contribute to an improved DQI-A score, the significant difference between lunch types may not be apparent in the current study as free drinking water is available for all children attending school in England, regardless of the type of lunch consumed [(102)]. Another potential reason for this lack of significant difference is that due to DQI-A only being explored as total diet, children may potentially consume poorer quality food and drinks outside of school which may reduce any positive impact of school food policies on total diets. Valizadeh and Ng (2020) indicated that post-implementation of US school food policy, outside-of-school diet quality significantly decreased despite overall improvements, using NHANES data (two 24-hour recalls) [(149)], this may also be the case in the UK. A systematic review by Micha *et al.* (2018), as mentioned previously, explored the impacts of school food policies on children's diets [(134)]. Potential compensatory changes outside of school were evaluated by exploring in-school versus habitual dietary intakes, an example of this is that the restriction of soft drinks in school has the potential to result in increased intakes outside of school [(134)]. The differences observed in the current ASH11 study between lunchtime and total diet nutrient intakes highlight that there are differences in the healthiness of foods and drinks consumed during lunch at school and food consumed outside of school.

School lunch type had an effect on total diet nutrient intakes for %E from fat, saturated fat (%E and grams), calcium, sodium, and iron intakes. There are few recent studies that look at the impact of school lunch types on children's total dietary intakes and these report mixed findings, as discussed in Chapter 2. The findings from this study differ from many of the previous findings reported in Chapter 2, for example, Tugault-Lafleur *et al.* (2018) looked at differences between school lunch types dietary intakes in children aged 6-17 years in Canada [(140)]. Similar findings to the current study were reported for fibre (packed lunch consumers had higher intakes), and total fat (school lunch consumers had higher intakes) [(123)]. In contrast to the current study, Tugault-Lafleur *et al.* (2018) reported no difference between lunch types for saturated fat, sugar (both grams), sodium and calcium [(123)]. Another study, by Harrison *et al.* (2011) explored the differences in total diets between lunch types for 1696 children aged 9-10 years in England, using four-day weighed food diaries [(210)]. Similar to the current study, there was no significant difference in energy intakes between school lunch types, however, Harrison *et al.* also reported no difference in %E from fat between lunch types and SL consumers had higher NSP intakes which contrast to our findings [(210)]. These mixed findings in comparison to other studies highlight that there is inconsistent evidence in relation to the impact of school food policies on total diet nutrient intakes. This could be due to several reasons including a different number of days of dietary data collected, however, could also be due to the different age groups included in the above studies.

For lunchtime intakes, the current study found that school lunch type had an effect on lunchtime nutrient intakes for saturated fat (%E), PL consumers had higher %E saturated fat. This is generally in agreement with many other studies (highlighted in Chapter 2), including a study by Pearce *et al.* (2013) which explored the impact of earlier school food policy in England [(87)]. This highlights that despite a lack of change across years, SL consumers generally consume less %E saturated fat at lunch than PL consumers, regardless of policy change.

7.2.3 Impact of IMD on children's dietary intakes

Studies have reported the impact of socioeconomic status on dietary intakes using various measures as an indicator of deprivation (e.g., free, or reduced-price lunches, parental education). Generally, evidence suggests that socioeconomic status has an effect on diet, for both children and adults. This may include children from lower socioeconomic groups having poorer diets with lower intakes of fruit and vegetables, higher intakes of more unhealthy foods such as soft drinks, and foods high in fat, salt, and sugar [211-213]. The high cost of healthy food items is widely recognised as being a main barrier to eating a healthy diet [214]. It has also been widely noted that low-nutrient, energy-dense foods usually cost less and are therefore popular among more deprived groups [214]. Despite this, the findings in this study did not find any evidence that socio-economic status had an impact on children's mean dietary intakes for DQI-A scores and nutrient intakes. This contrasts with other studies that reported diet quality scores and nutrient intakes are generally worse in children from more deprived backgrounds [121, 215]. Béghin *et al.* (2013) explored the impact of parental socioeconomic status on European children's diet quality, (aged 12-18 years), using a modified version of the DQI-A [216]. This study reported that parental occupation level (a measure of socioeconomic status) was associated with children's diet quality, with less deprived children having higher diet quality scores than more deprived children [216]. Eustachio Colombo *et al*. (2020) explored the impact of school lunches on dietary intakes in 2002 Swedish children aged 11-15 years using two 24-hour recalls and differences by parental education being used as a measure to estimate socioeconomic status [217]. Children of parents with lower education levels had lower energy, fibre, and iron intakes compared with children of higher-educated parents [217]. As highlighted in Chapter 2, Vernarelli and O'Brien (2017) reported that in 2190 US children aged 4-19 years, those receiving free school lunches had lunchtime intakes of better nutritional quality (for example, lower saturated fat and sodium intakes) than eligible children consuming lunch from another source [138]. However, no significant differences were found for children eligible for/receiving reduced-price lunches [138]. The lack of significant impact in the current study could potentially be a result of the study sample being more deprived than the national average, as highlighted above. Although nutrient intakes across the deprivation groups were poor, the provision of free school meals (not examined in the current study) may potentially help account for the lack of differences in lunchtime intakes. For the current study, eligibility for free school meals is likely to be high due to the deprived sample as the eligibility for the school involved was 44.2% [181], however, it is important to note that even if children are eligible for free school meals doesn't mean that they take up free school meals [218].

7.3 School food policies: challenges and opportunities

7.3.1 Updated standards

As previously mentioned, school food contributes to approximately one-third of children's daily dietary intakes [86] and school food is therefore an important environment to help improve children's dietary intakes. The most recently implemented school food policy in England was 'The Requirements for School Food Regulations 2014' which is composed of entirely food-based standards [102]. The fact that children's diets remain poor despite some improvements highlights a need for revision to current school food policy. For example, the "Childhood Obesity: A Plan for Action" report highlighted sugar as one of the aspects of school food policy to improve. The high sugar intakes found in children participating in this study and the most recent NDNS further emphasise that this is one of the key nutrients that should be targeted to improve children's diets. Additionally, despite some positive changes to children's dietary intakes observed in the current study, use of food-based standards only for school food policy may not be sufficient to improve children's dietary intakes while in school.

7.3.2 Lack of consistent monitoring and future plans for monitoring

A lack of consistent monitoring of school food in England has been criticised repeatedly, including "The Broken Plate 2022" report from The Food Foundation which highlighted the lack of available data on compliance to the school food policy [78]. This report outlined a scheme from the Soil Association called "Food for Life Served Here" which awards schools bronze, silver, or gold accreditation based on annual inspections which include evaluating compliance to school food policies [78]. The Guy's and St Thomas' Charity published a report in 2020 titled "Serving up children's health" and indicated that for 60 schools (primary and secondary) across London, 73% of schools had a lunch menu compliant with school food policies [219]. However, it was also found that although 73% of menus were compliant, this did not necessarily translate to what children consumed. For example, 97% of children consumed the unhealthier options available (e.g., pizza, wedges). This report also indicated that for 60% of the secondary schools reviewed, the food available during break time did not meet regulations set by school food policy and tended to include foods high in fat, salt, and sugar including sausage rolls and cookies. It was also found that although awareness of school food policies was high, the fact that it applies across the entire school day was less well-known [219].

This lack of awareness around what exactly is included in current school food policy highlights a need for more support for school caterers and other stakeholders involved (e.g., headteachers) to improve compliance to school food policies.

In 2022, the government published a report "Levelling Up the United Kingdom" which outlined plans to improve the compliance of food and drinks available to school food polices (mentioned in Chapter 1). A pilot is currently underway by the Department of Education and Food Standards Agency to test an approach assisting local authorities to monitor and aid compliance to school food policies [(85)]. This report also outlined plans for schools to voluntarily outline their 'whole school approach' to school food, with plans to make this mandatory in the future [(85)]. Improving compliance to school food policies should ensure the foods available in schools are healthy, however, there is evidence to show that what is on offer does not always reflect what children choose to consume [(219)]. Additionally, a study by Devine *et al.* (2023) in children aged 11-13 years and school staff, highlighted that children generally choose the unhealthier food options available in school [(220)].

7.3.3 Improving the school food environment

Improving and making changes to the school food environment would potentially help to improve children's diets by encouraging children to consume school meals and make healthier choices. As outlined in Chapter 1, the school food environment can be defined as "all spaces, infrastructure, and conditions inside and around school premises where food is available, obtained, and/or consumed" [(50)]. Improving the foods available in schools could potentially encourage children to make healthier food choices while in school, however as highlighted previously, children tend to choose unhealthier options when available [(90, 91, 219)]. A systematic review by Cohen *et al.* (2021) evaluated policies and strategies to increase school meal uptake in the US [(221)]. The review highlighted several policies and strategies associated with improved uptake and content of school lunches including increased food choice, improving palatability of foods available, increased duration of lunchtime, and limiting access to competitive foods (e.g., soft drinks, confectionery) [(221)]. A study by Rosettie *et al.* (2018) found that, in US children aged 5-18 years, improving the school food environment through increased provision of fruit and vegetables and the restriction of soft drinks improved children's dietary intakes for these food groups specifically [(222)]. A systematic review by Rose *et al.* (2021) looked at the impacts of school-based interventions and policies on children's diets. This review found that school-based programmes including nutrition education interventions, interventions increasing the availability of healthier options in school, and free or reduced-price fruit and vegetables, had the potential to improve children's diets when in school, particularly interventions that involve more than one component [223]. It was also reported that policy-led multicomponent interventions that are included in the school day are the most effective, as they encourage a 'whole school approach' to healthy eating [223]. Making changes to the school food environment and the food environment around schools, including updating current school food policies and implementation of other strategies has the potential to improve children's diets by encouraging healthier food choices.

7.3.4 Barriers to school food policy implementation and monitoring

To ensure compliance to school food policies and to update policy effectively, potential barriers to successful implementation should be considered. First, food and drinks available may meet standards but may not necessarily be what children actually consume and children may prefer the unhealthier options available [90, 91, 219]. Several studies have explored the barriers to the successful implementation of school food policies including two systematic reviews by Ronto *et al.* (2020) and Nguyen *et al.* (2021), and have highlighted the following barriers as key factors to consider, some of which have already been mentioned above [224, 225]:

- Cost and availability of healthier food options: this could potentially result in increased cost for meal ingredients for school canteens and caterers and ultimately lead to increased cost of school meals for children [225].
- Issues surrounding the sourcing of compliant foods and drinks: this could potentially result in an increased need for more support for caterers from experts (e.g., nutritionists) to identify suitable foods and drinks and ensure they are compliant with policy [225].
- Lack of knowledge or understanding of school food policies: this could include a lack of understanding of the purpose of policy or a lack of awareness of exactly what is included in the school food policy. The issues surrounding this could be reduced by stakeholder involvement in policy development, ensuring adequate support is given to

schools for the implementation of policy and ensuring that policies easy to understand [224, 225].

- Lack of consistent monitoring: the implementation of a consistent monitoring system to ensure compliance to policy would increase the accountability of schools and prevent non-compliant foods from being on offer [224, 225].

7.4 Other policies and strategies to improve children's dietary intakes

In addition to updated school food policy, several other strategies have been implemented to improve diets in the UK, which may have had the potential to impact the diets of children involved in the current study. A review of systematic reviews by Hansen *et al.* (2022) outlined several policy types that may impact the food environment including food labelling, school food policies (mentioned above), price interventions, food marketing policies, food reformulation, portion size changes, and the retail and food environment, these are illustrated in Figure 7.1. The review identified price interventions (e.g., taxes) being associated with dietary change and generally targeted specific foods rather than individual nutrients, for example, soft drinks rather than sugar [226].

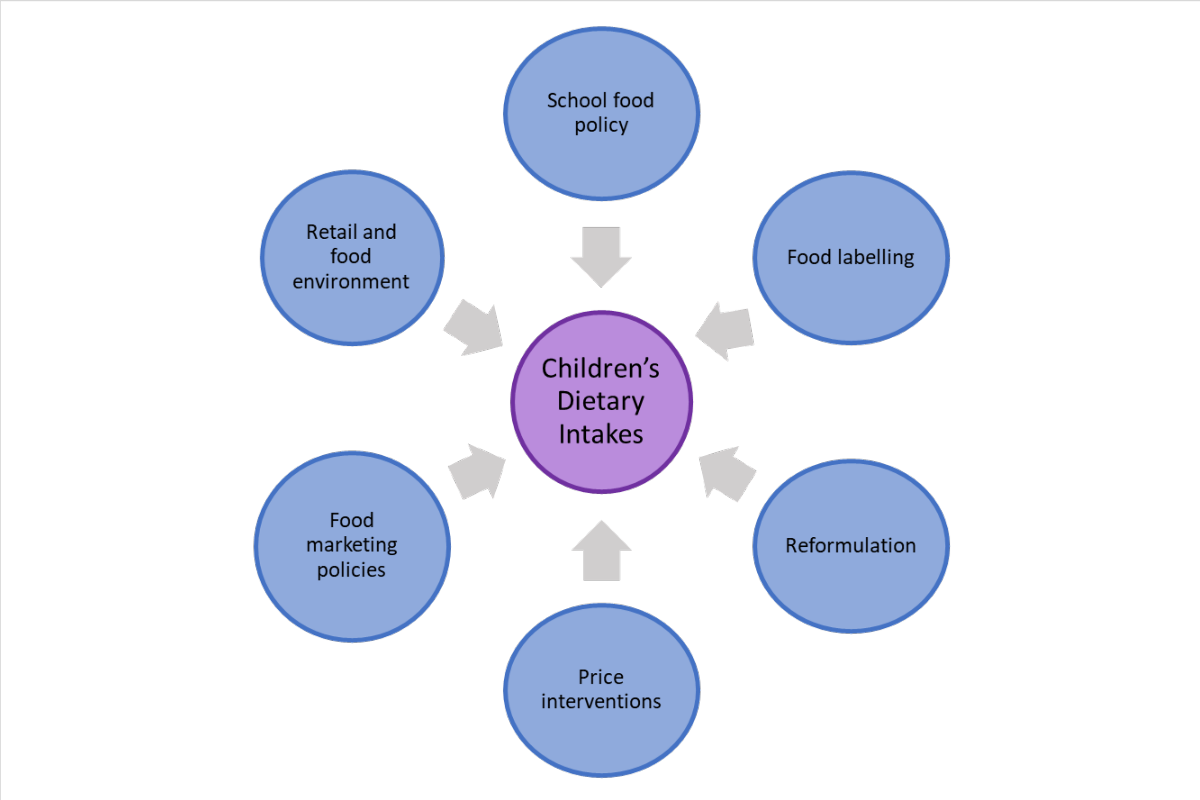


Figure 7.1 Examples of types of food policies that have the potential to influence children's diets

Food reformulation has been a strategy utilised by the UK government to improve the diets of the UK population. As mentioned previously the Soft Drinks Industry Levy was implemented in 2018 and may be a potential explanation for the change in soft drink consumption seen in the current study. The aim of this policy was to reduce sugar intakes by encouraging the reformulation of soft drinks to reduce the sugar content or reduce portion sizes (66). Additionally, a study by Cheng *et al.* (2022) reported that children's intakes of sodium decreased between 2008 and 2019, across all socioeconomic groups but especially in children from more deprived groups (227). The study highlighted this was potentially a result of the National Salt Reduction Programme, which began in 2003/4 and outlined targets for salt reduction in the UK and encouraged gradual food reformulation to reduce the salt content of food products, especially the highest contributors to salt intakes (227). The current study found a reduction in sodium intake across time which is potentially a result of food reformulation and the reduction in the sodium content of school food.

As with school food policies, there are several factors that must be considered to ensure effective implementation of food policies and strategies to improve children's diets. Several reviews have explored the barriers to effective implementation of food policies and strategies to improve diets, both for children and the general population [228, 229]. Examples of factors to consider outlined by these reviews include:

- Use of multi-level approaches are more likely to result in changes, best approaches used include taxes to encourage food reformulation and healthier food choice, marketing, or advertising standards for foods high in fat, salt, and sugar, and food labelling [228].
- Use the best available evidence as the basis for food policy [228, 229].
- Participation of relevant stakeholders in the development of strategies and policies to improve diets [228, 229].
- Effective strategy for monitoring and evaluation, to ensure compliance to polices and identify successful methods and areas for improvement [228, 229].
- Consider funding and resources to ensure the sustainability of policies and strategies [228].

7.5 Wider issues that may have had an impact on children's diets

In addition to what is mentioned above, there are several other factors that may have impacted children's diets between 2000-2022. For example, the UK voted to leave the European Union (known as 'Brexit') in 2016 and formally left in 2020, as a result, the National Food Strategy highlighted this as a key issue due to changing trade deals which may impact on food imports and therefore food pricing [83, 84]. Barons and Aspinall (2020) suggested that as a result of Brexit, there would likely be an increase in food prices as the UK imported around 30% of the UK's food supply from the European Union, which would be impacted by new trade agreements. This may result in increased food insecurity particularly in the most deprived households [230]. However, this is not the only issue that may have impacted children's diet in recent years. The COVID-19 pandemic has had a widespread impact on the UK's food system, including empty supermarket shelves during lockdowns, increased food bank usage and increased food insecurity [231]. Additionally, During the 2020 COVID-19 lockdown and subsequent school closures, the provision of free school meals for eligible children was provided in several ways including food vouchers and food parcels [232]. This, in combination with Brexit, may have had a negative impact on children's diets especially for those from more disadvantaged backgrounds through increased food prices and other issues with access to healthier foods [231]. The Food Foundation published "The Broken Plate Report 2022" and reported that it cost more on average to eat a healthy diet with healthier foods costing £8.51 for 1,000 kcal and unhealthy foods costing £3.25 for 1,000 kcal. Additionally, healthier foods increased in price by 5.1% between 2021 and 2022, and unhealthy foods by 2.5% [233]. This highlights some of the reasons for the differences in dietary intakes between socioeconomic groups in many studies despite the lack of significant difference observed in the current study. In addition, a report by The Association for Public Service Excellence published a report in 2022 commissioned by the All Party Parliamentary Group on School Food titled "Impact of food cost on school meals". The report highlighted that increasing food costs has had a negative impact on school food including the quality of food available, changes to menus (e.g., reduced variety of food on offer) and changes to food costs resulting in increased meal prices [234]. However, this was not considered in this thesis.

7.6 Strengths and limitations

This study had several strengths and limitations which are outlined in the sections below.

7.6.1 Strengths

7.6.1.1 Novelty of study

There is a lack of research examining the impact of the most recently implemented school food policy in England on children's dietary intakes. Only one other study by Taher *et al.* (2020) looked at the impact of school lunch type on children's diet quality in the UK and did not explore diet quality pre- and post-school food policy implementation [148]. The current study explored changes over time and considered the effect of lunch type. Further, no UK studies directly explore the impact of the 2014 policy on children's nutrient intakes. Taher *et al.* (2019 and 2020) and Haney *et al.* (2023) used NDNS data from 2008-2016 (Taher *et al.* (2019 and 2020)) and 2008-2017 (Haney *et al.* (2023)) and explored differences between school lunch types, as opposed to looking at differences pre- and post-implementation of school food policy [140, 148, 173].

7.6.1.2 Unique dietary dataset

The unique dietary dataset for children attending schools in the same area of Northumberland across time allowed for the exploration of dietary data across years pre-implementation (2000 and 2010) and post-implementation (2022) of current school food policy.

The current study used six days of dietary data and included a combination of weekdays and weekend days. As mentioned previously, this allows for day-to-day variations in children's diets to be considered and gives an indication of habitual dietary intakes. Additionally, as children completed the food diaries at two time points during the school year winter and then spring/summer, seasonal variations in children's diets were also considered. The majority of studies that have used DQI-A as a measure of diet quality only contain between two and four days of dietary data, for example, Vyncke *et al.* (2013) used 2 days of dietary data [22] and Taher *et al.* (2019) used 3 or 4 days of dietary data [173]. Similarly, studies exploring the impact of school food policies on nutrient intakes generally use between one and three days of dietary data (see Chapter 2).

Three-day (estimated) food diaries were used as the method of dietary data collection (completed at two timepoints). The main strengths of estimated food diaries include: food and drinks consumed are recorded when consumed, it isn't overly burdensome for participants to estimate portion sizes using household measures, diaries were pocket-sized and therefore easy to record food and drinks on-the-go. Some limitations include: interview can be lengthy which can discourage participants from completing diaries (majority of participants in current study completed data collection), some participants may record food consumed from memory and not at the point of consumption so information may not be accurate, participants may alter diets to make it easier to record or to conceal poor eating habits, can be burdensome for researcher to code diaries (reduced in current study by using Intake24). Weighed food diaries are regarded as the 'gold standard' in self-reported dietary assessment and have similar strengths and limitations though participants may report more accurate portions sizes than with an estimated food diary. However, the weighed method is more burdensome and fewer participants may have completed the six days of dietary data collection if this method was used [139]. Multiple 24-hour recalls were a potential method that could have been utilised. Strengths include low burden for participant to complete, and interviews may be quicker than those for three-day food diaries. However, the method requires participants to recall foods and drinks consumed, therefore some foods and drinks may be forgotten, participants may selectively recall what was consumed to conceal poor eating habits [(139)]. Another option that may have been used to complete dietary data collection is a food frequency questionnaire. Strengths include: low participant burden as doesn't require completing a diary for several days, food frequency questionnaires are designed to obtain habitual intakes and can capture foods that are consumed less often; these foods may not be noted in a three-day food diary. However, a limited number of foods can be included in the questionnaire. In addition, children may find it challenging to average intakes over a given time period, leading to reporting errors. Food frequency questionnaires require good memory to recall how often foods are consumed, and participants may overestimate intakes of healthy foods and underestimate unhealthy foods [(139)].

7.6.1.3 Use of opt-out (passive) consent

Opt-out consent was used to recruit children in the 2010 and 2022 studies, which differed from opt-in consent used in 2000. This allowed children, who often did not return forms to school, to participate in the study, this is especially important for children from more deprived groups [(184)]. If children did not want to take part, they were informed that they were able to withdraw at any point during the study. Most of the children eligible decided to participate in the 2022 study.

7.6.1.4 Exploring both lunchtime and total diet nutrient intakes

Most studies exploring the impact of school food policies on diet, focus on lunchtime or total diet nutrient intakes, not both. The current study explores both. Exploration of weekday lunchtime nutrient intakes allowed for the potential impacts of school food policy to be considered for lunchtime specifically, however, it is important to note that current school food policy does target food sold in schools during the entire school day. The current study also explored total diet nutrient intakes, which allows the aspects of the school food policy that covers the entire school day and the impact of school food policies on overall diets to be considered. Additionally, earlier work in the UK exploring lunchtime intakes looks at previously implemented school food policies, and not the most recent update of 'The Requirements for School Food Regulations 2014'.

7.6.2 Limitations

7.6.2.1 Cross-sectional study design

This study is a repeat-cross-sectional study design, and as a result, it is difficult to make causal inferences [235], limiting the extent to which changes in children's diets since 2000 can be linked to the implementation of school food policies in England.

7.6.2.2 Compliance of foods available in school

The current study did not assess the extent of school food policy compliance in terms of the foods and drinks available in the school canteen. Instead, children's lunchtime nutrient intakes were used to explore the potential impacts of the implementation of the most recent school food policy. Additionally, exploring the effect of school lunch type at both lunchtime and total diet allowed for potential impacts of school food policies to be considered.

7.6.2.3 Use of self-reported dietary intakes

There are several issues associated with self-reported dietary intakes in children and adolescents, including the tendency to misreport intakes. Misreporting can occur in several ways including intentionally not reporting some foods or drinks that were consumed, changing usual dietary intakes during dietary data collection, or forgetting to include some food items that were consumed [236]. For example, social desirability bias may result in children underreporting foods that are seen as less healthy or over-reporting foods that are seen as healthy in an effort to adhere to social norms, e.g., report higher fruit and vegetable intakes or lower intakes of confectionery [237]. Studies generally suggest that under-reporting is more common than over-reporting dietary intakes [238, 239]. Jones *et al.* (2021) found that for UK children participating in the Avon Longitudinal Study of Parents and Children, misreporting of energy intakes occurred in a large proportion of children, and being overweight or obese was associated with underreporting dietary intakes [238]. Further Jones *et al.* (2021) found that under and over-reporting was more common for non-core food items such as snacks (e.g., cakes and chocolate) than core food items like vegetables [239]. The method used to identify underreporting in the current study is outlined in Section 3.6.5 (intakes below 400 kcal and above 4000kcal were removed from analysis (no cases in the current study). A similar method to Jones *et al.* (2021) was not used as body composition data was not collected in the current study.

It is important to note that children's cognitive ability varies in this age group. Some children can recall what they consumed and estimate portion sizes more accurately than others [(240, 241)]. Using the food diary as an aid potentially helped mitigate this issue and improved the accuracy of reported dietary information. Additionally, motivation can also affect the accuracy of reporting dietary data. The use of engaging methods of dietary data collection and portion size estimation, such as Intake24, may help motivate children to report more accurate dietary information [(240)].

7.6.2.4 Issues surrounding portion size estimation

Another issue that should be considered is the reporting of fluid intakes, especially considering one potential explanation for DQI-A score improvement is increased water intake. A discussion paper by Warren *et al.* (2018) highlighted issues surrounding the assessment of beverage intakes in children and adolescents, including that water is potentially consumed in small amounts throughout the day potentially leading to errors in portion size estimation. Despite this issue, food diaries are considered a more reliable method to measure fluid intakes compared with other methods [(242)]. Further, despite the change in portion size estimation for the current study from previous ASH11 studies, there was good agreement in portion size estimation between the two methods used [(190)], and the data from 2022 was deemed suitable for comparisons to data from 2000 and 2010, this is discussed in Section 3.5.4.

7.6.2.5 Issues regarding classification of lunchtime intakes

Lunchtime intakes for analysis only considered food and drinks consumed during the lunchtime period on weekdays. In some cases, children only consumed a small snack at lunch and consumed more food either at break or after school. This resulted in only the small snack (e.g., flapjack) being included as lunchtime intakes, without taking into consideration the foods consumed at break or after school, before the evening meal. However, this only occurred in a small number of children and usually only for one day of dietary data (*n*=22).

7.6.2.6 Level of deprivation

The study population had higher levels of deprivation than the UK and Northumberland average, limiting the representativeness to a wider UK population. Additionally, as mentioned previously, this may help explain the lack of an effect of IMD on children's dietary intakes found in the current study. However, the level of deprivation in the study population could also be seen as a strength as it is difficult to recruit and obtain data from more deprived populations [(243)] and the current study gives insight into the diets of children from more deprived areas.

Further, socioeconomic status was estimated using the index of multiple deprivation (IMD) 2019, this does not measure individual-level deprivation but is an overall measure of deprivation within a local area in England, there is, therefore, a risk of misclassification bias [(244)].

7.6.2.7 Lack of anthropometric measurements and data regarding ethnicity

As mentioned in Chapter 3, due to COVID-19 restrictions and social distancing regulations, anthropometric data were not collected from children in 2022 and data from previous years was not used. Anthropometric data would have been useful to obtain for several reasons including to explore and identify possible misreporting of dietary intakes by comparing children's estimated energy requirements with their energy intakes [(245)].

No data regarding ethnicity of children was collected during the current study. As mentioned in Section 3.2, Northumberland predominately identifies as White British (96.1%) [(178)]. So, although the current study may reflect Northumberland in terms of ethnic diversity, results may not be generalisable for the wider population of England.

7.6.2.8 Analysis of food group intakes

Analysis of food groups was completed at a basic level and did not include regressions or other complex analyses, limiting inferences that can be made regarding intakes. The main purpose of the food group analysis was to help explain the findings of the more complex DQI-A analysis which looks at diets using food group intakes.

7.6.2.9 DQI-A categorisation and calculation

For the calculation of DQI-A, the food groups used were based on the Flemish food-based dietary guidelines, not the UK Eatwell Guide. There are some similarities and differences between these food group categories, outlined in Table 7.1. The main similarities between the food group categories are the water food group, meat, fish (and alternatives) group, and the fats and oils groups. The main difference for the food groups is that many of the food groups outlined in the Flemish guidelines are separated out, but in the UK Eatwell Guide are combined including fruit and vegetables, potatoes, bread, rice, pasta, and other starchy carbohydrates. Another difference includes confectionery and high-fat and sugar snacks, which for the purposes of DQI-A calculation are included in one of the nine relevant food groups outlined below and are also considered separately as non-recommended foods for calculation of the DEc component.

Table 7.1 Differences between Flemish food groups and UK Eatwell Guide food groups

Flemish food-based dietary guidelines (22)	**UK Eatwell Guide** (194)
Water (1500-2250 ml), Breads and cereals (150-360 g), Potatoes and grains (210-350 g), Vegetables (300-450 g), Fruit (250-375 g), Milk products (450-600 ml), Cheese (20-40 g), Meat and fish (and alternatives) (75-100 g), Fats and oils (10-15 g).	Potatoes, bread, rice, pasta, and other starchy carbohydrates, Dairy and alternatives, Beans, pulses, fish, eggs, meat, and other proteins, Fruit and vegetables, Oil and spreads, Water, Confectionery and high-fat and sugar snacks.

For the DAx and DEx sub-components (combined to be DEc component), minimum and maximum guidelines used were developed for a Flemish population as there are no UK maximum and minimum guidelines for food group intakes included in the Eatwell Guide. These same guidelines were also used by Taher *et al.* (2019 and 2020), which was also conducted in the UK. Another limitation of the DQI-A calculation method is that the DEx subcomponent may penalise individuals with high intakes of fruits and vegetables exceeding the maximum recommended recommendation (outlined in Chapter 3).

Children's mean DQI-A score was only explored at total diet. This was because the calculation of DQI-A scores is a complex process and guidelines used in the calculation are related to daily intakes. To consider the impact of school food policies on children's diet quality, the effect of school lunch type (school v home-packed lunch) was considered and accounted for in linear regression analysis.

7.7 What this study adds to the evidence base

The research presented in this thesis adds to the existing evidence base exploring the impacts of school food policies on children's diets, the key findings are noted below. Many studies examining the impact of school food policies explore either total diet or lunchtime nutrient intakes, but very few examine the impact on both. To my knowledge, there is no research currently published that explores the impacts of 'The Requirements for School Food Regulations 2014' on children's dietary intakes, pre-, and post-policy implementation.

- **Previous research (as noted in Chapter 2):**
    - There is very little research on the impact of school food policies on children's diet quality, especially in UK children. Additionally, in the one UK study that did explore this, only differences between school lunch types were examined and not pre- and post-policy implementation.
    - Most research on the impact of school food policies on children's total diet and lunchtime nutrient intakes in the UK examines the previously implemented school food policy from 2008.
    - Previous research used only between 1-4 days of dietary data.
- **This study:**
    - Involved six days of dietary data and includes both weekday and weekend data to give a better indication of habitual diet and to account for day-to-day variations in children's dietary intakes.
    - Pre- and post-policy implementation and differences between school lunch types were examined.

- This study found that children's diet quality improved post-implementation of school food policy in England. However, there was no evidence of an impact of either school lunch type or IMD on overall DQI-A scores.
- This study found that consistent with the literature, children's nutrient intakes did not meet current UK recommendations, and intakes for most nutrients studied decreased post-policy implementation, with no evidence of an impact of IMD on intakes.
- This study found evidence of a year by school lunch type interaction for most nutrients studied, with an overall decrease for most nutrient intakes. Also, no evidence of an impact of IMD on lunchtime nutrient intakes was found.

7.8 Working with schools

Children spend a large amount of their time in school and is therefore a good source of recruiting children for research studies. Additionally, the use of opt-out consent in this environment helped with recruitment, as noted in section 7.6.1. Teachers were able to remind children to complete their food diaries, which was appreciated and enhanced the dietary data collection process.

There were several challenges working in schools when conducting this research. First, recruiting schools to participate in the study came with its own challenges. As the current study is continuing from and adding to previous work which has been consistently carried out in the same schools in Northumberland every ten years since 1980, the priority was to contact those same schools to participate in the 2022 study. However, as mentioned in Chapter 3, several of the schools that were previously involved had either closed or merged to form an academy, leaving three potential schools to contact. Ultimately, one school declined to participate, one school did not respond, leaving one school willing to participate in data collection. Studies across various research areas have outlined challenges regarding gaining access to schools and recruiting children for research [246, 247]. An article by Rice *et al.* (2007) highlighted issues surrounding gaining access to schools for research and recruiting children including determining who to contact, concerns related to time required for research and implications for learning, ethical considerations, and obtaining consent [248]. Another study by Hatch *et al.* (2023) highlighted issues related to missing lessons and finding the best time of the school year to accommodate research activities (e.g., avoid the start of the school year and exam season) [247]. This may have been a greater issue following the COVID-19 pandemic where children lost lesson time because of school closures and at-home learning.

There are several logistical challenges when working in schools. As teacher schedules are generally very busy, arranging a time to access schools was difficult, especially between data collection time points, exam season, or school holidays, and would often require follow-ups and reminders to ensure access to school on relevant days. It was challenging to locate children who did not remember to attend their dietary interview with myself or the research assistant, especially when attending physical education classes. There were also some slight issues surrounding teachers who were less aware of the research being conducted and were reluctant to allow the child to leave class. Further, school absences due to COVID-19 and other reasons (appointments or sickness) resulted in some issues regarding food diary discussions with children immediately following the completion of recording dietary intakes, and three children had to complete a further three-day food diary.

7.9 Engagement and dissemination with school

Following discussions with the head teacher at the participating school, it was agreed that the research team would help organise a healthy eating event in the school. This took place after data collection was completed to avoid any dietary changes due to the event. A 'Write a Recipe Assembly' was organised with Nourish Food School (a mobile cookery school operating across North East England), which involved getting the children involved in cooking a healthy meal and competing for their preferred ingredients [249]. For this event, the year group (same year group involved in the study) was split into 3 sessions with approximately 60 children attending each session. Children were split into two teams, with two volunteers from each team cooking (four in total). The recipe for all sessions involved making a curry, either an Indian red curry or a Thai green curry. To get the opportunity to choose an ingredient, children were asked nutrition-related questions and whichever team got the question right was able to select one of the following ingredients: curry paste (Thai green or Indian red), protein (chicken or chickpeas) and vegetables (peppers or spinach), all other ingredients were provided to both teams. The staff from Nourish Food School talked through each ingredient and discussed other nutrition-related questions during the session. Examples of question topics covered during the sessions included: the importance/benefits of cooking from scratch, the role of protein in the diet, dietary recommendation for, and sources of salt. Once, both dishes were cooked, the staff from Nourish Food School, highlighted the cost per portion of each dish in comparison to ready meals/takeaways. All children had the opportunity and were encouraged to try both dishes once the session was complete, and the school was provided with copies of each recipe to distribute to all children. Examples of completed dishes from one of the sessions are displayed in Figure 7.2.

Figure 7.2 Finished dishes from Nourish Food School event at the participating school, left = Indian red chickpea curry, right = Thai green chicken curry

Prior to the beginning of the Nourish Food School session, key results from the current study were discussed with the staff running the event and the results were continually referred to during the cooking session and quiz (e.g., reduced salt intakes and sources of salt). Additionally, the results were also discussed with the headteacher of the participating school who also asked questions related to the results, for example, how the results compare to previous years, and to current UK recommendations.

7.10 Implications for practice and policy

There are several policy implications highlighted by the findings of the current study. First, as mentioned above despite the updated school food policy and some improvements, children's diets remain poor. Prior to the COVID-19 pandemic, school food policy in England was subject to an ongoing review, particularly the sugar content of school meals [72, 76], however, no changes have been announced and the government shifted focus to improving compliance to the current policy [77]. As mentioned in section 7.3, there is a lack of consistent monitoring of compliance to school food policies, though the government has announced methods to improve this in the "Levelling up the United Kingdom" White Paper in February 2022. Updating school food policies and ensuring consistent monitoring ensuring compliance may have the potential to further improve diets as children consuming school meals consume approximately one-third of their daily dietary intakes at school as mentioned previously [86]. Additionally, focus must be broader than just what is available at lunch, what children choose to consume should also be considered, as noted above. However, as packed lunches are not subject to school food policies and children can also bring food obtained out of school to consume alongside their school lunch [92, 93], the potential impacts of school food policy may be limited. Introduction of a packed lunch policy restricting the items that can be brought into school or packed lunch guidance encouraging healthier food choices may help improve foods consumed during the school day.

There have been calls for the expansion of free school meal eligibility criteria, especially following the COVID-19 pandemic and cost-of-living crisis. This was highlighted by the National Food Strategy recommending the less than the current £7,400 before benefits threshold to be expanded to £20,000 before benefits and also for those with no recourse to public funds to target more families experiencing food insecurity [84]. This would have the potential to improve the socioeconomic disparities in dietary intakes that are widely documented despite not being observed in the current study, however, as noted the lack of significant impact of IMD in this study may be a result of the deprived study sample.

Targeting children's diets through school food policy alone is potentially not enough to improve dietary intakes, other factors that influence children's diets should also be targeted, including retail and neighbourhood food environments. Further, the Soft Drinks Industry Levy was implemented in 2018 [66] and may have contributed to the changes in soft drink consumption observed in the current study. Further, the increased consumption of diet soft drinks compared with decreased non-diet varieties is promising, however, more research is required to further investigate changes across UK populations. Similar policies to address other areas of concern may be beneficial.

7.11 Future research required

There are several areas related to the current study to consider for future research to examine the impact of school food policies on children's diets, including:

- The study sample was more deprived than the national average, therefore similar research across wider socioeconomic groups could help ascertain potential impacts of socioeconomic status on children's diets and the impact of school food policies on children's diets.
- The use of qualitative methods with school caterers and relevant school staff could be utilised to explore the implementation of school food policy, and level of compliance and discuss any difficulties related to implementing standards (e.g., are the standards clear). This could potentially help determine the main areas that future school food policy should target and inform guidance that should be provided alongside policy change to improve children's diets in the UK.
- Future research could explore the level of compliance to school food standards, including the analysis of the foods on offer in schools, and comparisons between what is on offer, what is purchased, and what is consumed by children. This would allow for further exploration of the effectiveness of school food policies in improving children's dietary intakes at lunchtime.
- Qualitative work with school pupils to explore their opinions of school food, and how that impacts what food they consume in school could help to identify areas to improve school food.
- In-depth analysis of differences in dietary intakes by the location of where food is consumed e.g., home, school, out-of-home, could help to explore differences between dietary intakes in school and in other locations, and further help ascertain the impacts of school food policies and other food policies on children's diets.

- The calculation and analysis of children's diet quality at lunchtime could help explore the impact of school food policies when the policy has the largest potential impact on children's diets.
- More in-depth analysis of food group intakes for both lunchtime and total diet intakes, especially considering that school food policy in England is now entirely composed of food-based standards, would help to further examine potential impacts of school food policy on diets.
- The exploration of the impact of free school meals on children's diets and if it has a different impact on children's diets than for children who consume paid school lunches or home-packed lunches could be beneficial to explore the impact of school food policy on children's diets, especially in schools that include a high proportion of children from more deprived areas.

Aside from future research related to school food policies outlined above, the development of a UK-specific diet quality measure, using UK dietary guidelines would be beneficial to give a more accurate reflection of children's diet quality in the UK.

7.12 Overall summary and conclusions

This thesis has explored changes to children's dietary intakes in 2000, 2010, and 2022 in relation to changes to school food policy, by addressing the main aim:

> *To explore the impact of changes to school food policy on the diets of 11-12-year-olds in Northumberland (pre- and post-policy)*

Dietary data from 371 children aged 11-12 years was included in the current study across three years 2000, 2010, and 2022. These three years were studied as the 2000 data was collected prior to the implementation of school food policy in England, the 2010 data was post-implementation of 2008 school food policy, but prior to current policy and 2022 was post-implementation of current (2014) school food policy in England (a timeline of school food policy implementation for England is provided in Chapter 1).

The main aim was answered by addressing the following objectives:

Objective 1: To examine the food group intakes (soft drinks and fruit and vegetables) and diet quality of 11-12-year-olds in Northumberland at three time-points: 2000, 2010 and 2022 to consider the impact of changes to school food policy.

Firstly, regarding food group intakes, though overall intakes of soft drinks (diet and non-diet combined) did not significantly change over time, intakes of diet varieties increased, and non-diet decreased. This is a promising step to help lower the currently high sugar intakes observed in UK children, though soft drink consumption, and sugar intakes remain a key issue regarding children's diets. The findings for fruit and vegetable intakes (combined), however, are less promising, though intakes did not significantly change over time, the median intakes observed across years remain well below the five-a-day recommendation. Children's mean diet quality, using DQI-A, significantly improved across years. However, there was no evidence of an effect by school lunch type or IMD on children's mean DQI-A. Despite this improvement, it is important to note, that diet quality remains poor.

Objective 2: To explore changes to the mean nutrient intakes (total diet) of 11-12-year-olds in 2022 to the previous ASH11 studies (2000 and 2010) and with current recommendations.

Despite some improvements to children's diets, dietary intakes remain poor and do not meet current UK recommendations. Children's dietary intakes in 2022 met only current UK recommendations for %E fat and vitamin C. Mean energy, NSP, calcium, and iron intakes were below current recommendations, and mean %E saturated fat, %E NMES, and sodium intakes were above current recommendations. Mean intakes of most nutrients studied, decreased across years, however, vitamin C and calcium intakes increased across years. PL consumers had higher mean intakes of saturated fat, calcium, sodium, and iron than SL consumers. However, there was no evidence of an effect by IMD on children's mean total diet nutrient intakes.

Objective 3: To explore the mean lunchtime nutrient intakes at of 11-12-year-olds in 2022 to the previous ASH11 studies (2000 and 2010).

There was evidence of a statistically significant impact of year by school lunch type interactions for intakes of most nutrients studied, excluding %E saturated fat, with both SL and PL consumers having more favourable nutrient intakes for different nutrients. There was no evidence of a statistically significant difference in children's lunchtime nutrient intakes across IMD tertiles.

7.12.1 Conclusion

Overall, there have been some improvements to children's dietary intakes post-implementation of school food policy in terms of diet quality and nutrient intakes, however, children's diets remain poor. This is evidenced by the fact that children's nutrient intakes do not meet current recommendations for most nutrients studied and DQI-A scores indicate poor diet quality. Despite children's diets continuing to be a major public health issue, there is some limited evidence that the school food policy has improved children's dietary intake at lunchtime, but not total diet. This highlights the complexity of children's diets and the need for various policies and interventions to improve children's dietary intakes.

Childhood overweight and obesity rates in the UK are high and have widely been linked to poor diets as one of the main factors. Encouraging children to make healthier food choices from a young age remains vital to improving dietary habits, as habits formed in childhood have the potential to continue into adulthood.

Potential solutions to improve children's diets could include updating school food standards and modifying school food and drink availability. The continued high NMES intakes, both in total diet and at lunchtime, highlight a need for more strategies to improve this. Additionally, the negative change found for in some nutrient intakes, especially at lunchtime, may indicate that the re-introduction of nutrient-based standards would potentially be beneficial. The government had committed to updating school food policies, especially in terms of sugar content [72, 76]. However, the government has now shifted focus from updating to ensuring compliance to the current school food policy of 'The Requirements for School Food Regulations 2014' [77, 85]. Improving compliance to school food policies would potentially also help improve children's diets. Considering the barriers to successful implementation of school food standards through the involvement of relevant stakeholders including school caterers and head teachers would potentially help improve compliance. Additionally, the implementation of a consistent monitoring system and appropriate support to ensure compliance to school food policies is essential.

Further, additional policies are needed to address children's diets beyond school, particularly for foods high in fat, salt, and sugar. The development and implementation of policies like the Soft Drinks Industry Levy may help target specific areas of concern in children's diet. Other policies including recently implemented restrictions on the promotion of foods high in fat, salt, and sugar in-store and online, and the planned restrictions on advertising of these foods coming into force in 2025 [79-81], may help to improve children's diets and encourage healthier food choices.

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Appendix A. Ethical Approval Letter

03 November 2021

Faculty of Medical Sciences
Newcastle University
Medical School
Framlington Place
Newcastle upon Tyne
NE2 4HH

Rebecca McIntyre
Population Health Sciences

FACULTY OF MEDICAL SCIENCES: ETHICS COMMITTEE

Dear Rebecca

Title: An exploration of the impact of school food and wider policy changes on 11-12 year-olds dietary intake in Northumberland
Application No: 1861/695/2019 (Including amendment 1861_1)
Start date to end date: 01/03/2020 to 06/01/2024

On behalf of the Faculty of Medical Sciences Ethics Committee, I am writing to confirm that the ethical aspects of your proposal have been considered and your study has been given ethical approval.

The approval is limited to this project: **1861/695/2019 (Including amendment 1861_1)**. If you wish for a further approval to extend this project, please submit a re-application to the FMS Ethics Committee and this will be considered.

During the course of your research project you may find it necessary to revise your protocol. Substantial changes in methodology, or changes that impact on the interface between the researcher and the participants must be considered by the FMS Ethics Committee, prior to implementation.*

At the close of your research project, please report any adverse events that have occurred and the actions that were taken to the FMS Ethics Committee.*

Best wishes,

Yours sincerely

Marjorie Holbrough
On behalf of Faculty Ethics Committee

cc.
Professor Daniel Nettle, Chair of FMS Ethics Committee
Mrs Kay Howes, Research Manager

*Please refer to the latest guidance available on the internal Newcastle web-site.

Appendix B. Headteacher Information Sheet

An Exploration of the impact of school food and wider policy changes on 11-12 year-olds dietary intake in Northumberland

Information Sheet

Introduction
Since 1980, children from year 7 in your school have participated in the Northumberland School Food Study. Studies have been conducted every 10 years in order to find out about children's eating habits and how these have changed. The National Diet and Nutrition Survey found that a nationally representative sample of UK adolescents were consuming nearly 3 times the recommend sugar per day, and were not meeting the recommendation of 5 portions of fruit and vegetables per day. This study aims to explore if adolescents in Northumberland reflect the current literature regarding their age group. Previous studies have been helpful in health promotion in this region.

Who is doing the study?
Researchers at Newcastle University are conducting the study. The research is funded through Fuse-Newcastle University. All researchers will have enhanced DBS check and ethical approval has been granted by Newcastle University Ethics committee.

What is the study about?
This study looks at what food and drink 11-12y olds in Northumberland consume. It will focus mainly on sugars, fats and fruit and vegetable intake. The results can then be compared to results from previous years where the same age-groups were analysed in these schools.

What does the school have to do?

- We would like to work with the 11-12year olds in year 7 to collect dietary data; this will involve letters to parents re consent - we are using an opt out methods of recruitment for this study – which means consent forms only have to be returned if a parent does not wish for their child to take part in this study
- Pupils will record their diets using a 3-day diet diary and then attend a 50 minute interview with the researcher to go through the diaries using an online tool called Intake24.
- Provide names and postcodes of the year 7 pupils unless they have returned the opt-out form.
- We would like permission to use a room in the school during school hours
- We will bring our own laptops to complete the online aspect of the interview. Also, we would require to use internet to access and use the online dietary tool.
- We would like permission to interview participants about their dietary intake in order to expand on the information they provide in the diaries and to record their height, weight and percentage body fat

Do I have to take part?
You do not have to take part.

Are there any risks of taking part?
We do not foresee any risks in taking part in this study.

What will happen with the results?
All study information will be kept confidential and stored securely as per Newcastle University Protocols. All study findings will be anonymous and we will publish the findings in a health-related journal. All schools will receive a pupil-friendly newsletter or presentation from the research team to tell them about the study findings.

Thank you
To say thank you for taking part, we are happy to be able to offer your school a £50 gift voucher. Each pupil that participates will also receive a £10 voucher on completion.

What do I do now and further information
If you are happy for this study to take part in your school please contact me, or if you have further questions please do not hesitate to contact me:
Email: R.L.Mcintyre2@newcastle.ac.uk
Project Supervisor details:
Email: suzanne.spence@ncl.ac.uk
Tel: 0191 2087739

Thank you for your interest in this study.

Rebecca McIntyre
PhD Student
Email: R.L.Mcintyre2@newcastle.ac.uk
Address: Human Nutrition Research Centre
Population Health Sciences Institute
Faculty of Medical Sciences
M1.151 William Leech Building
Framlington Place
Newcastle
NE2 4HH

Appendix C. Participant information sheet and consent form

11th October 2021

Dear Parent / Guardian

An Exploration of the impact of school food and wider policy changes on 11-12 year-olds dietary intake in Northumberland

Since 1980, children in year 7 from your child's school took part in a study with the aim of finding out about their eating habits and how these have changed. The National Diet and Nutrition Survey found that UK adolescents were consuming nearly 3 times the recommended sugar per day and not meeting the recommendation of 5 portions of fruit and vegetables per day. This study aims to discover if adolescents in Northumberland reflect the current literature regarding their age group. Previous studies have been helpful in health promotion in this region.

We are delighted that your child's school has once again agreed to take part in this study. I am now inviting your child to take part in the 2021 study to see how diets have changed over the past few years.

Who is doing this study?

Researchers at Newcastle University are conducting the study. The research is funded by Fuse-Newcastle University. All researchers will have enhanced DBS checks and ethical approval has been granted by Newcastle University Ethics committee.

What we would like your child to do:

- Your child will be asked to write down everything they eat and drink for three days (Two weekdays and one weekend day). They will then be interviewed by a nutritionist to expand on this record and input the information into an online program called Intake24. This will be carried out on two occasions, once in Autumn/Winter and once in Spring/Summer terms.
- Your child will be measured for height, weight and body composition by the researcher working on the study. These measurements will be taken in private and all the information collected will be confidential.

The benefits of taking part:

- Previously children have enjoyed writing down what they eat and taking part in this study.
- On completion of two 3-day food diaries they will receive a **£10 voucher.**
- They will be making a contribution to their school's involvement.
- After the research is complete we will return to school to tell the children who took part, how their diet compared with diets of Year 7 children over the last 40 years.
- This study will take minimum time and effort and should not interfere with school work. Participation is voluntary and your child is free to leave the study at any time without the need to give any reason. If you have any queries about the study, please contact me at the email address below.

Are there any risks to taking part?

We do not foresee any risks in taking part in this study.

Will taking part be kept confidential?

All study information, including personal details, will be kept confidential and will not be made public. With your permission we may use anonymous extracts to report study findings.

What will happen with the results?

We will publish the study results in a health-related journal. All schools will receive a newsletter or presentation from the research team to tell them about the study findings.

Further Information
This study was approved by the Faculty of Medical Sciences Research Ethics Committee, part of Newcastle University's Research Ethics Committee. This committee contains members who are internal to the Faculty, as well as one external member. This study was reviewed by members of the committee, who must provide impartial advice and avoid significant conflicts of interests.

The consent form attached is to be completed if you **do not** want your child to take part in the study. If you are happy for your child to take part you do not have to do anything.

Yours sincerely

Rebecca McIntyre
PhD student
Newcastle University
Email: R.L.Mcintyre2@newcastle.ac.uk

Project Supervisor contact details:
Suzanne Spence
Address: Human Nutrition Research Centre
Population Health Sciences Institute
Faculty of Medical Sciences
M1.151 William Leech Building
Framlington Place
Newcastle
NE2 4HH
Tel: 0191 2087739
e-mail: suzanne.spence@ncl.ac.uk

Consent Form

Name of child ………………………………………………..

Class ………………………………………………..

School ………………………………………………..

What do I do now?

1. IF YOU ARE HAPPY FOR YOUR CHILD TO TAKE PART YOU DON'T NEED TO DO ANYTHING!

2. If you **DO NOT** wish your child to take part in any of this study please sign here

……………………………………………………………………………………………. and RETURN THIS PART OF THE LETTER TO SCHOOL.

Appendix D. Participant debrief sheet

An Exploration of the impact of school food and wider policy changes on 11-12 year-olds dietary intake in Northumberland

Participant debrief letter

Thank you for taking part in this study. This is a really important project and I appreciate your help. The information discussed will be confidential and your name or any other details will not be identifiable.

This study was approved by the Faculty of Medical Sciences Research Ethics Committee, part of Newcastle University's Research Ethics Committee. This committee contains members who are internal to the Faculty, as well as one external member. This study was reviewed by members of the committee, who must provide impartial advice and avoid significant conflicts of interests.

As a 'Thank you' you will receive a £10 voucher.

If you have any questions or have any concerns from taking part please feel free to contact me on 0191 2085276 or 2087739.

Once again, thanks for all your help.

Rebecca McIntyre
PhD Student
Newcastle University
E-mail: R.L.Mcintyre@newcastle.ac.uk

Supervisor contact details:
Suzanne Spence
Newcastle University
Tel: 0191 2087739
e-mail: suzanne.spence@ncl.ac.uk

Appendix E. HNRC Food groups

HFG_ID	HNRC Food Group Name	Notes and examples
0	Non Entered	
1	White bread/rolls	
2	Brown and wholemeal bread/rolls	
3	Sweet breads	malt bread, currant bread
4	Bread, other <8g/100g fat	bagel, chapatis (made without fat), milk bread, grilled papadums, pitta, rye bread, soda, flour tortillas, crumpets
5	Breakfast Cereal, sugar coated	sugar puffs, frosties
6	Breakfast Cereal, high sugar	sugar content above 30g total sugar per 100g
7	Breakfast Cereal, other	muesli, bran flakes
8	Breakfast alternatives	nutrigrain bar, pop tart, breakfast cereal bars
9	Rice	
10	Pasta	
11	Dehydrated convenience foods etc	supernoodles, pasta 'n' sauce, pot noodle, taste breaks
12	Tinned cereals	spaghetti in tomato sauce
13	Cereal based savouries	dumplings, yorkshire puddings
14	Sweet biscuits	excludes full coated biscuits
15	Savoury biscuits and baked goods	e.g. crackers, oatcakes, water biscuits, cheddars, cheese/savoury scones
16	Cakes	sweet buns, sweet pastries, fruit scones and custard tart (sweet but not savoury based items).
17	Milk based sweet puddings	(excluding yoghurts and canned/stewed fruits) e.g. rice pudding, semolina, blancmange, custard, trifles
18	Low fat yoghurt/fromage frais	
19	Whole milk yoghurt/fromage frais	
20	Canned/stewed fruit	
21	Milk, semi-skimmed	includes longlife semi-skimmed.
22	Milk, skimmed	includes dried and longlife skimmed.
23	Milk, whole	includes longlife whole, dried whole & any soya or goats milk.
24	Milkshakes	includes purchased & made from powder mix, made with all milk types.
25	Cream	single, double whipping & sterilised canned cream (excludes artificial creams & toppings).
26	Lower fat cheese	cottage cheese, reduced fat, low fat cheese spreads
27	Processed cheese	
28	Other cheese	edam, cheddar

HFG_ID	HNRC Food Group Name	Notes and examples
29	Cheese dishes	macaroni cheese, cheese sauce
30	Butter	includes half fat butter and other animal fats (e.g. lard)
31	Dairy fat spreads includes hard marg	
32	Low fat spreads	includes very low fat spreads
33	Polyunsaturated	
34	Low fat polyunsaturated	
35	Monounsaturated	
36	Oils	vegetable oil, olive oil
37	Eggs	whole egg, white, yolk, dried, boiled, fried, scrambled, omelette, poached.
38	Egg dishes	quiche, flan, scotch eggs
39	Bacon and ham	
40	Beef and beef dishes	
41	Pork and pork dishes	
42	Lamb and lamb dishes	
43	Chicken in batter	
44	Chicken/Turkey in breadcrumbs	
45	Chicken/Turkey dishes	
46	Liver and liver dishes	
47	Burgers and kebabs	
48	Sausages	
49	Pies and pastries	
50	Other meat	e.g. game
51	Fish in batter	all fried fish in batter
52	Fish in crumbs	fishcakes, fishfingers
53	Shellfish	e.g. prawns, mussels
54	Oily fish	
55	Other white fish	
56	Fish dishes	curry, seafood pasta, fish pie
57	Chips, oven	
58	Microwave chips	
59	Chips, fried	
60	Potato based crisps – low fat	
61	Potato based crisps – full fat	
62	Non-potato snacks	e.g. pretzels, tortilla crisps
63	Potato, roast	
64	Jacket potatoes	baked in skins

HFG_ID	HNRC Food Group Name	Notes and examples
65	Potato, other	
66	Potato products	e.g. wedges, waffles, croquettes
67	Baked beans	
68	Baked beans with sausages/burgers	
69	Peas	frozen, fresh, canned, dried & split.
70	Other vegetables (excluding potato)	carrots, green beans, pulses, cabbage, tomato base sauce, mushrooms, sweetcorn, stir fried vegetables, green salad
71	Vegetable dishes	vegetable curry, vegetable stew
72	Dressed salad dishes	potato salad, Greek salad, waldorf salad
73	Fresh fruit	
74	Dried fruit	
75	Nuts	
76	Seeds	
77	Sweets (non-chocolate)	toffee, boiled sweets, gums/jellies, mints, liquorice, raw jelly, popcorn.
78	Chewing gum	
79	Ice cream, ice cream desserts and lollies	
80	Chocolate covered ice cream bars	
81	Chocolate	includes all plain, milk & white chocolate bars & coated bars e.g. caramels & wafers and full coated chocolate biscuits.
82	Preserves and syrups	glace cherries, honey, jam, marmalade, lemon curd, marzipan, mincemeat, chocolate spread, ice cream topping
83	Sugar, table	demerara, white
84	Diet carbonated drinks (includes low calorie drinks)	
85	Other carbonated drinks (not diet)	
86	Fruit juices	e.g. fresh orange juice
87	Fruit drink, ready to drink (sweetened)	e.g. sunny delight, umbongo, five alive
88	Cordials & squashes	reduced sugar or low calorie squashes
89	Other cordials and squashes	excluding low calorie & reduced sugar.
90	Water	
91	Tea (excluding added sugar)	

HFG_ID	HNRC Food Group Name	Notes and examples
92	Coffee (excluding added sugar)	
93	Other hot drinks water and milk based	e.g. hot chocolate, ovaltine
94	Alcohol	
95	Ketchup	
96	Gravy	
97	Other sauces	e.g. vinegar, salad cream, tartare sauce, cook-in-canned sauce
98	Salt	
99	Soups	
100	Misc.	
101	Bread, other >8g/100g fat	naan, chapatis (made with fat), fried papadums, croissants, fried bread
102	Vegetables based rice dishes	
103	Meat based rice dishes	
104	Couscous, bulgar wheat	
105	Noodles and noodle dishes	
106	Non meat based pasta dishes	
107	Meat based pasta dishes	
108	Meat and potato dishes	
109	Non meat and potato dishes	
110	Cereal based savouries with vegetable or meat additions	bhajis, samosas, pakora, prawn toasts, spring rolls, meat filled spring roll
111	Non milk based sweet puddings	(excluding yoghurts and canned/stewed fruits) e.g. meringue, cheesecake, gateaux, jelly, fruit pies (pastry), crumble
112	Pizza	
113	Non meat containing savoury pies and pastries	
114	Pulses and lentils	
115	Quorn/TVP and dishes	
116	Infant foods.	
117	Herbs and spices	

HFG_ID	HNRC Food Group Name	Notes and examples
118	Reduced fat/ calorie dressings and accompaniments	reduced fat mayonnaise, salad cream, French dressing

Appendix F. DQI-A food group allocation

DQI-A Food Group	DQI-A Sub food group	Food/Drink item/HNRC food group
Water	Pure water	Water
	Other water, tea and coffee	Coffee (excluding added sugar) Tea (excluding added sugar) Other hot drinks water and milk based
	Soup	Soups
	Soft drinks, low calorie	Diet carbonated drinks (includes low calorie drinks) Cordials & squashes
	Soft drinks, not low calorie	Other carbonated drinks (not diet) Fruit drink, ready to drink (sweetened) Other cordials and squashes
	Alcohol	Alcohol
	Beverages dry weight	NONE
Bread and cereals	Wholemeal Bread and Brown, granary and wheat germ bread	Brown and wholemeal bread/rolls
	White Bread and other bread	White bread/rolls Bread, other <8g/100g fat Bread, other >8g/100g fat
	High Sugar Breakfast Cereals	Breakfast Cereal, high sugar Breakfast Cereal, sugar coated
	High fibre and other Breakfast Cereals	Breakfast alternatives Breakfast Cereal, other
	Buns, cakes, pastries and fruit pies	Cakes Non meat containing savoury pies and pastries Savoury biscuits and baked goods Sweet breads
	Other Puddings	Non milk based sweet puddings
	Biscuits	Sweet biscuits
	Sugar confectionery	Chewing gum Sweets (non-chocolate)
Potatoes and grains	Chips, Fried and Roasted Potatoes	Chips, fried Chips, oven Microwave chips Potato, roast Potato products
	Other Potatoes	Potato, other Jacket potatoes
	All Grains	Cheese dishes Couscous, bulgar wheat Dehydrated convenience foods etc Noodles and noodle dishes Pizza

DQI-A Food Group	DQI-A Sub food group	Food/Drink item/HNRC food group
		Pasta Rice Tinned cereals Cereal based savouries
	Nuts and seeds	Nuts
	Crisps and savoury snacks	Non-potato snacks Potato based crisps – full fat Potato based crisps – low fat
Vegetables	Salad and other raw vegetables	Dressed salad dishes
	Vegetables (not raw) Other vegetables	Baked beans Baked beans with sausages/burgers Non meat based pasta dishes Other vegetables (excluding potato) Peas Pulses and lentils Quorn/TVP and dishes Vegetable dishes Vegetables based rice dishes
	Herbs and spices and sauces	Herbs and spices Ketchup Salt
Fruit	Fresh fruit	Fresh fruit
	Other fruit (including dried, canned)	Canned/stewed fruit Dried fruit
	Fruit Juice and smoothies	Fruit juices
	Sugars, preserves, and sweet spreads	Sugar, table Preserves and syrups
Milk Products	Skimmed Milk and one per cent milk	Milk, skimmed
	Semi-skimmed Milk	Milk, semi-skimmed
	Whole Milk	Milk, whole
	Other Milk and Cream	Cream Milkshakes
	Nutrition Powders and Drinks	NONE
	Low-fat Yogurt and Fromage Frais	Low fat yoghurt/fromage frais
	Other Yogurt, Fromage Frais and Dairy Desserts	Whole milk yoghurt/fromage frais
	Milk Based Puddings	Milk based sweet puddings
	Dairy Ice Cream	Chocolate covered ice cream bars Ice cream, ice cream desserts and lollies
Cheese	Cottage Cheese	Lower fat cheese
	Cheddar Cheese	Other cheese
	Other cheese	Processed cheese

DQI-A Food Group	DQI-A Sub food group	Food/Drink item/HNRC food group
Meat	Beef, Veal and Dishes	Beef and beef dishes
	Lamb and Dishes	Lamb and lamb dishes
	Chicken and Turkey Dishes	Chicken/Turkey dishes Meat based rice dishes
	Coated chicken and turkey, manufactured	Chicken in batter Chicken/Turkey in breadcrumbs
	Pork and Dishes	Pork and pork dishes
	Bacon and ham	Bacon and ham
	Sausages	Sausages
	Burgers and Kebabs	Burgers and kebabs
	Meat Pies and Pastries	Pies and pastries
	Liver Dishes	Liver and liver dishes
	Other Meat and Meat Products	Cereal based savouries with vegetable or meat additions Meat and potato dishes Meat based pasta dishes Other meat Gravy
	Oily Fish	Oily fish
	White fish, coated or fried	Fish in batter Fish in crumbs
	Other white fish, shellfish and fish dishes	Fish dishes Other white fish Shellfish
	Eggs and Egg Dishes	Egg dishes Eggs
Fats and oils	Butter	Butter
	PUFA margarine	Polyunsaturated
	PUFA Vegetable Oils	NONE
	Low fat spread	Low fat polyunsaturated
	Reduced Fat Spread	NONE
	Other Margarine, Fats and Oils	Dairy fat spreads includes hard marg Monounsaturated Other sauces Oils
	Chocolate Confectionery	Chocolate

Appendix G. Breakdown of diet quality component score by food group and year

DQI-A Food group	DQc Component score						p-value
	2000 (*n*=166)		2010 (*n*=85)		2022 (*n*=120)		
	Mean	SD	Mean	SD	Mean	SD	
Water	-37.7	36.6	-35.7	47.6	11.7	51.8	p<0.001
Bread and cereals	-44.9	21.6	-34.4	24.1	-30.1	23.8	p<0.001
Potatoes and grains	-55.3	20.0	-50.3	23.8	-49.5	21.1	p=0.048
Vegetables	54.9	27.2	77.4	28.9	67.6	30.0	p<0.001
Fruit	-21.6	38.9	-22.9	66.6	-33.1	64.9	p=0.204
Milk products	34.4	35.9	36.5	45.0	32.1	60.9	p=0.811
Cheese	0	n/a	0	n/a	0	n/a	n/a
Meat and fish	-11.8	31.0	-16.8	39.5	-26.3	42.3	p=0.005
Fats and oils	-49.2	25.4	-68.8	30.8	-70.5	25.8	p<0.001
Overall DQc score	-25.0	20.5	-21.9	26.5	0.2	31.0	p<0.001