Income and food insecurity:

Impact on diet quality and micronutrient intakes of females living in the United Kingdom.

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FOREWORD

This research was completed as part of the Doctoral Training Programme (DTP), funded by the Bioscience Biotechnology and Research Council (BBSRC) under the supervision of Dr Lisa Coneyworth, Dr Susan Azam-Ali and Dr Simon Welham. The original research presented in this thesis was completed during the COVID-19 pandemic 2020-2022 as such some of the research was completed at a time when the UK was in “Lockdown” and restriction were in place for meeting people.

Prior to COVID-19, the research was focused on the ethnic diversity and iodine intake of Orang Asli population groups in Peninsular Malaysia. This research took place between April 2019 and March 2020. The research was stopped mid fieldwork in March 2020 when it became apparent the severity of COVID-19 and access to the Orang Asli population was rescinded by JAKOA (Department for Orang Asli). I returned to the UK on March 17th a day before movement restriction was introduced in Malaysia and 6 days before the first UK lockdown. Samples collected as part of this research (urine, food and salt samples) were unable to be shipped to the UK due to restrictions in Malaysia halting access to university facilities. To mitigate the impact of COVID-19 on the research it was evident of the need to alter the original research and focus on population groups in the UK. The research focus was changed to investigate micronutrient status, diet quality and food security status amongst different population groups in the UK as it was evident there was growing food insecurity in the UK and this was worsened by the COVID-19 pandemic, however, the evidence for nutritional security was lacking.

The original research in this thesis is written in the style accepted for, submitted for, or suitable for publication. Therefore, results chapters are presented in the style of a manuscript each containing their own introduction, methods, results and discussion. Where applicable, measures used in the collection of data have been included as an appendix and the published papers.

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Publications and presentations resulting from this research.

Thomas. M, Coneyworth, L. & Welham, S. (2022). Influence of income on diet quality and daily iron and zinc intake: analysis of the National Diet and Nutrition Survey of British females aged 11-14- and 15-18-years *European Journal of Nutrition*. Available at: doi: 10.1007/s00394-022-03000-z

Thomas, M., Eveleigh, E., Vural, Z., Rose, P., Avery, A., Coneyworth, L., & Welham, S., (2022). The impact of the COVID -19 pandemic on the food security of UK adults aged 20-65 years (COVID-19 food security and dietary assessment study. *Nutrients*, Available at: doi.org/10.3390/nu14235078

In final preparation for submission.

Thomas. M., O'Reilly, P., Coneyworth, L., & Welham, S. (2023). Food security status, diet quality and coping strategies amongst UK (United Kingdom) adults with an income from Universal Credit who received the £20 a week uprating during the COVID-19 pandemic: Benefits and Nutrition Study (BEANs), a cross sectional study.

Poster presentations.

Thomas, M., Coneyworth, L., Stubberfield, J., Pearce, J., & Welham, S. (2021). Investigating the iron and zinc content of a popular meal in the diet of UK children and its contribution to daily micronutrient intake for females aged 11–14 years. *Proceedings of the Nutrition Society, 80*(OCE1), E11. doi:10.1017/S0029665121000124

Thomas, M., O'Reilly, P., Rahardiyan, D., Sjögersten, S., Coneyworth, L., & Welham, S. (2021). Estimation of dietary iodine intake for adults living in North Sulawesi, Indonesia. *Proceedings of the Nutrition Society, 80*(OCE1), E37. doi:10.1017/S0029665121000380

Thomas, M., Coneyworth, L., & Welham, S. (2022). Social Supermarkets (SSMs) and redistribution of surplus food: What is the contribution to the micronutrient intake of a low-income population group in Coventry? Total Food Conference. University of Nottingham.

Reports written for external organisation.

Thomas, M., Engagement Strategy and Evaluation Methods (2021). Report written for Chef in Schools as part of Professional Internship Placement (PIPs). (Appendix D).

Thomas, M., Coneyworth, L., & Welham, S. (2022). Redistribution of surplus food in the contribution to the diet of low-income groups: Could this facilitate a 'Right to food' and address diet and health inequalities. Report written for Diane Williams, Henley Grub Hub Coventry. (Appendix E).

Abbreviations

B_1	Thiamine
B_2	Riboflavin
BMR	Basel Metabolic Rate
CiS	Chefs in Schools
COMA	Committee on Medical Aspects of Food Policy
DQI-1	Diet Quality Index- International
DQI-A	Diet Quality Index- Adolescents
DRV	Dietary Reference Values
EAR	Estimated Average Intake
EFSA	European Food Safety Authority
EI	Energy Intake
FAO	Food and Agricultural Organization
Fe	Iron
FIES	Food Insecurity Experience Scale
FRS	Family Resource Survey
H_2O_2	Hydrogen Peroxide Reactive Oxygen Species
HFIAS	Household Food Insecurity Access Scale
ID	Iron Deficiency
IDA	Iron Deficiency Anaemia
IMD	Indices of Multiple Deprivation
LRNI	Lower Reference Nutrient Intake
NDNS	National Diet and Nutrition Survey
NHS	National health service

PIPs	Professional Internship Placement
RNI	Reference Nutrient Intake
ROS	Reactive Oxygen Species
S.E.M	Standard Error of the Mean
S.E.S	Socio-Economic Status
SACN	Scientific Advisory Committee on Nutrition
T3	Triiodothyronine
T4	Thyroxine
USDA	United States Department of Agriculture
Zn	Zinc

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ABSTRACT.

Food insecurity in the UK is amongst the worse in Europe and was increasing before the COVID-19 pandemic and continues to increase as the UK is in the midst of a “Cost of Living Crisis”. Research has shown those at risk of food insecurity are more likely to be from low-income households, to be female, have children, have disability or are from ethnic and racial minorities. However, the monitoring of food security in the UK is in its relative infancy, it was not until 2019 that the USDA 10 question adult food security module was introduced into the Family Resource Survey, the first time all four nations of the UK food security was measured in private households.

The research in this thesis is primarily concerned with the prevalence and severity of food insecurity amongst different population groups in the UK at time when there was disruption to individual’s lives because of the COVID-19 pandemic and their ability to access food. Food access in terms of this research is defined as having the financial resources to purchase food. Furthermore, this research expands on the experience of food insecurity to understand the nutritional security of females in the UK and if there are differences in diet, diet quality and micronutrient intakes between income groups.

Whist understanding who is at the risk of food insecurity is of importance so too is nutritional security, research is needed to understand the contribution of different foods to energy and nutrient intakes amongst food insecure households and not just the quantity of food consumed. Diet is a factor in development of preventable diseases, and it is known a social gradient in diet and health exists. Food related ill health is costly to the individual and to society. The increasing prevalence of food insecurity in the UK is a public health concern, and diet and health inequalities are likely to widen disproportionately impacting those more likely to experience food insecurity and females in particular as they have higher physical requirement for some vitamins and minerals compared to males and when entering the child bearing years with inadequate levels of some minerals, this can negatively impact the growth and development of future generations[1].

As such, this researched focused on the nutritional security of adolescent girls and adult women because 1) the experience of food insecurity is associated with high rates of poverty, previous research indicates females are disproportionately represented in low income groups compared to men (Maynard et al., 2018). 2) Adolescent females have a higher requirement for iron compared to males from the age of 11 years onwards. Iron requirements are increased to support growth and development at this life stage in both males and females however there is a need to compensate for the loss of iron due to menstruation in females. Zinc requirements are higher for 11–14-year females compared to 15-18 years to support

[1] During pregnancy there is increased requirement for iron, particularly in the third trimester, to support the females' own requirements, plus those of the developing foetus. Anaemia with or without iron deficiency (IDA,) for the mother, is associated with decreased mental and working capacity (Resseguier et al., 2022) and is a factor in spontaneous abortion or low birthweight of the neonatal. For the child born to mothers with IDA there is evidence of association with autism (Resseguier et al., 2022). Insufficient iodine intake can impair cognition of adults, whilst deficiency during pregnancy is the leading cause of preventable brain damage. Additionally, women up to the age of 50 years have a higher requirement for iron because of menses.

increased physiological requirements at this life stage 3) Previous studies show adult women have lower intakes but higher requirement for some micronutrients compared to males (e.g., iron). A previous study showed riboflavin, iron and iodine intakes amongst females to be lower compared to males (Derbyshire, 2018).

The two published manuscripts and the manuscript in preparation for submission provide a unique contribution to the knowledge of food security and nutritional insecurity in the UK amongst different population groups. Whilst adolescent females are represented within national surveys, analysis of equivalised household income influence on diet and nutrient intakes are not fully explored. Adolescents is a time when there is greater autonomy in food choice and whilst this may explain some of the differences in diet and nutrient intake, food choice is also influenced by caregivers/ parental choice, which is in, part is influenced by the income available to spend on food. Manuscript 2 took place at a time when the UK and indeed the world were amid the COVID-19 pandemic, and as such, research into food and nutritional insecurity in the UK at this time was a burgeoning area. The study set out to understand the impact of the Covid-19 Pandemic on food and nutritional security across the income spectrum and if those with a lower equivalised household income were disproportionally impacted at a time when UK food retailers were unable to keep pace with consumer demand and movement restrictions were enforced.

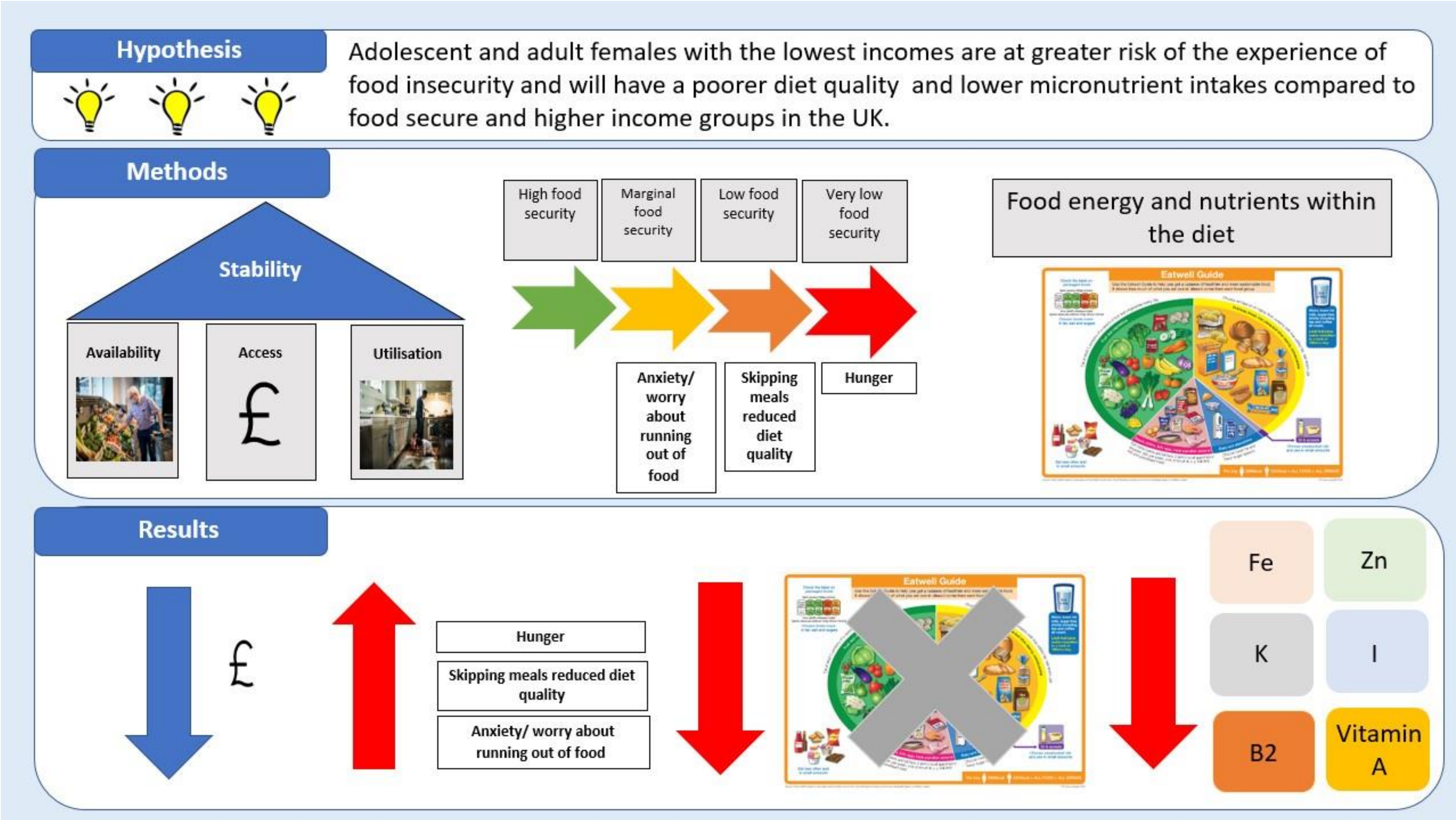
Study 3 expanded on paper two seeking to understand the Food and Nutritional security amongst those with an income from Universal Credit and the influence and subsequent removal of the £20 a week uprating to

Universal credit has on foodbank usage and food purchase. The novelty of the study was in its targeting to population groups across England, Scotland and Wales with an income from Universal Credit. Historically households with income from benefits in National Surveys are not fully representative and as such, sub-analysis of the data is not always possible due to the small sample sizes. Combined, the three cross sectional studies in this thesis find adolescent girls and adult women in the UK have a poorer diet quality, micronutrient intakes, which are low, compared to the RNI and a high percentage with dietary micronutrient intakes below the LRNI. The diets of lower income adolescents and adult women do not meet the criteria for food and nutritional security, as they do not have diet with sufficient quantity of nutritious foods. In general, the studies found a gradient in micronutrient intakes and diet quality when categorised by equivalised household income.

This work has highlighted the nutritional security of low income and food insecure female adolescents and adults to be poor when compared to their higher income and food secure counterparts. Highlighting the need for targeted interventions to address both food and nutrition insecurity in the UK.

ABSTRACT.

VISUAL ABSTRACT.



1 CHAPTER 1. INTRODUCTION

The aim of this chapter is to explore the definitions and concepts of food security, food insecurity and nutrition security, how, what, why they are measured, and how they are interlinked. Section 1.1 discusses the concepts of food security and refers to the relationship with income and poverty. There is also discussion on how measures of food insecurity differ to that of S.E.S and IMD as method for identifying who is at risk of diet and health inequalities in the UK. In section 1.3, nutrition insecurity is discussed and why it is important to consider alongside measures of food insecurity. Whilst section 1.6 is concerned with the prevalence of household food security in the UK.

Assessment of micronutrient intakes with a focus on Dietary Reference Values in the estimation of population group's micronutrient intakes are discussed in section 1.8, whilst biological markers for some micronutrients are covered in section 1.9 The physiological role and function of micronutrients as well as health outcomes associated with deficiency are discussed in section 1.10. Food security: Definitions and concepts.

The concept of food security has evolved since it was first defined by the World Food Conference in 1974, when at that time, the focus of food security was on ensuring an adequate and affordable food supply, both internationally and nationally (FAO, 2006).

Early definitions of food security were concerned with availability domain of food security and ensuring there were enough basic supplies of food stuffs, that if there were a widespread crop failure, acute food shortages could be avoided. The principal strategy to mitigate food shortages was to increase food production. The 'Green Revolution' as it was termed focused on technological advancements for increasing crop yields (Clapp et al., 2022). And the focus of the research at this time was on domestic and global food production, the role of natural disasters and price spikes on food security (Webb et al., 2006).

There was a shift in focus to the access domain of food security after Amartya Sen seminal work *Poverty and Famines* (1981). Which explored the concepts of entitlements to food, that while there may a sufficient quantity of food households are unable to access that foods if they do not have the means to do so (Webb et al., 2006).

Since then, there have been several iterations, the now widely accepted definition by the World Food Summit developed in 1996 which defines food security as:

"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2006).

The above definition applies to individuals, household, regional, national and global levels (Jones et al., 2013) and is concerned with macro and micronutrient components of the diet. The United States Department of Agriculture (USDA) in addition, stipulate for a household to be food secure, they require at a minimum, the ability to acquire foods in socially acceptable ways, defining socially acceptable ways as, without resorting to emergency food supplies, stealing or other coping strategies (USDA, 2022a).

The FAO, food security definition encompasses the four domains for ensuring food security. These are “food availability” concerned with food supplies, “access to adequate food” concerned with physical and economic access, “utilisation of food” concerned with food safety, knowledge of food preparation and cooking as well as health status, whilst “stability” is concerned with the stability across each of the domains (Charlton, 2016). If any one of the domains becomes unstable, due to instability of any of its determinate factors (Table 1.1) then food insecurity can ensue.

However, the concepts of food security continue to evolve and the High-Level Panel of Experts on Food Security and Nutrition Committee on World Food Security in recent years have highlighted the dimension of agency, and sustainability as necessary for food security. Agency refers to the ability of individuals to make their own choices regarding food whilst sustainability refers to the long term ability of the food systems to ensure food security without comprising food security for future generations (European Commission, 2023; HLPE, 2020).

Table 1-1. The domains of food security and their determinate factors.

Domain		Determinate factors
Stability	Food availability	Domestic productions
		Imports
		Food stocks
		Food aid
	Food access	Income and purchasing power (affordability)
		Transport (Public and personal)
		Types and quantity of shops available
	Utilisation	Food safety
		Diet quality and diversity
		Health status (i.e., ability to absorb nutrients)
		Food literacy (Knowledge of food preparation, cooking, safety, nutrition, costs)

Adapted from (Charlton, 2016) and (FAO, 2006).

Research in high income countries is predominately focused to the food access domain and the availability of economic resources for the procurement of food. Within the FAO definition it is not enough to have a sufficient quantity of food, the food also has to be good quality and not cause harm, that is the food is not rotten, is produced in sanitary conditions and not past its use by date to be food secure, it also has to be nutritious, whilst there may be sufficient calories the food need to provide the wide range of nutrients the human body requires for health and wellbeing (Schroeder and Smaldone, 2015). This differs to the measure of food insecurity in low-income countries where physical access and or availability to foods may comprised due to natural disasters- drought, famines or utilisation of the food by the body is impaired due to

1.1.1 The concept of the food security continuum.

The identification of a continuum in food insecurity was derived from research of low-income households' experience of hunger in the United

States, the complexity of food insecurity and differences in the way individual experience food insecurity within households (Loopstra, 2018). The experience of food insecurity has been shown to have four common core dimensions, these are as follows: 1) psychological, whereby a person experiences anxiety and worry about the ability to procure enough food, 2) qualitative, whereby a person adapts the diet by reducing quality and variety of the food in the diet. 3) quantitative, whereby the quantity of food is reduced, household stocks are depleted, and meals are skipped or there are whole days where a person does not eat at all. 4) The social aspect of food insecurity whereby changes are made in the method of procuring food, e.g., the need to acquire from a Foodbank or other charitable organisations. An inability to participate in social activities connected to food- e.g., going out for a meal or have family or friend round for dinner (Loopstra, 2018).

The food security continuum evolved out of the above descriptions and captures the increasing in severity of food insecurity from “high” or fully food secure to “very low food security” (Figure 1.2). There are four domains along the continuum and each of the domains are characterised by a distinct set of characteristics which may influence the diet and nutrient of those who experience any form of food insecurity (Figure 1.2). As the severity of food insecurity increases the quality of foods in the diet is comprised and at the extreme when there is ‘very low food security’ a reduction in the quantity of foods consumed which can mean skipping meals or going one or more days without eating. Ultimately the experience of food insecurity impacts on food patterns, diet quality and nutritional composition of individuals’ diet. The experience of food insecurity is similar across cultures (FAO, 2023a) in that there is anxiety or worry about having enough food to adapting the diet to mitigate not having enough food. This is discussed in further detail in section 1.2 food insecurity. Whilst food and nutrition security maybe thought of as one of the two same things, they are quite different but equally important for understanding food access and the quality of the foods accessed. Quality in this incidence is referring to the nutrient composition of the foods and if foods are optimal for health, that is, are they rich in nutrients to be encouraged in the diet such as vitamins and minerals but low in nutrients to be eaten less frequently and known to be detrimental to health when consumed in excess of requirements such as saturated fat, energy, sugar and salt.

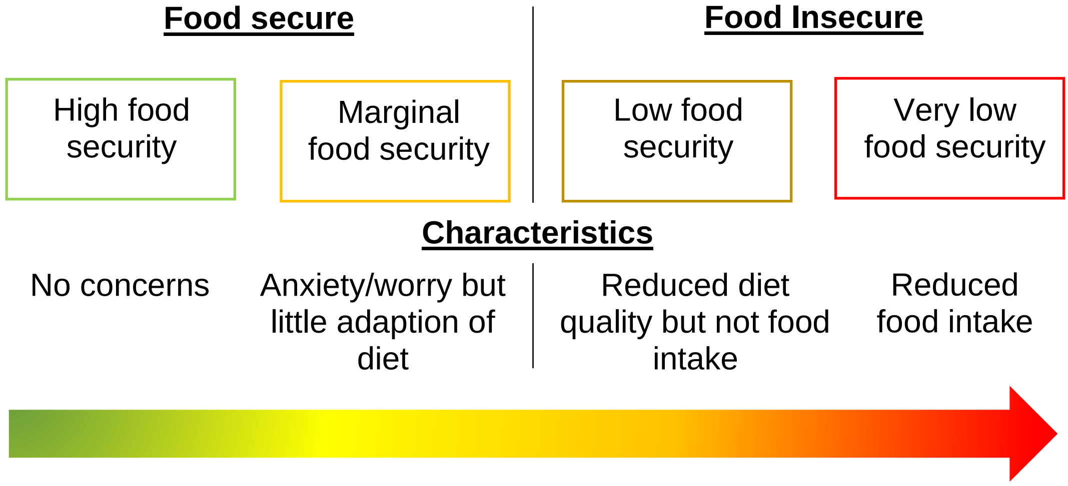


Figure 1-1. Continuum of food security scale and concepts. Adapted from the USDA

The measurement of food security in the UK is relatively recent (discussed in section 1.6) however, there is a long history of research investigating the relationship between diet and diet related health inequalities [2] and an individual's socioeconomic status. An individual's socio-economic status in

[2] Inequalities in diet contribute to overall inequalities in health (UK Parliament, 2022) .

the UK is defined by the type of work an individual does or did do if retired (GOV.UK, 2018). However, research investigating the relationship between S.E.S and diet and diet related health inequalities uses level of income, level of education or occupational status as an indicator of S.E.S. Although educational level will be a factor in type of work an individual can do and type of work will be a factor in the level of income that can be earned, they cannot be used interchangeably for measuring diet and diet related health inequalities as depending on the indicator used, it will determine the extent of the severity of the diet and diet related health inequalities observed (Darin-Mattsson et al., 2017). But as a general rule as socio-economic status increases so too does the quality of the diet, life expectancy and years lived without ill health (Stringhini et al., 2017).

However, the use of socio-economic status may not be able to capture who is at risk of food insecurity because of the complex nature of the drivers of food insecurity and the complexity of individuals. Thus broadly grouping people based on income, education or occupational status means there is a risk of over or under estimating the prevalence of food insecurity within S.E.S groups as there will be exceptions, not all in lower S.E.S will experience food insecurity due to monetary constraint, have a poor quality diet, develop diet related diseases and live with extended years in ill health or die earlier and vice a versa with higher S.E.S groups.

The English Indices of Deprivation of which there are 7 domains [3] are used to rank Lower Super Output Areas (LSOA), these are small geographical areas of approx. 1500 residents of which there are 32,844 in the UK from most deprived to least deprived. When combined these domains form the Indices of Multiple Deprivation (IMD). Research into the relationship between diet and diet related health inequalities have shown children aged 11 years in the most deprived areas to have a greater prevalence of overweight and obesity compared to least deprived areas (Noonan, 2020). In Scotland adults in the most deprived areas purchased less fresh fruit and vegetables compared to least deprived and the amount spent on food increased as deprivation decreased (Whybrow et al., 2018). Research in deprivation and health has meant considerable resources have been allocated to areas to tackle deprivation and address inequalities (Lloyd et al., 2023) . However the use of IMD for the prediction of food insecurity may not capture fully all who experience food insecurity due to monetary constraint and as is the case for S.E.S, it is the same for IMD being in a most deprived areas does not mean an individual will experience food insecurity and being in a least areas does not mean they won't experience food insecurity and vice a versa. Population groups within geographical

[3] The seven domains of the English indices of deprivation and their contribution (in brackets) when combined to form the Indies of Multiple Deprivation are as follows: Income (22.5%) measure the proportion of the population experiencing deprivation relating to low income. Employment (22.5%) measure the percentage of the working age population not in the labour market. Education (13.5 %) measure lack of attainment or skills. Health (13.5%) measure risk of premature death or years lost to ill health. Crime (9.3%) measure the risk of being a victim of crime. Barriers to housing and services (9.3%) measures the physical and finical accessibility to housing and local services. Living environment (93% measure quality of indoor and outdoor local life (GOV.UK, 2019).

areas are not homogeneous and household food security status differs depending on circumstances. Thus, there is a need to measure food security at the geographical level to fully understand the prevalence and severity of food insecurity within the UK and who is at risk of food insecurity and how this impacts diet and diet quality.

Food insecurity.

1.1.2 Definitions and concepts.

The definition of food insecurity is “the uncertainty and insufficiency of food availability and access that are limited by resource constraints, and the worry or anxiety and hunger that may result from it” (FAO, 2008). The term ‘Food Poverty’ may be used interchangeable with ‘Food insecurity’ however there is no widely accepted definition of ‘Food Poverty’ (Francis-Devine et al., 2022).

Food insecurity is a multidimensional problem (Righettini and Bordin, 2022) with multiple causes. However, In the UK and other high income countries low income is a major contributor to the experience of food insecurity. Low-income households with children and individuals living with a disability, are disproportionately impacted by the experience of food insecurity (Loopstra et al., 2019), as are racial and ethnic monitories groups and households in receipt of benefits (Maynard et al., 2018).

The experience of food insecurity can be chronic or transitionary and, in some instances, seasonal. In high-income countries, it is possible for people to experience chronic or transitory food insecurity due to a lack of monetary resources however, the severity of food insecurity experienced is variable and not all will experience the acute discomfort of hunger due to a lack of energy. Nevertheless, the characteristics of food insecurity at marginal and low food security can contribute to various forms of malnutrition having adverse repercussion for health and wellbeing (“Hunger,” 2021).

1.2 Nutrition Security.

1.2.1 Definitions and concepts.

Food security is a prerequisite for nutrition security (Ghattas, 2014) but being food secure is not enough to ensure nutrition security (Charlton, 2016; Jones et al., 2013) (Figure 1.1). The FAO in its 2012 report “The state of food insecurity in the world” defined nutrition security as

“A situation that exists when secure access to an appropriately nutritious diet is coupled with a sanitary environment, adequate health services and care, in order to ensure a healthy and active life for all household members” (FAO et al., 2012).

That is, there may be enough energy (kcal), but the food consumed is of poor quality in terms of food safety (unsafe to eat) or an individual’s health status does not facilitate the absorption of nutrients, or the food consumed does not provide the array of nutrients required for health. Nutrition security is concerned only with an individual’s (mal) nutritional status as a result of foods included in the diet and their health status (Righettini and Bordin, 2022), whilst food security is concerned with nutrition, it is also concerned with the availability, access, utilisation and stability of food systems and resources.

Diets which are energy dense but nutrient poor can result in “Hidden Hunger”, a term used to describe the deficiency of micronutrients (Lowe, 2021), so called because the effects of micronutrient deficiencies are not always discernible. However, the consequences to health are serious (Das and Padhani, 2022). Micronutrients refer to vitamins and minerals that are required by the body in small amounts. Deficiency and suboptimal intake can impair growth, development and cognition in children and adults. Health impacts of micronutrient deficiency are discussed in section 1.12 “Micronutrient deficiency and sub-optimal intakes on heath.”

There is also the paradoxical phenomenon of overweight and obesity associated with food insecurity (Benjamin Neelon et al., 2017; Carvajal-Aldaz et al., 2022; Dhurandhar, 2016; Gooding et al., 2012; Keenan et al., 2021). While it is suggested that low cost, energy dense, nutrient poor diets are factor in the overweight and obesity, the mechanism by which food insecurity leads to overweight and obesity is unclear (Brown et al., 2019).

1.3 Measures of household food security.

In the UK, food security is measured as part of the Family Resource Survey and the Food and You Survey using the 10 questions in the adult food security survey module (appendix A). The 10 questions of the survey assess a household ‘Access’ based on economic resource available for the purchase of foods (Table 1.1). As the questions progress the severity of food insecurity increases and in a worst-case scenario a person my skip meals or go whole days without eating.

There are several other tools available to measure food insecurity (Table 1.2) including U.S Household Food Security Module, an 18-item survey that includes questions designed to capture food security amongst children as well as adults for households with children.

Depending on the tool used and the methods for classifying food insecurity gives different values for prevalence of food insecurity. For example, the USDA 10 question adult food survey module combines the last two domains (low food secure and very low food secure) as food insecure. Whilst the HFIAS doesn't make a recommendation for the domains to be included the overall classification of food insecurity as such marginal food insecurity may be incorporated into the overall prevalence. The food insecurity experience scale (FIES) is an eight-item questionnaire that uses the raw score as a sliding scale to determine the severity of food insecurity, the higher the score, the increasing severity of food insecurity experienced. If using FIES to compare the prevalence of food security internationally, respondents are first assigned to the standard domains of the food security continuum. A positive answer to question "ate less", is assigned to the domain moderate/low food insecurity whilst a positive answer to the question "went whole day without eating" is assigned to the domain severe/ very low food insecurity. The USDA stratifies the raw score of the survey results to determine the domain of food insecurity experienced. As such an individual can have very low food insecurity even if they have not gone a whole day without eating. Therefore, if comparing the prevalence of food insecurity between and within population groups' survey type should be considered as results are likely to differ.

Furthermore, the time frame of either the previous 30-days or the previous 12 elicit different results due to the nature of food insecurity often being transient meaning a household who experience food insecurity one month but not the following may not register as food insecure if the 30-day time is used. It is estimated the 30-day time frame under estimate the prevalence of food insecurity by approximately 50% (Loopstra, 2019).

Table 1-2. Different types of food security survey tools and terms used for classification of food security status.

Organisation	Survey Tool	Terms	Domain of Food security assessed
USDA	U.S. 18 question*/Adult/ 6 item Food Security Module**	• High food security among adults • Marginal food security among adults • Low food security among adults • Very low food security among adults	• ACCESS
FANTA	Household Food Insecurity Access Scale	• Food secure • Mildly food insecure • Moderately food insecure • Severely food insecure	• ACCESS
Radimer/Cornell	Radimer/Cornell	• Food secure • Household insecure • Individual insecure • Child hunger	• ACCESS
FAO	Food Insecurity Experience Scale (FIES)	• Mild food insecurity though to • Severe food insecurity	• ACCESS

* Measures where appropriate, food insecurity of children living in the household
** Survey tool used in the UK to measure food security as part of the Family Resource Survey

1.4 Household Food Security: Why is it important to the UK?

Food insecurity is a growing public health problem with the prevalence of adult food insecurity being amongst the worse in Europe (UK Parliament, 2019). Even before the global COVID-19 Pandemic of 2020, food insecurity was increasing (The Food Foundation, 2021; Loopstra, 2020; Loopstra et al., 2019) whilst the ‘cost of living crises' continues to exacerbate the prevalence of food insecurity (O’Brien, 2022; The Food Foundation, 2022a).

The experience of food insecurity coupled with poor diet quality is a factor in adverse health outcomes and the development of diet related disease’s e.g., cardiovascular disease, diabetes some types of cancer, obesity and depression (Ejebu et al., 2018). Studies researching the impact of food insecurity and poor dietary quality on micronutrient deficiency in high income countries have shown a relationship between food security and iron deficiency with or without anaemia amongst children under 3 years of age (Park et al., 2009) children over 3 years, adolescents and adult women (Eicher-Miller et al., 2009; Moradi et al., 2018). A study from Canada reported those who died before their 65th birthday and were ‘moderately’ or ‘severely’ food insecure died on average 9.6 months earlier than their food secure counterparts (Men and Tarasuk, 2020). The risk of death for adults in the US with ‘very low food security status’ was reported to be twice that of those who were food secure (Walker et al., 2019). A strong correlation was observed between chronic disease and experience of food insecurity when living 200% below the federal poverty line in the US with a higher probability of chronic diseases as severity of food insecurity increased (Gregory, 2017).

Furthermore, the experience of food insecurity is detrimental to an individual’s physical and mental health (Blake, 2019; Jones et al., 2013), with food insecure females having higher rates of depression and anxiety (Maynard et al., 2018). The experience of food insecurity is associated with the adoption of unhealthy eating practices, linked to, obesity and malnutrition (Dhurandhar, 2016) food insecurity. Food insecure adults are more likely to have sub optimal nutrient intakes compared to food secure (Kirkpatrick and Tarasuk, 2008).

Malnutrition and unhealthy diets are a significant factor in development of disease (Lowe and Mahmood, 2022), food insecurity has been associated with increased prevalence of chronic diseases such as diabetes mellitus and cardiovascular disease (Hanmer et al., 2021) and food insecure adults more frequently access health systems than food secure (Hanmer et al., 2021; Loopstra et al., 2019). The cost to treat malnutrition and diseases associated with it is costly, placing a significant burden on the NHS. It is forecast, the cost to the NHS of treating malnutrition will be £19.6 billion per year by 2050 (Lowe and Mahmood, 2022).

Variations in household food security status exist in the UK depending on S.E.S (UKSSD, 2018) with lower SES households more likely to be food insecure (Brown et al., 2022). The relationship between S.E.S, diet and health inequalities is well established (Darmon and Drewnowski, 2015) (Livingstone et al., 2017). Analysis of the relationship between S.E.S based on dimensions of educational attainment or occupational status show those with a lower S.E.S are the more likely to have a diet that is energy dense, nutrient poor and contains fewer fruit and vegetables compared to those with a higher S.E.S (Galobardes et al., 2001; Alkerwi et al., 2015).

The experience of food insecurity is thought to further compromise the quality of the diet and may affect the overall energy and nutrient composition potentially adversely comprising an already poor-quality diet. Households in times of financial hardship/income instability or food price increase tend make to adjustments to the quality and the quantity of food consumed by 'trading down' to cheaper products (i.e. branded to non-branded items, cheaper cuts of meat) and this was more prominent in households in the bottom 20% of income quintile (Revoredo-Giha et al., 2019). Households adopting these measures could be considered to have 'a low food security status where quality of food is compromised but not the quantity of food. How this affects the nutritional composition of the overall food in the diet requires further research but a previous study suggest 'trading down' in a food category increases the uptake of products which are higher in saturated fats, sugar and salt (Revoredo-Giha et al., 2019).

However, not all households are able to 'trade down' because they are already buying the cheapest items, these are often the lowest income households (DEFRA, 2022a; Revoredo-Giha et al., 2019). Therefore, the next stage is the reduction of the quantity of food purchased resulting in the potential for reduced energy and nutrient intakes. This 'trading down' and reducing quantity of food compounds further an already lower quality diet widening further diet and health inequalities, preventing individuals from thriving and reaching their full potential economically and socially.

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The UK has a high degree of national food security (Stewart, 2019), and there is adequate levels of food available in the UK for each person of the population. The FAO Food Balance Data sheets indicates between the years 2018-2020 the average dietary energy supply was 138% of requirements (>3326.33 kcal/per capita/ per day) (FAO, 2023b).The UK produces a vast array of food for domestic consumption (Approximately 60%). In 2020, the UK produced 100% of domestic consumption of oats and barley and 90% of wheat. Per person per year, the UK produces 61kg of meat, 227 litres of milk and 172 eggs. However, foods such as fish are typical imported mainly due to preference for fish grown outside of UK water. Whilst fifty percent of the vegetables consumed in the UK are grown domestically and 16% of fruit consumed is grown domestically the remainder is imported (DEFRA, 2021).

Ensuring food security of all people is important; the consequence of food insecurity is detrimental to a country at regional, household and individual levels. Furthermore, the UK played a central role in the development of 2030 Agenda for Sustainable Development (Stewart, 2019) and committed to the sustainable development goals (SDGs) of which there are 17. Goal one (no poverty) and two (zero hunger) are closely tied and are of relevance to this research, however, the UK is not on track to meet these specific SDGs by 2030 (UKSSD, 2018).

Therefore, addressing food in security is of paramount importance and necessary for the overall development and productivity of a country (Jones et al., 2013). Regional variations emerge in diet, health, life expectancy and productivity of a country where there are high levels of food insecurity compared to other regions (Power et al., 2020).

1.5 Measurement of household food insecurity in the UK

Historically measurement of food insecurity in the UK has been inconsistent and fragmented (Pool and Dooris, 2021), whilst the U.S have been measuring the prevalence of food insecurity since April 1995 (USDA, 2022b; ENUF, 2022). However, It was the rapid rise of Food Banks in the UK that drew attention to the rising levels of food insecurity (Loopstra, 2018) but it wasn't until 2019 that the UK introduced routine monitoring of food (in)security as part of the Family Resource Survey (FRS). The tool used for the measure of food (in) security in FRS is the USDA ten question adult food security survey module (Appendix A) with a time frame of the previous 30 days. Monitoring of food security as part of the FRS will be used in tracking progress towards goal two "Zero Hunger" of the sustainable development goals (Loopstra, 2019; UK Parliament, 2019).

There is some concern that the previous 30-day period does not capture the true extent of food insecurity in the UK and using a period of the previous 12 months would be preferable. The scope of the FRS is such that the previous 30 days meets the objectives of the survey; in that it is collecting current data. However, the 30-day period may understate the true extent of food insecurity whilst preventing the understanding of the annual prevalence of food insecurity. Loopstra illustrates this with data from the United States which showed food insecurity prevalence when measured in the previous

30 days was 5.5 percentage points lower than when a 12-month time frame was used (Loopstra, 2019).

Prior to the inclusion of the USDA 10 adult food security measure in the FRS, the ‘Food and You Survey’ commissioned by the Food Standards Agency in 2009 and conducted biennially, has included the USDA adult food security module since Wave 4 (2016) but with a time frame of the previous 12 months.

However, these surveys are general population surveys and whilst they included households across different income levels with different sources of income (i.e., benefits) it is difficult to complete detailed analysis of population subgroups of interest such as those with an income from benefits due to low levels of participants within subgroups of interest (Nelson et al., 2007a).

There are limited measures of food insecurity within low-income population groups in the UK. However, the Low-Income Diet and Nutrition Survey published in 2007 sought to address this problem by surveying households in the bottom 15% of the population in terms of income (Nelson et al., 2007a). Assessment of food security status was completed using the USDA adult food security module with a period of previous 12 months and at that time, concluded those who were food insecure were protected from the experience of hunger.

Furthermore, foodbank usage has been used as a proxy indicator for the prevalence of food insecurity. However, this does not provide a true reflection of the prevalence of food insecurity as many who are experiencing food insecurity do not access a food bank (Boyle and Power, 2021; Lambie-Mumford et al., 2014)

Since March 2020, The Food Foundation has been tracking food insecurity (The Food Foundation, 2022a) However, they use three questions from USDA adult food security module to assess if people are food insecure. The questions capture moderate and severe experiences of food insecurity and use a period of the previous month and the previous 6 months. If people answer yes to any one of the questions, they are classified as food insecure.

The U.S adult food security module relates to the access domain of food security (Table 1.2) and is concerned with monetary resources for food purchases. The access domain does also relate to access to shops and transport, but the tool specifically asks about money for food (Mark Nord et al., 2000).

Research studies measuring the prevalence of food insecurity in the UK have employed different tools. For example, Pool and Dooris, 2021 used the Food Insecurity Experience Scale (FIES) in the study of 2000 mainland UK adults in February 2019.

Depending on the tool used the wording for dimensions of food security with the associated characteristics vary (Table 1.2). However, questions asked in each of the surveys are similar and capture the common dimensions of food insecurity.

As mentioned at the beginning of this section measurement of food insecurity in the UK has been inconsistent and fragmented (Pool and Dooris, 2021) and whilst FRS is now monitoring food security in the UK it may not be a true reflection of the prevalence or the severity due to the time frame utilized in assessment.

1.6 Prevalence of food insecurity in the UK and future projections.

Research studies into the prevalence of food insecurity in the UK are limited; therefore, this section will draw on the results from FRS 2020-2021, the Food and You Survey Wave 5, the Food Foundation food security tracking and relevant research studies.

1.6.1 UK and Regional variance.

The FRS 2020/21 collected data from a representative sample (n = 9059) of private households in the UK. Results indicate 7% of households in the UK were food insecure. The Food and You survey, a cross sectional study of adults living in England, Wales and Northern Ireland, collected data from around 3500 individuals used the same USDA food security tool as the Family Resource survey. Wave five of the Food and You Survey published in 2019 indicated that 10% of households were food insecure (Fuller et al., 2019), whilst the latest data from The Food Foundation food security tracking (period 21st to 23rd September 2022) which surveyed 4280 adults, found 18.4% of households were food insecure in the previous month (The Food Foundation, 2022a). Furthermore, this was a 4.6 percentage point increase from April 2022 and indicated a greater prevalence of food insecurity than that of the FRS and Food and You.

The Food Foundation survey is a reduced food security questionnaire and whilst nationally representative, participants are recruited via You Gov, which provides cash incentives for answering surveys. Therefore, this may provide an incentive for those with economic constraints to take part. Furthermore, the classification of food security is based on a reduced set of questions without screening questions. The USDA adult food security module is comprised of three sections, requiring a positive response in the previous section before moving to the next. This may be a factor in higher prevalence of food insecurity in the ‘The Food Foundation’ survey compared to the FRS because of the different methodologies for classifying food insecurity.

Pool and Dooris reported prevalence of food insecurity in the UK to be 14.2%; they used the FAO Food Insecurity Experience Scale. Due to the difference in methodology, questions and thresholds for categorizing food insecurity the authors acknowledge the results from their study are not directly comparable to that of other surveys (Pool and Dooris, 2021).

Regional differences in food security status persist in the UK with the FRS reporting households in the Northeast being 2.75 times more likely to be food insecure (11%) compared to the Southwest where 4% of households were food insecure. (Figure 1.3). Data from the Food Foundation food security tracking most recent survey also finds the North East was 1.97 times likely to be food insecure compared to the Southwest. However, the proportion of households who were food insecure was greater than that of FRS with the Food Foundation reporting 27.8% of households in the Northeast and 14.1% in Southwest being food insecure.

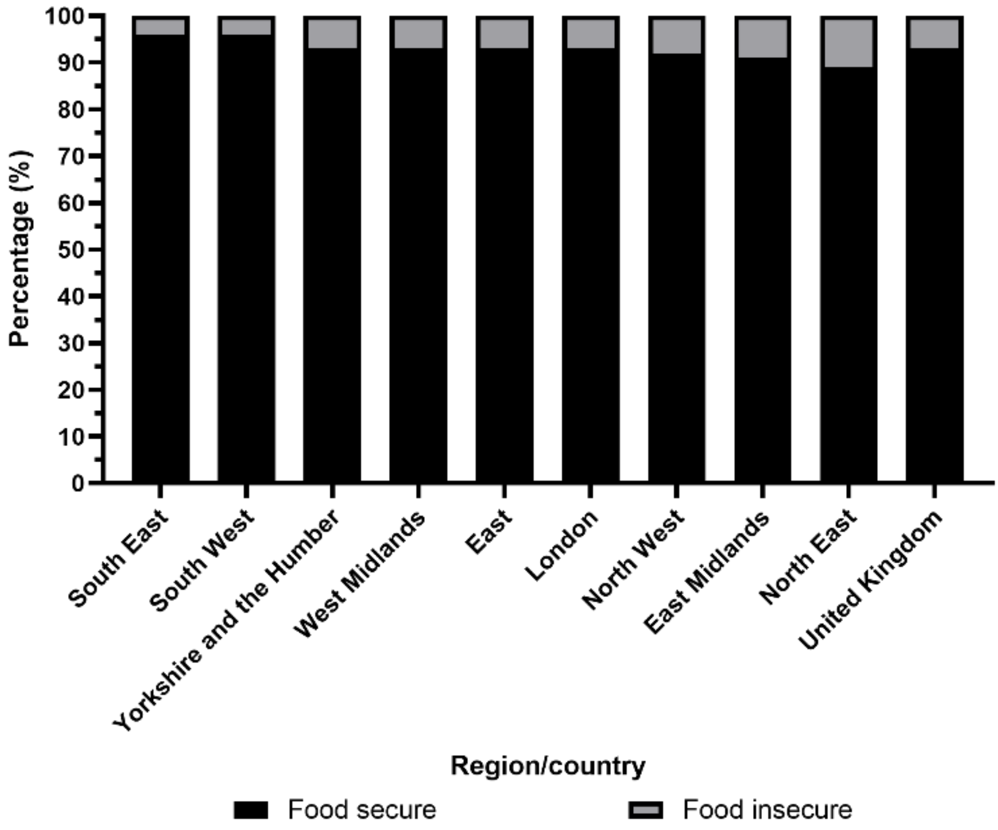

Figure 1-2. Proportion of households who are food secure food insecure by region and county. Adapted from the Family Resource Survey 2020/2021.

1.6.2 Household with low incomes.

The probability of being food insecure for low-income adults was found to have increased from 2004 to 2016 by 18.1 percentage points from 27.1% to 45.8% (Loopstra et al., 2019). The latest results from the FRS for the prevalence of food insecurity by total weekly gross income reports households with and weekly income of less £200, were twice as likely to food insecure compared to the average household (14% experienced food insecurity vs 7% of all households). These results are the same for households with and income between £200 and £400 per week. Food insecurity prevalence decreased incrementally as income increased. (Figure 1.4).

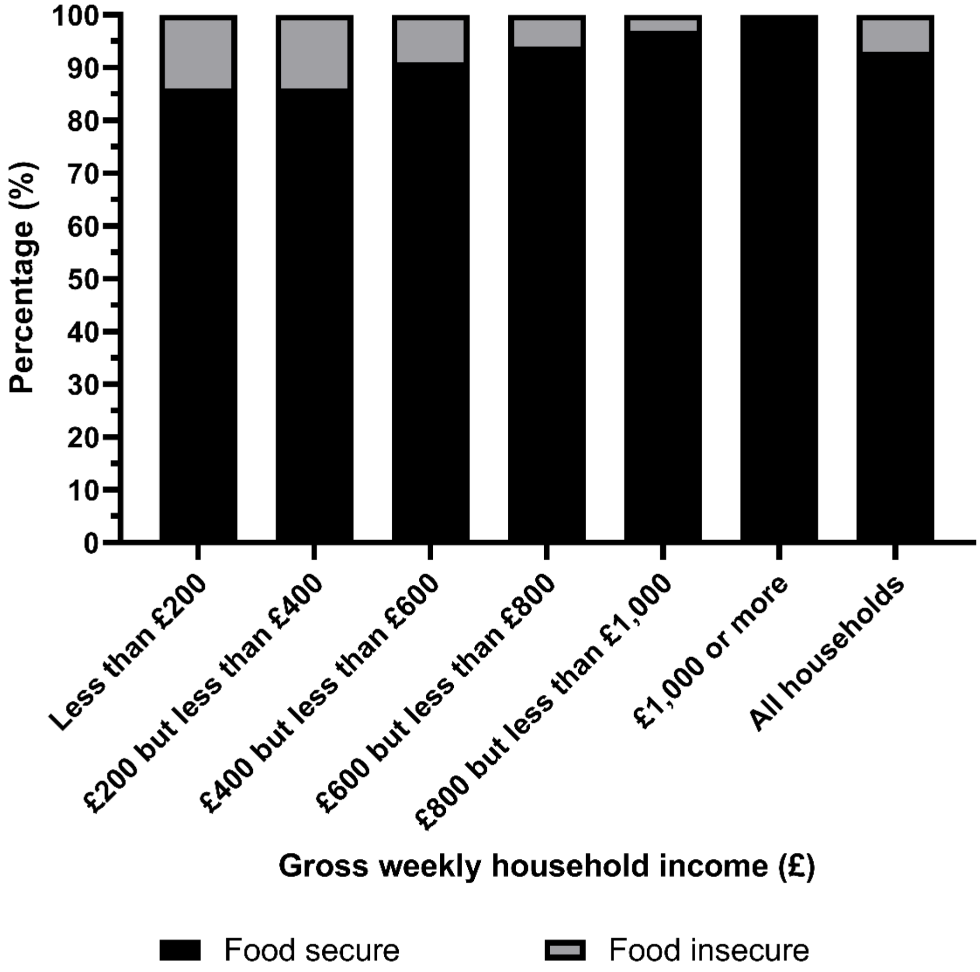

Figure 1-3. Household food security status by total gross weekly income adapted from FRS 2020/2021

1.6.3 Household in receipt of benefits.

Results from the FRS survey (2020/2021) reports households with any income-related benefit support were 3.4 times more likely to be food insecure compared to the average household (24% vs 7% respectively) (DWP, 2022). Whilst households in receipt, specifically Universal Credit, were 3.85 times more likely to experience food insecurity compared to an average household (27% vs 7%). Data from The Food Foundation reports households in receipt of Universal Credit as of September 2022 were 2.92 times more likely to be food insecure compared to the average household

(53.8% vs 18.4% respectively) during the same period. Furthermore, the proportion of food insecure households as surveyed by The Food Foundation increased by 11.7 percentage points from April 2022 (The Food Foundation, 2022a).

1.7 Drivers of food insecurity in the UK and other high-income countries.

The drivers of food insecurity in high income countries In recent years the UK has seen a stagnating wages (Prayogo et al., 2018) and increased living costs. For households in receipt of benefits there has been a gradual transition to a monthly UC payment from that of legacy benefits. There are six legacy benefits (housing benefit, income related employment and support allowance, income based job seekers allowance, child tax credit, working tax credit and income support) depending on the type of legacy benefit, are either paid every 4 weeks or every fortnight (GOV.UK, 2023).

Household with an income from UC have a higher prevalence of food insecurity compared to those on legacy benefits, results from the recent family resource survey 2021/22 indicate household on UC were between 1.6 to 1.9 times more likely to be food insecure compared to households with an income from legacy benefit (DWP, 2022).

The five-week wait when making a new claim for UC has been identified as a factor in food insecurity. Furthermore, if UC claimants miss a meeting with their work coach, sanctions are applied, decreasing the amount of benefit paid, additionally if sanctions are applied UC claimant can apply for a hardship loan but this is repaid from future universal credit payments decreasing the amount paid until the loan is repaid. Sanctions and deductions are identified as a factor in the experience of food insecurity (Prayogo et al., 2018).

Whilst Government policies, which restrict the income of households in receipt of benefits, including the benefit, cap, the bedroom tax and the two-child limit are associated with food insecurity. Households with an income from UC who are not affected by the above Government policies are also food insecure, highlighting the broad issue of food insecurity and benefits (Geiger et al., 2021).

Whilst there are groups of the population (e.g., asylum seekers, refugees) who have no recourse to public funds. They are reliant on third sector organisations for food and have been found to be at increased risk of experiencing prolonged food insecurity (Hamilton et al., 2022).

Increases in the “Cost of Living” are a factor in the rise of household food insecurity in the UK (Francis-Devine et al., 2022). which has seen a reduction in real term unemployment benefit amounts as monetary increases were not in keeping with the rate of with inflation, (Hetherington, 2022). The drivers of food insecurity are complex and poverty is a recognized factor in the experience of food insecurity, 16% of individuals living in relative poverty (income below 60% of the UK median) were in a food insecure household (Francis-Devine et al., 2022).

1.8 Why do we need to measure food insecurity when there is already evidence of the relationship between diet and health inequalities due to poverty, socioeconomic status and living in a deprived area (Indices of Multiple deprivation)?

In high income countries one of the root cause of food insecurity is widely accepted to be because of poverty (Hjelm et al., 2016) (Pollard and Booth, 2019). If a household is in poverty relative or absolute, then the ability to access foods which meet the definition of food security is prohibited because of economic constraint.

However, official definitions of poverty include ‘relative income poverty’ where a household has less than 60% of the equivalised median income for that year, whilst ‘absolute poverty’ is defined as less than 60% of the median income for 2010/201, uprated by inflation (JRF, 2015). However, it is argued the definition of poverty as 60% below the median income is an arbitrary measure and that individuals can be in poverty if their financial resources are not sufficient to meet their needs (Mack, 2016).

Peter Townsend invented ‘Relative Deprivation Theory off Poverty’ which defines poverty as those with resources well below that of the average individual or households, that they are effectively excluded from society as they are unable to take part in activities, ordinary living patterns and customs. (“Townsend Centre for International Poverty Research,” 2023) This approach is seen as a consensual or ‘perceived poverty’, where public opinion on what is needed for a minimum acceptable living standard is garnered and a poverty threshold determined related to income for those who lack necessities due to economic constraint. This approach to defining poverty encompasses both deprivation and income (Mack, 2016).

The Joseph Rowntree Foundation has developed the Minimum Income Standard (JRF, 2015). Whilst this is not a defined measure of poverty, it does build upon Townsend work. Household/ individuals living below minimum income standards but above the poverty threshold may be at risk of experiencing food insecurity as the income they have is not sufficient to meet what the general population perceives to be a necessary for a minimum standard of living. It is known the food budget is modifiable and as such an income below the MIS may mean money is taken from the food budget to pay other bills, thus potentially exposing households to the risk of food insecurity.

1.9 Assessment of population groups micronutrient intakes.

In the field of human nutrition, Dietary Reference Values (DRV's) are fundamental in the evaluation of dietary adequacy of individuals and groups, they are the scientific basis by which nutrition recommendations are derived and are pivotal in the setting of food based dietary guidelines (Powers, 2021). However, they cannot identify deficiencies within individuals due the variability in requirements person to person. In these instances, identification of deficiency is via biomarkers, however, not all micronutrients have a reliable biomarker, for example zinc. Biomarkers for iron, iodine, zinc, riboflavin and vitamin A, covered in section 1.9.

1.10 Dietary Reference Values (DRVs).

1.10.1 Definitions and classifications.

Dietary reference values previously were termed ‘recommended daily allowance’ (RDAs). The Committee on Medical Aspects of Food Policy (COMA) introduced the term ‘reference’ to reduce misunderstanding that the values in the DRVs are estimates of requirements and not recommendations for intakes.

In the UK, dietary reference values (DRVs) for food energy and nutrients were set in 1991 by the now disbanded COMA. The DRVs apply to healthy groups of people (groups are based on age, gender and physiological state such as pregnancy or lactation and are developed based on nutrient requirements at different life stages taking into consideration the amount of a nutrient required to maintain circulatory levels or enzyme saturation or tissue concentration, and levels to avoid deficiency (Figure 1.5).

DRVs may not be appropriate for those with different requirements due to disease, metabolic disorders or difficulties in the absorption of nutrients (DoH, 2008) and it is assumed that requirements of healthy individuals in a group are normally distributed (DoH, 2008). The term DRV covers Reference Nutrient Intakes (RNI), Estimated Average Requirements (EAR), Lower Reference Nutrient Intakes (LRNI), and Safe Intakes (SI) (BNF, 2021), (DoH, 2008). The values for micronutrients set by COMA in 1991 are still in use today (Powers, 2021) and table 1.3 and 1.4 lay out the RNI for vitamins and minerals for adolescents (11-18 years), adults (19- 50 years) and older adults (50+ years of age). Section 1.6.2 will define the DRVs in relation to micronutrients in more detail.

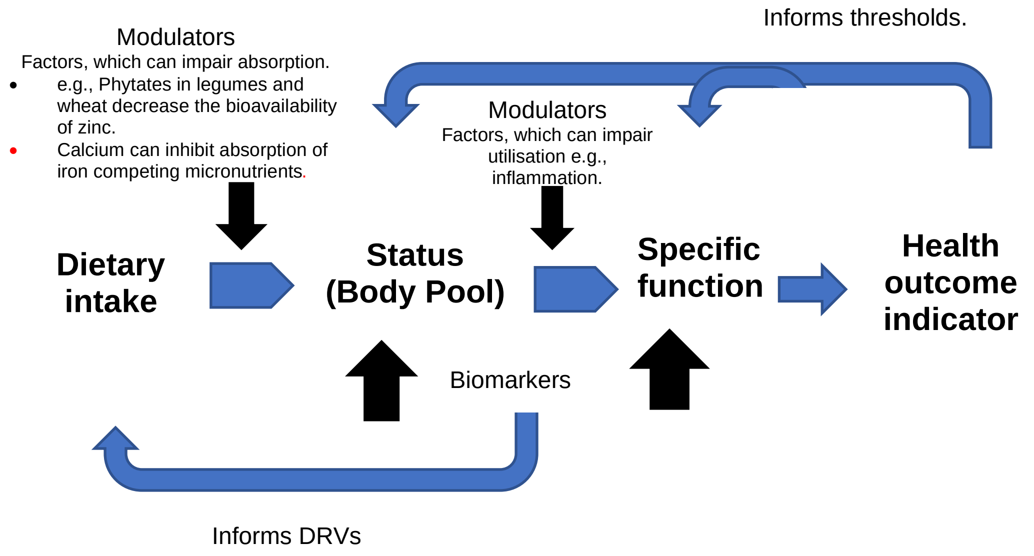

Figure 1-4. Schematic representation of the considerations that might influence the setting of dietary reference values (adapted from (Powers 2021).

1.10.2 Reference Nutrient intakes.

The RNI is set deliberately high at a notional two standard deviations away from the EAR (Figure 1.6) this is to ensure that requirements for a specific nutrient are met for the majority (97.5%) of a group. Many in the group will have lower requirements than that indicated by the RNI. In the case of women with very high menstrual losses, for example, the RNI for iron will not be sufficient and as such, supplementation is recommended (DoH, 2008). Similar disparities exist for other micronutrients, but for the most part, the RNI is a good indicator for general requirement.

If an individual has a nutrient intake above the RNI, it is highly likely that they will have a sufficient intake, if it is between the LRNI and the RNI, then the closer to the RNI, the chances of their intake being inadequate diminishes (Figure 1.7). However, to determine if an individual is deficient in a nutrient, a biological measure is required (where appropriate) (DoH, 2008), for example, hemoglobin or serum ferritin in the case of diagnosing iron deficiency with or without anemia .

Table 1-3. Reference Nutrient Intakes (RNI and Lower Reference Nutrient Intakes (LRNI) for vitamins amongst UK males and females aged 11-50+ years.

	Age (years)	**Thiamine** **mg/d (LRNI)***	**Riboflavin** **mg/d (LRNI)**	**Niacin** **mg/d (LRNI)***	**Vitamin B6** **mg/d (LRNI)****	**Vitamin B12** **µg/d**	**Folate** **µg/d**	**Vitamin C** **mg/d**	**Vitamin A** **µg/d**	**Vitamin D¥** **µg/d**
Males	11-14	0.9 (0.23)	1.2 (0.8)	15 (4.4)	1.2 (11)	1.2 (0.8)	200 (100)	35 (9)	600 (250)	10
	15-18	1.1 (0.23)	1.3 (0.8)	18 (4.4)	1.5 (11)	1.5 (1.0)	200 (100)	40 (10)	700 (300)	10
	19-50	1.0 (0.23)	1.3 (0.8)	17 (4.4)	1.4 (11)	1.5 (1.0)	200 (100)	40 (10)	700 (300)	10
	50+	0.9 (0.23)	1.3 (0.8)	16 (4.4)	1.4 (11)	1.5 (1.0)	200 (100)	40 (10)	700 (300)	10
Females	11-14	0.7 (0.23)	1.1 (0.8)	12 (4.4)	1.0 (11)	1.2 (0.8)	200 (100)	35 (9)	600 (250)	10
	15-18	0.8 (0.23)	1.1 (0.8)	14 (4.4)	1.2 (11)	1.5 (1.0)	200 (100)	40 (10)	600 (250)	10
	19-50	0.8 (0.23)	1.1 (0.8)	13 (4.4)	1.2 (11)	1.5 (1.0)	200 (100)	40 (10)	600 (250)	10
	50+	0.8 (0.23)	1.1 (0.8)	12 (4.4)	1.2 (11)	1.5 (1.0)	200 (100)	40 (10)	600 (250)	10

Table adapted from (DoH, 2008). ¥ Values from SACN (SACN, 2016).
*mg/1000kcal
**µg/g protein

Table 1-4. Reference nutrient intakes for minerals amongst UK males and females aged 11-50+ years.

	Age (years)	Calcium	Phosphorus	Magnesium	Sodium	Potassium	Chloride	Iron	Zinc	Copper	Selenium	Iodine
		mg/d	**mg/d**	**mg/d**	**mg/d**	**mg/d**	**µg/d**	**µg/d**	**mg/d**	**mg/d**	**µg/d**	**µg/d**
Males	11-14	1000	775	280	1600	3100	2500	11.3	9.0	0.8	45	130
	15-18	1000	775	300	1600	3500	2500	11.3	9.5	1.0	70	140
	19-50	700	550	300	1600	3500	2500	8.7	9.5	1.2	75	140
	50+	700	550	300	1600	3500	2500	8.7	9.5	1.2	75	140
Females	11-14	800	625	280	1600	3100	2500	14.8	9.0	0.8	45	130
	15-18	800	652	300	1600	3500	2500	14.8	7.0	1.0	60	140
	19-50	700	550	270	1600	3500	2500	14.8	7.0	1.2	60	140
	50+	700	550	270	1600	3500	2500	8.7	7.0	1.2	60	140

Table adapted from (DoH, 2008).

1.10.3 Estimated average requirements.

The EAR is the estimate of average requirement of a nutrient; it is the notional mean (Figure 1.6) as such 50% of a group will require more and 50% less.

1.10.4 Lower reference nutrient intake.

The LRNI is two standard deviations below the EAR (Figure 1.6), is sufficient for just 2.5% of a group, and will be inadequate for the majority of individuals. When an individual has a nutrient intake below the LRNI, it is likely they will not meet their requirements. This becomes more likely if 3% or more of a group are below the LRNI (Nelson et al., 2007b).

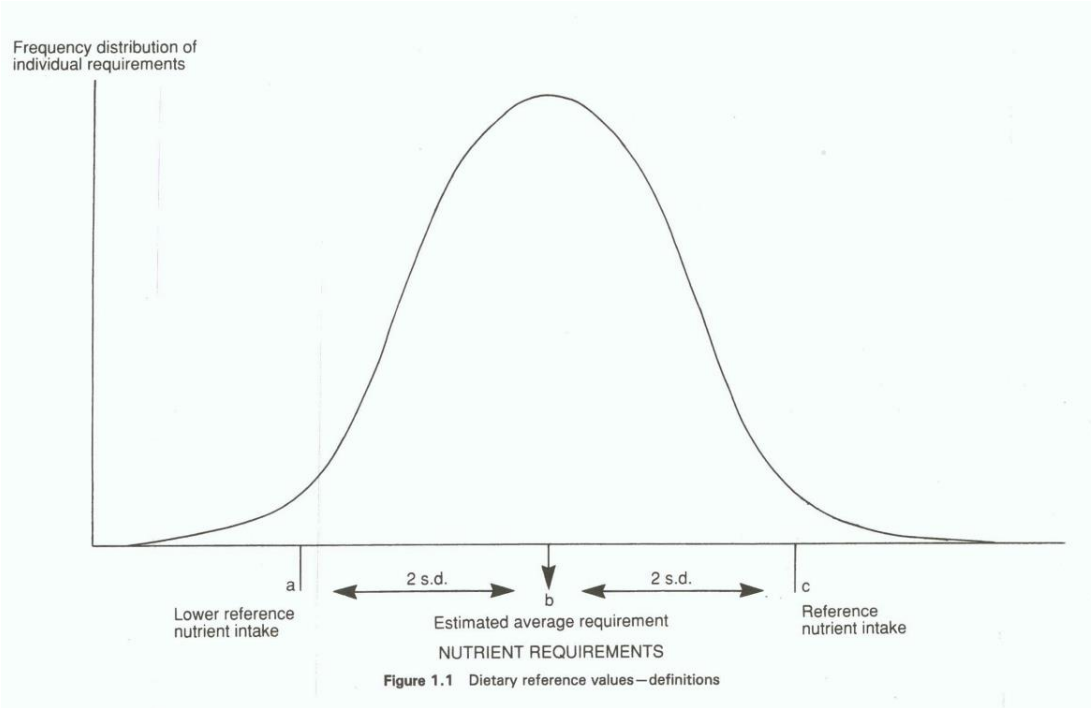

Figure 1-5. Gaussian distribution of nutrient intakes and dietary reference values definitions (Taken from DoH, 2008).

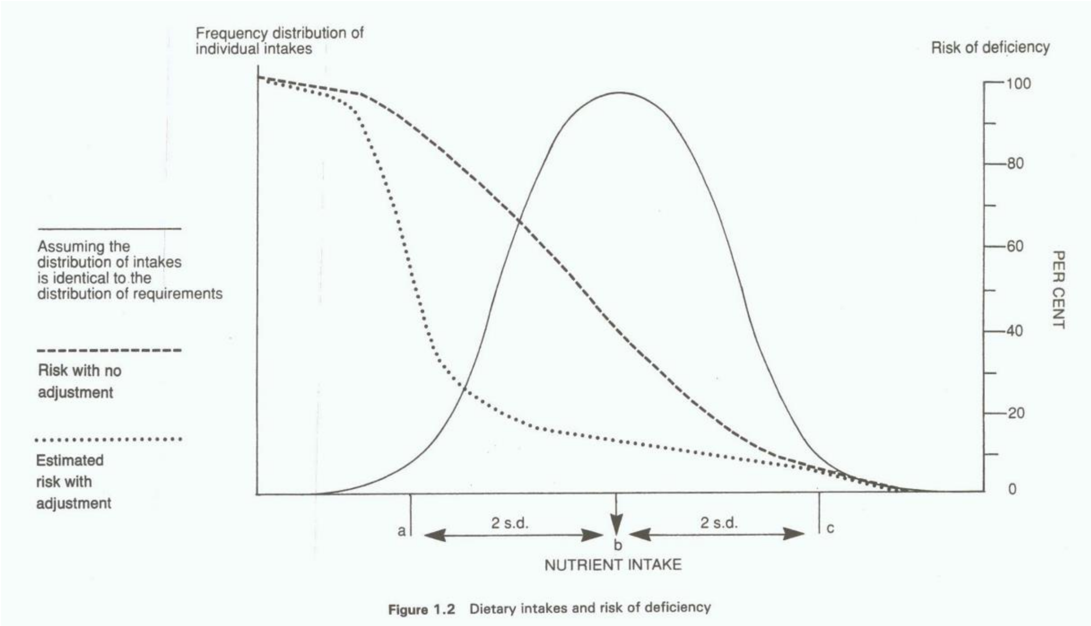

Figure 1-6. Dietary intakes and risk of deficiency (Taken from DoH, 2008).

1.10.5 Updates to the DRVs.

COMA has since been replaced by Scientific Advisory Committee on Nutrition (SACN) who in 2011 revised the EAR for energy (SACN, 2011). COMA used total energy expenditure (TEE) for the setting of EARs amongst population groups.

TEE is energy intake matching energy expenditure. Recent advancements in the doubly labelled water (DLW) method, the gold standard for measuring TEE in free-living individuals.[4] Coupled with a high prevalence of overweight and obesity within the UK, SACN, reviewed the EARs for energy using a factorial approach. Where TEE is a combination of (Basal Metabolic Rate

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4 The DLW method in principle requires the consumption of dose of water labelled with "Heavy" isotopes ^{2}H and ^{18}O. The rate of elimination of the isotopes, measured in urine, saliva or blood is required for the calculation of the daily volume of carbon dioxide production for the estimation of TEE (Berman et al., 2020).

(BMR) x Physical Activity Level (PAL), where BMR was predicted based on a range of reference healthy body weights and PAL was estimated from measures of DLW (SACN, 2011) . Energy values from SACN are higher than those of COMA but it is suggested if overweight groups consume the energy recommended for healthy weight groups, then a loss of weight should occur and conversely if underweight groups consume energy for a healthy weight group, then weight gain should occur (SACN, 2011).

In 2015 SACN made new recommendations for free sugar and fibre intakes in its report *Carbohydrates and Health* (SACN, 2015). The recommendations for fibre were increased to 30g d^{-1} (SACN, 2015) from a maximum of 24g d^{-1} (DoH, 2008). Whilst the term “free sugars” replaced that of COMA’s “Non-milk extrinsic sugars”, recommendations were made for no more than 5% of energy to be from free sugars (SACN, 2015) this is a decrease from COMA recommendation of 11% of food energy (DoH, 2008).

New recommendations for vitamin D intake made by SACN in its report *Vitamin D and Health* (SACN, 2016) set the RNI at 10µg d^{-1} for everyone aged over 4 years, previously an RNI was not in place except for children under 4 years and adults over 65 years of age and during pregnancy (DoH, 2008).

1.11 Biomarkers in the diagnoses of micronutrient deficiency amongst individuals and determination of micronutrient status in populations groups.

To determine if an individual is deficient in a vitamin or mineral it requires a biological sample, laboratory testing and comparison to published cut-off criteria for the assessment of deficiency. Biological samples typically collected are blood and urine; this next section will describe some of the micronutrient biomarkers relevant to the studies in this thesis. Furthermore, biomarkers are used in the validation of micronutrient intakes from dietary surveys and are an objective assessment of dietary exposure and nutritional status (MRC, 2023a).

1.11.1 Diagnosis of iron deficiency anemia and iron deficiency.

1.11.1.1 Haemoglobin.

Iron deficiency anaemia (it is possible to be iron deficient without anaemia) is diagnosed by haemoglobin status. Haemoglobin, an oxygen-binding protein, present in red blood cells and responsible for the red pigment of blood is required in the transportation of oxygen from the lungs to other tissues and for the removal of carbon dioxide from the tissues to the lungs for expulsion. Approximately 60% of the iron in the human body is utilised in haemoglobin (Gibney et al., 2009). Iron In the ferrous state (Fe^{2+}) is incorporated into the four globin protein subunits of haemoglobin along with a protoporphyrin ring (Farid et al., 2022), it is the iron atom that associates and dissociates the oxygen and carbon dioxide molecules, hence why, when an individual has iron deficiency anaemia, they can feel tired and breathless. Diagnoses of anaemia from haemoglobin levels is age and sex specific and ranges from mild to severe anaemia (WHO, 2011a) (Table 1.5).

Table 1-5. Haemoglobin levels to diagnose anaemia at sea level (g l^{-1})

Population	Non-anaemia	Anaemia		
		Mild	**moderate**	**Severe**
	g l^{-1}			
Children 6 - 59 months of age	>=110	100-109	70-99	<70
Children 5 - 11 years of age	>=115	110-114	80-109	<80
Children 12 - 14 years of age	>=120	110-119	80-109	<80
Non-pregnant women (15 years of age and above)	>=120	110-119	80-109	<80
Pregnant women	>=110	100-109	70-99	<70
Men (15 years of age and above)	>130	110-129	80-109	<80

Adapted from (WHO, 2011a)

1.11.1.2 Serum ferritin.

Approximately 20% of the iron in the body is stored within the protein ferritin, another store of iron is hemosiderin (Gibney et al., 2009). Ferritin may contain as many as 400-4500 atoms of iron(WHO, 2011b) and is stored within the liver, spleen and bone marrow (Abbaspour et al., 2014). The stores of iron are utilised in times when there is a high need, such as in pregnancy or during puberty. Ferritin is excreted into the plasma in small amounts and correlates well with total body iron stores (Abbaspour et al., 2014; WHO, 2011b).This is why serum ferritin is a good biomarker of iron stores. However, serum ferritin readings can be higher than the amount of iron stored in individuals who have illness/injury that causes inflammation (SAITO, 2014). Diagnose of depleted iron stores is age and sex specific with different criteria applied if an individual has an infection (WHO, 2020) (Table 1.6).

Table 1-6. Recommended cut-off values to define iron deficiency and risk of iron overload in apparently healthy and non-healthy individuals by age group.

	Serum ferritin (μg L^{-1})			
	Iron deficiency		Risk of iron overload	
	Apparently healthy individuals	Individuals with infection or inflammation	Apparently healthy individuals	Non-healthy individuals
Infants and young children (0–23 months)	<12	<30	-	-
Children under 5 years (24–59 months)	<12	<30	-	-
Children (5 to less than 10 years)	<15	<70	>150 females >200 males	>500
Adolescents (10 to less than 20 years)	<15	<70	>150 females >200 males	>500
Adults (20–59 years)	<15	<70	>150 females >200 males	>500
Older persons (60+ years)	<15	<70	>150 females >200 males	>500
Pregnant women	<15 (first trimester)	-	-	-

Adapted from (WHO, 2020)

1.11.2 Diagnosis of iodine deficiency in individuals and Iodine status amongst populations.

There are various biomarkers available to assess the Iodine status of individuals and populations, however, the two main biomarkers are Urinary Iodine Excretion (UIE), which assesses recent iodine intake in individuals and Urinary Iodine concentrations (UIC) which assess iodine status within populations. Absorption of ingested Iodine is high (>90%) (EFSA, 2014a) and in iodine replete individuals 90% of ingested iodine is excreted in the urine with 24-48 hours (EFSA, 2014a).

1.11.3 Urinary Iodine Excretion (individual and population level).

At the individual level, a 24-hour urine sample or at least 10 spot samples (10 ml of urine is sufficient) is required for assessment of recent iodine intake to within 20% (EFSA, 2014a),

1.11.4 Urinary Iodine Concentration (population level).

At the population level, 24-hour urine samples may be difficult to collect, therefore, a spot sample (not the first pass of the day and around 10 ml is sufficient for testing) is preferred and as long as there is a large enough sample size. Even though there is day to day and within the same day variation of iodine excretion in the individual, at the population level this is levelled out (WHO, 2013). The iodine intake and status of a population is determined by the median value of urinary iodine (EFSA, 2014a). Iodine intake values span from insufficient (<20µg/L) to excessive (≥ 300µg/L) in children aged over 6 years and adults, pregnant or lactating women have higher requirements for iodine, as such criteria for assessing iodine status differs to that of non-pregnant lactating adults (Table 1.7). Iodine status is measured along a spectrum from severe iodine deficiency to risk of adverse health consequences when intakes are excessive (WHO, 2013) (Table 1.7)

Table 1-7. Epidemiologic criteria for assessing iodine intake and status based on median urinary iodine concentrations in children aged 6 years and over, adults, pregnant and lactating women and children under 2 years of age.

Population group	Median urinary iodine (µg L^{-1})	Iodine intake	Iodine status
School-age children (6 years or older) and adults	<20	Insufficient	Severe iodine deficiency
	20–49	Insufficient	Moderate iodine deficiency
	50–99	Insufficient	Mild iodine deficiency
	100–199	Adequate	Adequate iodine nutrition
	200–299	Above requirements	May pose a slight risk of more than adequate iodine intake in these populations
	≥300	Excessive	Risk of adverse health consequences (iodine-induced hyperthyroidism, autoimmune thyroid disease
Pregnant women	<150	Insufficient	
	150–249	Adequate	
	250–499	Above requirements	
	≥500	Excessive	
Lactating women and children aged less than 2 years.	<100	Insufficient	
	≥100	Adequate	

Adapted from (WHO, 2013)

1.11.5 Zinc.

Plasma levels of zinc are a poor biomarker of dietary zinc intake, although dietary zinc can affect plasma levels, when intakes are sub-optimal, plasma zinc levels do not always decrease to reflect lower dietary intakes (Kuhnle, 2015) as such, plasma zinc is not a useful biomarker, although it is often used.

1.11.6 Riboflavin (Vitamin B2).

Riboflavin is a key building block for Flavin adenine dinucleotide (FAD), a coenzyme involved in a range of biochemical process including metabolizing carbohydrate, lipid and protein (Hampel, 2023a) into glucose for energy production (Mahabadi et al., 2021). Deficiency of riboflavin is associated with lower absorption of iron (Powers et al., 2011) and is a factor in IDA. Riboflavin status can be determined using erythrocyte glutathione reductase assay coefficient (EGRAC) which measures the activity of the enzyme before and after exposure to FAD. EGRAC >1.40 indicates deficiency (Powers et al., 2011). Whilst value of 1.2-1.4 indicate low riboflavin status and <1.2 relates to an acceptable riboflavin status (Hampel, 2023b)

1.11.7 Vitamin A.

Vitamin A is a fat-soluble vitamin required in immune function, vision and many other physiological processes. Deficiency in the UK is rare; however, serum retinol is measured as part of the NDNS. There are limitations associated with serum retinol as a biomarker due to illness decreasing serum retinol concentrations, however, it is recognised as a useful tool for assessing Vitamin A deficiency within population groups (Farebrother and Haskell, 2019).

1.12 Assessment of micronutrient intake and diet quality.

There are range of tools available for the collection of dietary data, table 1.8 provides brief details of the types of subjective dietary assessment methods available (MRC, 2023b). When selecting the tool to use, it is necessary to consider who the target population is, what time they have available, their age, literary, numeracy and English language skills, access to technology (computers, smart phones, etc.). Other considerations are the intended study hypothesis, duration of the study, financial resource available and the skill sets of the researchers required in analysis of the data.

Low-income population groups in the UK, were found to prefer the completion of four separate 24-hour dietary recall as opposed to a weighed inventory of foods, semi weighed 4-day diet diary and a food checklist (Holmes et al., 2008). Whilst NDNS, until recently collected dietary data using a paper based 4-day diet dairy, this has now changed to the completion of four computerised, 24-hour dietary recalls hosted by Intake24 (PHE, 2021).

1.12.1 Subjective dietary assessment methods.

Subjective dietary assessment methods rely on participants written or verbal responses, they are prone to bias, such as recall bias and social desirability bias. All measures of subjective dietary intakes amongst population groups are prone to underreporting in the region of 25% (Foster et al., 2019). However, there are numerous advantages to using subjective methods including affordability, suitable for use in large cohorts, are non-invasive and can be delivered in different formats (pen and paper, electronic device, web based) (MRC, 2023b).

Table 1-8. Subjective dietary assessment methods.

	What is assessed	How are estimates of diet derived?	Strengths	Limitations	References
Estimated food diaries	Energy intakes, most nutrients, foods and food groups	Food composition tables. Composite meals disaggregated.to individual foods and ingredients.	Recorded when consumed. Does not rely on memory	Time consuming for researchers to analyse. High participant burden	(MRC, 2023c)
Weighed food diaries	Energy intakes, most nutrients, foods and food groups	Foods are coded, entered into a database and matched to nutrient data.	Does not rely on memory. weight of food provided and does not rely on estimates	Time consuming for researchers to analyse. High participant burden	(MRC, 2023d)
24-hour dietary recall	Energy intakes, most nutrients, foods and food groups	Food composition tables. Composite meals disaggregated.to individual foods and ingredients.	Respondent burden is low depending on the number of recalls. Quick to administer. Does not alter food intake patterns	Rely on participant memory. Time consuming for researchers to analyse.	(MRC, 2023e)
Food frequency questionnaires	Habitual diet Energy and nutrient intake of diet Food and food groups	Standardized measures Food composition table	Respondent burden low Low Cost Capture habitual intake and foods not consumed regularly	Specified food list may not be fully representative of foods eaten	(MRC, 2023f)

1.12.2 Measures of diet quality.

The use of diet quality indices can be used for assessing compliance with food based dietary guidelines (Vyncke et al., 2013) and are recognised as an important measure of food security. Diets that align with the UK government dietary guidelines have been estimated to cost as much as 30% of the lowest income deciles disposable income (Scott et al., 2018). As such, a low income is prohibitive for meeting a diet that is optimal for health.

Different tools are available for estimating diet quality in different population groups including adolescents, adults, and the elderly. In this research the tools used were the diet quality index for adolescents (DQI-A) and the diet quality index- international (DQI-I). Majority of diet quality indices are concerned with diet, health outcome and chronic disease. To the best of our knowledge, studies investigating income, food security and diet quality in the UK are limited. Although it is recognized adolescents and adults with a higher socio-economic status (which is based on employment status; occupational social) have a higher diet quality globally (Darmon and Drewnowski, 2015; Kurotani et al., 2021; Livingstone et al., 2017). However, it is widely acknowledge the fundamental causes of food insecurity are economical derived (Drewnowski, 2022).

1.13 Micronutrient intake and status amongst female in the UK: adults and adolescents.

Studies estimating micronutrient intake and status amongst UK populations are often completed as data reuse projects using NDNS data (Buttriss, 2015; Derbyshire, 2018). In the UK, the general population aged.1.5 years and over, living in private households and women who are not pregnant or lactating, nutrient intake and nutritional status are estimated in the NDNS. The NDNS is a cross sectional survey recruiting a representative sample of approximately 1000 people per year (500 adults, 500 children). The survey started in 2008 and is now in its 11th year.

The next section will describe selected micronutrient intakes of adult women aged 19-64 years and girls aged 11-18 years as a percentage of the RNI and proportion below the LRNI using data from the NDNS (years 9-11 (2016/2017-20/182019)) (Table 1.9 and Table 1.10). Relevant studies that have used NDNS data will be referred too.

1.13.1 Adult women 19-64 years.

Mineral intakes from food sources amongst adult women aged 19-64 are low compared to the RNI for iron, iodine and selenium (Table 1.9) with a high proportion of the population below the lower reference nutrient intake (Table 1.9) which is of concern, as dietary intakes below the LRNI are when deficiency is likely to occur (Derbyshire, 2018). Analysis of years 1-6 of the NDNS for adults across midlife found riboflavin, iron and iodine intakes amongst females to be lower compared to males and women in their 20's had a greater percentage of the population below LRNI for iodine, iron compared to older women (Derbyshire, 2018). Section 1.13 will cover implications to health of suboptimal intakes and deficiencies. Vitamin A and riboflavin exceeded the RNI; however, there is still a high percentage below the LRNI (Table 1.9).

Table 1-9. Micronutrient intakes from food sources only; Vitamins and Minerals by NDNS rolling programme years 9-11 (2016/17 -2018/19)***. Adult women 19-64 years.***

Micronutrient		**Median % of RNI**	**% <LRNI**
Vitamins			
	Vitamin A	113	8
	Riboflavin	120	13
Minerals			
	Iron	70	25
	Zinc	107	7
	Iodine	89	12
	Selenium	69	46

Adapted from (PHE, 2020a).

1.13.2 Girls aged 11-18 years.

Girls aged 11-18 years met a lower percentage of the RNI for the selected vitamin and minerals and had a greater percentage below the LRNI compared to adult women (Table 1.10). It is suggested the increased autonomy in food choice is a factor for sub-optimal micronutrient composition of the diet amongst this population group. Previous studies have highlighted fruit and vegetable consumption among adolescents females to be below dietary recommendations whilst salt intakes are above recommendations (Duke, 2021; Rosi et al., 2019). Adolescent females with a high consumption of breakfast cereal consumption has been associated with dietary iron intakes above the Lower Reference Nutrient Intake (Thane et al., 2003) however, adolescents have been found to have a greater irregularity of breakfast cereal consumption compared to other age groups (Gaal et al., 2018).

Table 1-10. Micronutrient intakes from food sources only; Vitamins and Minerals by NDNS rolling programme years 9-11 (2016/17 -2018/19). Girls 11-18 years.

Micronutrient		**Median % of RNI**	**% <LRNI**
Vitamins			
	Vitamin A	73	18
	Riboflavin	98	22
Minerals			
	Iron	55	49
	Zinc	79	16
	Iodine	65	28
	Selenium	66	41

Adapted from (PHE, 2020a).

1.14 Micronutrient deficiency and sub-optimal intakes impact on health.

There are 29 known essential micronutrients (Stevens et al., 2022) required by the body in tiny amounts, not all have a DRV, but all are required for optimal health. A diet aligned with the UK government food based dietary guidelines as depicted by the Eatwell guide should provide sufficient micronutrients in the diet to support health. However, adherence to the nine dietary recommendations of the Eat well guide was found to be low in the UK with majority meeting 3 or 4 of the recommendations (Scheelbeek et al., 2020). This section will focus on iron, iodine, and zinc implication to health when intakes are suboptimal with or without deficiency amongst adolescent girls and adult women. Table 1.11 provides details of the main function of these minerals, food sources and methods for assessing status whilst table 1.12 provides detail for vitamin A and riboflavin.

1.14.1 Iron.

Depletion of iron stores leading to ID or IDA can occur due to suboptimal dietary iron intakes, increased needs (such as pregnancy), reduced absorption (e.g., chronic inflammation[5], competing minerals for divalent metal transporters[6]) Increased losses (e.g., menstruation or blood loss due to illness or injury) (Al-Naseem et al., 2021). Adolescents' girls and adult women of childbearing age are at increased risk of deficiency due to their high physiological requirements. In the adolescent, the body's demand for iron increases to support growth and development at puberty as well as the onset of menses. In the adult women high menstrual losses can deplete the bodies iron stores. During pregnancy the requirement for iron is increased as total blood volume increases by approximately 1.5 litres to supply the placental vascular bed and to mitigate against blood loss at delivery(Chandra et al., 2012). In the UK there is not a recommendation to increase iron during pregnancy. If iron stores are replete, plus the reduction of iron losses due to cessation of menstruation, this should be sufficient to support requirement in pregnancy although some women made need to supplement if entering pregnancy with depleted iron stores (DoH, 2008).

1.14.2 Iron deficiency anemia impact on fetus, neonate, girls, and women of childbearing age.

IDA during pregnancy is associated with fatigue, poor physical performance, reduce conative capability and impaired immune function in the mother(Abu-Ouf and Jan, 2015a). Women with IDA are at increased risk of

[5] Chronic inflammation can induce hepcidin expression independent of circulating iron levels (Hortová-Kohoutková et al., 2023). Hepcidin is a hormone and the principal regulator of iron homeostasis (Nemeth and Ganz, 2009) it reduces iron absorption by blocking the iron transporter, ferroprotein, reducing iron absorption at the duodenum and inhibits the release of iron from storage pools to functional pools (Al-Naseem et al., 2021)

[6] Iron and zinc inhibit the absorption of each other at the enterocyte, but the mechanism remains unclear (Kondaiah et al., 2019)

having a premature delivery, restricted foetal growth, a low birthweight neonate (Zhang et al., 2021). In the developing foetus, there is evidence that cognitive development of the child is impaired if the mother is ID during the final trimester of pregnancy (WHO, 2023).

1.14.3 Zinc.

Deficiency of zinc can manifest when dietary intakes are not sufficient to meet requirements and is the most common phenomenon for deficiency (Grzeszczak et al., 2020a). Good sources of zinc include animal-based products, shellfish, breakfast cereals. However co-consumption with foods such as legumes, seeds, soy products and whole grains decrease zinc absorption if consumed in excess due to the phytates, calcium and phosphate content within these foods binding zinc reducing bioavailability (Maxfield et al., 2023). Gastrointestinal disease such as malabsorptive syndrome Crohn's disease are a factor in in zinc deficiency (Grzeszczak et al., 2020b).

Children, adolescents and pregnant women are susceptible to zinc deficiency because of their increased physiological requirement to support growth and development (Gibson et al., 2002). Zinc is ubiquitous in the human body, being the second most abundant trace metal after iron, with the average 70kg human containing 2.3mg (McCall et al., 2000). Zinc is essential for many cellular processes as co-factor for>300 enzymes (Huang et al., 2015) involved in protein metabolism, DNA and RNA synthesis, essential to produce lean tissue (Gibney et al., 2009). Zinc also has a function in immune health (Calder, 2020).

Deficiency of zinc can impair a child's growth leading to stunting. Stunting is an indicator of zinc deficiency (Roohani et al., 2013). Zinc has a pivotal function in immune system in both the innate and adaptive immunity (Maares and Haase, 2016), and a role in antiviral immunity by preventing viruses from replicating (Calder, 2020). Thus, deficiency can leave an individual susceptible to diseases, as the immune system function is impaired.

Diets high in cereal products such as whole grains and low in animal products can increase the risk of deficiency. Anti-nutritional factors impair Zinc's bioavailability; they are present in legumes and cereal products. Phytates bind zinc, restricting the body's ability to absorb zinc from food sources.

1.14.4 Iodine.

Iodine is an essential component of the thyroid hormones, thyroxine (T_4) and triiodothyronine (T_3) required for metabolism, growth and development. Deficiency of iodine is the single biggest cause of preventable brain damage globally (Brantsæter et al., 2013). The human body contains 15-30mg of iodine, predominantly stored in the thyroid (Zimmermann et al., 2008). Requirements for iodine are increased by at least 50% in pregnancy and lactation to support both mother and child (Brantsæter et al., 2013). Deficiency of iodine during pregnancy can impair the fetus's growth and brain development, increase's risk of stillbirths and abortions (Zimmermann et al., 2008). Termed iodine deficiency disorders (IDD) the severity of the impacts to health span a spectrum from congenital hypothyroidism to goitre. Deficiency of iodine is along a continuum of mild to severe with mild deficiency having adverse implications for health in adolescent and adult women which includes impaired mental function (Kapil, 2007).

Table 1-11. Function of minerals in the human body, main dietary sources, health implication of deficiencies and methods for assessing status.

Micro-nutrient	Function	Common food sources	Content (mg/100g)	Deficiency symptoms	Assessing status	Reference
Iron	Component of: 1) Haemoglobin - required for oxygen transport**.** 2) Myoglobin - required for oxygen storage in muscle**.** 3) Cytochromes - required for energy production and enzymes in immune system function	Liver, raw, calf Beef, lean Pulses, raw Whole wheat flour Wheat flour, white Green leafy vegetables, raw	8.0 2.1 0.6-11.1 3.9 1.5-2.0 0.7 – 2.2	Iron deficiency Anaemia	Serum ferritin Haemoglobin volume	(Gibney et al., 2009)
Zinc	1) Present in all tissues**.** Required for: 1) Synthesis of lean tissue 2) Metabolism of proteins, carbohydrates, energy, DNA and RNA.	Liver, raw, calf Beef, lean Muscles, boiled Milk, cows Rice, raw polished Green leafy vegetables	7.8 4.3 2.1 0.4 1.8 0.2-0.6	Reduction or cessation in growth. Poor immune function	No ideal measurement for assessment of status	(DoH, 2008; Gibney et al., 2009)
Selenium	1) An antioxidant nutrient 2) Integral for glutathione peroxidase – an enzyme that protects against intracellular oxidative damage by catalysing the reduction of H_2O_2. 3) Component of iodothyronine deiodinases involved in the conversion of T4 to T3 (T3= biologically active thyroid hormone).	Brazil nuts, kernel only Tuna, flesh only, raw Eggs, chicken, yolk, raw Sunflower seeds, toasted Mackerel, flesh only, raw Trout, brown, raw	0.254 0.093 0.059 0.051 0.042 0.025	Keshan's disease Keshan-beck disease (commonly children)	Plasma or whole blood, hair and toenail	(DoH, 2008; Gibney et al., 2009; PHE, 2015; Ventura et al., 2017)
Iodine	1) Essential constitute of the thyroid hormones thyroxine (T4) and Triiodothyronine (T3)	Haddock, flesh only, raw Milk, semi-skimmed, pasteurised, average Sardines, flesh only, raw Eggs, chicken, whole, raw Yeast extract	0.320 0.003 0.079 0.050 0.049	Goitre, endemic congenital hypothyroidism, mental impairment	Urinary Iodine Concentration (UIC)	(Gibney et al., 2009; PHE, 2015)

Table 1-12. Function of vitamins in the human body, main dietary sources, health implication of deficiencies and methods for assessing status.

Micro-nutrient	Function	Common food sources	Content (mg/100g)	Deficiency symptoms	Assessing status	Reference
Vitamin A	Vision, immunity, growth and development and differentiation of tissues	Liver, lamb, raw	17.3	Dryness of the conjunctive and cornea. Night blindness	Serum retinol	(DoH, 2008)
		Carrot juice	11.36			
		Carrots, raw	11.76			
		Pate	7.32			
		Butter, salted	1.06			
Riboflavin	Building block of FAD (Flavin Adenine Dinucleotide) Required for the metabolism of carbohydrates, lipids and protein into glucose for energy metabolism	Beef, rump steak, barbecued, lean	0.32	Lesions of the mucocutaneous surfaces of the mouth	Erythrocyte glutathione reductase activity coefficient (EGRAC)	(DoH, 2008)
		Breakfast cereal, shredded wheat type with fruit, unfortified	0.28			
		Mushrooms, white, raw	0.27			
		Yogurt, whole milk, plain	0.27			
		Pizza, cheese and tomato, retail	0.15			

1.15 Justification of thesis.

There is a general understanding of the need for information on the prevalence and severity of food insecurity in the UK and its impact on energy and nutrient intakes across the food security continuum. Whilst there is national monitoring of food security (Family Resource Survey) and dietary intakes (National Diet and Nutrition Survey) in the UK, the surveys are independent of each other. This limits the ability to investigate at a national level the effect of household food insecurity on diet quality, energy and nutrient intake amongst different population groups in the UK. Furthermore, national level surveys do not fully represent all population groups, as such targeted surveys to understand the prevalence and severity of food insecurity amongst groups not fully represented in such as those in receipt of benefits are required.

Much of the previous research into diet and health inequality in the UK has focused on socioeconomic status and indices of multiple deprivation. Previous research has shown living in a deprived area or having a lower S.E.S is associated with poorer diet, poorer health outcomes and lower life expectancy. Research into diet and S.E.S has shown there is a socioeconomic gradient, in diet, whereby those with a higher socioeconomic status, diet quality is higher, (containing nutrient dense foods such as whole grains, fruit and vegetables) compared to those with a lower socio-economic status whose diet have been found to be typical energy dense and nutrient poor. Although total energy intakes and macronutrient composition of the diet are similar across socio-economic status (Darmon and Drewnowski, 2008) the micronutrient composition of the diet is likely to differ due to the different food types within the diet. This is of importance because of the essential role vitamins and minerals have in all biological processes of the human body. Sub-optimal intakes and deficiency of micronutrients have an adverse impact to development and health across the life course.

Therefore relying on S.E.S of IMD as an indicator of food insecurity does not allow for the individual experience and change in behaviour for mitigating the experience of food insecurity (e.g. change in quality and quantity of food) Hence, there is a need to understand the diet and nutrient intakes of those experiencing food insecurity alongside low income households to understand similarities and differences in the profile of foods consumed compared to food secure and non-low income households.

Furthermore, using an arbitrary measure of poverty, such as 60% below contemporary median income for that year as a proxy for food insecurity is contentious. Living in poverty does not always transcribe into the experience of food insecurity (Rose et al., 1998). In the UK, of the 11 million households living in relative poverty in 2021/22,15% were food insecure households (Francis-Devine et al., 2023).

Furthermore, the use of indices of multiple deprivation (IMD) as an indicator of food insecurity may miss individuals in the least deprived indices experiencing food insecurity as IMD categories are derived at the Lower Super Output area and not the individual experience of food insecurity.

The overall aim of this thesis is to understand who is at risk of the experience of food insecurity when there is instability in food access due to economic constraint or reduced physical access at a time when restrictions were in place on people movements to halt the spread of COVID-19. Additionally, we sought to understand the impact of a sudden reduction in income amongst households in receipt of UC and how this impacted food insecurity and food bank usage. This thesis also explores diet and nutrient intakes of adolescent females and adult women to understand the relationship between food security, income, and nutritional security status. Previous studies have shown females are more likely to live in poverty compared to males and for mothers when money is limited they are likely to make the budget stretch by going without themselves which is detrimental to their own physical and mental wellbeing (Bennett, 2014) Furthermore, females have been shown to have lower dietary intakes of micronutrient to males, despite in some cases having a higher requirement(e.g. iron) (Derbyshire, 2018).

The research in this thesis provides a unique view of food insecurity as it combines food insecurity measures with usual dietary intakes which we hypotheses will enable a greater understanding of the experience of food insecurity on the diet and how adaptations to the diet to mitigate the experience of food insecurity affect nutritional security. This research provides a novel contribution to the field of food insecurity by expanding and adding to the literature of food insecurity in the UK but also has an international context as the research explores the interconnectedness of food security- diet and nutritional security across different population groups.

1.16 Research Questions:

Manuscript 1: Research questions.

1: Does the iron, zinc and diet quality of adolescent females differ between younger (aged 11-14 years) and older adolescents (aged 15-18 years)?

2: Is there a difference in the iron, zinc and diet quality of adolescent females between equivalised household income quintiles?

3: Does socio-economic status (based on educational level achieved) of the main food provider influence iron and zinc intakes of adolescent females aged 11-14 years and 15-18 years?

Hypothesis manuscript 1:

It is hypothesised the diets of adolescent females living in a lower income households will have reduced dietary iron and zinc intakes whilst overall diet quality will be lower due to a difference in the types of food included in the diet. That as income increase so will iron, zinc and overall diet quality.

Manuscript 2: Research questions.

1: Does the risk of food insecurity during the first UK lock down differ between income groups?

2: Are those who were furloughed more likely to experience food insecurity during the first UK lookdown compared to those still in employment?

3: Are those having to self-isolate because of COVID-19 more likely to experience food insecurity compared to those not self-isolating but following government movement restriction guidelines.

4: As the percentage of household income spent on food increases the odds of experiencing food insecurity increases compared to those who spend a lower proportion of their income on food.

5: Does the energy, macro and micronutrient composition of the diet differ between food secure and food insecure females?

Hypothesis manuscript 2:

When there are shocks to the food system and instability for accessing foods, population groups not typically thought of as at risk of the experience of food insecurity are likely to report being food insecure.

Population groups already vulnerable to the experience of food insecurity will be pushed towards low and very low food insecurity and this will be in part caused by those experiencing anxiety or worry about running out of food increasing the purchase of lower cost food items to ensure there is stock of food. That this increase in purchasing food items suitable for long term storage depletes supermarket stocks, creating a need to source alternative products which may be higher in cost and as such increase's expenditure of household income on food. When expenditure on foods exceeds 10% of household income this will increase the odds for experiencing food insecurity.

Manuscript 3: Research questions:

1. What was the prevalence and severity of food insecurity amongst Universal Credit claimants in receipt of the £20 a week up lift in the following months after its removal?
2. Did Universal Credit Claimants perceive they had a greater need for support from Food banks after the removal of the uplift compared to before?
3. Does the diet, diet quality and micronutrient intakes of females in receipt of Universal Credit differ to the general population?

Hypothesis manuscript 3:

It is hypothesised the prevalence and severity of household food insecurity amongst universal Credit in the months after the removal of the £20 a week uplift will be above the national average for households in receipt of Universal Credit and push households towards needing support from the Foodbank. It is also hypothesised the prevalence and severity of food insecurity will differ amongst household in receipt of Universal Credit depending on household composition and employment status. That the removal of the £20 a week uprating will impact single adult households the greatest as it contributes a greater proportion to overall income. That the diets of females with and income from Universal credit will have a lower quality and micronutrient intakes compared to females in the general population.

1.17 Objectives.

Study 1

A data reuse project was conducted using NDNS data to understand the dietary iron and zinc intakes of adolescent's girls across equivalised income quintiles (1 = lowest - 5 = highest income).

Analysis of biomarkers for iron to understand prevalence of iron deficiency and the prevalence and severity of iron deficiency anaemia amongst adolescents aged 11-14 years and 15-18 years. Calculation of diet quality score and the relationship with income. Identification of foods and food groups contributing to dietary intakes of iron and zinc. The decision to split adolescent females into the two age groups is based on WHO criteria where early adolescence is aged 11-14 and late adolescence 15-18 years (Patton et al., 2016). Furthermore, energy requirements are lower in the 11–14-year-olds compared to 15–18-year-olds; however, 11-14 years old have an increased requirement for zinc compared to older adolescents (9.0mg d^{-1} compared to 7.00mg d^{-}1).

Study 2.

Conduct a national computerised survey amongst working aged adults in the UK with questions designed to capture characteristic information to enable subgroup analysis as well as collection of data related to shopping habits and food security during the first UK national "lockdown". Collect dietary data of participants electronically via the LIBRO App. Compare energy and nutrient intakes amongst food secure and food insecure females in the UK.

Study 3.

Conduct a computerised national survey amongst individuals with an income from Universal Credit who received the £20 a week uprating with questions designed to capture participant characteristics, shopping habits, food security, foodbank usage and their perception of the £20 a week uprating on food group intake. Collect 3 or 4 non-consecutive 24-hour dietary recalls online hosted by Intake24. Estimate diet quality, energy and nutrient intakes and compare to the general population using data from NDNS. Identification of the food sources contributing to energy and nutrients intakes.

1.18 Thesis structure.

The manuscripts in this thesis are presented in the order they were conducted. Chapter two contains the published manuscript for the study investigating the diet quality and iron and zinc intakes of adolescent females in the UK (Appendix C). Chapter three is the published study that investigated the Covid-19 pandemic on the food security of working age adults in the UK and impact on dietary intakes of females (Appendix D), Whilst chapter four is the manuscript in preparation for submission investigating the diet quality, micronutrient intakes of females with an income from UC and comparison to the general UK population.

Additionally, this thesis contains a report written during my three-month Professional Internship Placement (PIPs) with Chefs in Schools (Appendix F) and is an evaluation of head teacher's perception of Chefs in Schools (CiS) provision in their schools as part of CiS engagement strategy.

Furthermore, a report written for Henley Grub Hub on the provision of surplus foods and the contribution of micronutrient intakes is included in (Appendix G). Henley Grub hub used the report in discussion with Coventry Council for support in of the Coventry Food Network.

2 MANUSCRIPT 1. INFLUENCE OF INCOME ON DIET QUALITY AND DAILY IRON AND ZINC INTAKE: ANALYSIS OF THE NATIONAL DIET AND NUTRITION SURVEY OF BRITISH FEMALES AGED 11-14 AND 15-18 YEARS.

2.1 Authors contribution

M.T, LC, SW designed the study. **M.T,** collated the data from the National Diet and Nutrition Survey **(**NDNS), developed the method for preparing the data for analysis, carried out data analysis and produced the first draft of the manuscript. LC and SW contributed to the drafting and reviewing of the manuscript.

The published article can be found in Appendix C.

2.2 Abstract.

A negative socio-economic gradient exists for diet and health outcomes. Since cheaper diets are associated with increased energy and lower nutrient density, we investigated the influence of income on iron and zinc intakes and overall diet quality for adolescent (DQI-A) females aged 11-14 and 15-18 years. National Diet and Nutrition Survey (NDNS years 7&8) data for iron and zinc intake and overall diet quality was assessed by household income quintile across females aged 11-14 and 15-18 years. Equivalised household income positively correlated with Diet Quality Index for adolescents (DQI-A) ($P < 0.001$). Females aged 15-18 years in income quintiles (IQs) 1 and 2, had a greater proportion of respondents with low to intermediate DQI-A score compared to higher IQs ($P = 0.002$). NDNS data showed intake was negatively influenced by income amongst females aged 11-14 years for iron ($P = 0.009$) and zinc ($P = 0.001$) with those from the

lowest incomes consistently consuming significantly less than those from the highest. DQI-A was positively correlated with iron intakes for 11-14 ($P = 0.001$) and 15-18 years ($P < 0.001$). Forty one percent of 15–18-year-olds plasma ferritin stores were below the 15 µg L-1 and 21% had some form of anaemia. Cereal and cereal products were the greatest contributors of iron in all groups. Females in the lowest income groups are at greater risk of lower overall diet quality and inadequate iron and zinc intakes. Amongst older adolescents there is evidence of iron stores being depleted and increased prevalence of anaemia.

2.3 Introduction.

Iron and zinc are essential dietary minerals fundamental for growth and development (Anderson et al., 2012; Black, 1998). During adolescence, defined as the period spanning 10-19 years, females' physiological requirements for both minerals are increased due to the onset of puberty, (Gibson et al., 2002) increased growth and energy requirements (Langley-Evans, 2009) and loss due to menstruation (Jackson, 2011). This, coupled with low dietary intakes, can result in a low iron and zinc status (Samson et al., 2022). During the adolescent years, zinc accumulates in muscle and bone at an increased rate and sub-optimal intakes are associated with poor growth and reduced appetite (Langley-Evans, 2009). Adolescent females aged 11-14 years have a higher requirement for zinc compared to 15-18 years old, this may be because of pubertal growth spurt increasing the physiological requirement for zinc (EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA), 2014).

However, evidence suggests that their provision remains inadequate for many. The prevalence of anaemia in non-pregnant women in the UK is currently estimated at 14% (NICE, 2021) and levels in adolescent girls have previously ranged between 10% and 20% (Nelson, 1999).

Insufficiency of either mineral may negatively impact on adolescent females' physical and cognitive development (Langley-Evans, 2009; Sorhaindo et al., 2006). Sub-optimal iron intakes have been found to limit female adolescent cognitive function and school performance, whilst an increase in iron status improved learning (Nelson, 1999; Skolmowska and Głąbska, 2019). This implies that deficiency may be felt in the economic potential of adulthood (Horton and Ross, 2003).

Optimal intakes of either nutrient are required to ensure an effective immune response against invading pathogens and lessen the severity and duration of illness (Calder, 2020, 2013; Maares and Haase, 2016; Maggini et al., 2010). Iron and zinc deficiency has been shown to be a factor in recurrence of childhood respiratory tract infection whilst zinc supplementation in children decreases the incidence and prevalence of pneumonia (Calder, 2020).

Previous research has shown a decline in diet quality from childhood to adolescents and decreasing intakes of fruit, vegetables and milk but increasing consumption of sugar sweeten beverages (Caswell et al., 2013). This shift in adolescent female's dietary pattern may negatively impact quantity of dietary mineral intake. However, the rate of change in diet quality from childhood to adolescent and its influence on iron and zinc composition of the diet may be impacted by parents and caregivers socio- economic status (education and employment type) (Desbouys et al., 2020) and/ or level of deprivation of the neighbourhood of residence. Furthermore, low dietary intakes of both minerals may be influenced by economic status of the household.

Children living in a household with a lower socioeconomic status, where the occupation of the parent/care giver is listed as manual are more likely to have a daily iron intake below the LRNI compared to children living in households where the occupation is managerial or professional (Gibson and Sidnell, 2014). Furthermore, adolescents living in a household where parental/ caregivers' educational level (an indicator of socio-economic status) is higher, have been shown to a have a better diet quality and healthier dietary patterns (Desbouys et al., 2020).

Whilst living in an area with higher levels of deprivation have been found to have higher numbers of fast-food outlets compared to least deprived areas (Wise, 2018) and this may make it difficult for adolescents to choose healthier options (PHE, 2018).

Furthermore, increased agency and autonomy at this life stage for decision making around food, including frequency of eating out of home (Langley-Evans, 2009) (Neufeld et al., 2022), dietary preference such as adoption of vegetarian or vegan diets (Sergentanis et al., 2021) as well as the influence of their peers (Langley-Evans, 2009; Story et al., 2002). Furthermore, the local food environment local as wells as food available in the school environment are also factors in the diet of adolescent females. Whilst free school meals can be a way to increase intakes of healthy foods (Vik et al., 2019). Whilst studies in Bristol have shown adolescent living in the most deprived areas to have higher consumption of fast food (Fraser et al., 2012).

However, during lockdown it was found children consumed fewer fruit and vegetables especially among poorer groups (Baraniuk, 2020). It is of concern that socioeconomic status has been shown to be positively associated with micronutrient intake (Novaković et al., 2014) and there is evidence for a social gradient between diet quality and health outcome (Darmon and Drewnowski, 2015)**.** The ability to provide adolescent females with diets that align with nutritional guidelines is negatively impacted by household income. Diets more closely aligned with the government dietary guidelines may cost up to twice as much as those which are not (Darmon and Drewnowski, 2015; Steenhuis et al., 2011)**.** The cost of food may negatively influence the diversity of the diet and as such reduce the potential for obtaining an optimal quantity of micronutrients in low-income households. The price of food is a significant factor in determining purchasing decisions for low-income groups (Darmon and Drewnowski, 2015; Steenhuis et al., 2011), and cheaper diets are frequently associated with increased energy density and lower nutrient quality compared to higher cost diets (Weichselbaum and Buttriss, 2014).

A recent report from Public Health England which analysed the National Diet and Nutrition Survey (NDNS) for all years found daily iron and zinc intake significantly increased with household income for children aged 1.5-3 and 4-10 years. A trend for increased iron and zinc intake with increasing household income was additionally seen for adolescents aged 11-18 years (Bates et al., 2019).

If females living in households with a lower equivalised household income consume lower intakes of iron and zinc and have an overall lower diet quality, then it is of importance to identify the barriers to obtaining adequate intake of both minerals. The sources of the minerals in the diet as well as the eating occasions which are contributing to intakes, such as school meals, are required to be known for the development of interventions to reduce their risk of deficiency. In this study we therefore set out to establish the extent to which iron and zinc intakes and overall diet quality amongst adolescent females are affected by household income, parental/ caregivers' socioeconomic status and level of deprivation influence iron, zinc and diet quality intakes. This study aims to identify differences in types of foods consumed and eating occasions which might indicate potential routes for intervention.

2.4 Materials and methods.

Data for years 7&8 (2014/15-2016/16) of the UK NDNS rolling programme were sourced from the UK Data Service (University of Cambridge, MRC Epidemiology Unit, NatCen Social Research, 2021). Years 7&8 were chosen as they comprised the most recent version of the survey at the time of study and provided values of equivalised household income.

2.5 Assigning food and food groups from the NDNS to the Diet Quality Index for Adolescents.

NDNS food level data provides details of the type and quantity of food consumed. We used the variables ‘Food name’ and ‘Sub food group description’ to assign food groups to the categories laid out within the diet quality index for adolescent (DQI-A) as per previous studies (Vyncke et al., 2013) (Llauradó et al., 2016). The DQI-A is a validated tool comprised of three components; dietary quality (DQ), diet diversity (DD) and dietary equilibrium (DE) and is based on food groups within the Flemish food based dietary guidelines. These are similar to the UK food based dietary guidelines. This tool is validated and was used in the HELENA Study which assessed the DQI of Adolescents in 10 European cities (Llauradó et al., 2016; Vyncke et al., 2013). Milk alternatives were placed within the milk and dairy category. Savoury sauces and pickles, nutrition powders, artificial sweeteners and dietary supplements were not included in the analysis.

2.5.1 Calculation of DQI-A.

The diet quality index for adolescents was derived by calculating a mean score of the 3- or 4-day diet diaries for each of participants for each of the DQI-A components: diet quality, diet diversity and dietary equilibrium and dividing by 3. Foods were allocated to either a preference group (recommended for consumption), an intermediate group or a low nutrient, energy dense group and assigned a value of 1, 0 or –1 respectively (Vyncke et al., 2013)**.** The diet quality component is aligned with food based dietary guidelines and is concerned with making optimal food choices from each of the food groups (Vyncke et al., 2013; Llauradó et al., 2016). Food weighting values are multiplied by the quantity (physical weight) of food consumed. Results are summed and divided by the sum of total food consumed (g), then multiplied by 100. The diet diversity component represents the variety of food groups within the diet and is derived by averaging the total weight of food consumed and applying serving sizes as previously described (Llauradó et al., 2016). A score of 1 is given if weight of food in the 9 recommended food groups equals or exceeds the recommended serving size for that food group, 0 if below the recommended serving size. The diet diversity score is summed, divided by 9 and multiplied by 100. Dietary equilibrium component is calculated by subtracting the results from 'dietary adequacy' (which is concerned with meeting minimum recommended intakes) from 'dietary excess' subcomponents (which is concerned with exceeding the upper limits of recommended intakes) and multiplying by 100 (Vyncke et al., 2013). The higher the score the better the quality of the diet. Scores for DQI-A range from -33 to 100. Scores of –33 to 0 typically indicate a low diet quality, > 0 to 33 intermediate, >33 to 66 good and > 66 very good (Llauradó et al., 2016). We further condensed the values into two groups for the purpose of Chi Square analysis. These were -33 to 33% (low) and 33 to 100% (high).

2.6 Iron and zinc intake of females aged 11-14 and 15-18 years in the UK.

Person level estimated daily average intake of micronutrients for iron and zinc were available for children and adolescents (11-18 years of age). Mean values for iron and zinc were compared with age and gender specific reference nutrient intakes (RNI) and lower reference nutrient intake (LRNI).

Income quintiles (IQ) were created from established equivalised household income data provided by the NDNS for children aged 1-18 years in SPSS (IQ1 <£12152.43, IQ2 ≥ £12152.43, IQ3≥19230.42, IQ4 ≥£27541.95 and IQ5≥£43402.43). We created a separate variable of daily equivalised household income by dividing equivalised household income by 365 for use in liner regression analysis to understand the relationship between income, iron and zinc intakes and DQI-A. The contribution of food groups to average iron and zinc intakes were calculated from food level data. This was completed for total intakes in addition to separate analyses which examined solely those foods consumed in school. For analysis of school intakes, only foods which comprised either hot food provision or alternative foods purchased on school premises were included.

2.6.1 Sensitivity analysis “plausible” reporters.

“Plausible” reporters of energy intakes determined by calculating the Energy Intake / Basal Metabolic Rate (EI/BMR) and applying physical activity level (PAL) values and cut off points (age dependent). “Plausible” reporters were participants with EI/BMR ratio within the cut-off point values as previously published (2013). Low reporters were included in the analysis but highlighted to indicate caution in interpretation of findings.

2.6.2 Statistical analysis.

The statistical analysis was performed using the SPSS Statistical package (Version 26.0 and 27.0. Armonk, NY: IBM Corp, Released 2020). Participant characteristics are presented as means and standard error of the mean (S.E.M). DQI-A results are presented as means ± S.E.M.

Linear regression was used to determine whether daily equivalised household income predicts DQI-A, and if equivalised daily household income and DQI-A predict variance in iron and zinc intakes. Liner regression was also used to identify which food groups explained the variance in the DQI-A. Chi square analysis was performed to understand if the representation of participants with low to intermediate (-33 to 33) and intermediate to high DQI-A (>33) scores varied across income quintiles and if representation of "plausible" energy reporters differs across income quintiles. Normality of the distribution of the food data as grouped by the DQI-A tool evaluated using Shapiro-Wilks. Results of all food groups indicated non-normally distributed data ($P < 0.05$). Non-parametric Mann Whitney U tests performed for comparison of total weight of food consumed within each of the food groups for low to intermediate and intermediate to high DQI-A scorers. Results are presented as median with IQR.

Pearson's correlation was used to compare DQI-A, dietary mineral intakes with plasma ferritin, haemoglobin, and zinc levels.

The National Diet and Nutrition Survey person level dietary data were also analysed, with descriptive statistics computed for each of the population groups for the percentage of the population meeting the RNI, percentage of the population with an intake below 90% of the RNI and percentage of the population with intakes below the lower reference nutrient intake (LRNI). Food level data were grouped as per the NDNS results for food groups.

Normality of the data was determined, and the appropriate parametric or non-parametric test conducted. Kruskal-Wallis tests were performed to determine variation between daily iron and zinc intake across different income quintiles. Participants were excluded from the analysis for income quintiles when a value for equivalised household income was not provided.

2.7 Results.

2.7.1 Population characteristics.

The NDNS data for years 7&8 contained dietary information for 272 females aged 11-18 years but only 231 had details of household income (mean age 14.7 ± 0.15 years), of which 11-14 olds accounted for 47.8% (12.6 ± 0.10 years)- and 15–18-year-olds 52.2% (16.6 ± 0. 1 years). Participants without details of equivalized household income were excluded from the analysis when comparing income groups, dietary iron and zinc intakes and diet quality. The largest proportion of the respondents living in the most deprived areas of the UK were from the lowest income quintile (IQ1; 36.6%), whilst the largest proportion in the least deprived areas were those with the highest income (IQ5; 32.4%). Amongst females aged 11-14, 26.1% of those in IQ1 lived in the most deprived areas of the UK and 27.3% of IQ5 lived in the least deprived areas, whilst for females aged 15-18 years these proportions rose to 47.6% and 40.0% respectively.

2.7.2 Interaction between age groups - equivalised household income and dietary iron and zinc intakes.

A 2-way Anova did not reveal a significant interaction between equivalized household income and the two ages group on mean intake of daily dietary iron ($P = 0.07$). There was however for zinc ($P = 0.042$) although no significant difference in the mean zinc intakes by age group (P = 0.154) but there were significant differences between equivalised household income levels (P =0.015).

2.7.3 Overall Diet Quality.

All diet quality assessments varied positively with income and typically the food groups consumed in a greater quantity by those with a higher DQI-score were from the food groups associated with a higher micronutrient composition such as ‘fruits’ explaining 10% of the variance ($F(1,229)=23.92$ (P < 0.001), ‘vegetables’ explaining 28% of the variance ($F(1,229)=88.45$ (P <0.001), ‘milk products’ explaining 11% of the variance ($F(1,229)=27.84$ (P <0.001), ‘bread and cereals’ explaining 7% of the variance (F (1,229)=16.89 (P < 0.001), whilst those associated with a higher energy content such as ‘snacks and candy’ and ‘sugared drink and fruit juice’ did contribute 0% and 2% to the variance in DQI-A (F((1,229)=0.084 (P = 0.773; (F((1,229) = 4.26 P = 0.04 respectively). The food groups remained similar when broken down by age group with 11–14-year-olds with a higher DQI-A score consuming a greater weight of food from the food groups listed above and this was mostly the same for 15-18–year-olds.

2.8 Representation of participants with low or high DQI-A between the income quintiles.

The DQI-A (ranges from -33 to 100% (Llauradó et al., 2016) was 38.7 ± 0.92 on average across the population. When separated into age categories, DQI-A was 39.3 ± 1.2 and 38.2 ± 1.4 for 11–14-year-olds and 15-18-year-olds respectively. DQI-A varied considerably from -5.78 up to 72.74 and this range was present in all income quintiles. Chi Square analysis of the data for all females found that having a low to intermediate (-33 to 33%) or intermediate to high DQI-A (>33%) was moderately dependent on income quintile (Cramer's v = 0.307). A greater proportion of females in IQ1 and IQ2 had a DQI-A score of 33% or below (40.9% and 49.0%, respectively) compared to IQ3 (32.6%), IQ4 (25.0%) and IQ5 (5.4%; P <0.001). This was predominantly driven by outcomes for 15-18-year-olds (P = 0.002; Cramer's v = 0.379) as the association was not significant for the 11-14s (P = 0.282). In the older group, the proportions below DQI-A of 33% rose to 47.6% and 55.9% for IQs 1 and 2 (P = 0.002).

2.8.1 Relationship between equivalised household income and diet quality component (DQc) of DQI-A.

The dietary quality component of DQI-was low for both 11-14 (15.3 ± 2.85%) and 15–18-year-olds (11.6 ± 3.13; Range = -100 to +100). Income was directly associated with DQc (P = 0.001; β 0.216). For every £1 increase in weekly equivalised household income DQc increased 0.135%. Income was not a predictor of DQc for females 11-14 years (P = 0.293; β 0.057) but was for 15–18-year-olds (P < 0001, β 0.221) with every £1 increase in income resulting in an increase of DQc of 0.221%.

2.8.2 DQI-A and weight of food consumed within food groups.

For those with a low to intermediate DQI–A score (n = 73) their diets predominantly comprised a lower weight of fruits (26.3g, IQR 105.3g) compared to intermediate to high DQI-A score (n =158; 112.3g, IQR 149.4g; P < 0.001). They also consumed fewer 'vegetables' (39.1g, IQR 54.2g vs 84.3g, IQR 84g; P <0.001), 'milk products' (75.0g, IQR 112.2g vs 156.3g, IQR 170.1g; P<0.001), 'bread and cereal' (94.3g, IQR 54.5g vs 114.6g IQR 83.5; P = 0.002) and 'fats and oils' (5.3g, IQR 9.6g vs 9.7g, IQR 10.5g; P = 0.016) compared to intermediate to high DQI-A scorers. The food groups 'sugared drinks and fruit juice', 'snacks and candy', 'potatoes and grains' 'meat, fish and substitutes were all consumed in similar amounts between the DQI-A groups (P = 0.703; P = 0.871; P = 0.628; P = 0.912 respectively). The pattern was similar for both age categories with 11-14 low DQI-A consuming lower quantities of vegetables (44% less), fruits (67% less), 'meat, fish and substitutes' (17% less) and milk products (58% less) than high DQI-A and for 15-18-year-olds these values were 59%, 72% and 39% for vegetables, fruit and milk products respectively (P < 0.001). It was additionally of note that 15-18-year-olds in the low DQI-A group consumed 36% more free sugars than those from the higher DQI-A group (P = 0.004).

2.9 The influence of household income on iron, zinc and energy intake in UK female adolescents.

2.9.1 Iron.

Iron intakes of females aged 11-18 years were frequently below the RNI (Figure 2.1A & B dashed line). For those between 11-14 years (n = 130) 98% had an iron intake below the RNI (14.8mg/d) with 52% being below the LRNI (8.0 mg/d), whilst for females between 15-18 years, (n = 142) 58%, were below the LRNI, with 96% below the RNI (Figure 2.1E).

Daily iron intakes differed significantly across income quintiles (IQ) for females aged 11-14 years (P = 0.009) with those in IQ5 (61% of RNI) being significantly higher compared with IQ1 (just 42% of RNI; P = 0.014) and IQ3 (39% of RNI; P = 0.005). The IQ4 group (53% of RNI) consumed more than IQ3 (P = 0.035) and intake in IQ2 was considerably higher than for those in the adjacent quintiles (37% higher than IQ1 - P = 0.039 and 44% higher than IQ3 - P = 0.024). Females aged 15-18 showed similar intakes across income quintiles.

Plasma ferritin concentrations were generally in the normal range (41 – 400 µg L^{-1}) but were 27% lower in the 15-18 years group compared with the 11-14s (P = 0.02; Table 2.2). The proportion of 11-14s who fell below the 15 µg L^{-1} threshold indicator of low iron stores (WHO, 2011a) was 10% but amongst the older girls (15 – 18yrs) this reached 41%. Haemoglobin levels exceeded 120 g L^{-1} for the majority, however, 21% of females aged 15-18 years had some form of anaemia, with 14% showing mild (haemoglobin level between 110-119 g L^{-1}) and 7% moderate anaemia (haemoglobin 80-109 g L^{-1}).

DQI-A scores showed a significant positive relationship with iron intakes (β 0.303, P < 0.001) with every 1% increase in DQI-A resulting in a 0.066mg increase in iron for all participants. This was similar for 11-14 (β 0.301, P = 0.001; 0. 069mg increase per 1% DQI-A) and 15-18-year-olds (β 0.306, P =0.001). Neither ferritin nor haemoglobin correlated with DQI-A scores in either group.

2.9.2 Zinc.

Zinc intakes were low in both age groups (Figures 2.1C & D) with 39% of females aged 11-14-years and 13% in the 15 – 18 years category having a zinc intake below the LRNI (5.3 mg d^{-1}; Figure 2.1E). Only 11% of 11–14-year-old girls achieved the RNI for zinc (9.0mg/d), whilst 68% of 15-18 years group were below their respective RNI (7.0mg/d) (Figure 2.1E).

The zinc intakes of females aged 11-14 years also differed with household income (P = 0.001; Figure 2.1C), with those in quintile 1 being the lowest. This group showed a lower consumption (55% of the RNI) compared with IQ2 (81% of RNI; P = 0.026) and IQ5 (75% of RNI; P = 0.004). Similar to the findings for iron intake, 11–14-year-old females in IQ2 consumed significantly more zinc than those in the adjacent quintiles (32% higher than IQ1 - P = 0.026 and 40% higher than IQ3 – P = 0.026). Zinc intake did not differ with income quintile in the 15-18 years group (Figure 2.1D).

Daily zinc intakes were positively associated with DQI-A in all (β 0.373, P < 0.001), with 0.061mg (β 0.390 P < 0.001) and 0.071mg (β 0.306 P < 0.001) increases for each 1% increase in DQI_A (11-14 and 15-18 respectively).

2.9.3 Energy intake.

Females aged 11-18 years with values for body weight and equivalised household income were included in the analysis (n = 225) to identify “plausible” and “non-plausible” reporters of energy intakes (kcal). In total, 43.6% of females did not have a “plausible” energy intake. When analysed by age range, 37.3% of 11-14-year-olds (n = 110) and 50% of 15-18-year-olds (n =115) did not have “plausible” energy intakes. There were no differences in reporting reliability across income quintiles for either age group (P = 0.156, P = 0.252 respectively) (Table 2.1).

2.9.4 Contribution of different foods to iron and zinc intake.

Foods which had the greatest contribution to daily iron intakes were cereal and meat based (hereafter referred to as cereal and meat products; tables 2.3 and 2.4), with meat contributing an increasing proportion in older groups (P < 0.001; tables 2.6 & 2.7). These, in addition to vegetables, vegetable products and potatoes (hereafter vegetable products) and milk products were significant contributors to zinc intakes.

2.10 Females aged 11-14 years.

2.10.1 Iron.

Most of the iron intake in females aged 11-14 years was from cereal (52%), meat (14%) and vegetable products (12%; table 2.3). Flour containing foods contributed ~35% of the total iron intake whilst breakfast cereals, consumed by 62% of participants, contributed 16%. Although neither the quantity nor proportion of daily iron intake from breakfast cereals differed across income quintiles (P = 0.077 & P = 0.699 respectively) the total quantity of cereal-based products consumed did (P = 0.001; table 2.5). Of note, females in IQ2 consumed more than those in IQ1 (P = 0.047) and IQ3 (P = 0.001). Meat products were consumed by 98% of respondents and no differences in intake were observed between quintiles for either meat or vegetables. We estimated the bioavailable iron from each participant's diet by assuming that the absorption of iron from vegetable sources would be 10% of intake and that from animal sources (all assumed to be haem iron – meat and fish) would be 25% (Fairweather-Tait, 1992). For those who met the 1.4 mg day^{-1} threshold indicated as necessary for females of 11 – 18 years old (DoH, 2008), the iron derived from meat and fish was approximately 30% higher than for those who fell short of this level (P = 0.026).

2.10.2 Zinc.

Meat (31%) and cereal products (31%) were the main contributors to zinc intake with milk products providing most of the remainder (16%; table 2.4). The percentage contributions of food groups did not vary greatly between those achieving the 9 mg RNI, however when individuals were separated according to those who achieved 7mg (the RNI for all older age groups) and those who did not, then milk was shown to provide a significantly higher proportion of zinc (32% higher; P = 0.013) than for those below the 7mg threshold.

2.11 Females aged 15-18 years.

2.11.1 Iron.

Iron in 15 – 18-year-old females was again predominantly derived from cereal (46%), meat (17%) and vegetable products (15%; table 2.6). All participants reported consuming some form of meat. Again, 35% of daily iron intake was contributed by flour containing foods. Just 50% reported eating breakfast cereals. This resulted in only 12% iron provision by breakfast cereals. Iron provision from meat and fish combined were similar between those achieving the predicted 1.4 mg day^{-1} threshold compared with those below this level (P = 0.485). The proportion of iron obtained from meat was 23% greater than for the 11-14 age group (P < 0.001).

2.11.2 Zinc.

The largest contributor to zinc intake in 15–18-year-old females was meat (35%; table 2.7). Although this did not differ overall by income, the quantity of zinc derived from burgers and kebabs did, being significantly negatively associated with income level (P = 0.026). Cereals, milk and vegetables provided between 11% - 18% each. Vegetable consumption was positively associated with income (P = 0.028). Those who consumed less than the 7mg RNI, obtained a significantly greater proportion (18% higher; P = 0.029) of their zinc intake from cereal products compared with those whose intakes exceeded 7mg.

2.12 Contribution of school foods to iron and zinc intakes.

For many, particularly those on low incomes, school food provision would potentially contribute greatly to dietary intakes of critical nutrients. We therefore determined the intake of iron and zinc from school provided meals for 11-18-year-olds. Of the respondents who recorded diet diary days during school time, we found that across all ages, 45% consumed school provided meals of which 78% were cooked. The proportions of children consuming school meals were similar across income groups. Half of the girls who consumed school meals obtained around 25% (26.2% of total; IQR 18.4% - 35.3%) of their daily iron intakes from them, while for zinc, this was slightly higher at 30.2% of total intake (IQR 24.3% - 43.9%). School meals should provide 35% of requirements (Mucavele et al., 2013) and we found that this was the case for just 17% and 20% of girls for iron and zinc respectively across all age groups.

2.13 Impact of education and gender of main food provider.

Whilst higher levels of education are usually associated with higher household income and better diets, we found no evidence of a difference in the iron and zinc intakes of females 11-14 (P = 0.788, P = 0.487 respectively) and 15-18 years (P = 0.962, P = 0.872 respectively) when living in a household where the main food provider had a degree (n = 38, n = 32 respectively) compared to those who did not (n = 74, n = 76 respectively). Gender of the main food provider also was not associated with iron and zinc intakes in both age groups (11-14 years iron P = 0.397, zinc P = 0.460; 15-18 years iron P = 0.164, zinc P = 0.413).

2.14 Household income source.

Very few respondents were solely dependent on benefits (n = 20), whilst there were a number who received benefits in addition to income from employment (n =171). Because of the low numbers of the benefits only, both age groups were combined. Whilst females living in a household with income from employment had a numerically greater iron intake (8.23 ± 024 mg d^{-1}) compared to females living in a household with income solely from non-working sources (7.78 ± 0.58 mg d^{-1}) this was not significant (P = 0.539) and this was similar for zinc (employment 6.29mg ± 0.17 mg d^{-1}, solely benefits 5.75 mg ± 0.36 mg d^{-1}; P = 0.289).

2.15 Discussion

Iron and zinc deficiency continues to be of concern for many children in the UK. Our data indicated a decrease in iron and zinc from food sources amongst females aged 11-18 years compared with observations from previous years particularly amongst the older females (Weichselbaum and Buttriss, 2014). We found, similar to previous work, (Weichselbaum and Buttriss, 2014) that income influenced iron and zinc intake with those in the lowest income quintile most frequently consuming the least. We also showed that diet diversity was compromised in those from lower incomes, particularly for older adolescents. These observations suggest that there may be a considerable number of disadvantaged children who not only consume low quantities of iron and zinc but may be further compromised by the composition of the foods that can be afforded.

2.15.1 Intake levels.

Dietary iron and zinc intakes for females aged 11-14 and 15-18 years were low compared to the RNI and for many were below the LRNI, indicating that iron intake was insufficient to meet requirements at a time when the physiological demand to support growth and development is at its greatest (Jackson, 2011). The RNI is set at 14.8 mg d^{-1} for females aged 11-18 years and for non-menopausal women, to account for a typical daily iron loss of 0.8 mg d^{-1}, with an additional 0.6 mg d^{-1} due to menstruation, in the face of a bioavailability of iron from food sources of approximately 10% (Gibney et al., 2009). Therefore, for females to remain iron replete there is a requirement for 1.4 mg of iron to be absorbed from the diet daily (Gibney et al., 2009). Dietary iron intake for 11-14- and 15–18-year-olds was half of the

RNI, indicating suboptimal intakes which, if sustained, could lead to depletion of iron stores and anaemia. We found 10% of females aged 11-14 years had plasma ferritin levels below 15μg L^{-1}, potentially indicating low iron storage, although this may be more reflective of stores being utilised to support growth and development (Jackson, 2011) particularly since haemoglobin levels were normal in this group (Table 2.2). However, a large proportion (41%) of 15-18-year-old females had plasma ferritin levels < 15 μg L^{-1} with 21% of them having haemoglobin levels indicative of anaemia. Sustained suboptimal iron intake and increased physiological requirements may have resulted in development of anaemia in a subset of the 15–18-year-old girls in in this age group. Other factors which may contribute to anaemia, including B12 and folate intake and clinical factors, such as thalassemia, inflammatory conditions and haemolysis were not considered in this study, but they represent far less frequent causes of anaemia than low iron intake. Iron deficiency in the absence of anaemia can have adverse consequences on mental capacity and immune health (The Department of Health, 2013) and importantly, adolescents entering the reproductive years may not have sufficient iron stores to support the increased demand during pregnancy, estimated at 4-6 mg daily (Gibney et al., 2009). The frequency of anaemia in pregnancy has been recorded at levels as high as 46% in some UK cohorts (Nair et al., 2016; Pavord et al., 2020) representing a significant health risk for the mother and developing child (Abu-Ouf and Jan, 2015b) and it seems likely that those individuals who have been exposed to moderate iron deficiency during their teenage years, would likely comprise a significant proportion of this anaemic cohort.

The bioavailability of iron differs considerably between animal and plant-based foods. Iron from animal products is more bioavailable as it is in the form of haem iron, of which 25-30% is absorbed via the intestinal haem carrier protein 1 (HCP1 or SLC46A1). Iron from plant-based foods is predominantly in the form of Fe^{3+} which must be reduced to Fe^{2+} to enable its absorption through the divalent metal transporter 1 (DMT1 or SLC11A2). Consequently, only between 1 and 10% of the iron derived from plant sources is absorbed (Skolmowska and Głąbska, 2019). Zinc and iron are additionally impacted when acquired from plant-based sources, due to the presence of phytic acid which binds divalent ions, thereby inhibiting their absorption (Maares and Haase, 2020). Therefore, diets high in plant material can potentially have a significant negative impact on iron and zinc status even if they contain them in relatively high concentrations. Consumption of anti-nutritional factors was not analysed in this report, principally due to the dearth of reliable food level data but is a factor which needs be considered in future work to help gain an understanding of the relative impact on status that this may be having in the UK population.

Zinc intake was below the RNI for a large proportion of both age groups (78.3% of all females). We found a significant negative association between intake and household income (Figure 2.1), contrary to findings for previous NDNS cohorts (Thane et al., 2004) which reported no effect. Household inequality has been approximately stable over the last decade but was more volatile prior to 2010 (O’Neill, 2020), increasing sharply in non-retired households from 2002 to a peak in 2008 just before the economic downturn. The negative effect of declining household income on the ability of families to adequately feed their children is well documented (French et al., 2019; "Marmot Review report – 'Fair Society, Healthy Lives | Local Government Association," 2019; Scott et al., 2018). Differences observed between income quintiles for intake in females for both age groups for both iron and zinc, therefore, may reflect a negative impact of early life exposure to inequality. Previous data which did not find an association with household income (Thane et al., 2004) is derived from individuals who were living through a period of relative stability in the level of inequality (~1987 – 1997). It is of note that children who comprised the 11-14 years cohort in the 2014-2016 NDNS survey would have ranged from 0 – 2 at the start of the steep rise in inequality. It is possible that discrepancies in consumption may link to economic challenges occurring at the very start of their lives.

2.15.2 Underreporting.

Underreporting was widespread and was particularly high for 11–14-year-old females in IQ1 and IQ3 where 48% and 55% had "non-plausible" energy intakes. It has been shown that adolescent females are more likely to underreport energy intakes, particularly those with a higher BMI. Factors such as forgetfulness, eating meals outside of the home and being conscious of body weight and image impact reporting reliability (Livingstone et al., 1992)and this is particularly stark for adolescent females as up to 49% of respondents' energy intakes are low compared to estimated Basal Metabolic Rates (BMR) (Robinson et al., 1999).

The underreporting will have inevitably skewed data in our study to indicate a higher proportion of individuals consuming below the RNI. However, there would remain a significant proportion of girls aged 11-18 years studied who were marginally deficient for iron. This was evident from the numbers of girls aged 15-18 years with haemoglobin levels below the cut off point for diagnosis of anaemia. Whilst for 11–14-year-olds haemoglobin levels were above the threshold for anaemia, 10% had depleted serum ferritin stores, increasing to 41% in 15-18-year-olds. These values, whilst in of themselves are not the best indicators of status, do support the outcomes of low consumption levels seen in the dietary data.

2.15.3 DQI-A Outcomes

The results from our study found DQI-A for females aged 11-18 years overall, was 38.7% indicating average adherence to food based dietary guidelines. The results for DQI-A in this study are slightly higher compared to a previous published study which reported DQI-A of 31.4% for adolescent females (Llauradó et al., 2016). Overall females in highest income quintile, DQI-A score was greater than those in the lowest (47.9 % compared to 35.1 % respectively) and this was particularly pronounced amongst 15-18 years olds where DQI-A of females with the lowest income quintile was 16 percent lower compared to the females in the highest income quintile. Foods typically thought of as nutrient dense and low energy were consumed in lower quantities among females aged 15-18 years with a DQI-A score below 33% compared to those with a DQI-A above 33%, indicating that diets among girls in this age group in lower income quintiles are worse compared to their higher income peers. This was supported by the observation that free sugar consumption in those with a low DQI-A was higher than in high

DQI-A, and likely a consequence that these girls are making more autonomous dietary decisions.

2.15.4 Food contributions.

The food group which contributed the greatest proportion of dietary iron was cereal products. Of these, the main single contributor was flour (~36% for 11-14 years and ~34% for 15-18 years). This would suggest that flour contributed ~34% of the total iron intake with breakfast cereals providing another 17%. Of the remainder, around 28% was from meat and vegetable products. This highlights the value of appropriate fortification of flour and of consuming breakfast cereals which was not universal in these cohorts. The relative contribution of breakfast cereals to iron intakes suggests that those choosing not to consume them are at significant risk of falling further short of the recommended intake levels. It should also be noted that not all breakfast cereals are fortified equivalently, so there may be some value in standardisation of cereal fortification to help ensure their ability to enable adequate iron intakes.

We noticed a higher contribution (30%) to dietary iron from meat and fish in 11–14-year-old females able to achieve their iron intake requirements compared with those who were not. The widespread consumption of meat across the whole population would suggest that provision of iron from meat sources might represent a viable strategy for increasing iron levels, particularly for those who do not consume breakfast cereals. This may be particularly pertinent for females aged 15-18 years as meat contributed a significantly higher proportion of iron for them than for the younger group.

An important barrier to this would be cost. However, meals made from cheaper ingredients, whilst potentially lower in iron concentration, could still provide a cost-effective alternative. Females from lower income quintiles in the 15–18-year age group obtained proportionally more zinc from burgers and kebabs than those from the higher quintiles. A larger proportion of these teenagers may therefore be making their own dietary choices outside of the home than those from the wealthier backgrounds. This is likely to impede successful interventions aimed at improving diet quality and diversity as the routes of successful communication will be more limited.

2.15.5 Food cost.

The cost of foods influences the types purchased and diets aligned with government recommendation are more expensive than those which are not (Scott et al., 2018). Additionally, food cost is also a factor in the food security of households, especially if available foods are not affordable (Lee et al., 2013). Availability and affordability of foods and household food security has recently received attention due to the Covid-19 pandemic which resulted in panic buying of staple foods reducing the availability of lower cost food items (Power et al., 2020, p. 19). This reduced the size and quality of the diet of low-income households and increased food insecurity as they do not have the disposable income to purchase foods in bulk or to purchase higher cost alternatives. During Covid-19 schools were closed and the safety net of school food removed, although families of children eligible for free school meals (FSM) were supported with a £15 voucher per week to provide lunch for their child. However, for many other families on low income but not entitled to FSM, they had to bear the burden of increased food cost and increased quantities of food to be purchased to cover the meals not provided at school.

When the percentage of the population with an intake below LRNI exceeds 5% it may be a public health concern as clinically relevant deficiencies may occur (Derbyshire, 2018). This was highlighted in the SACN Iron and Health report (Jackson, 2011), which found toddlers, girls and women of reproductive age to be at increased risk of iron deficiency anaemia. This was particularly apparent if they were from low-income groups (Jackson, 2011). Greater provision therefore needs to be made for those in low-income groups to support adequate iron and zinc nutrition during childhood with greater emphasis placed on mechanisms which allow provision of important micronutrients. Novel mechanisms to facilitate access to and consumption of iron and zinc rich foods in children, particularly those from lower income households, are required with some urgency. The cost-of-living crisis has seen energy, fuel and food cost all increase in recent times (since late 2021) and disposable incomes decrease. Low-income households experience higher inflation compared to wealthy households (Hourston, 2022) and whilst there are government strategies in place to help reduce the burden such as the cost-of-living support from May 2022 (HM Treasury, 2022) These are one off payments. The increase to Universal Credit during the Covid-19 pandemic provided households with a steady source of income and the removal of the uplift in October 2021 left many worried they would not be able to feed their families and rely on coping strategies such as reducing quantity of food consumed and feeding children before adults (Trussel Trust, 2021), all of which may have negative impacts on the diet quality and micronutrient intakes of the most vulnerable population groups.

2.16 Conclusion.

The overall diet quality of UK female adolescents in the lowest income quintiles is notably worse than for their higher income peers and this negatively impacts the quantity of iron and zinc consumed. Furthermore, there is evidence for decreasing plasma ferritin and increasing prevalence of anaemia as females enter their late teen years. Persistent low intakes in the face of high physiological requirements will compound the prevalence of deficiency and adverse health outcomes associated with sub-optimal micronutrient intakes often seen in lower income groups. Interventions are required to increase iron and zinc intakes in female adolescents across all income quintiles with an emphasis on ensuring diets aligned with government dietary guidelines are accessible and affordable for all to ensure micronutrient intakes are adequate for the avoidance of ‘hidden hunger’ in the lowest income groups in the UK. Notably, we show that increasing income has a direct positive effect on DQI-A which in turn positively impacts iron and zinc intakes. School food is a good vehicle for the promotion of healthy diets and therefore, represents a potential avenue, outside of direct financial support, for improving health outcomes in adulthood and future generations as adolescent females enter the reproductive years.

2.17 Limitations.

This study investigates differences in iron and zinc intakes of adolescent’ females aged 11-18 years across equivalised income quintiles. Although equivalisation of income takes into consideration household size and composition and makes for a more meaningful comparison across household types and allows for analysis at the individual level (An Phriomh-Oifig Staidrimh, 2023). It should be noted all people that live in the household contribute to overall income and as such when analysing individual characteristics this should be taken into consideration. Although equivalisation of income is a validated method for measuring poverty and social exclusion indicators, other factors could influence dietary iron and zinc intakes. Therefore, the findings from this study should be interpreted with caution as the results were not adjusted for confounding factors such as socio-economic status (e.g., educational level, occupational status), or ethnicity or may have influenced iron and zinc intakes. It is has been previously shown different dimensions of socio-economic status are factors in type of diet consumed with lower educational or occupational S.E.S associated with poorer quality diets (Azizi Fard et al., 2021;Galobardes et al., 2001). Ethnicity is related to dietary patterns (Rashid et al., 2018) and may influence iron and zinc intakes depending on the types of food included in the diet. Despite the limitations, this study highlights iron and zinc intakes of adolescent females are below recommendations across all income groups but those in the lowest income quintile are disproportionally represented for dietary iron and zinc intakes below recommended reference nutrient intakes.

Table 2-1 Percentage of females aged 11-14 and 15-18 years with "non-plausible" energy intakes and summary description of weight, BMI and food energy intake from the National Diet and Nutrition Survey (NDNS) by income quintile.

Females	**Income Quintile**														
	Age (years)	**Total population**		**1**		**2**		**3**		**4**		**5**		**P value**
Number of "non-plausible" energy (kcal) reporters (%)	11 - 14	41	(37)	11	(48)	5	(31)	12	(55)	7	(25)	6	(29)	0.156
	15 - 18	57	(50)	11	(58)	17	(50)	5	(26)	16	(57)	8	(53)	0.252
Weight (kg) (S.E.M)	11 - 14	52.5	(1.36)	51.3	(3.49)	50.7	(3.77)	52.3	(2.57)	52.6	(2.33)	55.1	(3.52)	0.838
	15 - 18	64.0	(1.24)	66.8	(3.73)	62.9	(1.97)	57.7	(2.26)	65.5	(2.75)	67.9	(3.37)	0.131
BMI (S.E.M)	11 - 14	21.1	(0.46)	21.1	(1.04)	20.6	(1.37)	21.6	(0.94)	20.7	(0.87)	21.7	(1.21)	0.631
	15 - 18	23.8	(0.44)	24.8	(1.32)	24.1	(0.79)	21.1	(0.66)	24.2	(1.01)	24.6	(0.82)	0.052
Total energy diet only (kcal) (S.E.M)	11 - 14	1165	(41.03)	1096	(86.12)	1238	(144.23)	1047	(80.17)	1321	(55.29)	1283	(42.38)	0.118
	15 - 18	1225	(35.32)	1207	(83.24)	1224	(74.62)	1189	(85.76)	1250	(68.06)	1223	(87.28)	0.992

Number of respondents with a "non-plausible" total food energy (kcal) intake. Results are shown as mean and S.E.M for Total food energy (kcal) for "non-plausible" reporters. BMI and weight (kg) are shown as mean and S.E.M for total population with valid weight and equivalised income. Number of participants included in analysis females 11-14 years (n = 110), IQ1 n =23, IQ2 n =16, IQ3 n = 22, IQ4 n = 28, IQ5 n=21. Females 15-18 years (n =115), IQ1 n =19, IQ2 n =34, IQ3 n = 19, IQ4 n = 28, IQ5 n=15

Table 2-2. Plasma ferritin and haemoglobin, in females 11-14 and 15-18 years and by income quintile

	Total			IQ1			IQ2			IQ3			IQ4			IQ5			
Age (years)	N	Mean	S.E.M	n	Mean	S.E.M	n	Mean	S.E.M	n	Mean	S.E.M	n	Mean	S.E.M	n	Mean	S.E.M	P value
Plasma Ferritin (µg/L)																			
11-14	39	31.13	2.135	10	34.80	4.328	3	38.33	12.875	3	38.33	7.333	11	25.82	3.590	7	35.14	4.183	0.366
15-18	39	22.77	2.806	6	22.00	4.830	7	19.71	5.826	5	22.20	4.164	9	31.56	9.567	5	22.60	5.325	0.757
Haemoglobin (g/L)																			
11-14	41	134.71	1.146	11	135.82	2.053	3	132.67	0.882	4	136.75	4.366	12	132.58	2.924	6	136.00	1.807	0.786
15-18	42	129.74	2.002	6	133.17	2.272	8	128.13	1.726	4	123.75	8.290	9	132.56	4.285	7	134.57	3.497	0.244

Table 2-3. Percentage contribution of food and food groups to daily iron intake for females aged 11-14 years. NDNS years 7&8.

Females 11-14 years	**All (n=130)**		**Income quintile**										
Food group			**1 (n = 23)**		**2(n = 17)**		**3 (n = 24)**		**4 (n = 28)**		**5 (n = 22)**		
	Mean	**S.E.M**	**Mean**	**S.E.M**	**Mean**	**S.E.M**	**Mean**	**S.E.M**	**Mean**	**S.E.M**	**Mean**	**S.E.M**	**P value**
Cereal and cereal products	52.14	1.25	51.96	3.03	55.23	3.30	49.43	2.57	53.53	3.00	50.89	2.71	0.669
Pasta, rice, pizza, and other cereals	12.20	1.01	16.55	3.00	12.66	3.17	9.78	2.03	13.72	2.10	7 .40	1.56	0.074
White bread	10.73	0.82	9.29	2.08	10.72	2.60	11.07	1.95	12.97	1.72	10.23	1.94	0.500
Other breakfast cereals	8.33	1.16	6.89	2.44	12.98	4.32	4.95	2.27	11.91	3.10	3.58	1.71	0.111
High fibre breakfast cereals	7.77	1.18	6.07	2.76	7.12	2.84	11.39	3.56	3.97	1.95	10.39	2.87	0.259
Biscuits	4.76	0.48	3.82	0.82	2.66	0.58	4.15	1.65	5.04	0.77	7.54	1.42	0.029 *
Buns, cakes, pastries, and fruit pies	3.47	0.47	4.12	1.48	3.25	1.05	3.05	0.91	2.92	0.72	3.91	0.81	0.716
Brown, granary, and wheat germ bread	2.29	0.46	2.34	1.40	2.67	1.44	2.47	1.39	1.57	0.53	3.21	1.06	0.425
Whole meal Bread	1.85	0.41	1.48	0.88	2.91	1.71	2.12	0.90	1.03	0.57	3.20	1.33	0.428
Puddings	0.44	0.11	0 .14	0.12	0.26	0.16	0.46	0.24	0.24	0.14	1.43	0.51	0.111
Other Breads	0.29	0.23	1 .28	1.28	0.00	0.00	0.00	0.00	0.15	0.15	0.00	0.00	0.637
Meat and meat products	14.42	0.75	14.40	1.98	14.32	1.77	15.96	1.32	13.40	1.58	12.04	1.53	0.395
Beef and veal dishes	3.39	0.38	3.71	1.12	4.18	0.91	3.50	1.09	2.55	0.69	3.58	0.80	0.611
Chicken and turkey dishes	3.14	0.35	2.22	0.48	3.63	0.87	3.18	0.92	3.08	0.79	3.44	0.90	0.795
Coated chicken and turkey	1.50	0.23	1.54	0.59	1.97	0.69	1.84	0.72	1.66	0.49	1.01	0.36	0.969
Sausages	1.34	0.21	1.07	0.51	1.48	0.85	2.41	0.62	1.29	0.36	0.70	0.30	0.190
Bacon and ham	1.19	0.14	1.40	0.42	0.90	0.37	1.48	0.38	1.17	0.27	0.64	0.24	0.239
Burgers and kebabs	0.83	0.19	0.91	0.55	0.75	0.41	1.19	0.60	0.87	0.36	0.66	0.29	0.976
Lamb and lamb dishes	0.78	0.26	1.15	0.76	0.00	0.00	0.43	0.24	0.52	0.42	0.28	0.20	0.609
Pork and pork dishes	0.77	0.18	0.61	0.41	1.03	0.49	0.69	0.41	1.02	0.47	1.00	0.53	0.611
Meat pies and pastries	0.80	0.19	0.58	0.35	0.18	0.18	1.16	0.67	0.99	0.41	0.69	0.39	0.545
Other meat and meat products	0.46	0.18	1.22	0.79	0.03	0.03	0.07	0.05	0.25	0.15	0.02	0.02	0.532
Liver and dishes	0.22	0.17	0.00	0.00	0.45	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.222
Vegetable and potatoes	12.17	0.60	14.96	1.37	10.84	1.11	12.99	1.70	11.16	1.28	11.92	1.60	0.220
Vegetables (not raw) including vegetable dishes	6.14	0.47	6.27	1.08	5.77	0.99	6.39	1.28	5.67	0.95	7.09	1.33	0.943
Chips, fried and roast potatoes and potato products	3.07	0.33	5.23	1.23	2.98	0.62	3.17	0.63	3.18	0.74	1.32	0.28	0.064
Potatoes, potato salads and dishes	2.09	0.25	2.67	0.69	1.44	0.28	2.53	0.75	1.24	0.39	2.58	0.59	0.240
Salad and other raw vegetables	0.86	0.11	1.00	0.28	0.65	0.20	0.85	0.31	1.07	0.25	0.93	0.23	0.534

Percentage contribution of food and food groups to daily iron intake for females aged 11-14 years: NDNS years 7&8. Results are for total population and by income quintiles. ** One-way Anova significant at the $P < 0.001$ level. * One-way Anova significant at the $P < 0.05$ level. Values are expressed as means ± S.E.M.

Table 2-4. Percentage contribution of food and food groups to daily zinc intakes females 11-14 years: NDNS years 7&8

Females 11-14 years	Income quintile												
Food group	**All (n =130)**		**1 (n = 23)**		**2 (n = 17)**		**3 (n = 24)**		**4 (n = 28)**		**5 (n = 22)**		**P value**
	Mean	**S.E.M**	**Mean**	**S.E.M**	**Mean**	**S.E.M**	**Mean**	**S.E.M**	**Mean**	**S.E.M**	**Mean**	**S.E.M**	
Cereal and cereal products	31.31	0.99	31.82	2.46	31.19	2.43	30.99	1.99	32.68	2.49	31.19	2.53	0.989
Pasta, rice, pizza, and other cereals	12.31	0.88	14.46	2.13	11.80	2.27	11.57	2.13	13.82	2.09	8.96	1.90	0.242
White bread	7.14	0.53	6.08	1.20	6.98	1.69	7.47	1.25	8.92	1.24	6.88	1.25	0.510
Biscuits	2.39	0.25	2.03	0.51	1.52	0.39	2.40	0.87	2.43	0.41	3.47	0.67	0.120
High fibre breakfast cereal	2.08	0.32	1.03	0.48	2.12	0.74	2.59	0.86	1.45	0.67	2.95	0.88	0.225
Buns, cakes, pastries, and fruit pies	2.05	0.26	2.67	0.96	1.74	0.52	1.93	0.62	1.89	0.48	2.14	0.41	0.785
Brown granary and wheat germ bread	1.87	0.35	1.74	0.98	2.35	1.31	2.06	0.95	1.28	0.43	2.50	0.77	0.439
Wholemeal bread	1.51	0.34	1.37	0.79	2.20	1.22	1.61	0.65	0.92	0.53	2.55	1.20	0.497
Other Breakfast cereals	1.20	0.19	1.07	0.48	1.86	0.69	0.86	0.42	1.66	0.45	0.42	0.24	0.145
Puddings	0.51	0.12	0.29	0.20	0.62	0.30	0.51	0.26	0.20	0.11	1.32	0.53	0.255
Other breads	0.25	0.20	1.08	1.08	0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.637
Milk and milk products	16.24	0.90	15.38	1.72	16.33	2.60	11.84	1.68	17.73	2.32	18.45	2.11	0.172
Cheese	6.36	0.65	7.13	1.56	5.02	2.15	3.92	1.19	6.92	1.52	7.51	1.34	0.082
Semi Skimmed Milk	4.99	0.60	4.88	1.31	5.40	1.84	2.91	0.90	4.45	1.49	7.53	1.60	0.126
Whole milk	1.70	0.40	1.59	0.76	3.89	1.62	0.87	0.44	2.25	1.26	0.30	0.26	0.205
Yoghurt, fromage frais and other dairy desserts	1.63	0.22	1.21	0.55	1.20	0.57	2.16	0.70	1.31	0.44	2.30	0.46	0.074
Other milk and cream	0.64	0.20	0.15	0.10	0.40	0.29	0.39	0.32	1.46	0.66	0.17	0.06	0.043*
Ice Cream	0.48	0.09	0.42	0.16	0.32	0.18	0.38	0.18	0.69	0.25	0.45	0.24	0.571
Skimmed milk	0.34	0.15	0.00	0.00	0.10	0.10	1.20	0.76	0.26	0.20	0.18	0.18	0.446
One percent milk	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40	0.00	0.00	0.546
Meat and meat products	31.03	1.28	31.64	3.60	34.26	3.30	34.50	2.61	27.70	2.58	25.29	2.87	0.099
Beef and veal dishes	9.21	1.01	9.43	2.85	13.41	3.02	9.59	2.72	6.78	1.65	9.56	2.33	0.515
Chicken, turkey, and Dishes	5.99	0.64	5.26	1.14	8.30	2.38	6.33	1.92	5.79	1.28	4.79	0.73	0.824
Bacon and Ham	4.16	0.46	4.53	1.26	2.63	0.98	5.28	1.29	4.41	0.96	2.35	0.82	0.378
Burgers and kebabs	2.21	0.56	2.69	1.99	2.38	1.33	3.45	1.68	1.75	0.78	1.47	0.68	0.974
Sausages	2.09	0.31	1.66	0.77	1.84	1.11	3.58	0.90	2.15	0.58	1.24	0.50	0.191
Pork and Dishes	1.94	0.40	1.66	0.96	2.89	1.24	1.85	0.95	2.13	0.91	2.43	1.14	0.660
Lamb and Dishes	1.85	0.57	2.67	1.59	0.00	0.00	1.26	0.73	1.02	0.78	0.91	0.64	0.606
Coated chicken and turkey	1.83	0.28	1.51	0.51	2.42	1.11	1.86	0.67	2.18	0.69	1.43	0.47	0.976
Meat pies and pastries	0.84	0.22	0.46	0.28	0.10	0.10	1.07	0.65	0.81	0.35	1.03	0.70	0.525
Other meat, meat products and dishes	0.81	0.28	1.76	1.05	0.08	0.06	0.23	0.18	0.68	0.39	0.06	0.06	0.525

Liver and Dishes	0.09	0.07	0.00	0.00	0.22	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.222
Vegetable and potatoes	9.38	0.49	10.75	1.12	7.49	0.82	10.72	1.42	9.26	1.08	9.79	1.21	0.388
Vegetables (not raw) including vegetable dishes	4.53	0.38	3.89	0.74	3.77	0.70	5.25	1.18	4.53	0.97	5.70	0.92	0.593
Chips, fried and roast potatoes and potato products	2.59	0.27	4.11	0.92	2.32	0.52	2.81	0.50	3.07	0.68	1.22	0.30	0.031*
Other potatoes, potato salads and dishes	1.66	0.20	2.16	0.53	1.01	0.20	2.12	0.60	0.95	0.27	2.11	0.44	0.222
Salad and other raw vegetables	0.59	0.07	0.59	0.22	0.39	0.12	0.54	0.16	0.71	0.15	0.76	0.19	0.487

Percentage contribution of food and food groups to daily zinc intakes females 11-14 years: NDNS years 7&8. Results are for total population and by income quintiles. ** One-way Anova significant at the $P < 0.001$ level. * One-way Anova significant at the $P < 0.05$ level. Values are expressed as means ± S.E.M

Table 2-5. Daily weight of food and food groups consumed by females aged 11-14 years. NDNS years 7&8.

Females 11-14 years Food group	All (n=130)		Income quintile 1 (n = 23)		2 (n = 17)		3 (n = 24)		4 (n = 28)		5 (n = 22)		P value
	Mean	S.E.M	Mean	S.E.M	Mean	S.E.M	Mean	S.E.M	Mean	S.E.M	Mean	S.E.M	
Cereal and Cereal products	237.61	7.54	217.75	17.83	268.03	15.32	186.73	14.48	254.29	14.58	260.55	18.14	0.001*
Pasta, rice, pizza, and other cereals	104.06	6.05	113.28	16.34	119.85	19.77	71.69	8.60	115.73	12.00	87.85	12.03	0.086
White bread	55.47	4.15	39.40	7.44	56.76	13.13	49.44	8.39	67.53	8.60	60.63	12.01	0.299
Buns, cakes, pastries, and fruit pies	19.77	2.15	21.05	6.16	21.79	7.02	18.61	5.28	17.27	4.39	23.47	4.29	0.690
Biscuits	18.33	1.82	15.37	3.76	12.95	3.24	11.33	3.14	20.59	3.75	29.97	6.72	0.082
Other Breakfast cereals	8.80	1.40	8.29	3.88	12.43	4.25	5.85	3.39	12.31	3.51	3.48	1.61	0.109
High fibre breakfast cereal	8.77	1.37	4.25	1.99	10.76	4.20	8.88	2.88	8.38	3.81	12.38	3.56	0.285
Brown granary and wheat germ bread	7.96	1.45	5.14	2.75	9.56	5.27	7.86	3.66	5.33	1.88	13.65	4.56	0.352
Puddings	7.30	1.66	3.35	2.06	12.46	6.31	6.84	3.40	2.46	1.44	18.37	6.62	0.110
Wholemeal bread	6.11	1.40	3.28	1.83	11.48	6.67	6.22	2.68	3.97	2.28	10.75	4.45	0.403
Other breads	1.04	0.79	4.35	4.35	0.00	0.00	0.00	0.00	0.71	0.71	0.00	0.00	0.637
Meat and meat products	104.73	4.62	89.04	11.14	115.01	11.97	100.93	9.69	99.10	8.84	107.91	13.26	0.609
Chicken, turkey, and Dishes	34.18	2.94	25.28	5.93	45.64	10.07	29.90	6.47	31.85	6.17	39.09	7.55	0.326
Beef and veal dishes	16.59	2.29	14.29	4.14	17.11	3.69	19.32	8.50	10.50	2.97	21.27	5.63	0.467
Coated chicken and turkey	12.82	1.74	10.33	3.68	15.11	5.62	10.72	3.36	15.30	4.35	12.33	3.95	0.948
Bacon and Ham	12.68	1.42	11.37	3.11	11.37	4.64	13.72	3.31	13.90	3.20	7.69	2.79	0.511
Sausages	8.69	1.30	8.36	4.21	8.79	4.17	11.35	2.85	8.53	2.22	5.62	2.32	0.435
Pork and Dishes	5.80	1.43	2.48	1.48	9.41	4.05	4.05	1.99	5.85	2.35	11.60	6.66	0.479
Meat pies and pastries	4.97	1.17	4.17	2.38	1.18	1.18	5.13	3.25	6.32	2.66	5.97	3.37	0.550
Burgers and kebabs	4.22	1.04	5.94	3.88	5.34	3.27	4.64	2.48	4.22	1.70	3.05	1.63	0.976
Lamb and Dishes	3.02	1.04	4.48	3.09	0.00	0.00	1.84	1.16	1.21	0.89	1.18	0.83	0.606
Other meat, meat products and dishes	1.50	0.52	2.34	1.40	0.20	0.15	0.23	0.16	1.43	0.79	0.11	0.11	0.500
Liver and Dishes	0.27	0.20	0.00	0.00	0.88	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.222
Vegetable and potatoes	161.36	7.18	161.83	18.06	176.58	19.94	145.03	16.06	151.62	13.17	180.54	21.43	0.757
Vegetables (not raw) including vegetable dishes	66.34	4.47	53.71	10.55	81.49	11.44	58.25	12.00	60.85	9.88	84.16	11.19	0.077
Chips, fried and roast potatoes and potato products	35.60	3.43	49.03	10.88	38.52	6.99	33.27	6.21	42.08	8.69	22.34	5.50	0.231
Potatoes, potato salads and dishes	38.99	4.32	44.65	11.33	35.81	7.25	37.02	10.56	25.33	6.98	46.79	10.49	0.290
Salad and other raw vegetables	20.42	2.50	14.43	4.47	20.75	7.42	16.48	5.55	23.36	5.52	27.26	8.02	0.486

Daily weight of food and food groups consumed by females aged 11-14 years: NDNS years 7&8. Results are for total population and by income quintiles.
**One-way- Anova significant at the P<0.001 level. *One-way Anova significant at the P < 0.05 level. Values are expressed as means ± S.E.

Table 2-6. Percentage contribution of food and food groups to daily iron intake females 15-18 years. NDNS years 7&8.

Food group			Income quintile										P value
	All (n =142)		1 (n = 21)		2 (n = 34)		3 (n = 19)		4 (n = 28)		5 (n = 15)		
	Mean	S.E.M	Mean	S.E.M	Mean	S.E.M	Mean	S.E.M	Mean	S.E.M	Mean	S.E.M	
Cereal and cereal products	45.97	1.34	51.04	3.91	47.05	2.70	47.04	4.29	45.62	2.80	39.32	2.45	0.256
Pasta, rice, pizza, and other cereals	10.81	0.85	16.26	3.09	10.11	1.33	11.24	2.52	8.17	1.96	10.70	2.37	0.184
White bread	9.51	0.65	9.23	1.74	10.51	1.41	6.39	1.15	6.95	1.16	10.26	1.98	0.242
Other breakfast cereals	7.25	1.11	8.02	2.46	7.13	1.83	8.71	3.35	6.38	2.45	4.53	2.06	0.710
High fibre breakfast cereals	5.13	0.93	4.47	2.27	7.85	2.49	4.39	2.03	6.51	2.24	3.22	1.80	0.824
Biscuits	4.56	0.48	4.25	1.25	4.14	1.04	5.95	1.60	5.59	1.31	4.70	0.90	0.564
Buns, cakes, pastries, and fruit pies	3.23	0.53	2.53	0.96	4.21	1.54	4.89	1.55	2.31	0.98	2.48	1.18	0.802
Brown, granary, and wheat germ bread	2.88	0.47	2.52	1.04	2.13	0.61	1.75	0.74	4.75	1.79	1.94	0.88	0.618
Whole meal Bread	2.09	0.45	3.59	1.74	0.63	0.36	2.32	1.46	4.38	1.33	1.03	0.60	0.060
Puddings	0.35	0.09	0.16	0.11	0.33	0.16	0.32	0.26	0.58	0.26	0.24	0.19	0.852
Other Breads	0.17	0.12	0.00	0.00	0.00	0.00	1.07	0.86	0.00	0.00	0.22	0.22	0.092
Meat and meat products	17.18		18.81	2.79	17.11	2.18	18.30	3.02	16.71	2.19	11.59	2.47	0.503
Chicken, Turkey and Dishes	4.05	0.51	2.76	0.79	5.42	1.69	3.54	0.94	3.94	1.00	2.41	0.55	0.948
Beef and veal dishes	3.62	0.47	3.13	1.02	3.49	1.01	4.35	1.41	4.11	1.09	2.61	1.05	0.883
Coated chicken and turkey	2.48	0.35	2.49	0.94	2.53	0.75	2.39	1.03	1.65	0.51	1.95	0.77	0.990
Bacon and Ham	1.16	0.13	1.05	0.32	0.88	0.25	1.03	0.30	1.49	0.31	0.60	0.25	0.197
Sausages	1.36	0.21	1.58	0.61	1.40	0.47	1.21	0.51	1.69	0.53	0.88	0.51	0.775
meat pies and pastries	1.29	0.27	2.69	1.06	1.03	0.37	0.89	0.67	0.60	0.31	0.28	0.28	0.155
Burgers and kebabs	1.09	0.26	3.63	1.35	0.65	0.38	1.52	0.70	0.71	0.36	0.00	0.00	0.027
Lamb and Dishes	0.92	0.28	0.70	0.51	1.03	0.67	1.34	0.94	0.66	0.49	1.24	1.24	0.907
Pork and Dishes	0.60	0.19	0.66	0.32	0.64	0.56	0.22	0.11	0.82	0.38	0.89	0.89	0.635
Other meat, meat products and dishes	0.61	0.24	0.12	0.12	0.05	0.05	1.81	1.43	1.05	0.61	0.72	0.55	0.357
Vegetable and potatoes	15.02	0.77	11.09	1.36	15.94	1.65	11.80	1.73	15.01	1.99	21.36	2.34	0.007*
Vegetables (not raw) including vegetable dishes	8.56	0.71	5.37	1.28	9.52	1.43	5.33	1.28	8.89	1.87	14.16	2.77	0.012*
Chips, fried and roast potatoes and potato products	3.67	0.30	3.47	0.96	4.28	0.76	4.27	0.81	2.61	0.41	3.52	0.78	0.515
Potatoes, potato salads and dishes	1.83	0.20	1.49	0.35	1.51	0.48	1.30	0.43	2.46	0.51	1.72	0.55	0.409
Salad and other raw vegetables	0.95	0.12	0.76	0.27	0.64	0.13	0.90	0.29	1.06	0.27	1.96	0.78	0.750

Percentage contribution of food and food groups to daily iron intake females 15-18 years. NDNS years 7&8. Results are for total population and by income quintiles. ** One-way Anova significant at the $P < 0.001$ level. * One-way Anova significant at the $P < 0.05$ level. Values are expressed as means ± S.E.M.

Table 2-7 Percentage contribution of foods and food groups to daily zinc intake females 15-18 years: NDNS years 7&8.

Females 15-18 years **Food group**	**All (n =142)**		**Income quintile** **1 (n = 21)**		**2 (n = 34)**		**3 (n = 19)**		**4 (n = 28)**		**5 (n = 15)**		**P value**
	Mean	**S.E.M**	**Mean**	**S.E.M**	**Mean**	**S.E.M**	**Mean**	**S.E.M**	**Mean**	**S.E.M**	**Mean**	**S.E.M**	
Cereal and cereal products	17.70	0.73	17.32	2.18	17.03	1.31	17.51	1.80	20.49	2.10	14.97	2.05	0.582
White bread	5.93	0.42	5.24	1.01	6.96	0.94	4.32	0.79	4.35	0.78	6.29	1.69	0.312
Brown granary and wheat germ bread	2.45	0.40	2.00	0.77	2.81	1.05	4.10	1.23	1.83	0.87	1.97	0.93	0.492
Biscuits	2.10	0.24	2.15	0.90	1.59	0.36	2.47	0.63	2.82	0.72	2.24	0.57	0.363
Wholemeal bread	1.65	0.37	3.02	1.54	0.55	0.32	1.67	0.94	3.47	1.17	0.78	0.43	0.077
Buns, cakes, pastries, and fruit pies	1.54	0.24	1.08	0.39	1.39	0.48	0.91	0.34	2.25	0.76	1.12	0.52	0.789
Pasta, Rice, pizza, and other cereals	1.50	0.36	2.11	1.02	0.80	0.61	1.15	0.62	2.48	1.19	1.27	1.27	0.599
High fibre breakfast cereal	1.39	0.28	0.87	0.38	1.84	0.62	1.74	0.73	2.28	0.99	0.63	0.40	0.818
Other breads	1.13	0.24	0.87	0.36	1.09	0.32	1.16	0.51	0.97	0.42	0.68	0.33	0.834
Other Breakfast cereals	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.767
Puddings	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.000
Milk and milk products	11.04	0.74	10.16	2.03	10.14	1.43	11.43	2.33	14.10	1.63	11.87	2.60	0.295
Cheese	6.73	0.68	6.77	2.00	6.83	1.29	7.30	2.15	7.17	1.46	8.23	2.72	0.917
Other milk and cream	1.21	0.13	0.87	0.25	1.04	0.31	1.11	0.32	1.48	0.32	1.09	0.38	0.630
Yoghurt, fromage frais and other dairy desserts	1.16	0.18	1.11	0.46	0.64	0.24	0.36	0.19	2.58	0.64	1.30	0.54	0.036
Whole milk	0.62	0.16	0.15	0.14	0.69	0.27	0.80	0.38	0.71	0.46	0.05	0.05	0.363
Ice Cream	0.62	0.13	0.63	0.31	0.81	0.38	0.14	0.10	1.00	0.35	0.42	0.19	0.500
Semi Skimmed Milk	0.51	0.15	0.63	0.55	0.03	0.03	0.67	0.40	1.11	0.48	0.56	0.37	0.086
One percent milk	0.13	0.10	0.00	0.00	0.00	0.00	1.01	0.69	0.00	0.00	0.00	0.00	0.034*
Skimmed milk	0.06	0.03	0.00	0.00	0.10	0.10	0.05	0.05	0.06	0.04	0.21	0.21	0.767
Meat and meat products	35.46	1.39	37.39	3.93	36.37	2.93	38.48	3.38	32.32	3.09	29.19	4.88	0.421
Beef and veal dishes	8.80	1.07	7.75	2.40	8.96	2.35	11.28	3.28	9.45	2.35	6.46	2.76	0.860
Chicken, turkey, and dishes	6.44	0.55	4.38	0.93	7.29	1.34	5.43	0.84	5.63	1.23	5.56	1.31	0.841
Sausages	4.95	0.51	6.81	1.52	5.19	1.12	5.65	1.80	3.62	0.69	4.57	1.23	0.771
Bacon and ham	3.77	0.40	3.35	1.05	3.18	0.78	3.07	0.76	5.02	0.97	1.80	0.75	0.205
Coated chicken and turkey	3.12	0.48	3.23	1.48	3.82	1.26	2.46	0.96	1.73	0.54	2.71	1.18	0.969
Burgers and kebabs	2.38	0.58	7.91	2.85	1.45	0.91	3.29	1.62	0.99	0.56	0.00	0.00	0.026*
Meat pies and pastries	2.29	0.21	1.63	0.54	2.55	0.43	2.81	0.57	2.28	0.51	2.89	0.86	0.083

Lamb and dishes	1.93	0.54	1.27	0.92	1.93	1.13	2.94	1.84	1.52	1.05	2.64	2.64	0.898
Other meat, meat products and dishes	1.41	0.29	0.85	0.72	1.69	0.71	1.15	0.45	1.57	0.61	2.19	1.21	0.491
Pork and dishes	0.38	0.09	0.21	0.14	0.29	0.14	0.40	0.27	0.53	0.20	0.37	0.21	0.814
Vegetable and potatoes	13.16	0.90	10.85	2.52	16.30	2.03	11.01	1.45	13.22	2.31	15.68	3.08	0.185
Vegetables (not raw) including vegetable dishes	7.06	0.85	5.21	2.54	8.59	1.87	4.96	1.30	7.37	2.21	11.86	3.43	0.028*
Chips, fried and roast potatoes and potato products	3.04	0.23	2.78	0.75	3.69	0.57	3.60	0.57	2.33	0.38	2.54	0.65	0.240
Other potatoes, potato salads and dishes	2.00	0.29	2.34	0.83	2.21	0.70	1.61	0.61	2.87	0.78	1.15	0.61	0.692
Salad and other raw vegetables	1.06	0.31	0.53	0.32	1.81	0.90	0.84	0.37	0.66	0.29	0.13	0.11	0.407

Percentage contribution of foods and food groups to daily zinc intake females 15-18 years: NDNS years 7&8. Results are for total population and by income quintiles. ** One-way Anova significant at the $P < 0.001$ level. * One-way Anova significant at the $P < 0.05$ level. Values are expressed as means ± S.E.M.

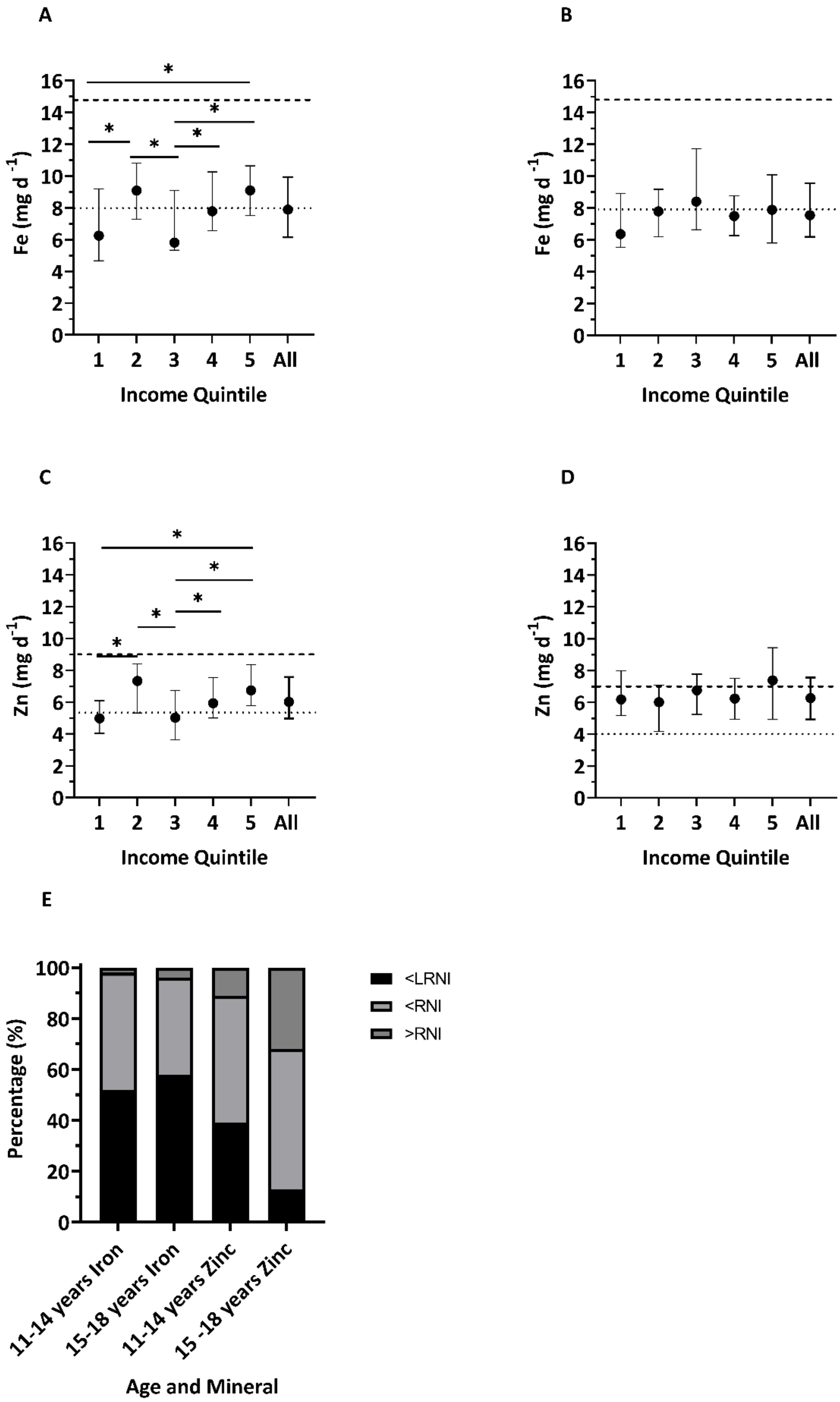

Figure 2-1 A-E. median and interquartile range for daily dietary iron (A) 11-14 year olds & (B)15-18 year olds) and zinc (C 11-14 year olds &D 15-18 year olds) intake (mg d-1) from food sources only: females aged 11-14 and 15-18 years across income quintiles (IQ) and (E) percentage of females aged 11-14 and 15-18 years with daily iron and zinc intakes below the Lower Reference Nutrient Intake (LRNI) and above or below the Reference

Nutrient Intake (RNI). Data sourced from the National Diet Nutrition Survey (NDNS) years 7 & 8 of the rolling programme.

Figure 2-1: A&B are median and interquartile range for daily dietary iron intake (mg d-1) from food sources only: females aged 11-14 (A) and 15-18 (B) years across income quintiles (IQ). Kruskal - Wallis test performed in IBM SPSSv26 to evaluate potential influence of equivalised household income on daily iron intake, post-hoc Mann-Whitney test performed when significance detected at the Kruskal - Wallis stage. Lower bound values for income quintiles are as follows: (IQ1) <£12152.43, (IQ2) ≥ £12152.43, (IQ3) ≥£19230.42, (IQ4) ≥ £27541.95, (IQ5) ≥£43402.43. Dotted line represents Lower Reference Nutrient Intake (LRNI), dashed line represents Reference Nutrient Intake (RNI). Number of participants included in the analysis with a valid income female 11-14 years IQ1 n=23, IQ2 n =17, IQ3 n =24, IQ4 n =28, IQ5 n =22. Females 15-18 years IQ1 n = 21, IQ2 n =34, IQ3 n =19, IQ4 n =28, IQ5 n =15

* Significant at the P < 0.05 level

Figure 2-1: C&D are median and interquartile ranges for daily dietary zinc intakes (mg d-1) from food sources only: females aged 11-14 (C) and 15-18 (D) years across income quintiles (IQ). Kruskal - Wallis test performed in IBM SPSSv26 to evaluate potential influence of equivalised household income on daily zinc intake, post-hoc Mann-Whitney test performed when significance detected at the Kruskal - Wallis stage. Lower bound values for income quintiles are as follows: (IQ1) <£12152.43, (IQ2) ≥ £12152.43, (IQ3) ≥£19230.42, (IQ4) ≥ £27541.95, (IQ5) ≥£43402.43. Dotted line represents Lower Reference Nutrient Intake (LRNI), dashed line represents Reference Nutrient Intake (RNI). Number of participants included in the analysis with a valid income female 11-14 years IQ1 n=23, IQ2 n =17, IQ3 n =24, IQ4 n =28, IQ5 n =22. Females 15-18 years IQ1 n = 21, IQ2 n =34, IQ3 n =19, IQ4 n =28, IQ5 n =15.

* Significant at the P < 0.05 level

Figure 2-1: E is percentage of females aged 11-14 and 15-18 years with daily iron and zinc intakes below the Lower Reference Nutrient Intake (LRNI) and above or below the Reference Nutrient Intake (RNI). Data sourced from the National Diet Nutrition Survey (NDNS) years 7 & 8 of the rolling programme. Number of participants: females, 11-14 years n = 130 and females 15 -18 years n = 142.

3 MANUSCRIPT 2. The Impact of the COVID-19 Pandemic on the Food Security of UK Adults Aged 20–65 Years (COVID-19 Food Security and Dietary Assessment Study)

3.1 Authors contribution

Conceptualization, L.C., and S.W.; methodology, M.T., E.E., Z.V., A.A., L.C. and S.W.; formal analysis, M.T., P.R., S.W.; data curation, M.T. and S.W.; writing—original draft preparation, M.T., P.R. and S.W., writing—review and editing, M.T., E.E., A.A., L.C., P.R., and S.W.; visualization, M.T.; supervision, S.W., and L.C.; project administration, L.C., and S.W.

The published article can be found in Appendix C.

3.2 Abstract

The first UK lockdown greatly impacted the food security status of UK adults. This study set out to establish if food procurement was adapted differently for different income groups and if this impacted dietary intakes disproportionately. Adults (*n* = 515) aged 20–65 years participated in an online survey with 56 completing a 3–4-day diet diary. Food availability was a significant factor in the experience of food insecurity. Similar proportions of food secure and food insecure adapted food spend during lockdown, spending similar amounts. Food insecure (*n* = 85, 18.3%) had a 10.5% lower income and the money spent on food required a greater proportion of income. Access to food was the biggest driver of food insecurity but monetary constraint was a factor for the lowest income group. The relative risk of food insecurity increased by 0.07-fold for every 1% increase in the

proportion of income spent on food above 10%. Micronutrient intakes were low compared to the reference nutrient intake (RNI) for most females, with riboflavin being 36% lower in food insecure groups (p = 0.03), whilst vitamin B12 was 56% lower (p = 0.057) and iodine 53.6% lower (p = 0.257) these were not significant. Coping strategies adopted by food insecure groups included altering the quantity and variety of fruit and vegetables which may have contributed to the differences in micronutrients.

3.3 Introduction.

The virus “severe acute respiratory syndrome coronavirus 2” which causes the coronavirus disease (referred to in the study from here as COVID-19) led to the United Kingdom (UK) first ‘‘lockdown’ down’ on the 23rd March 2020 until May 10th, 2020, when restrictions were eased (Johnson, 2022). The COVID-19 pandemic brought into sharp focus the concerns for population groups with increased vulnerability to the experience of food insecurity (having sustained physical and financial access to a safe and healthy varied diet that meets nutritional requirements). In the UK, these were typically young adults (18-24), households with children, minority ethnic groups, individuals with disabilities and low income and unemployed households resulting in many experiencing food insecurity for the first time (Power et al., 2020). In the first 3 weeks of the UK’s first COVID-19 lockdown more than 3 million people reported that they had gone hungry (Loopstra, 2020).

The stability of household food supply was unsettled during the first UK lockdown. Closure of workplace/ hospitality sector and schools. Meant it was no longer possible to purchase food for consumption outside the home.

As a result, and although the UK food supply chains had adequate produce, supermarkets struggled to keep pace with demand, individuals became more likely to over purchase (defined as buying more than necessary to sustain routine practices within a household) (Bentall et al., 2021). These individuals were more likely to be younger, female, having children living at home and either having a higher income or conversely, suffering from a loss of income (Bentall et al., 2021). For many with a higher income, this afforded the opportunity to buy extra, to the detriment of lower income groups who did not have the equivalent purchasing power (Power et al., 2020). Principal difficulties with the food supply were more a result of the many buying a little extra in time of uncertainty than from the few purchasing in excess (Bentall et al., 2021). Potentially compromising household food security status of the most vulnerable.

The COVID-19 pandemic had an impact on food security and nutrition security both directly (food shortages/ limited access to shops) and indirectly (loss of income/purchasing power; (Lamarche et al., 2021). The baseline situation of communities, households and individuals (i.e., low income, living in deprived regions and limited capacity for working at home) have been found to be a risk factor in the experience of food insecurity during COVID-19 (Lamarche et al., 2021).

To help households during the Covid-19 pandemic access food the government introduce ‘The Coronavirus Job Retention Scheme’ (1 March 2020-30th September 2021) paying up to 80% of an employee’s usual monthly salary (capped at £2500 per month) for some, this resulted in a loss of income of 20% or more (depending on baseline income) for others, their employers covered the remaining 20%. The aim of the scheme was to reduce the burden on social security. However, there was still a sharp increase in claims for Universal Credit (UC) during April and May 2020. The typical number of claims prior to COVID was ~200,000 per month (Mackley and McInnes, 2022). This increased to 1.2 million in April and 1.3 million in May 2020.

To support individuals who were clinically vulnerable to Covid-19 and instructed to ‘Shield’ (that is not leave their home) access food. The government introduced a food parcel scheme. To access the scheme individuals first had to register. The food parcels contained ambient food only (approx. 20kg) and were designed to last 7 days. Additionally, supermarkets provided priority online delivery slots, however, people details were needed to be passed on to the supermarkets first (Lambie-Mumford et al., 2022).

Households entitled to free school meals were initially provided with a £15 a week eGift card per child for the purchase of food from non-discounter supermarkets such as Sainsbury’s, Tesco, Asad, Morrisons, Waitrose and M&S but this was expanded in June to include Aldi, Iceland , the Food Warehouse store and McColl’s (Lambie-Mumford et al., 2022)

Experience of household food insecurity and poor diet directly contributes to increased incidence of disease and lower life expectancy (Liu and Eicher-Miller, 2021) (Eicher-Miller, 2020) (Gundersen and Ziliak, 2015). As previously mentioned, women and households with children were at increased risk of food insecurity. Although a low income does not always equate to being food insecure and similarly, the anxiety around food availability is not the sole preserve of those on lower incomes (Nord and Brent, 2002). The response to concerns of food security frequently results in similar dietary choices independent of background (Butcher et al., 2019; Litton and Beavers, 2021), with individuals and households experiencing food insecurity selecting high energy dense, nutrient poor, cheaper foods (Mello et al., 2010; Morales and Berkowitz, 2016) which may be perceived as better value for money and more accessible under the circumstances faced (Butcher et al., 2019). Fresh fruit and vegetables are often sacrificed at the expense of high fat, high sugar alternatives such as crisps and biscuits (Litton and Beavers, 2021; Morales and Berkowitz, 2016). As such the diets of females with or without children may have been detrimentally impacted in the first UK lockdown due to loss of income and or employment, increased caring responsibility as well as food shortages.

The primary objectives of this study were to assess the perceived impact of social isolation and movement restriction on food availability and food security amongst UK adults during the COVID-19 outbreak and to gain a general overview of the methods of food procurement as well as to compare the diets females who were food insecure to food secure to understand differences in diet and nutrient intakes.

Secondary objectives were to understand who was at risk of the experience of food insecurity during the first lockdown. And if the percentage of income spent on food increased the odds of the experience of food insecurity.

3.4 Methods.

This paper details the findings from a cross-sectional study which took place during the first UK Coronavirus-19 pandemic lockdown between 6th May and 10th July 2020 for adults aged between 20 and 65 years who were not in education. An online survey (Appendix E) was designed to collect general demographic information (age, gender, ethnicity, highest level of education attained, employment status, post-code), self-reported weight and height, household characteristics, indicators of food purchasing behaviour, food security and dietary change.

3.4.1 Participant recruitment.

Participants were recruited to the study via social media platforms (Twitter, Facebook), radio appearances, the University of Nottingham communication team and word of mouth. All participants were provided with information about the study and asked to give consent before completing the survey. The study was approved by the University of Nottingham's Faculty of Medicine and Health Sciences Research Ethics Committee (Ethics Reference Number 01-0420). This research project was completed in accordance with the declaration of Helsinki and recent alterations.

3.4.2 Equivalised income and income quintiles.

Questions were adapted from the National Diet and Nutrition Survey (NDNS) (University of Cambridge, 2022) to determine level of household income. Participants were asked to select an income bracket and the midpoint value of each income bracket was used in the calculation of equivalised household income (EHI), along with a household size score, adapted from the McClements scale where a value was assigned to each of the adults living in a household and, where applicable, to the children based on their ages (DWP, 2021a) (Muellbauer, 1979) (Shepshed, 2003). Household income was divided by the adapted McClements score to determine equivalised household income.

Participants were excluded from the analysis if household size was greater than 1.5 times the inter-quartile range. Consequently, 3 participants were excluded from the analysis. Two participants listed they had 11 children within the same age bracket and one participant was excluded as they listed, they had 11 children and 11 adults in each of the age brackets.

Income quintiles (IQ) were determined by splitting the equivalised income during lockdown into five percentiles as follows IQ1 (n = 98; 20.9%; <£25700.47), IQ2 (n = 90; 19.1%; £25700.47 - £39643.18), IQ3 (n = 99; 21.1%; £39643.18-£53277.84), IQ4 (n = 84; 17.9%; £53277.84-£75503.02), IQ5 (n = 99; 21.1% >£75503.02).

3.4.3 Food security measures.

Food security was assessed with questions adapted from the Household Food Insecurity Access Scale (HFIAS) (Coates et al., 2007) to determine influences of monetary resources and/or food availability over the previous 4 weeks (from the date of completing survey) on household food security.

The HFIAS assesses three different but related domains of food insecurity (Coates et al., 2007). Positive responses across the domains indicate increasing severity of food insecurity experienced. We adapted the questions to evaluate if the experience of food insecurity was because of a lack of money or lack of food.

Domain one is concerned with anxiety/worry of running out of food and asks the question (1) “Did you worry that your household would not have enough food”. Domain two includes three questions to assess if there was a reduction in the quality and variety of the food consumed. These questions asked (2) “were you or any household member not able to eat the kinds of foods you preferred because of a lack of money or lack of food available?”, (3) “Did you or any household member have to eat a limited variety of foods due to lack of money or food available?” and (4) “Did you or any household member have to eat same food that you really did not want to eat because of lack of money or lack of food available to obtain other types of food”.

The final domain asks five questions and is concerned with reduction in the quantity of food eaten and experience of hunger. The first asks (5) “Did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?”, and the second, (6) “Did you or any household member have to eat fewer meals in a day because there was not enough food?” Additional questions ask (7) “Was there ever no food to eat of any kind in your household because of a lack of money or lack of food available to get food?”, (8) “Did you or any household member go to sleep at night hungry because there was not enough food?” and (9) “Did you or any household member go a whole day and night without eating anything because there was not enough food” (Coates et al., 2007).

Participants were initially categorised into the food security domains of food secure or mild, moderate or severely food insecure. Two categories were then created comprising food secure and food insecure.

3.4.4 Shopping habits and food spend.

Participants were asked about their food shopping behaviours before and during the first UK national lockdown in reference to where food was purchased, how and how frequently (never less than once a month, 2–3 times per month, once a month, 2–4 times per week, 5–6 times per week, once a day, prefer not to say). The following question was asked with the following options for response "Which of following best describe where you purchased foods from? (Tick all that apply)": (1) Shop at one of the UK "Big Four" supermarkets (Tesco, Sainsbury's, Morrisons, Asda) (2) "In person", (3) "home delivery", (4) "Click and Collect" (5) Other supermarkets (Aldi, Lidl, Iceland, Netto). (6) "Other supermarket "(Waitrose, Marks and Spencer), (7) smaller shops (e.g., Co-op, Tesco express, Sainsbury local), (8)" Corner Shops (e.g., Happy Shopper, 7-11, Spar), (9) "Markets", (10) Local independents (e.g., butchers, bakers, green grocers). In addition, participants were asked whether they were self-isolating or shielding and their level of vulnerability. Individuals were asked about usual eating behaviours, dietary choices, perception of how food availability had changed, and how their diet had changed during the lockdown. Food spend was estimated for each household from the mid-point of the monetary bracket per week (<£46, £47–£69, £70–£90, £91–£115, £116–£138, £139–£161, >£162) selected by participants.

3.4.5 Energy and nutrient intakes.

Participants had the option to complete a 4-day food diary using the “Libro” app associated with professional dietary analysis software (Nutritics). Those who completed 3- or 4-day food diaries were included in the analysis (n = 56). We present the results for the total population of females and do not exclude non-plausible reporters due to the nature of the study assessing the impact of food insecurity on energy and nutrient composition of the diet. The macronutrient and micronutrient composition of each participant’s diet was calculated by the Nutritics software. Analysis of the micronutrient composition of the diet and food security status was completed for the total population. Females were stratified by age as per the reference nutrient intake (RNI) categories to enable analysis of iron intakes (19-49 and 50^{+} years).

3.4.6 Sensitivity analysis.

The plausibility of energy intake was assessed by estimating Energy Intake: Basal Metabolic Rate EI:BMR ratio using the Schofield equation to estimate BMR and applying the Goldberg upper and lower and cut-off points specific to physical activity level (PAL; tables 3.6 and 3.7) (2013) (Dutch et al., 2021).

3.4.7 Data analysis.

Descriptive, parametric and non-parametric analyses were performed using SPSS (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp). Normality of the data was assessed in SPSS using Shapiro–Wilks.

Parametric data are presented as means and S.E.M (unless otherwise stated), non-parametric as medians with 25th and 75th percentile (median [25th – 75th percentile]). Chi-square was used for categorical variables to test the impact of income quintile on food security status. Relative risk was calculated for experience of food insecurity according to employment type, adherence to government guidelines for movement restriction, household income quintiles and food spend as a proportion of income. Dietary data were analysed for participants who completed 3 or 4 days of a food diary. Parametric and non-parametric tests were completed in SPSS to test for difference in dietary intakes food secure and food insecure.

3.5 Results

3.5.1 Participant characteristics.

This study recruited 515 participants between 20 and 65 years of age (43 ± 0.5 years) of which the majority were female (n = 435, 84%) with an average age of 43 ± 0.6 years. Males (n = 79; 15%) had a mean age of 43.5 ± 0.6 years (Table 3.1). One participant did not provide their sex. During the first lockdown, the proportion of participants in employment was 73.7% (n = 390) of which over half were employed full time (51.6%), 15.5 % (n = 82) part time and 6.6% were self-employed (n = 35). The proportion of respondents not in paid employment was 26.4 % of which retirees accounted for 6.6 % (n = 35) and furloughed workers 9.8 % (n = 52). There were 14 participants who selected more than one option for employment type.

The study cohort was disproportionately represented by those who had successfully accessed higher education. Most participants (n = 405; 78.6%) had completed their education to level 6 (undergraduate degree with honours or equivalent) or above, with 35.9% having an undergraduate degree, 30.3% a post graduate degree at master level or equivalent and 12.4% a PhD or DPhil. Only 0.4% reported having no qualifications. In the

UK, by contrast, between April 2020 and March 2021, approximately 20.8% of the population reported they had a degree level qualification or above (Office for National Statistics and Social Security Division, 2021).

The median equivalised household income for all participants with a valid household income prior to and during lockdown (n = 470) decreased 5.5% from £46969.22 [£33783.51 - £68130.11] to £44392.06 £28687.70 - £61474.59] per year. Prior to lockdown, 81.1% of households had an income above the UK median average household income for 2020 (£29,990). This reduced to 73.8% during the first lockdown. We found 5.3% (n = 25) of households had an income below 60% of the UK median (£13794.00; a level used for defining relative low income) prior to lockdown, which increased to 8.1% (n = 38) during lockdown. The largest group of households were two person (n = 200, 39.1 %; 3, 1.5 % with children) followed by 4 person (n = 103, 20.1 %; 78, 76 % with children) and 3 person (n = 100, 19.5 %; 47, 47 % with children). Single person households accounted for 14.5 % (n = 74). Households with children comprised over a third (30.1 %; n = 155).

Who was at risk of the experience of food insecurity?

3.5.2 Equivalised household income.

Four fifths of participants in this study were food secure (81.7%). Of those who experienced some form of food insecurity (18.3%), 2.9% indicated they were severely food insecure. Participants who provided details about household income before and during lockdown (n = 470) were split into income quintiles (IQ; Table 3.1). Households in IQ1 (income < £25700.47

per year) had the lowest proportion of food secure households (73.5 %) compared to 1Q2 (83.3 %), IQ3 (80.8 %), IQ4 (86.9 %) and IQ5, (85.9 %) and the highest percentage of severely food insecure (8.2 %) compared to participants in IQ2 (0 %), IQ3 (2 %), IQ4 (0 %) and IQ5 (3.0 %). Two participants who identified as severely food insecure in IQ3 (n=1) and IQ5 (n=1) had restricted diets due to coeliac disease. The participant in IQ3 stated.

“I follow a gluten free diet for coeliac disease, staple food availability was limited on the 2 weeks prior to 23rd march and for several weeks after”.

Additionally, one participant in IQ5 noted they were eating different brands of gluten free food available in smaller shops.

“I have coeliac disease and have been eating different brands of gluten free food during lockdown. I don’t have a car so have had to use local stores. I’ve mostly shopped in small stores”.

We then compared the odds of food insecurity during the first lock down amongst respondent who provided details of income at this point (n = 512) Participants IQ1 had significantly higher odds of food insecurity compared to those in IQ5 (OR = 2.02, CI: 1.02 – 4.01) (Table 3.2).

3.5.3 Employment type.

Employment status during lockdown was associated with relative likelihood of food insecurity. The self-employed had a significantly higher odds of experiencing food insecurity compared to participants who were in full time employment (P = 0.033), as did participants unable to work due to disability or sickness (P =0.007) and those who were unemployed and seeking work (P = 0.006) (Table 3.3).

The numbers for most groups changed during lockdown with reductions in the number of self-employed (20.5%), part-time (10.1%) and full-time employed (15.9%) and increases in the number of unemployed (114.3%). There were also increases in the number of people unable to work due to sickness or disability (50%), homemakers/full-time parents (41.7%) and retired (56.3). Thirty-four participants were additionally placed on furlough.

3.5.4 Following government guidelines on Isolating and Shielding.

The majority of participants (n = 442, 85.81%) at the time of the study were not self-isolating but following government guidance of social distancing. People not leaving their home because they were in the high-risk category accounted for 1.7% of the study population (n = 9). Individuals not leaving their home except to get essential items such as food and medicine accounted for 5.2% (n = 27). Whilst those not leaving the home because of living with someone who was vulnerable to the disease was 7.4% (n = 38) Participants who were living with someone vulnerable to Covid-19 were 1.88 (CI, 1.1 - 3.1) times more likely to report they were food insecure (P = 0.027; Table 3.4).

3.5.5 Concern for food availability.

Over a quarter of all adults (27.8%) in this study said they were worried their household would not have enough food at the start of the first lockdown, of which a tenth indicated this was sometimes or often true (10.5%). We split the participants into the categories of food secure (n = 421) and food insecure (n = 94) and found 81.5% of food secure (n = 343) were not worried about running out of food and just 29.8% of food insecure participants (n = 28) were not worried.

3.5.6 Eating preferred food by food security status and income quintile.

Analysis by income quintiles found similar proportions of participants indicating that they were unable to eat the type of foods they preferred due to lack of food available (P = 0.624). Participants in IQ1 also reported lack of money as a reason for not being able to eat the foods they preferred compared to IQ3 (P = 0.002), IQ4 (P = 0.016) and IQ5 (P = 0.009). Analysis by food security status indicated a greater proportion of food insecure participants (69.1%) were unable to eat the foods they preferred due to lack of foods available compared to food secure (36.1%; P <0.001). Eating non-preferred foods because of a lack of money was true for some amongst the food insecure (12.8 %) but not those who were food secure (0.0 %; P <0.001).

3.5.7 Differences in household income, food spend and food security status.

Most participants provided details of household income and food spend prior to and during Covid-19 (n = 468). There was an 11.1% difference in the median equivalised household income between food secure (n = 385) and food insecure (n = 85), with food secure households having on average £89.86 more per week during lockdown (P < 0.01). Median food spend per week during lockdown was similar for food secure (£86.03 [£60.18 -

£115.02]) and food insecure (£89.32 [£57.13 - £173.08]) per week; (P = 0.582). The proportion of income required for food spend in food secure respondents was 9.5% and food insecure 11.0% (Table 3.1).

3.5.8 Change in food spend amount per week during the first UK lockdown by food security status.

Median food spend during the first UK lockdown was £86.51 per week. Households who increased their food spend did so on average by 44.0 %, whilst households who decreased food spend did by 28.1 % (Table 3.5). Food secure and food insecure households who increased food spend, did so by a similar proportion (43.7 % and 46.7 % respectively). The percentage of income spent on food was numerically, but not significantly, greater for food insecure households compared to food secure (P = 0.151; Table 3.5). When households' food spend remained the same during lockdown, food insecure households spent a greater proportion of their income on food compared to food secure (P = 0.003; Table 3.5).

3.5.9 Proportion of income spent on food and odds of food insecurity.

The proportion of household income spent on food in the UK averages 10.8% (DEFRA, 2022b) with those in the highest income quintile spending less (8.0%) (JFK, 2022). The results from binary ordered logistic regression (unadjusted) found respondents who spent 15% (n = 25) or more of their household income on food (income and food spend equivalised) were 2.43 [CI:(1.004 -5.882)] times more likely to experience food insecurity compared to respondent who spent less than 5% of their income on food (P = 0.049). (Figure 3.1).

3.5.10 Shopping habits.

As shown previously, in person shopping reduced during lockdown and this occurred for food secure (P < 0.001) and food insecure participants (P < 0.001), however the frequency of shopping in person during lockdown was lower for food insecure (2.98 ± 1.54) compared to food secure (3.32 ± 1.35; P = 0.05). This coincided with a slight increase in the frequency of using click and collect in both food secure (P < 0.001) and food insecure groups (P = 0.017). Whilst there was not a significant difference in click and collect between food secure and food insecure groups during lockdown, there was a clear trend, appearing higher in food insecure compared with food secure (P = 0.067). There was a reduction in the frequency of shopping at the big four UK supermarkets and discounter supermarkets for all households during lockdown (P < 0.001).

3.5.11 Eating habits.

Participants were asked to self-report if they thought they had eaten less than, about the same or more than their usual diet since the 23rd of March 2020. Those who were classified as food insecure (n = 94) were 2.1 (CI 1.4 -3.0) times more likely to report they thought they were eating less than usual their usual diet, however the majority of respondents felt that their diet was as healthy as it was prior to lockdown. Despite this, food secure households reported a lower proportion of the population decreasing their fresh fruit intake (15.8%) compared to food insecure (32.3%; P = 0.060) as well as fresh vegetable intake (11.8% vs 35.1% respectively; P = 0.001).

Consumption of breakfast cereal remained the same for all (72.4% food secure and 61.3% food insecure).

3.5.12 Coping strategies.

We further asked participants to indicate if they had to employ any strategies to cope with not having enough food or money to buy food. Those who were food insecure more frequently relied on less preferred or less expensive foods than the food secure (P < 0.001). They were also 3.1 (CI 2.2 - 4.4) times more likely to reduce the quantity (P <0.001) and 4.1 (CI 2.8 -6.2) times more likely to reduce the variety of fruit and vegetables consumed (P < 0.001). Access to food banks was not reported by any respondents. Six out of the 8 people who reported purchasing food on credit were in the food secure category.

3.6 Diet diaries, nutrient intakes and food security status.

In total 6 males and 50 females completed a 3- or 4-day diet diary using the “Libro” app (Nutritics 2021). Because of low numbers of males, only data for females was analysed further for impact of food insecurity.

3.6.1 Energy for all participants.

A non-plausible energy intake below the lower Goldberg cut off point was found in 11 participants. None exceeded the higher cut off point. One individual who was food insecure had EI: BMR below the Golberg limit, whilst 10 food secure participants were below the lower cut off.

3.6.2 Energy intake and BMI.

Energy intakes of all females aged 19-65 years was 1751 ± 50.50 kcal. Seven food secure participants (12.5%) had an EI: BMR ratio below the lower cut off point but were not excluded from the analysis. Food secure (n = 44) and insecure (n = 6) had similar energy intakes (1728 ± 53.85 kcal and 1924 ± 136.37 kcal respectively). The BMI of food secure participants was within the healthy range (23.4) whilst those for the food insecure fell within the overweight category (28.5) although there was no significant difference between the two groups.

3.6.3 Macronutrients.

Carbohydrate intake provided slightly below the recommended 50% of energy for both food secure (44.0 ± 1.2%) and food insecure 42.9 ± 4.2% (P = 0.763), whilst energy from total fat exceeded the recommended 33% (36.5 ± 1.1% and 36.9 ± 3.2% food secure and insecure respectively) but did not differ between the groups (P = 0.898). The 11% energy from saturated fat was similarly exceeded for both food secure and insecure (12.7 ± 0.7 % and 12.5 ± 1.5% respectively; P = 0.933) as was protein intake (151.0% and 157.5% of DRV; P = 0.511). There were comparable intakes of fibre for both food secure and food insecure ~75% of the DRV (22.6g [18.5 - 29.67] and 22.5g [20.3 - 27.3] respectively; P = 0.965) and free sugar consumption was within the recommendations of ≤5% of energy for both groups (food secure - 2.1% [1.1 - 5.0%] and food insecure - 1.6% [0.7 - 5.1]; P = 0.456).

3.6.4 Micronutrients – vitamins.

Intakes of most vitamins were similar, but B2 (riboflavin) was significantly negatively influenced by food insecurity (Figure 3.2: A-D). Those who were classed as food insecure consumed 36% less riboflavin than food secure individuals with values of 0.7 mg [0.6 - 1.1] and 1.1 mg [0.9 - 1.5] respectively (P = 0.030; Figure 3.2A).

Food secure females exceeded the RNI for folate (104.9% of the RNI) whilst food insecure intakes were lower than the RNI (82.6%), but no significant difference was found between groups (P = 0.222; Figure 3.2B).

Intakes of vitamin B12 were numerically very different between groups (2.5 μg [1.4 - 3.9] and 1.1 μg [0.5 - 2.5] for food secure and insecure respectively), but this difference did not quite achieve significance (P = 0.057; Figure 3.2C). Vitamin A requirements for females 19^{+} in the UK are set at 600 μg^{-d}. Food insecure females had a low intake compared to the RNI (59.4% of the RNI) and consumed 51.6% less vitamin A compared to food secure individuals but again the difference, while considerable was not significant (P = 0.311; Figure 3.3D).

3.6.5 Micronutrients – minerals.

Mineral intakes were not seen to vary significantly, however, consumption levels for several minerals were routinely low and also showed large numerical differences indicating trends towards lower intakes amongst the food insecure group (Figure 3.3: A-E).

Iron intakes of females 19-49 years (n =26) were low compared to the RNI with 96.2% consuming below the RNI (14.8 mg d^{-1}) and 57.7% below the lower reference nutrient intake (LRNI; 8.0 mg d^{-1}). Amongst those who were food insecure, iron intakes were 28.9% lower but not significantly so compared to food secure (5.65 ± 1.31 mg d^{-1} vs 7.96 ± 0.70 mg d^{-1}; P = 0.198; Figure 3.3A). Iron intakes were slightly higher in females over 50 years (8.37 ± 0.70 mg d^{-1}) compared to 19-49 years and, as requirements are lower in this group, the proportion below the LRNI and RNI was reduced to 12.5% and 54.2% respectively. Only two participants were food insecure in the over 50 group, so comparisons could not be made by food security status (Figure 3.3B).

Zinc from dietary sources was low compared to the RNI for the majority of females 19-65 years (median 84.2% [58.1 – 106.1] of RNI), with 70.0% below the RNI and 24.0% below the LRNI. This did not differ with food security status ($P = 0.439$; Figure 3.3C).

Iodine intakes were also low compared to the RNI (140µg d^{-1}) for all (41.8% [23.3 - 66.7]) with 92.0% below the RNI and 54.0% below the LRNI (70 µg d^{-1}). Whilst intake in food insecure females was 53.6% lower (46.1 µg d^{-1} [22.0 – 66.2]) compared to food secure (70.8 µg d^{-1} [34.3 – 99.6]) this was not significant ($P = 0.257$).

Only two females aged 19-65 years in our study had a dietary intake of selenium above the RNI (60 µg d^{-1}), with the remainder below the RNI and 74.0% were below the LRNI (40 µg d^{-1}). No differences were detected between the food security groups ($P = 1.000$; Figure 3.3E).

3.7 Discussion.

In this study we found that lockdown de-stabilized the access to food and the perception of accessibility across all income domains, not exclusively those on lower incomes. However, those households with the lowest incomes did experience food insecurity more severely than those with higher incomes. We show that food insecurity is felt and feared in affluent groups as well as those on low incomes and that the anxiety around limited food availability drives behaviour change to ensure the security of personal acquisition. Although it must be noted this study utilised a convenience sampling method and as such the survey population is not representative of the general population. The respondents in this study were typically overrepresented for those earning above the national median wage and educational attainment, as such the prevalence of food insecurity during the first UK lock is likely to be under reported in this study.

We find that the intake of a number of micronutrients is significantly below requirements and for vitamin B2 this is exacerbated by the presence of food insecurity. We found that, under lockdown conditions, having a low income, being self-employed or unemployed (for whatever reason), living with people vulnerable to disease and having children, greatly increased the likelihood of reduced food security. Notably these factors in addition to limitations in availability, increased anxiety about household food provision. These findings are in line with previous work (Sharma, 2020; Clay and Rogus, 2021; Raifman et al., 2021; Molitor et al., 2021), but in this study, we specifically highlight the fact that these same factors are relevant to more affluent groups. Those categorised as food insecure were less able to eat preferred foods both due to availability and financial constraints and their shopping trips were reduced compared to food secure. It has been suggested that this may be because individuals with a higher level of education tend to have a more diverse diet from the outset (Ogundijo et al., 2021). There did not appear to be a movement to cheaper shops for the food insecure, but rather they appeared to try to replace it with click and collect (albeit the association was not quite significant). We additionally saw clear trends indicating reduced intakes of important nutrients (e.g., riboflavin) in the food insecure group.

The nature of the participants, representing a relatively affluent cohort, highlighted an important aspect of the “food insecure” group. These people were, for the most part, very well educated and earning reasonable salaries, certainly to a level that would not be expected to be associated with food insecurity. Their responses, however, clearly indicated that they were either experiencing difficulties or had greater anxiety around their food security status, their responses, however, clearly indicated that they were either experiencing difficulties or had greater anxiety around their food security status, these findings align with a study in the US which found 19% of participants during the initial stages of COVID-19 (mid-March 2020) who had a very low food security status, had a high income (>$59,000 a year) whilst 21% with a graduate degree indicated they had a very low food security status(Wolfson and Leung, 2020). A recent study suggested that a higher percentage of people reporting they were moderately or greatly affected during the pandemic in their shopping habits had postgraduate degrees compared with school, college or undergraduate degree holders (Ogundijo et al., 2021). Higher qualification levels were suggested to be associated with a more significant impact on food purchasing due to greater anxiety driving food purchases in the face of reduced variety of foods that are customarily available to them. This may have prompted our respondents to answer positively regarding worrying about running out of food, but this worry resulted in stockpiling and over-purchasing, thereby limiting further availability both for themselves and lower income households.

Covid-19 exposed fragilities in procuring food as the household income changes (Power et al., 2020) but we found both food secure and food insecure households adjusted their shopping habits similarly. This suggested that, for this study population, experience of food insecurity was primarily due to a lack of food availability rather than affordability, although households with the lowest incomes did indicate financial constraint was a factor in worrying about running out of food. Although income decreased in all groups, the proportional reduction was lower for food secure households, which may have afforded them the ability to still purchase food at the same level or potentially greater as a result of the reduction in extraneous costs (e.g., travel to work)(ONS, 2022a). Food budget modification was probably either limited or not required in this group. However, for other households the higher percentage loss of income may have caused the food budget to be modified to pay for other household bills and costs. Limited availability of foods was the principal reason for the experience of food insecurity in this study and this was worsened by limited availability of supermarket delivery services, minimum spend and delivery cost associated with shopping online and restrictions on movement hampering access to shops (ERRA, 2021). During the first lockdown the infrastructure for click and collect and home delivery increased to cope with the demand (Rigby, 2020; McKevitt, 2020), thereby diminishing the likelihood of limited food availability for wealthier households in subsequent lockdowns. This was probably of limited value to lower income households because of the constraint that the requirement for a minimum spend imposes (Spurlock et al., 2020).

The increase in food spend by wealthier households limited the availability of certain types of foods for others, such as core staple items of pasta, rice and bread. The week before the first UK lockdown was imposed, increases in purchasing were observed across all social classes compared to the same time the previous year, however households who were more affluent increased purchasing compared to less affluent groups (PHE, 2020b).

Our data follows a similar trend to national data in that food insecurity was experienced at a greater level by younger individuals and those with a lower household income (DEFRA, 2021). Furthermore, our results concur with studies researching the experience of food insecurity internationally, in that there was an increase in the experience of food insecurity during and after the initial lockdowns (Benites-Zapata et al., 2021; Dondi et al., 2021; Gaitán-Rossi et al., 2021; Kang et al., 2021; Kent et al., 2022; Niles et al., 2020)Households experiencing food insecurity spent a significantly greater proportion of income on food. Furthermore, we found that the prevalence and severity of food insecurity was greatest for households when the proportion spent on food and non-alcoholic beverages exceeded 13% of equivalised household income. Engle’s law states that the proportion of income spent on food decreases as wealth increases (Drewnowski, 2003). Here, we further show that as the proportion of income spent on food increases, the risk of food insecurity increases directly with it (Figure 3.1). Within this population of relatively affluent individuals, we found that, above a percentage spend of 10% on food, the relative risk of food insecurity increased by 0.07 for every 1% increase in proportion of income spent on food. It is unclear what the proportional increase in risk might be for lower income groups, but it can be envisaged that this is likely to be higher than in this case. With current food price increases, the proportional increase in food spend has already increased (Indu et al., 2022) latest data for commonly consumed food and drink items show prices have risen by 9.8% in the previous 12 months to June 2022 (Indu et al., 2022) placing a significant burden on all, but most severely those on low incomes.

Data from DEFRA showed that the proportion of household spend on food and non-alcoholic drinks in the UK in 2018/19 was 10.6%, whilst for those in the lowest 20% income quintile this was 14.7% (DEFRA, 2020). So, prior to covid, these discrepancies were already apparent (Connors et al., 2020; Ellie Thompson et al., 2019) and with the increased cost of living alongside the removal of the £20 uplift in universal credit (The Food Foundation, 2022b), the proportion for the lowest income group will either be higher or have reached a threshold spend beyond which access to food banks or simply doing without food, becomes commonplace.

A Food Foundation survey during the Covid-19 Pandemic found that 14% of adults living with children reported experiencing moderate or severe food insecurity from March to September 2020 (~ 4 million people including 2.3 million children). The same survey found that 12% adults living with children said they skipped meals, whilst 4% said that they had gone without food for a whole day because they could not afford or access food (School Food Matters, 2020). The UK Food Standards Agency (FSA) previously showed that adults living with children and particularly those on low incomes are more likely to experience food insecurity. Whilst most older people are food secure, around 10-20% of those aged 55 years and above experience some level of food insecurity (Fuller et al., 2019).

We evaluated the dietary intakes of participants, albeit with a relatively small sample size. Riboflavin intakes were low compared to the RNI for food insecure females (77% of the RNI) with 67% below the LRNI. Riboflavin functions in a diverse array of redox reactions critical in cell metabolism via the cofactors, flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD) respectively. These cofactors act as important electron carriers in metabolism (e.g., succinate dehydrogenase) and in fatty acid oxidation. Recent evidence indicates that riboflavin deficiency can precipitate the development of anaemia and sub optimal intakes are known to negatively impair iron utilization and hemoglobin synthesis (Powers et al., 2011). Other research shows riboflavin deficiency causes metabolic dysregulation in animals (Prentice and Bates, 1981) and can impact on the utilisation of other important B vitamins such as folate, vitamin B12 and Vitamin B6 (Thakur et al., 2017; Powers, 2003). In addition to riboflavin, a general trend showing a reduction of vitamin B12 and vitamin B6 is also reported in participants, although these changes were not statistically significant. B vitamins, including B12 and B6 are known to be important in the metabolism of phospholipids and neurotransmitters and as such, deficiencies can cause haematological and neurological problems (Shipton and Thachil, 2015). Moreover, adequate intakes of vitamin B1, B2, B12, B3 are associated with lower risk of NAFLD (Vahid et al., 2019) and both B6 and B12 appear important in the metabolic pathway responsible for homocysteine metabolism, a marker for cardiovascular diseases (Zaric et al., 2019). Combined, it is feasible that sub-optimal levels of B vitamins, as reported in the current study, could predispose individuals to various health related problems.

Another trend observed in the current research was a reduction in vitamin A status in participants. Vitamin A has roles in growth, and in the prevention of night blindness (Tanumihardjo et al., 2016) and reduced vitamin A status increases the risk of infection (Thurnham et al., 2003). Marley et al (2021) recently demonstrated that in patients replete or having abnormal levels of vitamin A have increased rates of inflammation and C-reactive protein. This study pointing to an important roles of vitamin A in mitigating rates of inflammation.

3.8 Limitations of the study.

The data is in this study is largely self-reported, however, the tools used are validated methods. Although the tools in this study have been used in previous studies (e.g., HFIAS), they were not tested for the demographic in this study. Furthermore, the overall survey itself was not piloted prior to launch. This alongside the survey being completed online meant it was not possible to ascertain if the wording of the questions was fully understood by the participants.

The population who participated in the study had above average levels of education and income and as such cannot be reflective of the general population. However, it does highlight food insecurity can be felt in population groups not typically thought to experience food insecurity.

Indicating the prevalence of food insecurity in the UK is likely to be higher than reported and impacting a wider demographic of the UK population.

Although it must be noted, the statistical approach used in this study did not adjust for confounding factors (e.g., educational attainment or occupational status), as such the results for the experience of food insecurity across income levels may have altered if cofounding factors were taken into account.

There have been limited studies measuring actual dietary intakes in food insecure groups, so by successfully utilizing a dietary monitoring app to capture food intake in geographically or socially isolated people across the age spectrum, as in this case, we have shown that this potentially represents a feasible means of obtaining dietary intake information in groups less physically accessible. We have additionally shown that the HFIAS tool, most usually employed to measure food insecurity as a result of financial/resource constraint, can usefully be employed to assess the impact of food availability in a western population. Using these approaches, we show that groups at risk of food insecurity when faced with an unreliable food supply chain, can be identified. The results may aid policy maker's decisions for the supply of funds/support for population groups at risk of the experience of food insecurity in the future.

3.9 Conclusions.

Anyone can be food insecure or at least feel that they are. For those on higher incomes, "necessary" expenditure (e.g., debt servicing, elevated household bills) may prohibit prior freedoms of food purchasing if income is reduced or added financial burdens are placed upon them (children returning home, requirement to care for elderly relatives, energy, and mortgage cost increases). Additional drivers such as accessibility can further amplify the perception of personal food instability, all of which can result in disproportionate purchasing. These factors add to the burden of patent food insecurity amongst those with lower incomes as their ability to purchase what remains is compromised due to available choice and cost, with healthier foods in general being more expensive.

In this study, we found that despite mostly being in receipt of incomes approximating to the national average or higher, food insecurity was still experienced by nearly 20%. Those who experienced food insecurity had a lower household income (10.5% less) and were required to spend a much greater proportion of it (16% more) on food compared with food secure participants. However, food insecurity was predominantly driven by a lack of available food, although those in lower income groups indicated that financial constraint was a significant factor. Furthermore, when spend on food exceeded 13% of income the risk of experiencing food insecurity increased by 1.6-fold ($p = 0.016$).

Deficiency related diseases will be much more prevalent in those who are food insecure in the UK, and here we found that riboflavin intakes were 36% lower amongst food insecure compared to food secure individuals ($p = 0.03$). Whilst not significant, vitamin B12 intake was 56% lower and iodine, 53.6% lower in the food insecure, indicating a broader potential for deficiency in subgroups of food insecure participants. However, deficiency related diseases may still occur in people who are food secure, as deficiencies for specific nutrients, such as iron, are not uncommon (e.g., iron).

In summary, we observed a significant level of food insecurity within a population not typically considered at risk as >50% received a household income equivalent to or greater than the national average, resulting in specific nutritional intake deficits. The use of the proportion of income required to be spent on food has the potential to be an indicator for the risk of food insecurity and may help identify groups at risk when food spend equals or exceeds 15% of income.

Table 3-1. Participant characteristics.

		All			Food Secure			Food Insecure			p value
		n	**Median**	**25th–75th Percentile**	***n***	**Median**	**25th–75th Percentile**	***n***	**Median**	**25th–75th Percentile**	
Age (years)		515	44.0	33–52	421	45.0	33–54	94	41.0	33–50	0.031 *
Height (m)	Male	77	1.80	1.75–1.85	62	1.80	1.75–1.85	15	1.80	1.78–1.85	0.395
	Female	423	1.65	1.61–1.70	346	1.65	1.61–1.70	77	1.63	1.61–1.68	0.095
	Missing	14	N/A	N/A	12	N/A	N/A	2	N/A	N/A	
Weight (kg)	Male	78	85.1	75.0–99.5	63	84.6	76.0–96.2	15	86.0	74.0–119.0	0.506
	Female	412	66.0	59.9–78.0	336	66.0	60.0–77.4	76	67.3	58.2–81.8	0.837
	Missing	24	N/A	N/A	21	N/A	N/A	3	N/A	N/A	
BMI	Male	76	26.1	23.7–30.1	61	25.9	23.7–29.8	15	27.1	23.1–31.1	0.681
	Female	403	24.3	21.6–28.3	329	24.2	21.7–28.1	74	24.8	20.9–28.8	0.789
	Missing	35	N/A	N/A	30	N/A	N/A	5	N/A	N/A	
Equivalised income per week (£)		470	853.69	551.69–1182.20	385	853.69	580.56–1243.71	85	763.83	288.69–1123.28	0.038 *
Food spend per week (£)		468	86.51	59.74–116.33	383	86.06	60.19–115.02	85	89.32	57.13–124.14	0.582
Proportion of income (%)		466	9.9	6.4–16.3	381	9.5	5.7–15.4	85	11.04	7.3–21.7	0.011 *
Household size		512	2.0	2.0–4.0	418	2.0	2.0–4.0	94	3.0	2.0–4.0	0.140
Sex		***n***		**(%)**	***n***		**(%)**	***n***		**(%)**	
	Male	79		(15.3)	64		(15.2)	15		(16.0)	0.861
	Female	435		(84.5)	356		(84.6)	79		(84.0)	
	Missing	1		(0.2)	1		(0.2)	n/a		n/a	
Income quintiles	1(<£25,700.47)	98		(20.9)	72		(18.7)	26		(30.6)	0.117
	2 (>£25,700.47)	90		(19.1)	75		(19.5)	15		(17.6)	
	3 (>£39,643.18)	99		(21.1)	80		(20.8)	19		(22.4)	
	4 (>£53,277.87)	84		(17.9)	73		(19)	11		(12.9)	
	5 (>£75,503.02)	99		(21.1)	85		(22.1)	14		(16.5)	

Comparison between food secure and food insecure groups for Age (years), height (m), weight (kg), equivalised income, food spend, and the proportion of income spent on food as well as household size and body mass index (BMI) tested with MANN Whitney U (* indicates significance at the $p < 0.05$ level). Differences in the frequency of individuals represented in food secure and food insecure groups for sex and income quintile were tested with Pearson Chi Sq. (* significant at the $p < 0.05$ level). n/a = not applicable

Table 3-2. ODDs of food insecurity amongst the income quintiles during the Covid-19 lockdown.

Income Quintile (per Year (£))	*n*	OR	(CI) Lower	(CI) Upper	*p* Value
1 (<£25,700.47)	140	2.02	1.02	4.01	0.043
2 (>£25,700.47)	90	1.21	0.55	2.68	0.631
3 (>£39,643.18)	99	1.44	0.68	3.07	0.342
4 (>£53,277.87)	84	0.92	0.39	2.14	0.837
5 (>£75,503.02)	99	REF	REF	REF	REF

OR = Relative Risk.
CI = Confidence Interval.
n Number
ǂ Percentage who were food insecure.
* Significant at the $p < 0.05$ level (Binary logistic regression)

Table 3-3. Odds of the experience of food insecurity by employment status prior to and during the first Covid-19 lockdown.

Employment Status	**Food Secure v Food Insecure Prior to covid-19 lock down**					**Food Secure v Food Insecure During the first UK lock down**				
	n	**OR**	**CI lower**	**CI Upper**	***p* Value**	***n***	**OR**	**CI lower**	**CI Upper**	***p* Value**
Full time	320	REF	REF	REF	REF	269	REF	REF	REF	REF
Self employed	44	1.89	0.91	3.90	0.086	**35**	**2.34**	**1.07**	**5.13**	**0.033**
Part-time	89	0.79	0.40	1.54	0.483	80	0.65	0.30	1.39	0.267
Unable to work due to sickness or disability	**8**	**8.40**	**1.95**	**36.20**	**0.004**	**12**	**5.11**	**1.58**	**16.59**	**0.007**
Homemaker	12	1.68	0.44	6.41	0.448	17	1.57	0.49	5.05	0.446
Unemployed	**7**	**12.59**	**2.38**	**66.64**	**0.003**	**15**	**4.47**	**1.54**	**12.97**	**0.006**
Retired	32	0.52	0.15	1.77	0.297	50	1.12	0.51	2.48	0.774
Furloughed	n/a	n/a	n/a	n/a	n/a	34	0.50	0.15	1.69	0.262
Prefer not to say	2	5.04	0.31	81.81	0.256	2	5.11	0.31	83.30	0.252

Association of employment type/status prior to and during lockdown and odds of food insecurity. Values for the odds of food insecurity (95% confidence intervals) are shown Reference group, Full time employed. The total number in each group (*n*) is also indicated. Binary logistic regression.

Table 3-4 Relative risk of food insecurity when following government movement restriction guidelines.

QN		Relative Risk (RR) Of Food Insecurity If in Listed Government Guidelines					
		n	**Ŧ (*n*)**	**ǂ (%)**	**RR**	**(CI)**	***p* Value**
1	Not self-isolating but following government guidance on social distancing	442	(72)	(16.3)	0.5	(0.4–0.8)	0.005 *
2	Self-isolating for 7 days, following symptoms	2	(1)	(50.0)	2.8	(0.7–11.2)	0.244
3	Self-isolating for longer than 7 days following symptoms, because you still have a temperature (above 37.8 °C)	1	(1)	(100.0)	5.5	(4.6–6.6)	0.034 *,¥
4	Self-isolating for LONGER than 14 days following symptoms in a member of your household, because YOU have developed symptoms during this time	0	(0)	(0.0)	n/a	n/a	0.636 ¥
5	Not leaving your home because you are at a VERY HIGH RISK of COVID-19 and have received a letter from the NHS (Shielding)	9	(1)	(11.1)	0.6	(0.1–3.9)	0.313 ¥
6	Not leaving your home except to get essential items such as food and medicine because you are at HIGH RISK of COVID-19, e.g., are 70 or older, pregnant, have diabetes, taking medication that can affect your immune system.	27	(9)	(50.0)	1.9	(1.1–3.4)	0.037 *,¥
7	Not leaving your home because someone in the household is more vulnerable to the virus (i.e., not high risk but at greater risk)	38	(12)	(31.6)	1.8	(1.1–3.1)	0.027 *
8	Status isolating or not Prefer not to say	3	(0)	(0.0)	n/a	n/a	0.412 ¥

QN = Question number; RR = Relative Risk; CI = Confidence interval; Ŧ Number of people who food was insecure; ǂ Percentage of employment type food insecure; ¥ cells have an expected count of less than 5; * Significant at the $p < 0.05$ level (Pearson Chi-Square). n/a = not applicable.

Table 3-5 Change in food spend from prior to, to during lockdown by food security status.

			Food Spend Change Groups			
			Increase	Stayed Same	Decrease	*p* Value
Total	*n*		174	209	83	
	Percentage of income spent on food (%)		11.5 [a]	8.74 [b]	9.2 [b]	0.001 **
	Percentage of group (%)		(37.3)	(44.8)	(17.8)	
	Change in food spend (£)		+33.57	0	−30.31	
	EQVINC Weekly income (£)	Median	853.69	853.69	878.11	0.380
		25th	597.11	530.07	584.1	
		75th	1297.42	1182.2	1129.32	
Food secure	*n*		144	174	63	
	Percentage of income spent on food (%)		11.4 [a]	7.9 [b]	9.2[b]	<0.001 **
	Percentage of group (%)		(37.8)	(45.7)	(16.0)	
	Change in food spend (£)		+32.38	0	−28.88	
	EQVINC Weekly income (£)	Median	853.69	853.69	853.69	0.716
		25th	609.97	575.49	548.52	
		75th	1279.16	1269.49	1176.70	
Food insecure	*n*		30	35	20	
	Percentage of income spent on food (%)		14.3 [a]	10.6 [a,b]	8.4 [b]	0.047 *
	Percentage of group (%)		(35.3)	(41.2)	(23.5)	
	Change in food spend (£)		+39.89	0	−35.9	
	EQVINC Weekly income (£)	Median	891.17	561.51	909.56	0.028 *
		25th	520.34	225.86	629.03	
		75th	1366.22	935.85	1024.57	
p value	Food secure v food insecure percentage of income		0.151	0.003 *	0.866	
p value	Food secure v food insecure Change in EQVINC Weekly income (£)		0.780	0.002*	0.802	

Kruskal–Wallis used to test for differences in the proportion of income spent between the food spend groups for food secure and food insecure, Mann–Whitney U to test for difference between food secure and food insecure EQVINC = Equivalised household income, Letters differentiate significance across the categories * Significant at the $p < 0.05$, ** Significant at the $p < 0.001$.

Table 3-6. Schofield equations for estimating BMR (kcal/d) from weight (kg).

	BMR (kcal/d)	
Age (Years)	**Males**	**Females**
10-17	17.7 x Wt. + 658.2	13.4 x Wt. + 692.6
18-29	15.0 x Wt. + 692.1	14.8 x Wt. + 486.6
30-59	11.5 x Wt. + 873.0	8.1 x Wt. +845.6
60+	11.7 x Wt. + 587.7	9.1 x Wt. + 658.4

WT = weight

Table adapted from PILOT-PANEU project.

Table 3-7 Physical Activity Level (PAL) values for category of physical activity (age dependent) and the corresponding lower and upper cutoff values.

Age group (years)	**Category of Physical Activity**	**PAL**	**Lower Cut-off**	**Upper cut-off**
18-69	Low	1.4	0.872	2.249
	Moderate	1.6	0.996	2.570
	Vigorous	1.8	1.120	2.892
70-74	Low	1.4	0.872	2.249
	Moderate	1.6	0.996	2.570

PAL = Physical Activity Level

Table adapted from PILOT-PANEU project.

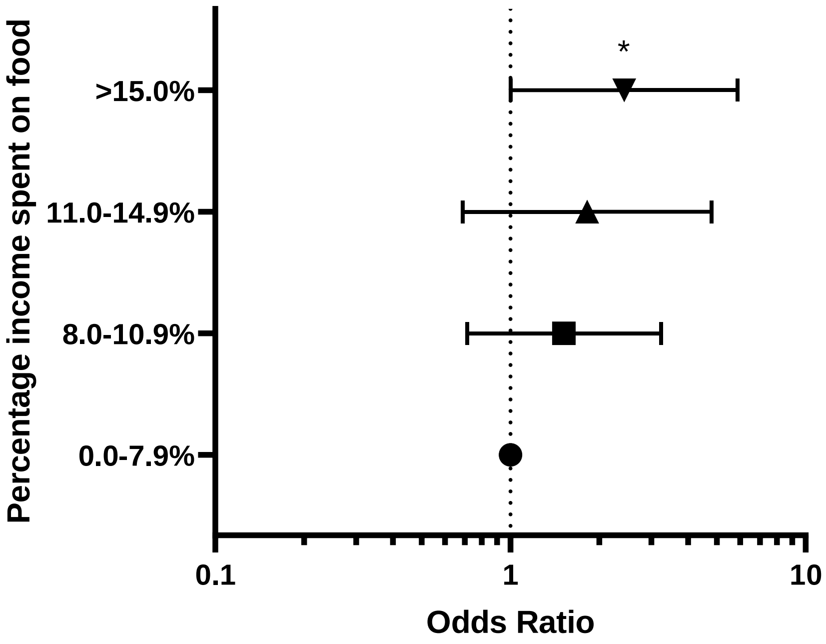

Figure 3-1. The odds of experiencing food insecurity compared to respondents who spend <7.9% (ref group) of income on food and non-alcoholic beverages. Results shown are relative odds ratio with 95% confidence intervals. Respondents were included in the analysis if they provided details of their income and food spend (n = 468). * Significant at the $p < 0.05$ level

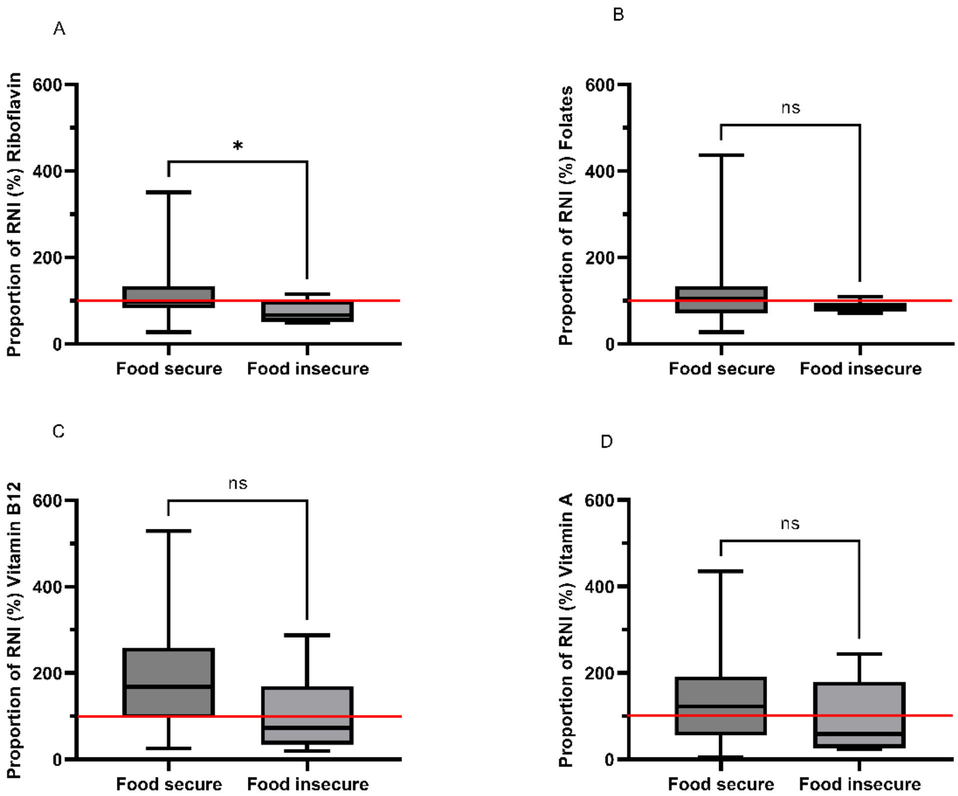

Figure 3-2 (A–D) The proportion of the Reference Nutrient Intake (RNI) met for vitamins amongst food secure (n = 44) and food insecure (n = 6) females aged 20–65 years. The red line indicates 100% of the RNI. * Significant at the $p < 0.05$. ns = non-significant.

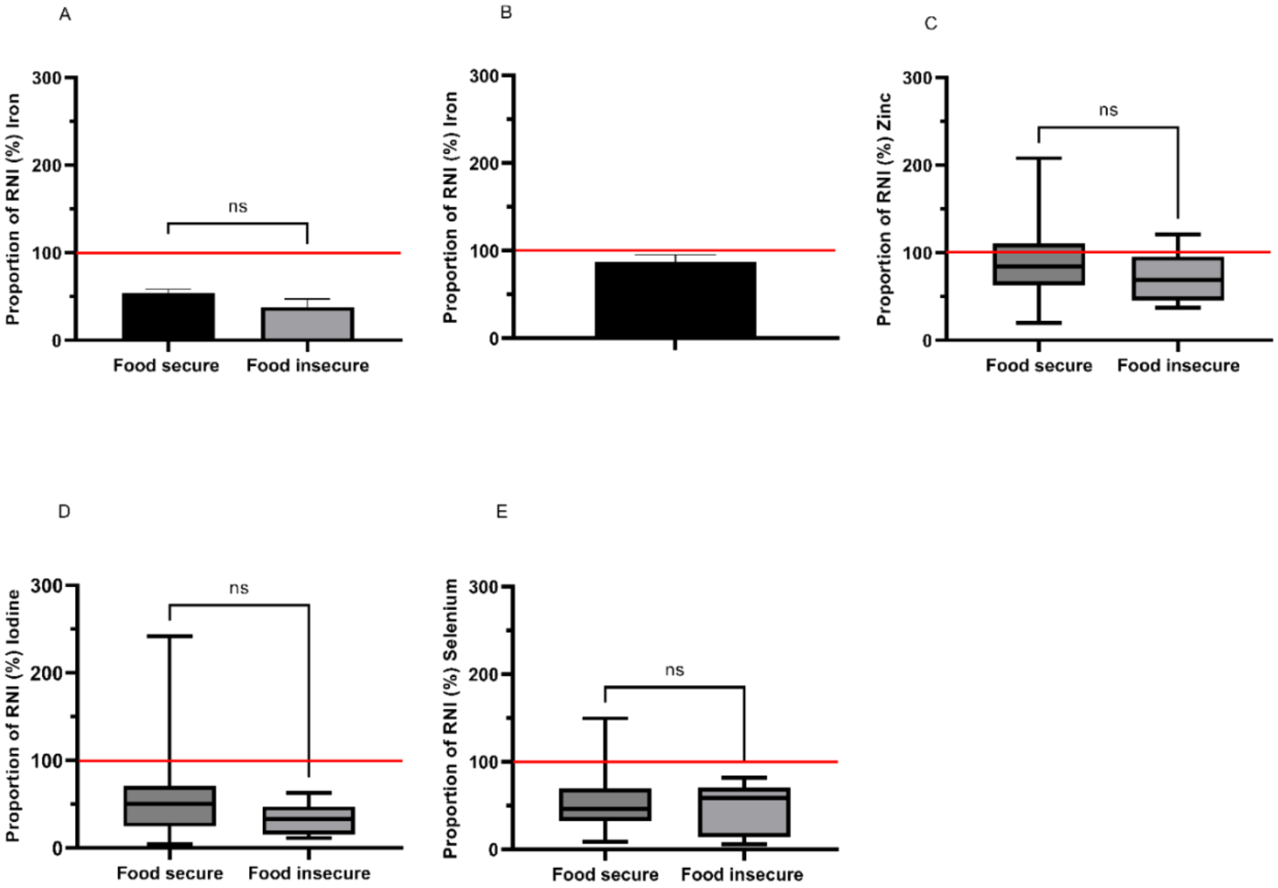

Figure 3-3. The proportion of the Reference Nutrient Intake (RNI) met for minerals amongst food secure (n = 44) and food insecure (n = 6) females aged 20–65 years. The red line indicates 100% of the RNI. ns = non-significant.

4 Food security status and diet following the removal of the uplift to Universal Credit: Benefits and Nutrition Study (BEANs), a cross sectional study.

4.1 Authors contribution

Conceptualization, **M.T**, L.C, and S.W.; methodology, **M.T**., P.OR. and S.W.; formal analysis, **M.T**., P.OR., S.W.; data curation, **M.T**. and S.W.; writing—original draft preparation, **M.T**., P.OR. and S.W., writing—review and editing, **M.T**. and S.W.; visualization, **M.T**., supervision, S.W., and L.C.; project administration, **M.T.** and S.W.

4.2 Abstract.

Objectives.

This study's primary objectives were to measure the prevalence and severity of household food insecurity amongst adults in receipt of UC at a time when the uprating had recently been removed. To investigate the £20 a week uprating and subsequent removal on Food Bank usage. Assess the perceived barriers to accessing food during the Covid-19 pandemic and since the easing of restrictions. Estimate the diet quality and micronutrient intakes of females in receipt of UC compared to females of the same age within the general population, stratified by income.

Methods.

The prevalence and severity of food insecurity is measured using the USDA adult survey food security module. Dietary intake estimated with four non-consecutive computerised 24-hour dietary recalls and diet quality assessed

using the Dietary Quality Index- International tool. The National Diet and Nutrition Survey years 9-11 provided a comparator for understanding differences in nutrient intakes of females with an income from UC to the general population when stratified by equivalised income. Binary logistic regression models were used to understand factors associated with food insecurity and severity amongst UC claimants.

Results.

This cross-sectional survey collected data from 349 participants (mean age 41 years; 73.4% women) with an income from UC and who received the £20 a week uprating. Many participants with and income from UC were food insecure (89.4%) with 64% having “very low food security”. Most perceived the £20 a week uprating increased fruit and vegetable intake (58.7%) and 66.5% felt the loss of the uprating had decreased intake. Foodbank access increased by 72% after the removal of the uprating. Total diet quality of females aged 23-61 years was lower (45.9%) compared to females of the same age in the NDNS EQV tertiles (49.6% -55.8%; P = 0.023 - P <0.001). Vitamin A as a percentage of the Reference Nutrient Intake (RNI) significantly lower (69.2%) compared to NDNS EQV (94.1% -135.3%; P = 0.006 – P<0.001) as was selenium (48.3%) compared to NDNS EQV (63.1% -75.8%; P = 0.008 - P <0.001). A greater proportion of women with an income from UC were below the Lower Reference Nutrient Intake (LRNI) for riboflavin (30.2%) compared to NDNS EQV (15.3% – 7.2%; P =0.021 – P <0.001) and for zinc (20.9%) compared to NDNS EQV (8.4% - 0.0%; P =0.016 – P<0.001).

Conclusions.

The prevalence and severity of food insecurity amongst UC claimants is detrimental to their nutritional security. The £20 a week uprating could be proactive against food and nutritional insecurity as many felt it had afforded them the opportunity to increase fruit and vegetable intake. However, the diets of females claiming UC does not meet the definition of food and nutrition security. We show evidence for increased diet quality and micronutrient intake amongst females as income increases therefore the re-introduction of the £20 a week uprating to UC could help to improve diet quality and micronutrient intakes amongst female UC claimants.

4.3 Introduction.

Households that are unable to obtain sufficient quantity and quality of food at all times and for all member of the household either because of insufficient economic resources or other resources are food insecure (USDA, 2022a). The two levels of food insecurity are low food secure, and very low food security (USDA, 2022a). The experience of food insecurity has been shown to be associated with low wages, living poverty, having a disability, being unemployed, living in a household with children and with socio-economic status (Rose et al., 1998) (Raifman et al., 2021) (Connors et al., 2020) (The Food Foundation, 2023). The experience of food insecurity is also strongly linked with ill health (Drewnowski, 2022).

In the UK, the Welfare System provides financial support to many households with a low income in the form of Universal Credit (UC), which is paid monthly to eligible working adults with a low income, and/or adults who are not in paid work or cannot work. Universal Credit was introduced in April 2013 in four postcode areas of the North West, full service roll out was completed in December 2018 (DEFRA, 2023). Universal Credit replaces six social security benefits and tax credits (Kennedy, 2023)[7] often termed legacy benefits. The move to UC from legacy benefits in some cases may have reduced the amount a person was entitled to, whilst for others the amount entitled to increased (Kennedy, 2023). The reforms to the benefit system and polices introduced by the Government such as the 5 week wait time for the first payment of UC after claiming, the benefit cap, 2 child limit, under occupancy penalty and sanctions have all been highlighted as factors in the experience of food insecurity (Geiger et al., 2021)..

In November 2021, 4.8 million households in the UK were in receipt of UC (DEFRA, 2022c) with a median monthly payment value to households of £680 (DEFRA, 2022c). As of August 2022, there were 2.5 million households claiming legacy benefits and tax credits (DEFRA, 2023). During the Covid-19 pandemic those on UC credit received a £20 a week uprating to their standard allowance, whilst for those on legacy benefits this was not the case. Research has shown the £20 a week uprating was associated with an improvement in food insecurity compared to those on legacy benefits (Geiger et al., 2021). However, there was still a high percentage of those on UC (47%) who experienced food insecurity (Geiger et al., 2021).

[7] Universal Credit replaces the following legacy benefits.

- Income based-Jobseeker’s Allowance
- Income- related Employment and Support Allowance
- Income Support
- Housing benefit
- Child Tax Credit
- Working Tax Credit

The amount of UC a household receives is dependent on the age of the claimants (under 25's receives a lower monthly standard allowance compared to over 25's), if you are single or in a couple, have children, pay for childcare costs, have housing costs, or if you have a disability or health condition. Working households have their UC reduced by £0.55 for every £1.00 of income earned (GOV, 2023) March 2020 at the start of the COVID-19 Pandemic the UK government introduced a £20 a week uprating to UC to help with the additional costs faced during lockdown for one year. This was extended by a further 6 months before officially ending on the 6th of October 2021. In 2020/2021, only 7% of UK households indicated that they regarded themselves as food insecure ((DWP, 2022). In contrast, household receiving UC were 5.7 times more likely to be food insecure than the general population, the proportion of households receiving UC who experienced food insecurity was 40% of which 14% were marginal, 12% low and 15% with very low food security (DWP, 2022).

Income is a significant factor in food purchasing and low-income households have limited choice in the types of food available due to their restricted budgets. The paradox of food insecurity and obesity is well documented (Yang et al., 2018) (Aceves-Martins et al., 2018) (Benjamin Neelon et al., 2017) (Keenan et al., 2021) (Jenkins et al., 2021) (Pilgrim et al., 2012). Cheaper foods are frequently those with the highest caloric density and lack micronutrients. Experience of food insecurity is thought to commonly results in greater adoption of these foods at the cost of those which, whilst more expensive per calorie, are nonetheless good sources of vitamins and minerals, for example fruit and vegetables ((Jenkins et al., 2021). This leads to suboptimal intakes of micronutrients and excessive consumption of fat and sugar.

Monitoring of food security in the UK is as part of the Family Resource Survey which uses the 10-question adult food security module. Whilst it is known the experience food insecurity follows a continuum of increasing severity. however, the impact food insecurity on nutritional security requires further research. The characteristics of experiencing low food security is reduced quality, variety, and preference of food in the diet but the quantity of food is not reduced (Drewnowski, 2022), whilst experience of very low food security is associated with constrained food budgets and reduction in the quantity of food consumed and caloric intakes (Drewnowski, 2022). People with very low food security often adopt coping strategies including skipping meals, going hungry or eating smaller meals ((Drewnowski, 2022). These adaptations to diet are likely to adversely impair the nutrient profile of the diet.

Research into the experience of food insecurity and micronutrient intakes of population groups in receipt of benefits the UK is limited, as such, in this study, we set out to investigate the diet quality and micronutrient intakes of females with an income universal credit (UC) claimant. Females were the focus of the dietary analysis as they have been shown to adapt their dietary practices ensure other member of the household are able to eat. (Bennett, 2014).

It is hypothesised the prevalence and severity of household food insecurity amongst universal Credit in the months after the removal of the £20 a week uplift will be above the national average during the covid-19 pandemic and push households towards needing support from the Foodbank. It is also hypothesised the prevalence and severity of food insecurity will differ amongst household in receipt of Universal Credit depending on household composition and employment status. That the removal of the £20 a week uprating will impact single adult households the greatest as it contributes a greater proportion to overall income. That the diets of females with and income from Universal credit will have a lower quality and micronutrient intakes compared to females in the general population. The study also investigates participants' perceptions of the usefulness of the £20 per week uprating and the consequences of its subsequent removal on food group purchases and foodbank usage. We highlight the extent of the disparity in diet quality between UC claimants and the UK general population and find significant impacts on food security status of the removal of the UC uplift.

4.4 Methods.

4.4.1 Study design.

This cross-sectional study was completed during the months of September 2021 to April 2022 amongst households in England, Scotland, and Wales with an income from Universal Credit, who were in receipt of the £20 a week uprating and aged between 18 and 65 years of age. The data collected during the survey pertained to participants sex, age, employment, household income, household size, foodbank usage, shopping behaviours, food expenditure and food security status in the previous 30 days ((USDA, 2022c). This information was collected using a single online survey hosted by Jisc (Jisc, 2022).

Advertising of the study was targeted to regions of England, Scotland, and Wales with high numbers of persons in receipt of Universal Credit as detailed on the Department of Work and Pensions Universal Credit Claimants Map (Table 4.8). Participants were recruited to the study at three time points (September 2021, February 2022, and April 2022) via two-week blocks of advertisements on Facebook distributed by Reach PLC. In addition to online recruitment, during December 2021, participants were recruited in person at a Foodbank, and leaflets distributed at a Social Supermarket in Coventry. Participants were given the option to take part in a further study investigating dietary intakes.

Dietary information was collected for three or four non-consecutive days using Intake24(Intake24, 2022) an online version of the 24-hr dietary recall which uses the multiple pass method. Dietary information from this Benefits and Nutrition Study (BEANs) was compared with age and sex matched participants of the National Diet and Nutrition Survey (NDNS) years 9-11. Comparison of the BEANs data to the NDNS data was conducted to identify similarities and differences in micronutrient intakes and diet quality between universal credit claimants and the general population. Participants were excluded from the dietary analysis if they were pregnant or breast feeding.

4.4.2 Diet Quality Index-International (DQI-I).

This study used the Diet Quality Index-International to estimate overall diet quality, the methods are explained in detail by Kim et al (Kim et al., 2003). In brief the four major categories of the DQI-I are: variety (evaluates variety in food groups, and within protein sources), adequacy (assesses foods and nutrients in the diet required in sufficient quantities for a healthy diet), moderation (evaluates food and nutrients in the diet associated with chronic diseases), overall balance (examines the ratio of energy obtained from macronutrients and the ratio of saturated fat to PUFA and MUFA). The maximum DQI-I score available is 100 and is derived from the sum of the sub-category criteria in each of the main categories. Variety accounts for 20%, adequacy 40%, moderation 30%, and overall balance 10% of the total DQI-I score.

The adequacy category concerns the dietary components required in sufficient quantities for a healthy diet. The recommended quantities of vegetables, fruit, grains, and fibre is dependent on energy intake (kcal) as describe by Kim et al ((Kim et al., 2003). In this study we used the energy recommendations and created the groups <1700 kcal, >=1700 - <2700 kcal and >=2700 kcal for scoring. For example, Individuals with an energy intake <1700kcal, to score the maximum in the vegetable category they would need to consume 3 servings (240g) whilst someone with an energy intake between >1700 kcal and below 2700kcal would require 4 servings (320g) and over 2700kcal 5 servings (400g) (Table 4.9). Weights applied to servings in food groups can be found in table 4.10. We used the Eatwell guide criteria for foods high in fat, salt and sugar and recommended to be consumed with less frequency.

4.4.3 Intake24 dietary data.

Anonymised dietary data was downloaded from Intake24 and matched to participant's survey data from Jisc and processed before analysis. Data output from Intake24 includes Energy (kJ and kcal), macronutrients, micronutrients, food groups and disaggregation variables as well as meal name and time, and portion size (g/ml). Daily energy and nutrient intakes without supplements were calculated from the sum of intakes for energy and nutrients and divided by the number of 24-hour recalls completed to give an average daily intake. Percentage of the RNI (Reference Nutrient Intake) met for vitamins and minerals was calculated based on age and sex requirements as per UK dietary recommendations ((The Department of Health, 2013)

4.4.4 National Diet and Nutrition Survey (years 9-11).

We used data from the National Diet and Nutrient Survey years 9-11 for adults aged 23-61 years. Datasets were combined for person level dietary data and individual level data and the following variables of interest extracted: sex, equivalised income tertiles and energy and nutrients intakes. Food level dietary data was used for estimating the energy intakes from foods high in fat salt and sugar and used in the calculation of the DQI-I.

4.4.5 Sensitivity analysis.

Misreporting of energy intakes in the BEANs study and NDNS were evaluated using European methodology (EFSA, 2014b). The Schofield equation for estimating basal metabolic rate using height and weight was applied and Goldberg cut-off points based on Physical Activity level of 1.4 applied. We applied an activity level of 1.4 to the BEANs and NDNS data because activity data was not collected as part of the BEANs study. The decision to keep the criteria the same between the two surveys was made to provide consistency.

4.4.6 Exclusion criteria and data quality control.

We invited people aged 18-65 years in the UK who had an income from UC and received the £20 a week uprating. Participants were excluded from the analysis if they did not meet the inclusion criteria. Not all participants who meet the inclusion certain completed all components of the survey as such they were excluded from the analysis for that section. Participants who were women and completed three or four 24-hour dietary recalls and who were not pregnant, or breastfeeding were included in the analysis for diet quality and nutrient intakes. We matched the age of females in our study to those in the NDNS for comparison of diet quality and nutrient intakes.

4.4.7 Statistical analyses.

We describe the characteristics of BEANs participants with frequency and percentages for the total population and by dichotomised food security status (food secure, food insecure). All data presented as frequency and percentages are analysed with Chi Square this includes Foodbank usage categorised by access type for the total population and across the three different time points of the study. We also performed McNemar change test to understand if participants use of a foodbank differed after the removal of the uprating to before the uprating was introduced.

Dietary data is presented for females in the BEANs study and compared to females of the same age across NDNS Tertiles. Parametric variables are presented as means and S.E.M and analysed with student T Test for comparison of BEANs to each of the NDNS tertiles and One-Way Anova, Bonferroni corrected for analysis of the parametric variables for NDNS tertiles only. Non-paramedic variables are presented as medians (25th and 75th percentile) and tested with Mann Whitney-U for comparison of BEANs to each of the NDNS tertiles and Kruskal Wallis, Bonferroni corrected test to understand differences between the NDNS tertiles only.

The DQI-I total score and main category scores are presented as means and S.E.M for BEANs and NDNS tertiles. We present the frequency and percentages of participants within each of the sub-categories of the DQI-I, furthermore, we present estimates of the total score achieved in the sub-categories of the DQI-I using mean and S.E.M, however, non-parametric test performed because the scoring system is ordinal and not continuous. Energy data are presented as medians (25th and 27th percentile) and we present the frequency and percentages of females underreporting energy intakes for BEANs and NDNS tertiles. Micronutrient data are presented as the frequency and percentage of females below the Lower Reference Nutrient Intake (LRNI) and the percentage of the Reference Nutrient intake (RNI).

4.5 Results.

4.5.1 Population characteristics.

A total of 349 participants met the inclusion criteria and provided complete responses, of whom 89% were food insecure, most of whom (64%) had “very low food security” (Table 4.1 and Table 4.13). The population was mostly female (> 70%), British (> 90%) and either single or divorced, separated, or widowed (> 70%). The level of education was high with > 40% having achieved equivalent to level 4 and above (first year of a degree), but almost 60% were not in paid employment. Most participants (65%) were overweight with two fifths being obese. However, around 6% of the total population were underweight (n = 20) of this n = 5 had “low food security” and n = 15 “very low food security”.

4.5.2 Household income, food spending, food bank usage, food security and coping strategies.

The average disposable median equivalised household income in the UK in 2021 was approximately £603 week^{-1} (ONS, 2022b). For those receiving UC, household income was only £153.60 week^{-1} [£98.36 -£283.04]. The proportion spent on food by UC recipients was consequently much higher, reaching 1.9 times the national average (14.4% (DEFRA, 2022d)) at 27.0% [19.5% - 57.9%]. Whilst households with children spent 2.2 times the national average at 31.0% [19.5 – 57.9%] and households without children spent 1.7 times the national average at 25.0% [19.5% -51.9%]. Those in working households in general spent a lower proportion of income (26.0% [17.7% – 44.2%]) than those not in work (27.8% [21.3% - 57.5%]; $P = 0.054$) and this was directly linked with relative income (£213.93 vs £117.09). It was notable that nearly a third of food insecure households had to spend more than half of their household income on food.

The severely restricted household spending power had clear impacts on food access and coping behaviours. Prior to the loss of the uplift, a third of participants reported accessing food banks (Table 4.2), however removal of the £20 week^{-1} increased food bank use by 72% (Table 4.2; $P < 0.001$). Employment status was a significant factor in determining requirement after the removal of the uplift, with those not in full time employment having a significantly higher odds of accessing Foodbank than those with an income from work (P = 0.048). Having children did not increase the odds for Foodbank support after the removal of the uplift when compared to two adult household without children (Table 4.3).

4.5.3 Increasing odds of food insecurity by socio-demographic variables.

Table 4.4 presents the result from binary ordered logic regression. After adjusting for household income, participants not in employment had a significantly higher odds of food insecurity compared to participants in employment with a claim for UC. One and two adult household(s) with three or more children had significantly higher odds of severe food insecurity after adjusting for household income compared to one adult households with one child. Universal Credit claimants who did not identify as White had a significantly lower odds of experiencing food insecurity compared to UC claimants who identified as White. Lower educational attainment was associated with increased odds of severe food insecurity amongst Universal Credit claimants with those achieving either GCSE and A Levels having significantly higher odds or severe food insecurity compared to those who had achieved a first degree or equivalent.

4.5.4 Coping strategies.

Across all participants, 45% said that they had lost weight because there was not enough money for food. This was principally driven by reducing meal sizes, the number of meals and resorting to fasting for full days. Amongst those who had said they lost weight 98% (n = 155) said they ate less because there was not money for food, and 67.1% (n = 106) said they had not eaten for an entire day because there was not the enough money for food.

Meal skipping or reducing meal size because of a lack of money was commonplace (77%) among food insecure participants (Table 4.13) and over 60% reported reducing the number of meals in the previous seven days. More severe coping strategies including not eating for entire days was employed by 40% of participants, of whom more than half did so more than once per week. Where households with children experienced very low food security (n = 113) almost all (90.3%) reported, limiting portion size at mealtimes, reducing food variation in meals (85.8%), and restricting consumption by adults for small children to eat (81.4%). The proportion reducing the number of meals eaten in a day was similarly high (77.9%) and over half (57.5%) of respondents skipped entire days without eating.

4.5.5 Diet quality is heavily impacted by financial deprivation.

Assessment of diet quality highlighted that the coping strategies adopted by many resulted in significant limitations in the dietary diversity of people dependent on UC. The diet quality index reflects the frequency of consumption of desirable foods (e.g., fruit and vegetables), undesirable foods (e.g., saturated fat, cholesterol) the breadth of foods consumed, achievement of RNI for specific important nutrients (e.g., iron) and the overall balance of macronutrients and fatty acids. Scores range from 0 to 100. In order to understand the significance of the dietary data obtained, we compared intakes with those of NDNS (years 9-11) participants stratified into tertiles by equivalised household income (EQV1, EQV2 and EQV3). Overall DQI-I scores were 8.06% lower amongst females in the BEANs group (45.9 ± 1.40) compared to EQV1 (P = 0.023), 14.60% lower compared to EQV2 (P <0.001) and 21.57% lower compared to EQV3 (P<0.001; Table 4.3) which was principally due to limited variety(35.77% less than EQV1, 47.26% less than EQV2 and 61.51 less than EQV 3; P <0.001) and adequacy (13.04% less than EQV2 and 23.15% less than EQV3; P <0.001; Table 4.5).

BEANs participants' diets included the fewest food groups compared to NDNS tertiles, with only 48.9% consuming 2 or more different sources of protein, whilst for those in EQV1 and EQV2, approximately 60% had 2 or more different sources and this increased to 68.7% of individuals in EQV3 (P = 0.001; Table 4.5). The main food groups contributing to protein intake amongst BEANs participants were cereal and cereal products (42.4% [30.2 – 58.9%]) of which white bread/rolls accounted for 15.6% [9.1 -29.8%]. Whilst meat and meat products provided 18.4% [5.0% – 27.9%] and milk and milk products provided 9.8% [5.0 -14.5%], with semi skimmed milk (2.7% [0.0 – 6.8%]) and other cheese (0.9% [0.0 – 5.2%]) being the top two sources. Whilst meat and meat products were the main contributor to protein intakes of females in EQV 1, 35.6% [22.0% - 47.7%], EQV 2, 35.6% [23.9 – 43.4%] and EQV 3, 32.0% [16.8% – 40.8%], followed by cereal and cereal products (EQV 1, 21.4% [15.7% - 29.3%], EQV 2 21.1% [15.1 – 27.0%] EQV 3 19.4% [13.7% - 26.7%] of which Pasta, Rice and other cereals was the top contributor, followed by white bread.

Over a third (34.9%) of BEANs participants did not record a single serving of vegetables (1.0% of EQV1 and 0% for EQV2 or EQV3 with zero consumption). Around 60% of the NDNS cohort recorded consuming 2 or more servings of vegetables. This was only achieved by 11.6% of BEANS participants who additionally consumed few if any fruit (71.8% consumed 1 or none; Table 4.6).

Conversely, BEANS participants were significantly higher consumers of grain containing foods compared with all NDNS tertiles ($P<0.001$), however this was solely due to high consumption of white bread (133.81g [62.8 – 228.0]). Bread consumption amongst BEANS participants (175g day^{-1} [101 - 239]) was around 3 times higher than all NDNS income tertiles (EQV1 - 63 day^{-1} [30 - 94]; EQV2 - 59g day^{-1} [35 - 87]; EQV3 - 53g day^{-1} [28 - 81]; $P<0.001$ for all). Consumption of breakfast cereals did not differ between groups.

When asked about the impact of the £20 a week uprating on food purchases, most (58.7%) felt that this had enabled an increase in fruit and vegetable consumption, but that this had been greatly reduced with its loss (66.5% of participants). The majority also felt that the loss of the uplift had negatively impacted their ability to purchase meat (64.7% of participants), fish and seafood (52.6% of participants) and dairy products (41.9% of participants. (Figure 4.1).

4.5.6 Nutrient intake is heavily compromised in those receiving UC.

4.5.6.1 Macronutrients.

Intake of almost all macronutrients was numerically lower than for any of the NDNS cohorts and, contrary to expectations, this was true even those more commonly increased in low-income groups including total sugars, total fat and saturated fat (Table 4.7). Energy, protein and fat intakes were significantly reduced compared with EQV3 ($P<0.05$) and this was similarly the case for energy ($P=0.023$) and protein compared with EQV2 ($P<0.001$), while for fat there was a trend, but this did not quite reach significance ($P=0.06$). Those in the lowest income quintile (EQV1) had higher intakes of energy (7%), protein (6%) and fat (10%), but again, these were not significant ($P=0.123$, $P=0.135$ and $P=0.169$ respectively). Saturated fat intake, however, was considerably lower than for all income tertiles ($P<0.001$; Range 42%-54%). In addition, we noted that the restricted fruit and vegetable intakes indicated by participants in the survey was clearly reflected in AOAC fibre intakes which were reduced by 18%, 32% and 50% compared with all NDNS tertiles EQV1, EQV2 and EQV3 respectively ($P<0.01$; Table 4.7).

Recording of very low ("non-plausible") energy intakes was frequent among BEANS participants (46%) and considerably more so than for NDNS respondents in all income tertiles, but this was only significant for comparisons with EQV2 (21%; $P=0.024$) and EQV3 (22%; $P=0.002$). While the number of EQV1 participants underreporting was fewer (31%), the difference did not reach significance ($P=0.107$) as see for other parameters. (Table 4.9). BEANs participants obtained 45.4% of energy from cereal and cereal products with "white bread/rolls" providing 14.4% [9.1% – 28.4%]

consumed by 95.3%. Meat and meat products contributed 10.8% of energy with 76.7% of individuals indicating they included meat and meat products in their diet, the main contributor was chicken and turkey dishes providing 2.3% of energy which was consumed by 32.6%. Whilst meat-based pasta dishes provided 2.2% of energy, this was eaten by 20.9% of individuals. Burgers and kebabs were eaten by 25.6% of individuals and contributed 2.0% of energy from meat and meat products. Milk and milk products accounted for 7.2% of energy, with 95.3% including this food group. The main contributors to energy from milk and milk products were semi skimmed milk (2.4%) consumed by 67.4% of individuals and cheese (2.1%) consumed by 53.5%. Vegetable and vegetable products provided 6.5% of energy with 86.0% including this food group in the diet. The main contributors were jacket potatoes 1.5% eaten by 30.2% of individuals, fried chips (1.2%), consumed by 27.9% and other potatoes (1.1%) included by 30.2%.

4.5.6.2 Micronutrients.

Micronutrient intakes reflected the pattern seen for macronutrients with the majority being consumed in lower quantities than by NDNS participants (Table 4.8). Compared with EQV3, intakes of all except calcium were significantly reduced in BEANS participants ($P<0.01$ for all except potassium – $P=0.04$). Comparison with EQV2 showed significant reductions in intake of vitamins A, B6, C and B12, as well as thiamine, niacin, folate, potassium, magnesium, copper, zinc, iodine, selenium and iron ranging from 10% to 40% (Table 4.8). The EQV1 group showed more similarity with BEANS participants for most micronutrients, although in all but one case, intakes were higher and for vitamin A, selenium and iron, this was significantly so. It was noteworthy that comparisons within NDNS cohorts showed intakes for EQV1 to be consistently lower than those of the higher income brackets ($P < 0.001$).

The proportional attainment of RNI was consequently lower for BEANS participants when compared with the NDNS groups and the majority of these differences were significant. Similarly, the proportion of BEANS respondents consuming less than the lower reference nutrient intake (LRNI; enough for the lowest 5% of the population) was higher than NDNS participants. We noted that, whilst the level of intake of many BEANS participants approached or exceeded the RNI for riboflavin, the proportion below the LRNI was more than twice that of any other group ($P = 0.021$ – $P<0.001$; Table 4.9). Also, a much lower proportion of BEANS respondents met the RNI for vitamin A than did EQV1 (46.5%; $P = 0.006$), EQV2 (56.5%; $P < 0.001$) and EQV3 (67.1%; $P<0.001$; Table 4.9).

The source of riboflavin in the diet amongst females in BEANs was mainly from cereal products (39.7%, 0.5 µg d^{-1} 0.2 µg d^{-1} – 0.7 µg d^{-1}]) with white bread/rolls being the main source (14.0%). Milk products contributed 17.5% and non-alcoholic beverages 6.8 %.

Around a third of the vitamin A in the diet amongst BEANs participants was from cereal products (33.4%), with white bread/rolls contributing 21.7%, milk products providing 10.6% whilst vegetable products provided 5.3%.

We saw similar patterns for intake of several important minerals. As a result of low intakes, BEANS participants fell more frequently below the LRNI and had far fewer achieving the RNI for most minerals when compared with NDNS cohorts. Only half of the BEANS participants managed to consume ~50% or more of the RNI for iron (in the under 50s; RNI 14.8 mg d^{-1}) and selenium, a proportion which was significantly lower than for all NDNS groups. Additionally, the proportion of participants below the LRNI for iodine and zinc were 1.9 to 6.8 times higher than for all NDNS groups (P<0.001 to P = 0.023). The proportion of BEANs participants aged 50 years and over with iron intakes below the LRNI was numerically greater than EQV 1 (42.9& v 18.2%) but did not reach significance P=0.140).

Cereal products, in particular bread, were significant contributors to the intakes of several minerals among BEANS participants. They provided 45.6% of zinc (3.0 mg d^{-1} [2.0 mg d^{-1}- 4.5 mg d^{-1}]) of which white bread/rolls provided 19.7%. (1.0 mg d^{-1} [0.6 mg d^{-1}- 2.2 mg d^{-1}]), 57.3% of iron (4.3 mg d^{-1} [2.8 -6.3 mg d^{-1}] - bread contributing 22.3%), and 57.8% of dietary selenium (18.0 µg d^{-1} [9.7 µg d^{-1} – 28.3 µg d^{-1}]) more than a third of which was from bread (7.0 µg d^{-1} [2.7 µg d^{-1} – 17.2 µg d^{-1}]). Meat products were important for zinc (16.5% of which burgers and kebabs were the highest contributor) and selenium intakes (15%), but less so for iron where it accounted for just 7.4% (0.5 mg d^{-1} [0.1 mg d^{-1} -1.6 mg d^{-1}). Milk was a good source of zinc in the diet of BEANs participants supplying 11.5% (0.7 mg d-^{1} [0.4 mg d-^{1}- 1.0 mg d-^{1}] with semi-skimmed milk and cheeses such as cheddar/edam contributing 3.8%.

Median iodine intake from food sources amongst BEANs participants (105 µg d^{-1} [62.9 µg d^{-1} – 154.4 µg d^{-1}] was lower compared to the EQV 2 (P = 0.026, and EQV 3 P = <0.001). Milk was a good source of iodine amongst

BEANs participants, contributing 29.8%, but this was lower than NDNS tertiles where milk and milk products contributed 1.2 - 1.3 times as much iodine compared to BEANs (EQV 1, 36.9% [20.8% -53.7%], EQV 2, 37.5% [22.5% -51.9%] and EQV 3, 38.1% [23.6% - 54.8%]). Cereal and cereal products contributed 26.2% amongst BEANs participants of which white bread rolls provided 12.3%. Cereal products contributed 3.6 – 6.6 times as much Iodine compared to the NDNS tertiles where iodine from cereal and cereal products decreased as the EQV increased (EQV 1, 7.4% [3.3 %-13.5%], EQV 2, 6.5% [3.4 -11.7%] and EQV 3, 5.5% [2.3% - 10.3%].

4.6 Discussion.

The link between diet, socioeconomic status and health outcomes is well established with individuals receiving low incomes having less healthy diets and living more years with ill health compared to those with higher incomes (Everest et al., 2022) (Darmon and Drewnowski, 2015) (Darmon and Drewnowski, 2008). Here we show that people in receipt of universal credit are required to spend such a high proportion of their income on food that they must adopt severe coping strategies, such as meal reduction and even whole day fasting, in order to provide food for household members, particularly children. What they are able to provide is inadequate to support their own nutritional requirements as they are reliant on cheap, nutrient poor foods with minimal dietary variation.

We additionally found a significant dependence on the £20 week^{-1} uplift in Universal Credit (UC). Its loss resulted in an almost doubling of reliance on food banks. Previous reports have suggested that the introduction of the £20 week^{-1} uprating to UC coincided with a reduction in the prevalence of poverty (Francis-Devine, 2022) and had provided protection from food insecurity (The Food Foundation, 2022b). This may be in part due to the uprating effectively representing a temporary reversal of the pre-imposed cuts to low-income households (ESRC, 2021).

The experience of food insecurity in the UK has risen since the 2008 financial crisis (Bell et al., 2021) continues to increase since the COVID-19 pandemic (Everest et al., 2022) (Bell et al., 2021). The UK average household food spend in 2019/2020 was 10.8% of income with those in the lowest 20% spending 14.7% (DEFRA, 2022a). We found participants in the BEANs study spent above the national average and above that of the lowest 20% on average spending 27% of income on food. A previous study found when the proportion of income spent on food exceeded 13%, households were 1.6 times more likely to experience food insecurity (Thomas et al., 2022). The greater percentage of income spent on food suggests incomes are too low and food costs are placing a greater burden on households with an income from UC compared to the general population. In this study we investigated participant's perception of the £20 a week uprating to UC and its subsequent removal on their food group intake. Most thought it had increased their fruit and vegetable intake and maintained their intake of other food groups. Many also felt that the removal of the uprating had resulted in a decrease in fruit and vegetable intake, meat, fish and seafood. Fruit and vegetables are typically consumed in lower quantities amongst lower income groups (French et al., 2019), suggesting that the uprating to UC afforded the ability to participate in healthier dietary practices.

We also wanted to understand how the removal of the uprating influenced include foodbank usage. The Trussel Trust has reported an increase in the number of people accessing their services since the removal of the uprating to UC, however, figures are a comparison to the previous year (Radford, 2022) and we suggest the figures are not solely based on UC Claimants. However, the results from this study align with Trussel Trust findings in that the removal of the uprating to UC was a driver of Foodbank usage, in our study, an additional 21% of the population accessed a foodbank after the removal of the uprating, an increase of 72%.

Our study found that the majority of individuals receiving UC were experiencing food insecurity, with 63.9% having a “very low food security” status (Table 4.12). Our results are higher than the those from the Family Resource Survey released in March 2021 for the financial year 2019-2020 which indicated 27% of people with an income from Universal Credit were food insecure and of these, 15% had “very low food security” (DWP, 2022), our results are also above the estimated national average of 20% of adults in England, Wales and Northern Ireland experiencing food insecurity since the COVID-19 lockdown (Loopstra, 2020). It is suggested the study design may be a factor in the higher prevalence of food insecurity recorded as a convenience sampling was used to recruit participants as such it may not be fully representative of those with an income from universal credit. Results from the low-income diet and nutrition survey (LIDNS) in 2007 found 29% of respondents lived in a food insecure household at that time but were generally protected from the experience of a lack of food and hunger (Nelson et al., 2007c).

A “very low food security” status is indicative of the experience of hunger. Coping strategies utilised by food insecure (Table 4.14) with 82% not able to afford balanced meals and 28% not eating for a whole day. These figures represent a considerable increase from the LIDNS where 36% said they could not afford to eat balanced meal and 5% were unable to eat for a whole day (Nelson et al., 2007c). The impact of such levels of food deprivation were apparent from the numbers of people recorded as underweight (6.3%; Table 4.1). All were from the food insecure group. Furthermore, the prevalence of underweight was more than 3 times greater than the national UK average (1.8%) (Baker, 2022).

When completing the dietary analysis of females aged 23-61 years, it was evident most were reliant on white bread/rolls as a source of energy and nutrients. This aligns with a previous study which found those who were food insecure consumed bread rolls in a greater quantity compared to food secure (Armstrong et al., 2021). Bread in the UK has been a staple food for many years and a major contributor to energy and nutrient intakes but even as early as 1981 it was noted bread consumption was declining (Great Britain, 1981) and continues to decline (Lockyer and Spiro, 2020). Despite this, BEANs participants obtained a greater percentage of their energy (14.4%) from white bread than seen in previous work which found that adults aged 19-64 years obtained on average 7% of energy from white bread (Lockyer and Spiro, 2020).

The bread and flour regulations 1998 stipulate the essential ingredients of wheat flour in the UK amongst other ingredients are calcium carbonate (not less than 235 mg $100g^{-1}$ not more than 390 mg $100g^{-1}$) iron (not less than

1.65 mg 100g $^{-1}$), Thiamine (not less than 0.24 mg 100g $^{-1}$) and nicotinic acid (not less than 1.60 mg 100g $^{-1}$)(GOV, 1998). White bread was consumed in greater quantity in lower income households in the UK households over 40 years ago (Great Britain, 1981) and is still a major component of the diet today for low-income groups. Whilst thiamine and calcium intakes were close to, or exceeded the RNI, iron intakes were low compared to the RNI and a high percentage were below the LRNI, indicating a need for other food sources of iron in the diet other than bread. It is possible that the UC receiving respondents in this study are having to resort to bread as a means of feeling sufficiently full. The consumption of larger quantities of bread places people at potential risk of sugar spikes as white bread has a high glycaemic index. Reliance on bread increases the glycaemic burden of their diets and exposes people to a range of damaging outcomes.

There was a gradient in the diet quality and micronutrient intakes of females aged 23-61 years with those in the BEANs study having fewer food groups in the diet, less variety in protein sources and a lower number of servings of desirable food groups such as fruit and vegetables, compared to females across the NDNS tertiles. This is suggested to be factor for the greater percentage of BEANs participants with vitamin intakes below the LRNI for Riboflavin and vitamin A and meeting a lower percentage of the RNI for minerals (iron, selenium, iodine, zinc, potassium) with the difference between BEANs and the tertiles increasing as income increased (Table4.7).

Assessing overall diet quality (DQ) provides an insight into how well dietary guidelines are being met and is a favourable method when considering dietary risk factors and health outcomes, compared with assessing singular nutrients, as overall diet has a greater effect on health outcomes (Petersen and Kris-Etherton, 2021) (Miller et al., 2022). Previous studies have investigated the experience of food insecurity on DQ and micronutrient intakes, however, they are focused on US populations (Hanson and Connor, 2014) (Leung and Tester, 2019), whilst UK (and US) based studies, have mostly explored the relationship between food insecurity and obesity (Yang et al., 2018) (Shinwell et al., 2022) (Pilgrim et al., 2012) (Carvajal-Aldaz et al., 2022) (Brown et al., 2019) or solely macronutrient composition(Shinwell et al., 2022).

The Diet Quality Index International (DQI-I) was chosen for this study as it included micronutrient intakes and separated out aspects of the diet which, when consumed in excess, or in deficit, can have a negative influence on overall DQ. Furthermore, for this study, although interested in dietary risk factors and health outcomes, the objective was to compare different population groups DQ and not the association of DQ with adverse health outcomes which is the primary focus of other indices developed for assessment of diet quality (Wirt and Collins, 2009).

The requirement for vitamins and minerals varies from person to person depending on age, sex, lifestyle, physiological state, and health status (DoH, 1991). Dietary Reference Values (DRV) for energy and nutrients were developed to assess the adequacy of different population group's diet and not at the individual level (DoH, 1991) and as such, the RNI for vitamin and minerals are set at a level which would be adequate for 97.5% of the population, that is many will require a lower amount, and a few will require more. At the opposite end is the LRNI which will meet the requirement for 2.5% of the population. When intakes are below the LRNI deficiency is likely to occur (Derbyshire, 2018) and if greater than 3% of the population are below the LRNI then deficiency in population groups is more likely (Nelson et al., 2007c) with normal health unlikely to be maintained over long periods (Mensink et al., 2013) this we suggest creates a public health problem and interventions for addressing sub-optimal micronutrient intakes are required.

Females aged 23-61 years in the BEANs study had a greater proportion of the population with intakes below the LRNI for riboflavin compared with NDNS tertiles within which percentage below the LRNI, decreased as income increased (Table 4.7). Food sources of riboflavin include milk, eggs, fortified breakfast cereal, mushrooms, and plain yogurt ("Vitamins and minerals - B vitamins and folic acid," 2017), the main source of riboflavin in the diet of BEANs participants was cereal and cereal products (white bread/rolls being the main source in this food group), followed by milk and milk products. The percentage of females below the LRNI in our study was double that compared to previous studies which found 12% of adult female's intakes were below the LRNI ((Mensink et al., 2013) (Derbyshire, 2018), whilst the LIDNS reported this value to be 15% (Nelson et al., 2007c).

Many of the participants in the study experienced food insecurity and although energy and nutrient intakes were not assessed by food security status due to the small sample size, it is suggested riboflavin intake is negatively influenced by the experience of food insecurity as seen in a previous UK based study which showed riboflavin intake in food insecure participants to be 36% less compared with food secure (Thomas et al., 2022).

Part of the B group of vitamins, riboflavin is water soluble and 95% bioavailable (EFSA et al., 2017) found in the diet as free riboflavin and as flavin adenine dinucleotide (FAD) and flavin mononucleotide (FMN). FAD and FMN are cofactors involved in energy metabolism and the metabolism of niacin and vitamin B6(EFSA et al., 2017). Deficiency of riboflavin has been implicated in the development of anaemia due to reduced capacity of riboflavin enzymes in releasing iron from ferritin stores (Powers et al., 2011) Therefore, females with low intakes of riboflavin and/or iron may be a risk of the development of anaemia.

Vitamin A intakes were low compared to the RNI (69.2%) amongst females in the BEANs study compared to the NDNS tertiles, this aligns with a previous study which found women living in households in the UK and in receipt of benefits had a lower daily vitamin A intake (Anderson, 2007), whilst the LIDNS Survey reported 10% of adult female's vitamin A intakes were below the LRNI, lower compared to our study where 11.6% were below the LRNI.

Vitamin A is obtained in the diet from animal sources such as cheese, eggs, dairy products, oily fish, and liver as preformed vitamin A (predominantly retinal and retinyl esters) and as pro-vitamin A carotenoids in plant-based foods such as carrots, spinach, mango, and apricots. The main source of vitamin A amongst females in the BEANs study was cereal and cereal products. A food group not usually thought of as a good source of vitamin

A, thus highlighting the need for interventions which enable diversification of the diet of population groups with an income from UC. Vitamin A is important for immune function (EFSA, 2015a) and deficiency of vitamin A can lead to vitamin A deficiency anaemia by the worsening of a low iron status (EFSA, 2015a).

The requirement for iron, its roll and function in the human body and the consequences of deficiency are well documented as are the low intakes amongst females in the UK. However, our study found women with an income from UC had lower iron intakes compared with females across the income tertiles. Sub-optimal iron intakes and deficiency can impair immunity and alter mood (EFSA, 2015b) and for women entering the reproductive years with depleted iron stores can have adverse implications for both mother and child pre and postpartum. Evidence suggests memory and spatial awareness of adolescent girls who were anaemic as toddlers is altered and infants and children who are iron deficient have delayed attention and poor social skills (EFSA, 2015b).

4.7 Limitations.

This study took place at a time when the UK was experiencing the impacts of the COVID-19 pandemic on people’s everyday lives and the UK started to see the first signs of the cost-of-living crisis in which the cost of fuel and food increased. This may be a factor in the greater proportion of participants experiencing food insecurity compared to earlier studies. Additionally, the study design may be a factor in the greater percentage of respondent experiencing food insecurity compared to other survey data. This study utilised a convenience sampling approach, as such may not be representative of the population with an income from Universal credit. It is possible the study recruited participants with an interest in this subject area. This study combined existing measure and novel questions to gather data, however the study was completed online and was not piloted prior therefore we are unable to go back and ask participants for missing information. In addition, while response to the survey was robust, the number who subsequently provided full dietary data was limited. The data presented here provide an indication of the severity of the impact of life on UC, but a larger scale study is necessary to obtain a clearer picture and assess the consequences for health.

4.8 Conclusion.

In conclusion, our study provides in depth analysis of the diet quality, food group, micronutrient intakes and food security status of females with an income from UC. We found females had a lower diet quality and less diverse diet compared to the general population. Furthermore, the uprating to increase their fruit and vegetable intake whilst the removal decreased fruit and vegetable intake and increased the need to access a Foodbank. Energy and nutrients from food sources showed a reliance of cereal and cereal products with white bread/rolls being a major source of energy, macro, and micronutrients within the diet. Reliance on a few foods is an indicator of food insecurity and the restrictiveness of the diet of females with and income from UC may predispose them to the sub optimal intakes of micronutrients which may be further compounded due to the bioavailability of nutrients for example iron and zinc being better absorb from animal-based sources as opposed to plant based and fortified foods. The situation of UC claimant's ability to procure food could be facilitating growing inequalities in diet and health amongst UK female’s and future generations. Policies are required which reduce the burden of food cost and promote diversification of the diet amongst low-income groups in the UK.

Table 4-1. Participant's characteristics and comparison between food security statuses amongst BEANs participants.

Variables	Total		Food security status				
			Food-secure		Food- insecure		P value
	n	(%)	n	(%)	n	(%)	
			37	(10.6)	312	(89.4)	
Gender							
Male	90	(25.8)	11	(29.7	79	(25.3)	0.719
Female	256	(73.4)	26	(70.3)	230	(73.7)	
Other	3	(0.9)	0	(0.0)	3	(1.0)	
Age groups years							
16-25	25	(7.2)	2	(5.4)	23	(7.4)	0.748
26-35	84	(24.1)	12	(32.4)	72	(23.1)	
36-45	125	(35.9)	12	(32.4)	113	(36.2)	
46-55	69	(19.8)	6	(16.2)	63	(20.2)	
56-65	45	(12.9)	4	(10.8)	41	(13.1)	
Educational level							
>level 6 (Postgraduate)	21	(7.4)	3	(8.1)	18	(5.8)	0.391
Level 4 - level 6 (First year degree up to degree level)	101	(35.6)	16	(43.2)	84	(26.9)	
Up to level 3 (A Levels, level 3 NVQ BTEC, Advanced GNVQ)	67	(23.6)	6	(16.2)	60	(19.2)	
Up to level 2 (GCSE A*- C)	64	(22.5)	6	(16.2)	58	(18.6)	
Up level 1 (GCSE (D-F)	14	(4.9)	0	(0.0)	14	(4.5)	
Other	17	(6.0)	1	(2.7)	16	(5.1)	
Ethnicity							
White	326	(92.9)	31	(83.8)	293	(93.9)	0.126
Mixed or multiple ethic groups	10	(2.8)	2	(5.4)	8	(2.6)	
Asian or Asian British	7	(2.0)	2	(5.4)	5	(1.6)	
Black, African, Caribbean, or Black British	6	(1.7)	1	(2.7)	5	(1.6)	
Other ethnic group	2	(0.6)	1	(2.7)	1	(0.3)	
Marital status							
Married/Living with partner	99	(28.2)	11	(29.7)	87	(27.9)	0.204
Single	163	(46.4)	21	(56.8)	142	(45.5)	
Divorced/ separated from partner/widowed	89	(25.4)	5	(13.5)	83	(26.6)	
Number of children financial dependent							
None	175	(49.9)	11	(29.7)	164	(52.6)	0.012
1 to 2 children	133	(37.9)	22	(59.5)	109	(34.9)	
3 or more children	43	(12.3)	4	(10.8)	39	(12.5)	
Free school meals							
yes	113	(70)	15	(71.4)	96	(69.6)	0.862
No	48	(30)	6	(28.6)	42	(30.4)	
Equivalised household income							
<£100 per week	134	(38.2)	5	(13.5)	128	(41.0)	<0.001
£100-£200pw	76	(21.7)	4	(10.8)	71	(22.8)	
£200-£300pw	63	(17.9)	10	(27.0)	53	(17.0)	
£300-£400pw	42	(12.0)	8	(21.6)	34	(10.9)	
£400-£500pw	16	(4.6)	5	(13.5)	11	(3.5)	
>£500pw	20	(5.7)	5	(13.5)	15	(4.8)	
Equivalised food spend							
£0-£30pw	100	(28.5)	4	(10.8)	96	(30.8)	0.046
£30-£60pw	95	(27.1)	12	(32.4)	82	(26.3)	
£60-£90pw	99	(28.2)	11	(29.7)	87	(27.9)	
>£90pw	57	(16.2)	10	(27.0)	47	(15.1)	
Equivalised food spend percent of income (%)							
0-10%	27	(7.7)	4	(10.8)	23	(7.4)	0.012
10-20%	62	(17.7)	12	(32.4)	50	(16.0)	
20-30%	104	(29.6)	6	(16.2)	98	(31.4)	
30-40%	40	(11.4)	8	(21.6)	32	(10.3)	
40-50%	23	(6.6)	2	(5.4)	20	(6.4)	

>50%	95	(27.1)	5	(13.5)	89	(28.5)	
Employment status							
Going to school, college, or university full-time	4	(1.1)	3	(8.1)	1	(0.3)	<0.001
Going to school, college or university and working	5	(1.4)	0	(0.0)	5	(1.6)	
In full or part-time employment	94	(26.8)	18	(48.6)	75	(24.0)	
Not working at the moment	200	(57.0)	14	(37.8)	185	(59.3)	
Health (perceived)							
Very good	11	(3.2)	5	(13.5)	6	(1.9)	<0.001
Good	88	(25.2)	13	(35.1)	74	(23.9)	
Fair	131	(37.5)	12	(32.4)	119	(38.4)	
Bad	102	(29.2)	4	(10.8)	98	(31.6)	
Very Bad	17	(4.9)	3	(8.1)	13	(4.2)	
BMI							
Underweight range (<18.5)	20	(6.3)	0	(0)	20	(7.1)	0.431
Healthy weight range (>18.5 - <25)	81	(25.5)	9	(25.7)	72	(25.5)	
Overweight range (>25 - <30)	79	(24.8)	9	(25.7)	70	(24.8)	
Obesity range (>30)	138	(43.4)	17	(48.6)	120	(42.6)	

Table 4-2. Comparison of frequency and access of foodbank amongst BEANs participants at different time points during the study.

	Total	
Categories	**n**	**(%)**
Not accessed the food bank before or after	140	(44.3)
Accessed foodbank before and after.	93	(29.4)
Accessed after food bank after but not before.	67	(21.2)
Accessed foodbank before but not after.	16	(5.1)
Total	**316**	**(100)**

Table 4-3. Odds of accessing a Foodbank after the removal of the £20 a week uprating by household type.

	Total				
Household type	**n**	**OR**	**CI Lower Limit**	**CI Upper Limit**	**P value**
Solo adult HH 1 child	54	0.98	0.38	2.55	0.970
Solo adult HH 2 children	27	0.73	0.25	2.18	0.572
Solo adult HH >= 3 child	24	0.39	0.12	1.25	0.114
2 adult HH 1 child	26	0.58	0.19	1.75	0.330
2 adult HH 2 children	22	1.38	0.43	4.45	0.595
2 adult HH >= 3 child	18	0.30	0.08	1.11	0.071
sol adult HH no child	126	0.76	0.32	1.81	0.536
2 adult household no child	25	**REF**	**REF**	**REF**	**REF**
Total	**322**				

HH = Household

Binary logistic regression

Table 4-4 Odds of increasing severity of food insecurity amongst Universal Credit claimants by socio demographic characteristics in England, Scotland and Wales

		Food secure/marginal vs low /very low food secure		**Food secure, marginal/low vs very low food secure**	
		Model 1	**Model 1 (Income adjusted)**	**Model 2**	**Model 2 (Income adjusted)**
		OR	OR	OR	OR
Gender					
	Men	REF	REF	REF	REF
	Women	1.232 (0.582 -2.607)	1.273 (0.586-2.765)	1.101 (0.670-1.810)	1.123 (0.674-1.870)
Age					
	19-25 years	1.122 (0.191-6.603)	1.426 (0.219 -9.264)	1.714 (0.596 - 4.935)	2.030 (0.676 -6.100)
	26-35 years	0.585 (0.177-1.933)	0.706 (0.204 -2.444)	1.083 (0.516 -2.274)	1.313 (0.608 -2.834)
	36-45 years	0.919 (0.280 - 3.010)	0.922 (0.271-3.136)	1.366 (0.676 -2.761)	1.473 (0.715 -3.034)
	46-55 years	1.024 (0.272 -3.853)	1.171 (0.290 -4.730)	1.037 (0.481 -2.235)	1.101 (0.499 -2.427)
	56-65 years	REF	REF	REF	REF
Ethnicity					
	White	REF	REF	REF	REF
	Other ethnicity	0.335 (0.125 - 0.901)	0.306 (0.108 0.866)	0.415 (0.182 - 0.945)	0.386 (0.165 -0.900)
Marital status					
	Married/Cohabitating	REF	REF	REF	REF
	Single/ widowed/ divorced/ other	1.167 (0.486 - 2.798)	1.184 (0.479 - 2.928)	0.890 (0.494 -1.605)	0.883 (0.482 -1.616)
Qualifications					
	Higher degree	1.622(0.458 -5.748)	1.996 (0.498 -8.007)	2.070 (0.854 - 5.015)	2.145 (0.851 -5.409)
	First degree	REF	REF	REF	REF
	Diplomas	0.977 (0.313 -3.046)	0.857 (0.267-2.751)	1.980 (0.814 - 4.818)	1.875 (0.756 - 4.649)
	A level + GCSE	2.233 (0.828 - 6.017)	1.816 (0.657 -5.020)	**2.464 (1.243 -4.885)**	**2.172 (1.077 - 4.379)**
	Level 2 and below	2.512 (0.632 - 9.980)	2.217 (0.528 -9.316)	1.398 (0.607 - 3.220)	1.169 (0.494 -2.770)
	Other qualifications	3.349 (0.392-28.584)	2.844 (0.323-25.029)	**5.040 (1.293 - 19.646)**	**4.600 (1.151 -18.387)**
	No qualification	2.595 (0.813 -8.282)	2.027 (0.613-9.708)	2.066 (0.984 - 4.338)	1.673 (0.777 - 3.601)

Work status					
	In paid employment	REF	REF	REF	REF
	Not in paid employment	**2.747 (1.374 -5.494)**	**2.342 (1.144 -4.794)**	1.323 (0.819-2.138)	1.095 (0.663 -1.808)
Household structure					
	2 adult household no child	1.633 (0.411 -6.487)	1.856 (0.425 -8.107)	2.069 (0.801 -5.345)	2.177 (0.808 -5.868)
	sol adult HH no child	**3.265 (1.218 -8.755)**	2.06 (0.727 -5.834)	**2.092 (1.122-3.900)**	1.482 (0.768 -2.861)
	2 adult HH >= 3 child	N/A	N/A	**3.103 (0.999 -9.641)**	**5.310 (1.575 -17.906)**
	2 adult HH 2 children	0.694 (0.208 -2.32)	0.992 (0.275 -3.581)	1.494 (0.554 -4.207)	2.039 (0.719 -5.784)
	2 adult HH 1 child	1.769 (0.447 -6.669)	1.738 (0.419 -7.198)	**2.716 (1.039 -7.100)**	**2.782 (1.033 -7.491)**
	solo adult HH >= 3 child	1.122 (0.317 -3.973)	1.344 (0.347 -5.203)	**2.808 (1.207 -7.676)**	**3.324 (1.157 -9.549)**
	solo adult HH 2 children	1.327 (0.379 -4.645)	1.362 (0.374 -4.956	1.353 (0.559 -3.275)	1.417 (0.569 -3.526)
	solo adult HH 1 child	REF	REF	REF	REF
Region					
	Yorkshire and the Humber	2.000 (0.707 -10.52)	5.477 (0.496 -13.042)	1.603 (0.366-3.932)	1.844 (0.462 -7.365)
	West Midlands	2.719 (0.409 -9.785)	4.082 (0.704 -23.663)	1.458 (0.41 -6.262)	1.792 (0.437 -7.346)
	South East	1.969 (0.502 -14.723)	3.326 (3.326 -19.682)	1.250 (0.299 -5.23)	1.703(0.394 -7.369)
	North West	N/A	N/A	1.667(0.398 -6.974)	2.068 (0.48 -8.919)
	North East	3.562(0.358 -10.821)	3.916 (0.531-28.892)	1.667 (0.374 -7.424)	1.786 (0.395 -8.089)
	London	N/A	n/A	0.833 (0.179 -3.884)	0.782 (0.164 -3.729)
	East of England	6.75 (0.605 -75.27)	**14.92 (1.141 -195.003)**	1.806 (0.391 -8.348)	2.643(0.546 -12.793)
	East midlands	2.893 (0.686 -12.197)	4.243 (0.943 -19.088)	1.477 (0.426 -5.12)	1.744 (0.493 -6.175)
	South West	REF	REF	REF	REF

Rows highlighted in bold are significant at the p<0.05 level.

Statistical test Binary logistic regression

Table 4-5. Comparison of Diet Quality Index-International (DQI-I) and percentage within subcategories for females aged 23-61 years with an income from Universal Credit (BEANs) and per the criteria for equivalised income tertiles in the National Diet and Nutrition Survey (years 9-11).

Component	Score	Scoring Criteria	BEANs (n =43)		Lowest EQV1 (n = 202)			Middle EQV 2 (n = 202)			Highest EQV 3 (n = 249)		
			Mean	S.E.M	Mean	S.E.M	p value	Mean	S.E.M	p value	Mean	S.E.M	p value
Overall DQI (Diet Quality Index) Score ₸	0-100 points		49.3	1.37	51.6[a]	0.71	0.164	54.4[b]	0.66	0.001	57.1[c]	0.54	<0.001
Variety	**0-20 points**		**Beans n**	**%**	**EQV1 n**	**%**	**p value**	**EQV2 n**	**%**	**p value**	**EQV3 n**	**%**	**p value**
Overall food group variety (meat/poultry/fish/eggs; dairy/beans; grain; fruit; vegetable) ¥	0-15 points	≥1serving from each food groups =15	2	4.7	26	12.9	<0.273	45	22.3	0.003	81	32.5	<0.001
		Any 1 food missing/d=12	14	32.6	77	38.1		80	39.6		99	39.8	
		Any 2 food groups missing/d = 9	18	41.9	68	33.7		56	27.7		51	20.5	
		Any 3 food groups missing = 6	5	11.6	23	11.4		18	8.9		13	5.2	
		≥ 4 food groups missing/d = 3	4	9.3	8.	4.0		3	1.5		5.	2.0	
		None from any food groups = 0	2	4.7	26	12.9		45	22.3		81	32.5	
Within-group variety for protein source (meat, poultry, fish, dairy, beans, eggs) ¥	0-5 points	≥ 3 different sources/d = 5	12	27.9	60	29.7	0.02	61	30.2	0.001	67	26.9	<0.069
		2 different sources/d = 3	15	34.9	86	42.6		94	46.5		123	49.4	
		From 1 source/d = 1	13	30.2	55	27.2		47	23.3		55	22.1	
		None = 0	3	7.0	1	0.5		0	0.0		4	1.6	
Adequacy	**0-40 points**												
Vegetable group[1¥]	0-5 points	≥ 3-5 servings/d=5, 0 servings =0											
		≥ 100% = 5	1	2.3	20	9.9	<0.001	30	14.9	<0.001	62	24.9	<0.001
		<100-50%= 3	7	16.3	62	30.7		87	43.1		108	43.4	
		<50% = 1	28	65.1	113	55.9		83	41.1		78	31.3	
		0 = 0	7	16.3	7	3.5		2	1		1	0.4	
Fruit group [1¥]	0-5 points	≥ 2-4 servings/d=5, 0 servings =0											
		≥ 100% = 5	3	7	32	15.8	0.479	39	19.3	<0.013	74	29.7	<0.001
		<100-50%= 3	6	14	28	13.9		33	16.3		60	24.1	
		<50% = 1	17	39.5	76	37.6		93	46		96	38.6	
		0 = 0	17	39.5	66	32.7		37	18.3		19	7.6	

Grain Group[1¥]	0-5 points	≥ 6-11 servings/d = 5, 0 servings/d = 0											
		≥ 100% = 5	4	9.3			<0.001	3	1.5	<0.001	2	0.8	<0.001
		<100-50%= 3	16	37.2	47	23.3		38	18.8		40	16.1	
		<50% = 1	23	53.5	152	75.2		159	78.7		203	81.5	
		0 = 0	0	0	3	1.5		2	1		4	1.6	
Fibre[1¥]	0-5 points	≥20-39g/d =5, 0, /d=0											
		≥ 100% = 5	8	18.6	43	21.3	0.271	56	27.7	0.04	112	45.0	<0.001
		<100-50%= 3	24	55.8	128	63.4		123	60.9		130	52.2	
		<50% = 1	11	25.6	31	15.3		23	11.4		7	2.8	
		0 = 0	0	0	0	0		0	0		0	0	
Protein[¥]	0-5 points	≥10% of energy/d = 5, 0% of energy/d = 0											
		≥ 100% = 5	42	97.7	199	98.5	0.693	200	99.0	0.047	247	99.2	0.361
		<100-50%= 3	1	2.3	3	1.5		2	1.0		2	0.8	
		<50% = 1	0	0	0	0		0	0		0	0	
		0 = 0	0	0	0	0		0	0		0	0	
Iron[2¥]	0-5 points	100%RNI = 5, 0% of energy/d = 0											
		≥ 100% = 5	4	9.3	21	10.4	0.296	31	15.3	0.005	68	27.3	<0.001
		<100-50%= 3	21	48.8	121	59.9		133	65.8		143	57.4	
		<50% = 1	18	41.9	60	29.7		38	18.8		38	15.3	
Calcium[¥]	0-5 points	100%RNI = 5, 0% of energy/d = 0											
		≥ 100% = 5	24	55.8	86	42.6	0.144	96	47.5	0.120	150	60.2	0.006
		<100-50%= 3	14	32.6	99	49.0		95	47.0		94	37.8	
		<50% = 1	5	11.6	17	8.4		11	5.4		5	2.0	
Vitamin C[¥]	0-5 points	100%RNI = 5, 0% of energy/d = 0											
		≥ 100% = 5	22	51.2	127	62.9	0.263	158	78.2	0.001	222	89.2	<0.001
		<100-50%= 3	14	32.6	56	27.7		32	15.8		25	10.0	
		<50% = 1	7	16.3	19	9.4		12	5.9		2	0.8	
Moderation	**0-30 points**												
Total fat [¥]	0-6 points	≤ 20% of total energy/d = 6	3	7	6	3.0	0.402	4	2.0	0.195	4	1.6	0.096
		>20-30% of total energy/d = 3	11	25.6	47	23.3		50	24.8		60	24.1	
		>30% of total energy/d = 0	29	67.4	149	73.8		148	73.3		185	74.3	
Saturated fat[¥]	0-6 points	≤7% of total energy/d = 6	3	7	15	7.4	0.985	9	4.5	0.451	12	4.8	0.807
		>7 - 10% of total energy/d = 3	7	16.3	31	15.3		50	24.8		46	18.5	

		> 10 % of total energy = 0	33	76.7	156	77.2		143	70.8		191	76.7	
Cholesterol[3¥]	0-6 points	≤ 300 mg/d = 6	40	93.0	188	93.1	0.997	188	93.1	0.997	231	92.8	0.998
		>300-400 mg/d = 3	2	4.7	9	4.5		9	4.5		12	4.8	
		>400 mg/d = 0	1	2.3	5	2.5		5	2.5		6	2.4	
Sodium[¥]	0-6 points	≤2400mg/d = 6	37	86	179	88.6	0.589	172	85.1	0.495	204	81.9	0.324
		>2400 - 3400 mg/d = 3	4	9.3	19	9.4		26	12.9		40	16.1	
		>3400mg/d = 0	2	4.7	4	2.0		4	2.0		5	2.0	
Empty calorie Foods [¥]	0- 6 points	≤3% of total energy/d = 6	3	7	16	7.9	0.967	18	8.9	0.914	24	9.6	0.786
		>3-10%of total energy/d = 3	11	25.6	49	24.3		52	25.7		55	22.1	
		>10%of total energy/d = 0	29	67.4	137	67.8		132	65.3		170	68.3	
Overall, Balance	**0-10 points**												
Macronutrient ratio (Carbohydrate: protein: fat) [¥]	0 - 6 points	55~65:10~5:15~25 = 6	0	0	1	0.5	<0.643	0	0.0	0.028	0	0.0	0.006
		52~68:9~16:13~27=4	3	7	7	3.5		2	1		2	0.8	
		50~70:8~17:12~30 = 2	4	9.3	14	6.9		12	5.9		11	4.4	
		otherwise = 0	36	83.7	180	89.1		188	93.1		236	94.8	
Fatty acid ratio (PUFA: MUFA:SFA) [¥]	0 – 4 points	P/S= 1~1.5 and M/S = 1~1.5 = 4	0	0	4	2.0	0.360	3	1.5	0.238	4	1.6	0.277
		Else if P/S = 0.8 ~1.7 and M/S = 0.8 ~1.7 = 2	1	2.3	13	6.4		18	8.9		20	8.0	
		Otherwise = 0	42	97.7	185	91.6		181	89.6		225	90.4	

1, Based on calorie intake groups <1700kcal, >=1700-<2700, >=2700.
2, Based on the RNI age specific
3, No value for Cholesterol with the NDNS data set- an average of the BEANs results applied to the NDNS participants.
Ŧ, independent T Test used to test for differences between BEANs and Lowest, Middle, and highest NDNS tertiles
¥, Chi Square test used to test for difference in the frequency of participants within the subcomponents categories compared to BEANs

Table 4-6. Comparison of Diet Quality Index-International (DQI-I) scores for females aged 23-61 years with an income from Universal Credit (BEANs) and per the criteria for equivalised income tertiles in the National Diet and Nutrition Survey (years 9-11).

		BEANs	(n = 43)	Lowest EQV1	(n = 202)		Middle EQV2	(n = 202)		Highest EQV3	(n = 249)	
	score range	score	S.E.M	score	S.E.M	P value	score	S.E.M	P value	score	S.E.M	P value
Total DQI score [1]	0-100	49.3	1.37	51.6[a]	0.71	0.164	54.4[b]	0.66	0.001	57.1[c]	0.54	<0.001
Overall variety [1]	0-20	12.1	0.63	13.4	0.26	0.043	14.3	0.26	0.001	14.9	0.23	<0.001
Variety [2]	0-15	9.3	0.46	10.3	0.21	0.059	11.2	0.20	<0.001	11.9	0.18	<0.001
Within group variety [2]	0-5	2.7	0.26	3.0	0.11	0.0287	3.1	0.10	0.148	3.0	0.09	0.251
Adequacy combined [1]	0-40	22.3	0.79	23.5	0.39	0.204	25.3	0.38	<0.001	27.8	0.29	<0.001
Vegetable [2]	0-5	1.3	0.16	2.0	0.10	<0.001	2.4	0.10	<0.001	2.9	0.10	<0.001
Fruit [2]	0-5	1.2	0.22	1.6	0.12	0.194	1.9	0.12	0.003	2.6	0.11	<0.001
Grain [2]	0-5	2.1	0.20	1.5	0.06	<0.001	1.4	0.06	<0.001	1.3	0.05	<0.001
fibre [2]	0-5	2.9	0.20	3.1	0.08	0.219	3.3	0.09	0.031	3.8	0.07	<0.001
protein[2]	0-5	5.0	0.05	5.0	0.02	0.694	5.0	0.01	0.471	5.0	0.01	0.361
Iron [2]	0-5	2.3	0.20	2.6	0.09	0.172	2.9	0.08	0.003	3.2	0.08	<0.001
Calcium [2]	0-5	3.9	0.21	3.7	0.09	0.240	3.8	0.08	0.596	4.2	0.07	0.320
vitamin C [2]	0-5	3.7	0.23	4.1	0.09	0.118	4.4	0.08	<0.001	4.8	0.04	<0.001
Overall moderation [2]	0-30	14.4	0.66	14.3	0.32	0.855	14.4	0.30	0.928	14.0	0.26	0.525
Total fat [2]	0-6	1.2	0.28	0.9	0.11	0.341	0.9	0.10	0.352	0.8	0.09	0.269
Sat fat [2]	0-6	0.9	0.27	0.9	0.13	0.961	1.0	0.12	0.554	0.8	0.10	0.947
Cholesterol [2]	0-6	5.7	0.17	5.7	0.08	0.994	5.7	0.08	0.994	5.7	0.07	0.953
sodium [2]	0-6	5.4	0.23	5.6	0.08	0.604	5.5	0.09	0.935	5.4	0.09	0.572
empty calorie foods [2]	0-6	1.2	0.28	1.2	0.13	0.995	1.3	0.14	0.751	1.2	0.13	0.990
Overall balance [1]	0-10	0.5	0.18	0.5	0.09	0.987	0.4	0.07	0.497	0.3	0.06	0.378
Macro ratio [2]	0-6	0.5	0.17	0.3	0.07	0.315	0.2	0.04	0.040	0.1	0.03	0.007
Fatty acid ratio [2]	0-4	0.0	0.05	0.2	0.05	0.162	0.2	0.05	0.092	0.2	0.05	0.112

[1] values are means and standard error of the mean – test conducted independent T Test
[2] values are estimates and standard error of the mean (S.E.M) - test conducted Mann Whitney U

Table 4-7. Daily macronutrient intakes from diet only amongst females aged 23-61 years in BEANs and the NDNS year's 9-11 Equivalised household income tertiles.

	BEANs			Lowest (n =202) EQV1				Middle (n =202) EQV 2				Highest (n =249) EQV 3			
	Median	**Percentiles**		**Median**	**Percentiles**			**Median**	**Percentiles**			**Median**	**Percentiles**		
		25	75		25	75	**P value**		25	75	**P value**		25	75	**P value**
Total energy (kcal) diet only	1443	(1086)	(1723)	1520[a]	(1204)	(1771)	0.310	1546[a]	(1296)	(1799)	0.080	1660[b]	1330	1946	0.006
Protein (g) diet only	55.4	(39.1)	(78.3)	59.3[a]	(49.5)	(73.4)	0.331	66.0[a]	(52.0)	(79.0)	0.040	68.8[b]	58.5	82.2	0.002
Fat (g) diet only	51.4	(35.2)	(60.1)	57.6[a]	(39.8)	(71.7)	0.068	57.6[ab]	(43.8)	(71.5)	0.017	61.8[b]	47.1	79.7	<0.001
Saturated fatty acids (g) diet only	17.6	(13.4)	(25.8)	21.4	(13.9)	(27.6)	0.272	19.9	(14.8)	(27.5)	0.285	21.6	15.5	29.1	0.032
Carbohydrate (g) diet only	187.4	(142.6)	(230.7)	182.5	(145.1)	(217.9)	0.813	187.7	(145.5)	(224.4)	0.904	189.8	149.5	230.4	0.613

P values are comparison of BEANs to NDNS equivalised household income tertiles.
Superscript letter denotes significant differences between the NDNS Equivalised household income tertiles.

Table 4-8. Daily micronutrient intakes from diet only amongst females aged 23-61 years in BEANs and the NDNS year's 9-11 equivalised household income tertiles.

	Beans (n =43)			Lowest (n =202) EQV 1				Middle (n=202) EQV 2				Highest (n =249) EQV 3			
		Percentiles			Percentiles				Percentiles				Percentiles		
	Median	(25)	(75)	Median	(25)	(75)	P value	Median	(25)	(75)	P value	Median	(25)	(75)	P value
Vitamin A (retinol equivalents) (µg)	410.8	(288.5)	(547.4)	564.6^{a}	(354.3)	(835.8)	0.003	656.6^{a}	(424.6)	(995.3)	<0.001	811.6^{b}	(497.1)	(1377.2)	<0.001
Thiamine (mg)	1.1	(0.9)	(1.6)	1.2^{a}	(0.9)	(1.5)	0.857	1.3^{b}	(1.1)	(1.6)	0.097	1.4^{c}	(1.1)	(1.7)	0.003
Riboflavin (mg)	1.2	(0.8)	(1.7)	1.2^{a}	(0.9)	(1.5)	0.639	1.3^{a}	(1.0)	(1.6)	0.198	1.5^{b}	(1.2)	(1.9)	0.001
Niacin equivalent (mg)	25.5	(18.5)	(35.8)	27.4^{a}	(21.9)	(34.0)	0.634	30.1^{ab}	(24.2)	(36.7)	0.116	31.6^{b}	(26.2)	(37.2)	0.023
Vitamin B6 (mg)	1.3	(0.9)	(1.7)	1.3^{a}	(1.1)	(1.6)	0.189	1.4^{a}	(1.1)	(1.8)	0.019	1.5^{b}	(1.2)	(1.8)	<0.001
Vitamin B12 (µg)	3.5	(2.0)	(4.9)	3.8^{a}	(2.6)	(5.1)	0.221	3.9^{ab}	(2.9)	(5.4)	0.040	4.5^{b}	(3.1)	(5.7)	0.004
Folate (µg)	169.3	(119.6)	(201.8)	172.4^{a}	(135.6)	(225.5)	0.161	189.5^{a}	(150.2)	(231.9)	0.006	219.1^{b}	(174.5)	(277.4)	<0.001
Vitamin C (mg)	43.5	(27.7)	(100)	50.0^{a}	(32.6)	(81.7)	0.522	64.0^{b}	(44.2)	(99.5)	0.019	80.9^{c}	(55.0)	(111.3)	<0.001
Sodium (mg	1651.7	(1253.9)	(2092.4)	1696.5	(1347.2)	(2131.2)	0.815	1670.9	(1339.7)	(2178.4)	0.733	1862.9	(1408.5)	(2248.1)	0.252
Potassium (mg)	2199.3	(1710.7)	(2841.9)	2274.5^{a}	(1871.9)	(2709.7)	0.762	2483.2^{b}	(2030.3)	(3000.6)	0.034	2756.7^{c}	(2347.6)	(3282.9)	<0.001
Calcium (mg)	714.7	(490.5)	(956.9)	648.1^{a}	(496.9)	(849.6)	0.246	679.1^{a}	(522.4)	(856.6)	0.422	773.7^{b}	(609.4)	(945.5)	0.350
Magnesium (mg)	203.9	(158.6)	(276.3)	204.9^{a}	(164.8)	(251.9)	0.760	229.4^{b}	(185.6)	(277.6)	0.128	260.5^{c}	(217.1)	(313.3)	<0.001
Phosphorus (mg)	1002.9	(679.1)	(1358.0)	1022.1^{a}	(812.4)	(1243.3)	0.872	1090.1^{a}	(876.9)	(1297.0)	0.238	1170.2^{b}	(1002.1)	(1404.8)	0.009
Copper (mg)	0.9	(0.6)	(1.1)	0.9^{a}	(0.7)	(1.1)	0.294	1.0^{b}	(0.8)	(1.2)	0.010	1.1^{c}	(0.9)	(1.5)	0.000
Zinc (mg)	6.4	(4.7)	(8.8)	6.8^{a}	(5.4)	(8.2)	0.646	7.4^{a}	(5.9)	(8.9)	0.131	8.0^{b}	(6.4)	(9.7)	0.004
Iodine (µg)	104.2	(60.4)	(146.9)	111.8^{a}	(80.0)	(144.8)	0.211	124.4^{a}	(90.4)	(156.6)	0.018	140.4^{b}	(101.7)	(200.6)	<0.001
Selenium (µg)	27.38	(21.8)	(48.6)	37.9^{a}	(28.3)	(48.0)	0.021	40.1^{a}	(31.2)	(52.5)	<.001	45.5^{b}	(34.2)	(56.9)	<0.001
Iron (mg) <=50 years	7.9	(5.6)	(9.28)	8.5^{a}	(6.5)	(10.5)	0.193	9.2^{a}	(7.1)	(11.0)	0.024	10.2^{b}	(7.7)	(11.9)	<0.001
Iron (mg) >50 years	6.3	(4.0)	(11.1)	7.4^{a}	(5.3)	(9.4)	0.262	8.7^{b}	(7.3)	(10.2)	0.013	9.8^{b}	(8.1)	(11.9)	<0.001

P values are comparison of BEANs to NDNS equivalised household income tertiles.
Superscript letter denotes significant differences between the NDNS Equivalised household income tertiles.
<=50 years n = 36
>50 years n =7

Table 4-9. Comparison of energy and micronutrient intakes **(**%of the RNI and % below LRNI) amongst females aged 23-61 years with an income from Universal Credit (BEANs) per the criteria for equivalised income tertiles in the National Diet and Nutrition Survey (years 9-11).

	Beans (n = 43)			**Lowest (n =202) EQV 1**				**Middle (n=202) EQV 2**				**Highest (n =249) EQV 3**			
	Median	**percentiles 25th**	**percentiles 75th**	**Median**	**percentiles 25th**	**percentiles 75th**	**P value**	**Median**	**percentiles 25th**	**percentiles 75th**	**P value**	**Median**	**percentiles 25th**	**percentiles 75th**	**P value**
Energy (kcal)	1443	(1086)	(1723)	1520[a]	(1204)	(1771)	0.310	1546[a]	(1296)	(1799)	0.08	1660[b]	1330	1946	0.006
N (total)		**n**	**(%)**	**n (total)**	**n**	**(%)**	**P value**	**n (total)**	**n**	**(%)**	**P value**	**n (total)**	**n**	**(%)**	**P value**
Percentage underreport -ting [β]	38[Ŧ]	19	(50.0)	183[ŦŦ]	57	(31.1)	0.026	183[ŦŦ]	38	(20.8)	<0.001	233[ŦŦŦ]	50	(21.5)	<0.001
Nutrient		% <LRNI	Median % RNI	% <LRNI	Median % RNI	Chi square LRNI	Mann Whitney % RNI	% <LRNI	Median % RNI	Chi square LRNI	Mann Whitney % RNI	% <LRNI	Median % RNI	Chi square LRNI	Mann Whitney % RNI
Riboflavin		25.6	112.7	15.3	110.9	0.106	0.455	12.9	118.3	0.035	0.136	7.2	135.4	<0.001	<0.001
Vitamin A		16.3	68.5	12.9	94.1	0.552	0.006	8.9	109.4	0.147	<0.001	3.6	135.3	<0.001	<0.001
Folate		11.6	84.6	11.9	86.2	0.963	0.117	6.4	94.7	0.236	0.003	2.8	109.6	0.07	<0.001
Vitamin B12		4.7	233.6	2.5	250	0.437	0.147	0.5	263	0.024	0.021	2.0	299.4	0.295	0.002
Vitamin C		7.0	108.7	1.5	125	0.034	0.456	1.0	159.9	0.012	0.015	0.0	202.4	0.001	<0.001
Vitamin B 6		n/a	106.0	0.0	110	n/a	0.146	0.5	118.3	n/a	0.012	0.0	127.8	n/a	<0.001
Thiamine		0.0	142.3	0.0	151	n/a	0.502	0.0	161.8	n/a	0.029	0.0	176.1	n/a	<0.001
Selenium		69.8	46.3	55.9	63.1	0.095	0.008	49.5	66.8	0.016	<0.001	38.2	75.8	<0.001	<0.001
Iron<=50 yrs.[$]		52.8	53.1	42.4	57.4	0.353	0.041	31.9	62.4	0.042	0.003	26.3	68.7	<0.006	<0.001
Iron >50 yrs.[$$]		28.6	72.0	18.2	84.6	0.520	0.546	8.2	99.6	0.093	0.074	1.4	112.7	<0.047	<0.001
Potassium		37.2	62.8	31.7	65	0.483	0.574	23.3	70.9	0.058	0.017	14.1	78.8	<0.001	<0.001
Iodine		32.6	74.4	17.3	79.9	0.023	0.277	9.4	88.9	0.000	0.026	4.8	100.3	<0.001	<0.001
Magnesium		23.3	75.5	16.8	75.9	0.319	0.829	10.4	85.0	0.021	0.037	4.4	96.5	<0.001	<0.001
Calcium		16.3	102.1	12.4	92.6	0.490	0.677	8.4	97.0	0.115	0.996	0.0	110.5	0.008	0.009
Zinc		20.9	91.8	8.4	97.6	0.045	0.257	6.4	105.2	0.010	0.030	n/a	114.1	<0.001	<0.001
Sodium		0.0	103.2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Copper		n/a	70.9	n/a	73.3	n/a	0.294	n/a	83	n/a	0.010	n/a	95.3	n/a	<0.001

Ŧ five participants did not record a height or weight
ŦŦ 19 participants did not record a height or weight
ŦŦŦ 16 participants did not record height or weight

β Height& weight only
$ Number of participants in study under 50 years BEANS (n = 36), NDNS Tertiles 1 (n =158), NDNS tertiles 2 (n = 158), NDNS tertiles 3 (n = 175)
$$ Number of participants in study over50 years BEANS (n = 7), NDNS Tertiles 1 (n =44), NDNS tertiles 2 (n = 44), NDNS tertiles 3 (n = 74)
β Height& weight only
n/a =not applicable

Table 4-10. Areas targeted as part of social media campaign.

Area	City/Town
Northeast and East midlands	Norwich, Ipswich, Northampton, Lincoln, Nottingham, Loughborough, Stoke on Trent
West Midlands	Coventry, Worcester, Birmingham, Dudley, West Bromwich
Wales	Cardiff, Swansea, Newport
North and Central England	Bradford, Leeds, Rotherham, Sheffield
Northeast England	South Shields, Middlesbrough, York, Kingston upon Hull
Scotland	Edinburgh, Glasgow, Dundee, Aberdeen
Northwest England	Manchester, Oldham, Warrington
London and Essex	Poplar, Walthamstow, West Thurrock, Ealing, Hounslow, Peckham, Bromley, Stratford, Harlesden, Southend on Sea
Southern England	Eastbourne, Brighton, Reading, Slough, Luton, Milton Keynes, Banbury

Table 4-11 Number of servings or weight (g) of food in the adequacy category required to achieve maximum score of 5 based on energy intake groups.

	Food group			
	Vegetables	**Fruits**	**Grain**	**Fibre**
Energy (kcal)	**Number of servings**			**Weight (g)**
<1700	3	2	>= 6	20
>=1700- <2200	4	3	>= 9	25
>=2700	5	4	>= 11	30

Adapted from the scoring system as describe by (Mariscal-Arcas et al., 2007)

Table 4-12. Serving sizes based on BDA (British Dietetic Association) serving size guidelines (average taken for milk and milk products based on portion size for milk and yogurt),

DQI category		Food group	Serving size (g)	Half serving size (g)
Overall variety	Within group variety	Meat	90	45
Overall variety	Within group variety	Poultry	90	45
Overall variety	Within group variety	Fish	140	70
Overall variety	Within group variety	Eggs	120	60
Overall variety	Within group variety	Milk and milk products	170	85
		Dairy (cheese)	30	15
Overall variety	Within group variety	Dairy (Beans)	150	75
Overall variety	Adequacy	Grains (Bread and cereal)	35	
Overall variety	Adequacy	Grains (Rice and pasta)	150	
Overall variety	Adequacy	Fruits and vegetables	80	

Variety within protein sources, values >= ½ a serving were considered as a meaningful quantity as per recommendations in Kim et al study.

Table 4-13 Question answer rate by food security status amongst BEANs participants.

Food security domain	Question	Household food security status: High n	(%)	Marginal n	(%)	Low n	(%)	Very low n	(%)	Food secure n	(%)	Food insecure n	(%)
Total food security		12	(3.4)	25	(7.2)	89	(25.5)	223	(63.9)	37	(10.6)	312	(89.4)
Anxiety and uncertainty about household food supply	*We worried whether our food would run out before we got money to buy more.*	0	(0)	15	(4)	67	(19)	222	(64)	15	(4)	289	(83)
Insufficient quality	*The food that we bought just didn't last, and we didn't have money to get more.*	0	(0)	7	(2)	53	(15)	218	(62)	7	(2)	271	(78)
	We couldn't afford to eat balanced meals.	1	(0)	14	(4)	70	(20)	217	(62)	15	(4)	287	(82)
Insufficient food intake	*Did you or other adults in your household ever skip or cut meals because there wasn't enough money for food?*	-	-	-	-	46	(13)	223	(64)	-	-	269	(77)
	Was that for three days or more?	-	-	-	-	25	(7)	190	(54)	-	-	215	(62)
	Did you ever eat less than you felt you should because there wasn't enough money for food?	-	-	-	-	43	(12)	220	(63)	-	-	263	(75)
	Were you ever hungry but didn't eat because there wasn't enough money for food?	-	-	-	-	12	(3)	217	(62)	-	-	229	(66)
	Did you lose weight because there wasn't enough money for food?	-	-	-	-	7	(2)	150	(43)	-	-	157	(45)
	Did you or other adults in your household ever not eat for a whole day because there wasn't enough money for food?	-	-	-	-	2	(1)	140	(40)	-	-	142	(41)
	Was that for three days or more?	-	-	-	-	0	(0)	98	(28)	-	-	98	(28)

Only affirmative answers are counted.
All questions were asked relating to the last 30 days.
n = 349 responded to food security questions

Table 4-14. Coping strategy answer rate of by food security status amongst BEANs participants.

	Household food security status											
	High		Marginal		Low		Very low		Food secure		Food insecure	
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
Rely on less preferred and less expensive foods?	4	(1)	13	(4)	58	(17	213	(61)	17	(5)	271	(78)
Reduce the amount of fruit and vegetable intake?	1	(0)	7	(2)	56	(16)	209	(60)	8	(2)	265	(76)
Reduce the variety of fruit and vegetable intake?	2	(1)	10	(3)	55	(16)	205	(59)	12	(3)	260	(75)
Borrow food, or rely on help from a friend or relative?	0	(0)	4	(1)	28	(8)	156	(45)	4	(1)	184	(53)
Access the Food Bank	0	(0)	1	(0)	18	(5)	100	(29)	1	(0)	118	(34)
Purchase food on credit?	3	(1)	2	(1)	18	(5)	91	(26)	5	(1)	109	(31)
Send household members to eat elsewhere?	1	(0)	2	(1)	11	(3)	83	(24)	3	(1)	94	(27)
Limit portion size at mealtimes?	1	(0)	2	(1)	44	(13)	191	(55)	3	(1)	235	(68)
Restrict consumption by adults in order for small children to eat?	1	(0)	1	(0)	20	(6)	119	(34)	2	(1)	139	(40)
Feed working members of the household at the expense of non-working members?	0	(0)	0	(0)	12	(3)	56	(16)	0	(0)	68	(20)
Reduce number of meals eaten in a day?	1	(0)	4	(1)	39	(11)	178	(51)	5	(1)	217	(62)
Reduce food variation in meals? (Eat the same foods at each meal occasion or eat the same foods for consecutive days)	3	(1)	10	(3)	61	(18)	190	(55)	13	(4)	251	(72)
Skip entire days without eating?	1	(0)	1	(0)	13	(4)	138	(40)	2	(1)	151	(43)

Only affirmative answers are counted.
All questions were asked relating to the last 30 days.
n = 348 responded to coping strategy questions.

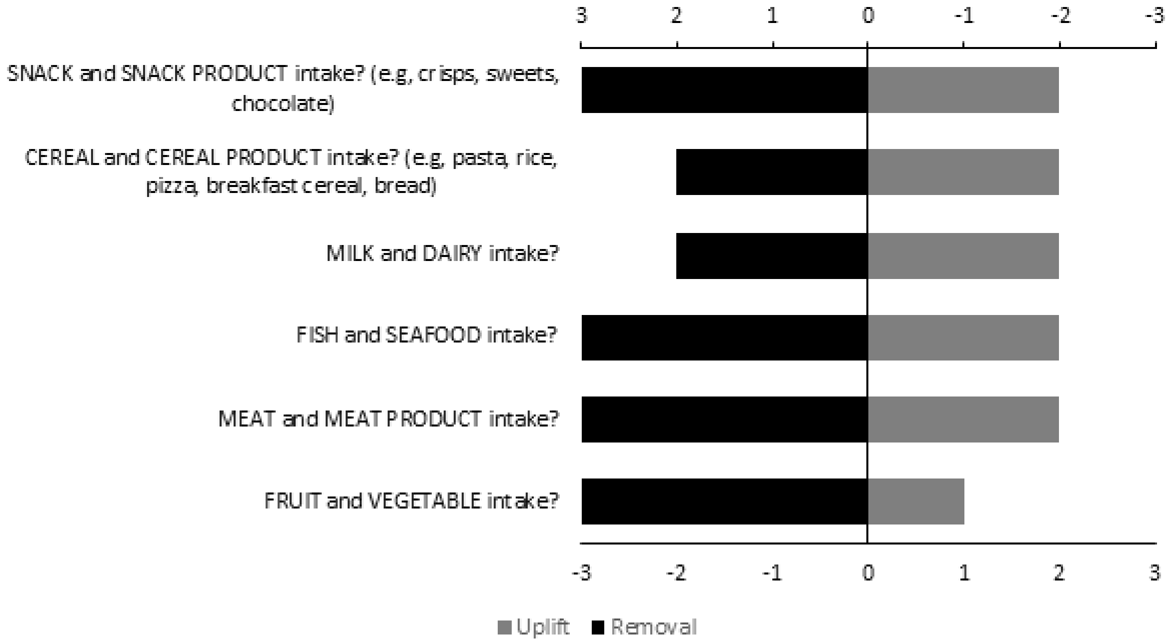

Figure 4-1 Perceived change in food category intake since the £20 a week uprating to Universal credit was introduced and from its subsequent removal. Results are the mode of each category. A total of 349 respond to questions of how the uprating influenced food category intake.

5 General Discussion

5.1 Introduction.

The two published manuscripts and the manuscript in preparation for publication each have a discussion section, evaluating the results in context of the literature available at the time of publication. The following sections discuss the key themes from the research and suggestions for future work.

5.2 Summary background.

It is well documented in high income countries, that there are social and environmental barriers which can impede access to a healthy diet for people with low incomes (Attree, 2006; McFadden et al., 2014). Furthermore, a social gradient in health is known to exist. Disadvantaged population groups have higher rates of diet related diseases such as diabetes, cardiovascular disease, and some forms of cancer (Darmon and Drewnowski, 2015). However, it has been noted in European counties, that there is a lack of systematic studies on food insecurity (Nielsen et al., 2017). It was not until 2019, that measurement of food insecurity (which measure access to food in relation to money) in the UK included all four countries (Loopstra, 2019). The first set of results were published in March 2021, indicating 14% of UK households experienced some form of food insecurity (6% marginal and 4% low or very low food security (DWP, 2021b) although for classification of food insecurity only “low” and “very low food security” are considered food insecure. Results in years’ 2020/2021 of the FRS suggest a slight reduction in food insecurity in the UK as 11% of the general population experienced some form of food insecurity of which 5% “marginal” food secure and 3% “low” or “very low food secure”.

Low-income does not always necessarily mean an individual is food insecure, but they may be nutritionally insecure. Previous studies have reported that individuals with a low income are more likely to have a diet with lower quantities of fruit and vegetables, purchase less healthful foods and consume a greater quantity of sugar sweetened beverages compared to higher income groups (French et al., 2019). Furthermore, observations from epidemiological studies noted micronutrient intakes were more effected than macronutrient intakes by Socio-Economic Status, this was suggested because of increasing refined cereals within the diet as income decreased (Darmon and Drewnowski, 2008). Micronutrient deficiencies are thought to impact over 2 billion people worldwide and it is suggested that of these, 3% are in high income countries (60 million people) (Chaudhuri et al., 2021).

5.3 Key findings.

5.3.1 General overview of findings.

Combined, the three cross sectional studies in this thesis find adolescent girls and adult women in the UK have a poorer diet quality, micronutrient intakes which are low compared to the RNI and a high percentage with dietary micronutrient intakes below the LRNI. The diets of lower income adolescents and adult women do not meet the criteria for food and nutritional security as their diets do not have sufficient quantity of nutritious foods. In general, the studies found a gradient in micronutrient intakes and diet quality when categorised by equivalised household income. However, it must be noted there are limitations in the statistical methodology.

Confounding factors that may have influenced the relationship between household income and diet were not taken into consideration e.g., educational attainment, occupation. Furthermore, the studies 2 and 3 used convenience sampling and as such are not representative of the general population therefore the results are representative of the population participating in the studies at the time. Even with these limitations the studies highlight disparities in nutrient intakes with those in the lowest income groups disproportionately impacted.

5.3.2 Manuscript 1.

Adolescents living in lower income households consumed fewer vegetables, milk products and bread and cereal products but their intake of sugar sweetened beverages, snacks and candy were consumed in similar quantities to adolescents in higher income households this is in contrast to previous studies which found consumption of sugar weekend beverages to be greater in lower income households compared to higher income households(French et al., 2019). Whilst we were unable to assess the food security status of adolescents the findings from this paper support the need for development/consideration of nutrition security in conjunction with food security measures. Whilst the terms nutrition security and food security are often used interchangeable, they are quite different in their focus, with food security concerned with enough foods and nutrition security concerned with the nutrient in the food contributing positively to health and wellbeing. Previous research has shown the energy intakes does not vary between socio-economic status (Darmon and Drewnowski, 2008). The results result from this study follow similar pattern (Table 2.1) whereby energy intakes are similar across the equivalised income groups for females aged 11-14 and 15-18 years. Although, estimated dietary iron and zinc intakes vary numerical across the income groups in both age categories females aged 11-14 years in income quintiles 1 and 3 had a significantly lower iron intake compared to those income quintiles 5. It is known self-reported dietary surveys are prone to misreporting and under reporting of energy intakes. Under reporting of energy intakes is common amongst adults with excess weight, this is also the case for children (3-18 years) (Ravelli and Schoeller, 2020). Furthermore, under reporting of energy intakes has been found to be common amongst groups living in more deprived areas or with lower educational attainment (Grech et al., 2021) this could have biased our results as majority of females in both age groups in income quintile 1 were also living in the most deprived areas.

5.3.3 Manuscript 2.

High income households change shopping and food spending behaviour to ensure adequate food supply. This may be to the detriment of lower income households who do not have the purchasing power to buy in bulk. Drivers of food insecurity are not solely due to a lack of monetary resources. The “availability” domain of food security is a factor in the experience of food insecurity across income groups when the retail sector is unable to keep pace with demand.

The finding that high income households experienced food insecurity during COVID-19 pandemic was surprising and highlights the fragility of food security at the household level when external factors alter food supply. As the UK navigates the cost-of-living crisis, this research may aid in identifying population groups at risk of food insecurity and the development of interventions to protect the most vulnerable.

5.3.4 Manuscript 3.

Women in receipt of UC are disproportionally represented for intakes of micronutrients below the LRNI (riboflavin, magnesium, selenium, zinc, and iodine) compared to the general population. We did not find evidence for women with an income from UC consuming a greater quantity of high fat, salt, sugar foods compared to the general population. What the study did find was a reliance on bread in particular white bread for energy and nutrients in the diet of women with and income from UC.

5.3.5 Who is at risk of experiencing food insecurity and to what severity?

The prevalence of food insecurity in the UK is increasing, even before COVID-19 pandemic and the characteristics of those at risk are well documented (low income, younger age, living with disability, households with children, households from minority ethnic groups)(Francis-Devine et al., 2022). As discussed in Chapter 1, the UK has amongst the worse levels of adult food insecurity in Europe. The measure of food insecurity in the past has been fragmented and inconsistent and it’s only since 2019 that USDA adult food security module was included in the FRS which is used in the tracking of the UK’s progress towards the SDGs. The UK is not on target to meet the SDGs one (No Poverty) and two (Zero Hunger).

The experience of food insecurity and its causes are complex, but many agree, food insecurity is a symptom of low income(Francis-Devine et al., 2022). However, this research highlights that food insecurity can be experienced by higher income households also although the severity of food insecurity for this group is marginal and characterized by anxiety and worry.

5.4 Measuring food security, diet quality, and energy and nutrient intakes.

5.4.1 Measuring food security.

In this research two different survey tools were used to quantify household food insecurity (HFIAS, and USDA adult food security module). The reason for the difference in survey tools used was in in part due to the wording in each of tools. The USDA focus is on lack of monetary resources for the experience and food insecurity whilst the HFIAS measurement tool is concerned with resources. The HFIAS was used at the time when there were restrictions on movement and the retail sector struggled to keep pace with demand. It was felt the HFIAS survey was better suited at the time as it could be adapted for both monetary and availability of foods. The HFIAS and USDA adult food security survey capture the characteristics of food insecurity along the spectrum from anxiety and worry about running out of food, adapting the quality of food in the diet to reducing the quantity of food and skipping whole days without food. However, in the COVID-19 study the classification of food insecurity included the category “mild” food insecurity. Whilst in the UC study the classification of food insecurity included “low” and “Very low food security” in future work it is suggested to use the USDA tool and the classification criteria as it is aligned with national data and allows for comparison between the data sets. Experience of food insecurity may be an indicator that a household has other forms of material deprivation (Bartelmeß et al., 2022).

5.4.2 Diet quality.

The WHO/FAO have suggested that for a healthy diet at least 20 and maybe up to 30 biologically distinct foods, primarily plant based, are required each week for a healthy diet (FAO, 2003). The UK Government Food Based Dietary Guidelines (FBDG) recommend eating a variety of food from five food groups. It is recommended fruit and vegetables contribute 39%, carbohydrates 37%, proteins 12%, dairy and alternatives 8%, oils and spreads 1% and foods high fat, sugar, and salt 3% (PHE, 2016). Results from a recent study evaluating adherence to the Eatwell guide found just 0.1% of the UK population meet all nine recommendations for diet, which includes recommendations for quantities of total fat, saturated fat, sugar, salt, fibre per day and portions of fish and red and processed meat per week. Individuals who had an intermediate to high adherence to the Eatwell guide were found to have a 7% reduced risk of total mortality (Scheelbeek et al., 2020).

The diet quality of lower income adolescents and adult women suggests low adherence to the Eatwell guide compared to higher income counterpart as such it is suggested the experience of household food insecurity will limiting people potential and widening diet and health inequalities in the UK as well as placing a financial burden on society and the NHS because of the cost of treating diseases associated with malnutrition.

Females in receipt of Universal Credit have poorer diet quality, lower micronutrient intakes and a higher proportion of the population below the LRNI for certain micronutrients compared to the general population. Taken together this indicates there are likely deficiencies of micronutrients amongst UC claimants. Furthermore, the lower diet quality, diversity of food groups and variety of protein sources in the diet are an indicator of low food security and micronutrient deficiencies. Measuring food and nutritional insecurity in the UK.

5.4.3 Energy intakes

Underreporting of energy intakes was widespread amongst adolescents and females with an income from UC but not for females who participated with the COVID-19 study, this may be in part due to classification of food insecurity including “mild” characterised by anxiety and worry but not a with a change in dietary habits whilst in the UC study, classification of food insecurity was “low” and “very low food security”. These two groups are characterised by reducing quality of foods in the diet and skipping meals or going whole days without eating.

5.5 The proportion of income spend on food.

Consuming a variety of foods aligned with government recommendations has been found to cost more than unhealthy diets (Darmon and Drewnowski, 2015), although a study in Australia found a healthy diet consistent with healthy eating guidelines cost less than current spend on food but was still unaffordable for low income households (Love et al., 2018) whilst a study in the UK found a healthy diet to cost twice as much as an unhealthy one (Morris et al., 2014).

Households in the UK with the lowest 20% of income spend proportionally more of their income on foods compared to average UK households although the amount spent overall is less (DEFRA, 2018). This Indicates that food costs have a greater burden on lower income households. In the Covid-19 study we found when the proportion of income spent on food exceeded 13% the risk of food insecurity is increased 1.6-fold. Recent data on food affordability indicates the average household spent 14% of their expenditure on food and those in the lowest 20% spent 18.3% of expenditure on food (DEFRA, 2022d). This highlights an increased burden on household budgets because of the rise in food costs across society but the burden is still the greatest amongst those with the lowest income.

5.6 Support available for low-income households.

The UK Government provide healthy start vouchers and free school meals to support low-income households' access to food. However, there are calls for widening of inclusion criteria to support those on low income but above threshold for benefits. In 2018 changes were made to the criteria for free school meals, an income threshold of £7400 was introduced when previously there was none (Bradshaw, 2018). Therefore, a family earning ≥ £7400 per year are not eligible for free school meals worth £437 per year based on 190 school day.

Prior to Covid-19, recipients of working benefits had not seen an increase in their income as rates were frozen at the 2015/2016 cash value, the period between 2013 and 2015 also saw increases in working age benefits capped at 1%. However, the government has lifted the freeze, and benefits are now in line with the consumer price index (CPI) resulting in a 1.7% increase

(McInnes and Kennedy, 2021). Whilst this is good news, the benefits affected by the freeze are around 6% lower in 2020/21 than if they had kept pace with CPI indexation (McInnes and Kennedy, 2021).

During the Covid-19 pandemic the UK government introduced changes to welfare provision including the provision of free school meal vouchers to the value of £15 per child for eligible households. Furthermore, funds were made available for charitable organizations working directly with low-income groups to support social supermarkets aiding access to affordable food.

5.7 Recommendations.

It is recommended to continue the research into food security with the inclusion of nutritional security in sub-population groups in the UK. To aid in the understanding of nutritional security the development of criteria assessing nutritional security.

Further research is needed to understand how any uprating to benefits impacts on food security and nutritional security. To aid in the understanding of the role income has in affording protection from the experience of food insecurity and how this influences diet quality, energy, and nutrients intakes.

Monitoring of disease associated with poor diet and its connection to food and nutritional insecurity is required to gain an understanding of who is at risk, prevalence of nutrient deficiency and impact on health now and in the future, including for offspring, who, when deficiencies of certain micronutrient in the mother during pregnancy are detrimental to the growth and development of a child and can include stunting and impaired cognitive development and growth.

The human body physical requirement for micronutrients is small hence the term micronutrient but the impact to health is vast if intakes are suboptimal. Whilst it is recognised there is a social gradient in health and those living in the most deprived areas, are disproportionally impacted, research is needed to understand the experience of food insecurity, who is experiencing food insecurity and its effect on diet and the foods contributing to micronutrient intakes. It is necessary to investigate food insecurity alongside established indicators of poor diet and ill health such as Socio-Economic Status (SES) or Indices of Multiple Deprivation (IMD) for identification and targeting of resources to address diet and health inequalities. Food insecurity is predominantly caused by economic restrictions and can be experienced along the SES spectrum and within in all IMD’s. How communities support those experiencing food insecurity differ depending on the resources available in different locations.

Research is required amongst population groups who are not always fully represented in national surveys, such as households with an income from benefits to truly get an understanding as to the prevalence and severity of FIS across different population groups as well as an understanding of how food insecurity is experiences is it chronic or transitory are they multiple time points throughout the year when food insecurity is experienced.

It is important to characterize the impact of FIS on diet and micronutrient intakes to inform polices to best support interventions which are then able to provide support and access to nutritious foods that are cultural appropriate, enable choice and are sourced in socially acceptable ways to move people to a high food secure status. There is a need to reverse the growing levels of food insecurity and address the diet and health inequalities associated with the experience of food insecurity.

5.8 Conclusions.

This work has highlighted the nutritional security of low income and food insecure female adolescents and adults to be poor when compared to their higher income and food secure counterparts, highlighting the need for targeted intentions to address both food and nutrition insecurity in the UK.

A key feature of this work is the assessment of nutrient intakes alongside income and food security status in population groups who may not always be represented fully in national surveys. Whilst we know majority of the UK population are food secure, we do not have a full insight into sub-population group's food and their nutritionally security, as such further research into this area is recommended,

6 References

Abbaspour, N., Hurrell, R., Kelishadi, R., 2014. Review on iron and its importance for human health. J. Res. Med. Sci. Off. J. Isfahan Univ. Med. Sci. 19, 164–174.

Abu-Ouf, N.M., Jan, M.M., 2015a. The impact of maternal iron deficiency and iron deficiency anemia on child’s health. Saudi Med. J. 36, 146–149. https://doi.org/10.15537/smj.2015.2.10289

Abu-Ouf, N.M., Jan, M.M., 2015b. The impact of maternal iron deficiency and iron deficiency anemia on child’s health. Saudi Med. J. 36, 146–149. https://doi.org/10.15537/smj.2015.2.10289

Aceves-Martins, M., Cruickshank, M., Fraser, C., Brazzelli, M., 2018. Child food insecurity in the UK: a rapid review. Public Health Res. 6, 1–162. https://doi.org/10.3310/phr06130

Alkerwi, A., Vernier, C., Sauvageot, N., Crichton, G.E., Elias, M.F., 2015. Demographic and socioeconomic disparity in nutrition: application of a novel Correlated Component Regression approach. BMJ Open 5, e006814. https://doi.org/10.1136/bmjopen-2014-006814

Al-Naseem, A., Sallam, A., Choudhury, S., Thachil, J., 2021. Iron deficiency without anaemia: a diagnosis that matters. Clin. Med. 21, 107–113. https://doi.org/10.7861/clinmed.2020-0582

An Phriomh-Oifig Staidrimh, 2023. Equivalised Income - CSO - Central Statistics Office [WWW Document]. URL https://www.cso.ie/en/releasesandpublications/ep/p-silc/surveyonincomeandlivingconditionssilc2022/equivalisedincome/ (accessed 7.17.23).

Anderson, A.S., 2007. Nutrition interventions in women in low-income groups in the UK. Proc. Nutr. Soc. 66, 25–32. https://doi.org/10.1017/S0029665107005265

Anderson, C.P., Shen, L., Eisenstein, R.S., Leibold, E.A., 2012. Mammalian iron metabolism and its control by iron regulatory proteins☆. Biochim. Biophys. Acta 1823, 1468–1483. https://doi.org/10.1016/j.bbamcr.2012.05.010

Armstrong, B., Reynolds, C., Martins, C.A., Frankowska, A., Levy, R.B., Rauber, F., Osei-Kwasi, H.A., Vega, M., Cediel, G., Schmidt, X., Kluczkovski, A., Akparibo, R., Auma, C.L., Defeyter, M.A.A., Tereza da Silva, J., Bridge, G., 2021. Food insecurity, food waste, food behaviours and cooking confidence of UK citizens at the start of the COVID-19 lockdown. Br. Food J. 123, 2959–2978. https://doi.org/10.1108/BFJ-10-2020-0917

Attree, P., 2006. A critical analysis of UK public health policies in relation to diet and nutrition in low-income households. Matern. Child. Nutr. 2, 67–78. https://doi.org/10.1111/j.1740-8709.2006.00055.x

Azizi Fard, N., De Francisci Morales, G., Mejova, Y., Schifanella, R., 2021. On the interplay between educational attainment and nutrition: a spatially-aware perspective. EPJ Data Sci. 10, 1–21. https://doi.org/10.1140/epjds/s13688-021-00273-y

Baker, C., 2022. Obesity statistics. House of Commons Library.

Baraniuk, C., 2020. Fears grow of nutritional crisis in lockdown UK. BMJ m3193. https://doi.org/10.1136/bmj.m3193
Bates, B., Collins, D., Cox, L., Nicholson, S., Page, P., Roberts, C., Steer, T., Swan, G., 2019. National Diet and Nutrition Survey: Years 1 to 9 of the rolling programme (2008/2009-2016/2017): Time trend and income analyses. 56.
Bell, Z., Scott, S., Visram, S., Rankin, J., Bambra, C., Heslehurst, N., 2021. Food insecurity and the nutritional health and well-being of women and children in high-income countries: protocol for a qualitative systematic review. BMJ Open 11, e048180. https://doi.org/10.1136/bmjopen-2020-048180
Benites-Zapata, V.A., Urrunaga-Pastor, D., Solorzano-Vargas, M.L., Herrera-Añazco, P., Uyen-Cateriano, A., Bendezu-Quispe, G., Toro-Huamanchumo, C.J., Hernandez, A.V., 2021. Prevalence and factors associated with food insecurity in Latin America and the Caribbean during the first wave of the COVID-19 pandemic. Heliyon 7, e08091. https://doi.org/10.1016/j.heliyon.2021.e08091
Benjamin Neelon, S.E., Burgoine, T., Gallis, J.A., Monsivais, P., 2017. Spatial analysis of food insecurity and obesity by area-level deprivation in children in early years settings in England. Spat. Spatio-Temporal Epidemiol. 23, 1–9. https://doi.org/10.1016/j.sste.2017.07.001
Bennett, F., 2014. Poverty through a Gender Lens: Evidence and Policy Review on Gender and Poverty.
Bentall, R.P., Lloyd, A., Bennett, K., McKay, R., Mason, L., Murphy, J., McBride, O., Hartman, T.K., Gibson-Miller, J., Levita, L., Martinez, A.P., Stocks, T.V.A., Butter, S., Vallières, F., Hyland, P., Karatzias, T., Shevlin, M., 2021. Pandemic buying: Testing a psychological model of over-purchasing and panic buying using data from the United Kingdom and the Republic of Ireland during the early phase of the COVID-19 pandemic. PLOS ONE 16, e0246339. https://doi.org/10.1371/journal.pone.0246339
Berman, E.S.F., Swibas, T., Kohrt, W.M., Catenacci, V.A., Creasy, S.A., Melanson, E.L., Speakman, J.R., 2020. Maximizing precision and accuracy of the doubly labeled water method via optimal sampling protocol, calculation choices, and incorporation of 17O measurements. Eur. J. Clin. Nutr. 74, 454–464. https://doi.org/10.1038/s41430-019-0492-z
Black, M.M., 1998. Zinc deficiency and child development. Am. J. Clin. Nutr. 68, 464S-469S.
Blake, M.K., 2019. More than Just Food: Food Insecurity and Resilient Place Making through Community Self-Organising. Sustainability 11, 2942. https://doi.org/10.3390/su11102942
BNF, 2021. Nutrition Requirements.
Boyle, N.B., Power, M., 2021. Proxy longitudinal indicators of household food insecurity in the UK. Emerald Open Res. 3, 16. https://doi.org/10.35241/emeraldopenres.14311.1
Bradshaw, J., 2018. UK introduces new income threshold for free school meals 2.

Brantsæter, A.L., Abel, M.H., Haugen, M., Meltzer, H.M., 2013. Risk of suboptimal iodine intake in pregnant Norwegian women. Nutrients 5, 424–440. https://doi.org/10.3390/nu5020424
Brown, A.G.M., Esposito, L.E., Fisher, R.A., Nicastro, H.L., Tabor, D.C., Walker, J.R., 2019. Food insecurity and obesity: research gaps, opportunities, and challenges. Transl. Behav. Med. 9, 980–987. https://doi.org/10.1093/tbm/ibz117
Brown, H., Mills, S., Albani, V., 2022. Socioeconomic risks of food insecurity during the Covid-19 pandemic in the UK: findings from the Understanding Society Covid Survey. BMC Public Health 22, 590. https://doi.org/10.1186/s12889-022-12964-w
Buttriss, J.L., 2015. Folate status in the UK. Nutr. Bull. 40, 153–157. https://doi.org/10.1111/nbu.12148
Calder, P.C., 2020. Nutrition, immunity and COVID-19. BMJ Nutr. Prev. Health 3, 74–92. https://doi.org/10.1136/bmjnph-2020-000085
Calder, P.C., 2013. Feeding the immune system. Proc. Nutr. Soc. 72, 299–309. https://doi.org/10.1017/S0029665113001286
Carvajal-Aldaz, D., Cucalon, G., Ordonez, C., 2022. Food insecurity as a risk factor for obesity: A review. Front. Nutr. 9.
Caswell, J.A., Yaktine, A.L., Allotments, C. on E. of the A. of F.R. and S., Board, F. and N., Statistics, C. on N., Medicine, I. of, Council, N.R., 2013. Individual, Household, and Environmental Factors Affecting Food Choices and Access, Supplemental Nutrition Assistance Program: Examining the Evidence to Define Benefit Adequacy. National Academies Press (US).
Chandra, S., Tripathi, A.K., Mishra, S., Amzarul, M., Vaish, A.K., 2012. Physiological Changes in Hematological Parameters During Pregnancy. Indian J. Hematol. Blood Transfus. 28, 144–146. https://doi.org/10.1007/s12288-012-0175-6
Charlton, K., 2016. Food security, food systems and food sovereignty in the 21st century: A new paradigm required to meet Sustainable Development Goals. Nutr. Diet. 73, 3–12. https://doi.org/10.1111/1747-0080.12264
Chaudhuri, S., Roy, M., McDonald, L.M., Emendack, Y., 2021. Coping Behaviours and the concept of Time Poverty: a review of perceived social and health outcomes of food insecurity on women and children. Food Secur. https://doi.org/10.1007/s12571-021-01171-x
Clapp, J., Moseley, W.G., Burlingame, B., Termine, P., 2022. Viewpoint: The case for a six-dimensional food security framework. Food Policy 106, 102164. https://doi.org/10.1016/j.foodpol.2021.102164
Clay, L.A., Rogus, S., 2021. Impact of Employment, Essential Work, and Risk Factors on Food Access during the COVID-19 Pandemic in New York State. Int. J. Environ. Res. Public. Health 18, 1451. https://doi.org/10.3390/ijerph18041451
Coates, J., Swindale, A., Bilinsky, P., 2007. Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide: Version 3: (576842013-001). https://doi.org/10.1037/e576842013-001

Connors, C., Malan, L., Canavan, S., Sissoko, F., Carmo, M., Sheppard, C., Cook, F., 2020. The lived experience of food insecurity under Covid-19 41.

Darin-Mattsson, A., Fors, S., Kåreholt, I., 2017. Different indicators of socioeconomic status and their relative importance as determinants of health in old age. Int. J. Equity Health 16, 173. https://doi.org/10.1186/s12939-017-0670-3

Darmon, N., Drewnowski, A., 2015. Contribution of food prices and diet cost to socioeconomic disparities in diet quality and health: a systematic review and analysis. Nutr. Rev. 73, 643–660. https://doi.org/10.1093/nutrit/nuv027

Darmon, N., Drewnowski, A., 2008. Does social class predict diet quality? Am. J. Clin. Nutr. 87, 1107–1117. https://doi.org/10.1093/ajcn/87.5.1107

Das, J.K., Padhani, Z.A., 2022. Alleviating hidden hunger: an infallible bridge to improved health and nutrition. Lancet Glob. Health 10, e1539–e1540. https://doi.org/10.1016/S2214-109X(22)00421-1

DEFRA, 2023. Completing the move to Universal Credit: Learning from the Discovery Phase [WWW Document]. GOV.UK. URL https://www.gov.uk/government/publications/completing-the-move-to-universal-credit-learning-from-the-discovery-phase/completing-the-move-to-universal-credit-learning-from-the-discovery-phase (accessed 8.18.23).

DEFRA, 2022a. Family Food 2019/20 [WWW Document]. GOV.UK. URL https://www.gov.uk/government/statistics/family-food-201920/family-food-201920 (accessed 12.14.22).

DEFRA, 2022b. National Statistics Family Food 2019/20 [WWW Document]. GOV.UK. URL https://www.gov.uk/government/statistics/family-food-201920/family-food-201920 (accessed 8.15.22).

DEFRA, 2022c. Universal Credit statistics, 29 April 2013 to 13 January 2022 [WWW Document]. GOV.UK. URL https://www.gov.uk/government/statistics/universal-credit-statistics-29-april-2013-to-13-january-2022/universal-credit-statistics-29-april-2013-to-13-january-2022 (accessed 9.13.22).

DEFRA, 2022d. Family Food 2020/21 [WWW Document]. GOV.UK. URL https://www.gov.uk/government/statistics/family-food-202021/family-food-202021 (accessed 1.21.23).

DEFRA, 2021. United Kingdom Food Security Report 2021: Theme 4: Food Security at Household Level [WWW Document]. GOV.UK. URL https://www.gov.uk/government/statistics/united-kingdom-food-security-report-2021/united-kingdom-food-security-report-2021-theme-4-food-security-at-household-level (accessed 10.27.22).

DEFRA, 2020. Data for chart 2.2: Trend in share of spend going on food and non-alcoholic beverages in low income and all UK households, 2003-04 to 2018-19 - GOV.UK [WWW Document]. URL https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/908880/foodstatisticspocketbook-shareofspendonfood-13aug20.csv/preview (accessed 10.4.21).

DEFRA, 2018. Food statistics pocketbook 2017 [WWW Document]. GOV.UK. URL https://www.gov.uk/government/statistics/food-statistics-pocketbook-2017 (accessed 6.17.19).

Derbyshire, E., 2018. Micronutrient Intakes of British adults across mid-life: A secondary analysis of the UK National Diet and Nutrition Survey. Front. Nutr. 5. https://doi.org/10.3389/fnut.2018.00055

Desbouys, L., Méjean, C., Henauw, S.D., Castetbon, K., 2020. Socio-economic and cultural disparities in diet among adolescents and young adults: a systematic review. Public Health Nutr. 23, 843–860. https://doi.org/10.1017/S1368980019002362

Dhurandhar, E.J., 2016. The food-insecurity obesity paradox: A resource scarcity hypothesis. Physiol. Behav. 162, 88–92. https://doi.org/10.1016/j.physbeh.2016.04.025

DoH (Ed.), 2008. Dietary reference values for food energy and nutrients for the United Kingdom: report, 18. Impression. ed, Report on health and social subjects. TSO, London.

DoH, 1991. Dietary Reference Values A Guide 1991. Crown copyright, London.

Dondi, A., Candela, E., Morigi, F., Lenzi, J., Pierantoni, L., Lanari, M., 2021. Parents’ Perception of Food Insecurity and of Its Effects on Their Children in Italy Six Months after the COVID-19 Pandemic Outbreak. Nutrients 13, 121. https://doi.org/10.3390/nu13010121

Drewnowski, A., 2022. Food insecurity has economic root causes. Nat. Food 3, 555–556. https://doi.org/10.1038/s43016-022-00577-w

Drewnowski, A., 2003. Fat and Sugar: An Economic Analysis. J. Nutr. 133, 838S-840S. https://doi.org/10.1093/jn/133.3.838S

Dutch, D.C., Golley, R.K., Johnson, B.J., 2021. Diet Quality of Australian Children and Adolescents on Weekdays versus Weekend Days: A Secondary Analysis of the National Nutrition and Physical Activity Survey 2011–2012. Nutrients 13, 4128. https://doi.org/10.3390/nu13114128

DWP, 2022. Family Resources Survey: financial year 2020 to 2021 [WWW Document]. GOV.UK. URL https://www.gov.uk/government/statistics/family-resources-survey-financial-year-2020-to-2021 (accessed 12.11.22).

DWP, 2021a. Household below average income series: quality and methodology information report FYE 2020 [WWW Document]. GOV.UK. URL https://www.gov.uk/government/statistics/households-below-average-income-for-financial-years-ending-1995-to-2020/household-below-average-income-series-quality-and-methodology-information-report-fye-2020 (accessed 2.9.22).

DWP, 2021b. Family Resources Survey: financial year 2019 to 2020 [WWW Document]. GOV.UK. URL https://www.gov.uk/government/statistics/family-resources-survey-financial-year-2019-to-2020/family-resources-survey-financial-year-2019-to-2020 (accessed 6.21.21).

EFSA, 2015a. Scientific Opinion on Dietary Reference Values for vitamin A. EFSA J. 13, 4028. https://doi.org/10.2903/j.efsa.2015.4028

EFSA, 2015b. Scientific Opinion on Dietary Reference Values for iron. EFSA J. 13, 4254. https://doi.org/10.2903/j.efsa.2015.4254
EFSA, 2014a. Scientific Opinion on Dietary Reference Values for iodine 57.
EFSA, 2014b. Guidance on the EU Menu methodology. EFSA J. 12, 3944. https://doi.org/10.2903/j.efsa.2014.3944
EFSA, 2013. Example of a protocol for identification of misreporting (under- and overreporting of energy intake) based on the PILOT-PANEU project.
EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA), 2014. Scientific Opinion on Dietary Reference Values for zinc. EFSA J. 12, 3844. https://doi.org/10.2903/j.efsa.2014.3844
EFSA, Turck, D., Bresson, J.-L., Burlingame, B., Dean, T., Fairweather-Tait, S., Heinonen, M., Hirsch-Ernst, K.I., Mangelsdorf, I., McArdle, H.J., Naska, A., Nowicka, G., Pentieva, K., Sanz, Y., Siani, A., Sjödin, A., Stern, M., Tomé, D., Van Loveren, H., Vinceti, M., Willatts, P., Lamberg-Allardt, C., Przyrembel, H., Tetens, I., Dumas, C., Fabiani, L., Forss, A.C., Ioannidou, S., Neuhäuser-Berthold, M., 2017. Dietary Reference Values for riboflavin. EFSA J. 15, e04919. https://doi.org/10.2903/j.efsa.2017.4919
Eicher-Miller, H.A., Mason, A.C., Weaver, C.M., McCabe, G.P., Boushey, C.J., 2009. Food insecurity is associated with iron deficiency anemia in US adolescents. Am. J. Clin. Nutr. 90, 1358–1371. https://doi.org/10.3945/ajcn.2009.27886
Ejebu, O.-Z., Whybrow, S., Mckenzie, L., Dowler, E., Garcia, A.L., Ludbrook, A., Barton, K.L., Wrieden, W.L., Douglas, F., 2018. What can Secondary Data Tell Us about Household Food Insecurity in a High-Income Country Context? Int. J. Environ. Res. Public. Health 16. https://doi.org/10.3390/ijerph16010082
Ellie Thompson, Abby Jitendra, Sumi Rabindrakumar, 2019. 5 weeks too long: Why we need to end the wait for Universal Credit.
ENUF, 2022. Measurement of household insecurity | ENUF [WWW Document]. URL https://enuf.org.uk/39-2/ (accessed 1.9.23).
ERRA, 2021. Covid-19 and the issues of security in food supply (No. 7). House of Commons.
ESRC, 2021. The impact of ending the COVID-19 £20 uprating of Universal Credit and Working Tax Creditdf. ESRC.
European Commission, 2023. COMMISSION STAFF WORKING DOCUMENT Drivers of food security.
Everest, G., Marshall, L., Fraser, C., Briggs, A., 2022. Addressing the leading risk factors for ill health. The Health Foundation. https://doi.org/10.37829/HF-2022-P10
Fairweather-Tait, S.J., 1992. Bioavailability of trace elements. Food Chem. 43, 213–217. https://doi.org/10.1016/0308-8146(92)90176-3
FAO, 2023a. The Food Insecurity Experience Scale: Measuring food insecurity through people’s experiences.
FAO, 2023b. FAOSTAT [WWW Document]. U. K. G. B. North. Irel. URL https://www.fao.org/faostat/en/#country/229 (accessed 8.9.23).
FAO, 2008. An Introduction to the basic concepts of Food Security.
FAO, 2006. Food Security. FAO’s Agriculture and Development Economics Division (ESA).

FAO (Ed.), 2003. Diet, nutrition, and the prevention of chronic diseases: report of a WHO-FAO Expert Consultation ; [Joint WHO-FAO Expert Consultation on Diet, Nutrition, and the Prevention of Chronic Diseases, 2002, Geneva, Switzerland].

FAO, WFP, IFAD, 2012. The state of food insecurity in the world - 2012. FAO, Rome.

Farebrother, J., Haskell, M., 2019. Vitamin A | OpeN-Global | King's College London [WWW Document]. URL https://www.kcl.ac.uk/open-global/biomarkers/vitamin/vitamin-a (accessed 1.23.23).

Farid, Y., Bowman, N.S., Lecat, P., 2022. Biochemistry, Hemoglobin Synthesis, in: StatPearls. StatPearls Publishing, Treasure Island (FL).

Foster, E., Lee, C., Imamura, F., Hollidge, S.E., Westgate, K.L., Venables, M.C., Poliakov, I., Rowland, M.K., Osadchiy, T., Bradley, J.C., Simpson, E.L., Adamson, A.J., Olivier, P., Wareham, N., Forouhi, N.G., Brage, S., 2019. Validity and reliability of an online self-report 24-h dietary recall method (Intake24): a doubly labelled water study and repeated-measures analysis. J. Nutr. Sci. 8, e29. https://doi.org/10.1017/jns.2019.20

Francis-Devine, B., 2022. Poverty in the UK: statistics.

Francis-Devine, B., Danechi, S., Malik, X., 2023. Food poverty: Households, food banks and free school meals.

Francis-Devine, B., Yago Zayed, Aleksandra Gorb, Xameerah Malik, Shadi Danechi, 2022. Food poverty: Households, food banks and free school meals (Research Briefing). House of Commons.

Fraser, L.K., Clarke, G.P., Cade, J.E., Edwards, K.L., 2012. Fast Food and Obesity: A Spatial Analysis in a Large United Kingdom Population of Children Aged 13–15. Am. J. Prev. Med. 42, e77–e85. https://doi.org/10.1016/j.amepre.2012.02.007

French, S.A., Tangney, C.C., Crane, M.M., Wang, Y., Appelhans, B.M., 2019. Nutrition quality of food purchases varies by household income: the SHoPPER study. BMC Public Health 19, 231. https://doi.org/10.1186/s12889-019-6546-2

Fuller, E., Urszula, B., Davies, B., Mandalia, D., Stocker, B., 2019. The Food and You Survey - Wave 5.

Gaal, S., Kerr, M.A., Ward, M., McNulty, H., Livingstone, M.B.E., 2018. Breakfast Consumption in the UK: Patterns, Nutrient Intake and Diet Quality. A Study from the International Breakfast Research Initiative Group. Nutrients 10. https://doi.org/10.3390/nu10080999

Gaitán-Rossi, P., Vilar-Compte, M., Teruel, G., Pérez-Escamilla, R., 2021. Food insecurity measurement and prevalence estimates during the COVID-19 pandemic in a repeated cross-sectional survey in Mexico. Public Health Nutr. 24, 412–421. https://doi.org/10.1017/S1368980020004000

Galobardes, B., Morabia, A., Bernstein, M.S., 2001. Diet and socioeconomic position: does the use of different indicators matter? Int. J. Epidemiol. 30, 334–340. https://doi.org/10.1093/ije/30.2.334

Geiger, B.B., Edmiston, D., Scullion, L., Summers, K., de Vries, R., Ingold, J., Robertshaw, D., Young, D., 2021. Hunger and the welfare state Food insecurity among benefit claimants in the UK.

Ghattas, H., 2014. Food Security and Nutrition in the context of the Global Nutrition Transition. Food and Agriculture Organisation of the United Nations, Rome.

Gibney, M.J., Lanham-New, S.A., Cassidy, A., Vorster, H.H., 2009. Introduction to human nutrition, 2nd ed. Wiley-Blackwell.

Gibson, R.S., Heath, A.-L.M., Ferguson, E.L., 2002. Risk of suboptimal iron and zinc nutriture among adolescent girls in Australia and New Zealand: causes, consequences, and solutions. Asia Pac. J. Clin. Nutr. 11, S543–S552. https://doi.org/10.1046/j.1440-6047.11.supp3.10.x

Gibson, S., Sidnell, A., 2014. Nutrient adequacy and imbalance among young children aged 1–3 years in the UK. Nutr. Bull. 39, 172–180. https://doi.org/10.1111/nbu.12087

Gooding, H.C., Walls, C.E., Richmond, T.K., 2012. Food Insecurity and Increased BMI in Young Adult Women. Obesity 20, 1896–1901. https://doi.org/10.1038/oby.2011.233

GOV, 2023. Universal Credit [WWW Document]. GOV.UK. URL https://www.gov.uk/universal-credit/how-your-earnings-affect-your-payments (accessed 1.24.23).

GOV, 1998. The Bread and Flour Regulations 1998 [WWW Document]. URL https://www.legislation.gov.uk/uksi/1998/141/contents/made (accessed 12.14.22).

GOV.UK, 2023. How and when your benefits are paid [WWW Document]. GOV.UK. URL https://www.gov.uk/how-to-have-your-benefits-paid (accessed 6.9.23).

GOV.UK, 2019. English indices of deprivation 2019 [WWW Document]. GOV.UK. URL https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019 (accessed 8.14.23).

GOV.UK, 2018. Socioeconomic status [WWW Document]. URL https://www.ethnicity-facts-figures.service.gov.uk/uk-population-by-ethnicity/demographics/socioeconomic-status/latest (accessed 8.14.23).

Great Britain (Ed.), 1981. Nutritional aspects of bread and flour: report of the Panel on Bread, Flour and other Cereal Products, Committee on Medical Aspects of Food Policy, Report on health and social subjects. H.M.S.O, London.

Grech, A., Hasick, M., Gemming, L., Rangan, A., 2021. Energy misreporting is more prevalent for those of lower socio-economic status and is associated with lower reported intake of discretionary foods. Br. J. Nutr. 125, 1291–1298. https://doi.org/10.1017/S0007114520003621

Gregory, C.A., 2017. Food Insecurity, Chronic Disease, and Health Among Working-Age Adults.

Grzeszczak, K., Kwiatkowski, S., Kosik-Bogacka, D., 2020a. The Role of Fe, Zn, and Cu in Pregnancy. Biomolecules 10, 1176. https://doi.org/10.3390/biom10081176

Grzeszczak, K., Kwiatkowski, S., Kosik-Bogacka, D., 2020b. The Role of Fe, Zn, and Cu in Pregnancy. Biomolecules 10, 1176. https://doi.org/10.3390/biom10081176

Hamilton, L.K., Thompson, C., Wills, W., 2022. Hostile Environments: Immigration and Food Poverty in the UK. https://doi.org/10.18745/PB.25713

Hampel, D., 2023a. Vitamin B2 (riboflavin)| OpeN-Global | King’s College London [WWW Document]. URL https://www.kcl.ac.uk/open-global/biomarkers/vitamin/vitamin-b2 (accessed 1.20.23).

Hampel, D., 2023b. Human biomarkers for measuring riboflavin intake and status | OpeN-Global | King’s College London [WWW Document]. URL https://www.kcl.ac.uk/open-global/biomarkers/vitamin/vitamin-b2/human-biomarkers-for-measuring-riboflavin (accessed 1.20.23).

Hanmer, J., DeWalt, D.A., Berkowitz, S.A., 2021. Association between Food Insecurity and Health-Related Quality of Life: a Nationally Representative Survey. J. Gen. Intern. Med. 36, 1638–1647. https://doi.org/10.1007/s11606-020-06492-9

Hanson, K.L., Connor, L.M., 2014. Food insecurity and dietary quality in US adults and children: a systematic review. Am. J. Clin. Nutr. 100, 684–692. https://doi.org/10.3945/ajcn.114.084525

Hetherington, G., 2022. Main out-of-work benefit sees its biggest drop in value in fifty years | JRF [WWW Document]. URL https://www.jrf.org.uk/press/main-out-work-benefit-sees-its-biggest-drop-value-fifty-years (accessed 6.9.23).

Hjelm, L., Mathiassen, A., Wadhwa, A., 2016. Measuring Poverty for Food Security Analysis: Consumption- Versus Asset-Based Approaches. Food Nutr. Bull. 37, 275–289. https://doi.org/10.1177/0379572116653509

HLPE, 2020. Food security and nutrition: building a global narrative towards 2030.

HM Treasury, 2022. Millions of most vulnerable households will receive £1,200 of help with cost of living [WWW Document]. GOV.UK. URL https://www.gov.uk/government/news/millions-of-most-vulnerable-households-will-receive-1200-of-help-with-cost-of-living (accessed 6.22.22).

Holmes, B., Dick, K., Nelson, M., 2008. A comparison of four dietary assessment methods in materially deprived households in England. Public Health Nutr. 11, 444–456. https://doi.org/10.1017/S1368980007000559

Horton, S., Ross, J., 2003. The economics of iron deficiency. Food Policy 28, 51–75. https://doi.org/10.1016/S0306-9192(02)00070-2

Hortová-Kohoutková, M., Skotáková, M., Onyango, I.G., Slezáková, M., Panovský, R., Opatřil, L., Slanina, P., De Zuani, M., Mrkva, O., Andrejčinová, I., Lázničková, P., Dvončová, M., Mýtniková, A., Ostland, V., Šitina, M., Stokin, G.B., Šrámek, V., Vlková, M., Helán, M., Frič, J., 2023. Hepcidin and ferritin levels as markers of immune cell activation during septic shock, severe COVID-19 and sterile inflammation. Front. Immunol. 14.

Hourston, P., 2022. Cost of living crisis [WWW Document]. Inst. Gov. URL https://www.instituteforgovernment.org.uk/explainers/cost-living-crisis (accessed 6.22.22).

Huang, L., Drake, V.J., Ho, E., 2015. Zinc1. Adv. Nutr. 6, 224–226. https://doi.org/10.3945/an.114.006874

Indu, G., McIntyre, Hughes, I., 2022. Food Prices Tracking: July Update | Food Foundation [WWW Document]. URL https://foodfoundation.org.uk/news/food-prices-tracking-july-update (accessed 8.16.22).

Intake24, 2022. Intake24 | Home [WWW Document]. URL https://intake24.co.uk/ (accessed 10.31.22).

Jackson, A., 2011. Iron and health. Stationery Office, London.

Jenkins, R.H., Aliabadi, S., Vamos, E.P., Taylor-Robinson, D., Wickham, S., Millett, C., Laverty, A.A., 2021. The relationship between austerity and food insecurity in the UK: A systematic review. EClinicalMedicine 33, 100781. https://doi.org/10.1016/j.eclinm.2021.100781

JFK, 2022. Household spending | JRF [WWW Document]. URL https://www.jrf.org.uk/data/household-spending (accessed 8.17.23).

Jisc, 2022. Online surveys. URL https://www.onlinesurveys.ac.uk/ (accessed 10.28.22).

Johnson, B., 2022. Prime Minister’s statement on coronavirus (COVID-19): 10 May 2020 [WWW Document]. GOV.UK. URL https://www.gov.uk/government/speeches/pm-address-to-the-nation-on-coronavirus-10-may-2020 (accessed 2.21.22).

Jones, A.D., Ngure, F.M., Pelto, G., Young, S.L., 2013. What Are We Assessing When We Measure Food Security? A Compendium and Review of Current Metrics. Adv. Nutr. 4, 481–505. https://doi.org/10.3945/an.113.004119

JRF, 2015. What is poverty? | JRF [WWW Document]. URL https://www.jrf.org.uk/about-us/what-is-poverty (accessed 7.18.23).

Kang, Y., Baidya, A., Aaron, A., Wang, J., Chan, C., Wetzler, E., 2021. Differences in the early impact of COVID-19 on food security and livelihoods in rural and urban areas in the Asia Pacific Region. Glob. Food Secur. 31, 100580. https://doi.org/10.1016/j.gfs.2021.100580

Kapil, U., 2007. Health Consequences of Iodine Deficiency. Sultan Qaboos Univ. Med. J. 7, 267–272.

Keenan, G.S., Christiansen, P., Hardman, C.A., 2021. Household Food Insecurity, Diet Quality, and Obesity: An Explanatory Model. Obesity 29, 143–149. https://doi.org/10.1002/oby.23033

Kennedy, S., 2023. Universal Credit: a checklist before claiming.

Kent, K., Murray, S., Penrose, B., Auckland, S., Horton, E., Lester, E., Visentin, D., 2022. The new normal for food insecurity? A repeated cross-sectional survey over 1 year during the COVID-19 pandemic in Australia. Int. J. Behav. Nutr. Phys. Act. 19, 115. https://doi.org/10.1186/s12966-022-01347-4

Kim, S., Haines, P.S., Siega-Riz, A.M., Popkin, B.M., 2003. The Diet Quality Index-International (DQI-I) Provides an Effective Tool for Cross-National Comparison of Diet Quality as Illustrated by China and the United States. J. Nutr. 133, 3476–3484. https://doi.org/10.1093/jn/133.11.3476

Kirkpatrick, S.I., Tarasuk, V., 2008. Food Insecurity Is Associated with Nutrient Inadequacies among Canadian Adults and Adolescents. J. Nutr. 138, 604–612. https://doi.org/10.1093/jn/138.3.604

Kondaiah, P., Yaduvanshi, P.S., Sharp, P.A., Pullakhandam, R., 2019. Iron and Zinc Homeostasis and Interactions: Does Enteric Zinc Excretion

Cross-Talk with Intestinal Iron Absorption? Nutrients 11, 1885. https://doi.org/10.3390/nu11081885

Kuhnle, G.G.C., 2015. Biomarkers of Intake, in: Nutrition Research Methodologies. John Wiley & Sons, Ltd, pp. 90–107. https://doi.org/10.1002/9781119180425.ch6

Kurotani, K., Shinsugi, C., Takimoto, H., 2021. Diet quality and household income level among students: 2014 National Health and Nutrition Survey Japan. Eur. J. Clin. Nutr. 75, 969–975. https://doi.org/10.1038/s41430-020-00794-1

Lamarche, B., Brassard, D., Lapointe, A., Laramée, C., Kearney, M., Côté, M., Bélanger-Gravel, A., Desroches, S., Lemieux, S., Plante, C., 2021. Changes in diet quality and food security among adults during the COVID-19-related early lockdown: results from NutriQuébec. Am. J. Clin. Nutr. 113, 984–992. https://doi.org/10.1093/ajcn/nqaa363

Lambie-Mumford, H., Crossley, D., Jensen, E., Verbeke, M., Dowler, E., 2014. Household Food Security in the UK: A Review of Food Aid Executive Summary.

Lambie-Mumford, H., Loopstra, R., Gordon, K., 2022. Mapping responses to risk of rising food insecurity during the COVID-19 crisis across the UK [WWW Document]. URL https://www.sheffield.ac.uk/speri/research/current-projects/food-vulnerability-during-covid-19 (accessed 8.8.23).

Langley-Evans, S., 2009. Nutrition: A Lifespan Approach. John Wiley & Sons, Incorporated, Hoboken, UNITED KINGDOM.

Lee, A., Mhurchu, C.N., Sacks, G., Swinburn, B., Snowdon, W., Vandevijvere, S., Hawkes, C., L'Abbé, M., Rayner, M., Sanders, D., Barquera, S., Friel, S., Kelly, B., Kumanyika, S., Lobstein, T., Ma, J., Macmullan, J., Mohan, S., Monteiro, C., Neal, B., Walker, C., 2013. Monitoring the price and affordability of foods and diets globally. Obes. Rev. 14, 82–95. https://doi.org/10.1111/obr.12078

Leung, C.W., Tester, J.M., 2019. The Association between Food Insecurity and Diet Quality Varies by Race/Ethnicity: An Analysis of National Health and Nutrition Examination Survey 2011-2014 Results. J. Acad. Nutr. Diet. 119, 1676–1686. https://doi.org/10.1016/j.jand.2018.10.011

Livingstone, K.M., Olstad, D.L., Leech, R.M., Ball, K., Meertens, B., Potter, J., Cleanthous, X., Reynolds, R., McNaughton, S.A., 2017. Socioeconomic Inequities in Diet Quality and Nutrient Intakes among Australian Adults: Findings from a Nationally Representative Cross-Sectional Study. Nutrients 9, 1092. https://doi.org/10.3390/nu9101092

Livingstone, M.B., Prentice, A.M., Coward, W.A., Strain, J.J., Black, A.E., Davies, P.S., Stewart, C.M., McKenna, P.G., Whitehead, R.G., 1992. Validation of estimates of energy intake by weighed dietary record and diet history in children and adolescents. Am. J. Clin. Nutr. 56, 29–35. https://doi.org/10.1093/ajcn/56.1.29

Llauradó, E., Albar, S.A., Giralt, M., Solà, R., Evans, C.E.L., 2016. The effect of snacking and eating frequency on dietary quality in British

adolescents. Eur. J. Nutr. 55, 1789–1797. https://doi.org/10.1007/s00394-015-0997-8
Lloyd, C.D., Norman, P.D., McLennan, D., 2023. Deprivation in England, 1971–2020. Appl. Spat. Anal. Policy 16, 461–484. https://doi.org/10.1007/s12061-022-09486-8
Lockyer, S., Spiro, A., 2020. The role of bread in the UK diet: An update. Nutr. Bull. 45, 133–164. https://doi.org/10.1111/nbu.12435
Loopstra, R., 2020. Vulnerability to food insecurity since the COVID-19 lockdown.
Loopstra, R., 2019. Food insecurity measurement on the Family Resources Survey | ENUF [WWW Document]. URL https://enuf.org.uk/research-blogs/food-insecurity-measurement-family-resources-survey (accessed 6.21.21).
Loopstra, R., 2018. Interventions to address household food insecurity in high-income countries. Proc. Nutr. Soc. 77, 270–281. https://doi.org/10.1017/S002966511800006X
Loopstra, R., Reeves, A., Tarasuk, V., 2019. The rise of hunger among low-income households: an analysis of the risks of food insecurity between 2004 and 2016 in a population-based study of UK adults. J. Epidemiol. Community Health 73, 668–673. https://doi.org/10.1136/jech-2018-211194
Lowe, N.M., 2021. The global challenge of hidden hunger: perspectives from the field. Proc. Nutr. Soc. 80, 283–289. https://doi.org/10.1017/S0029665121000902
Lowe, R., Mahmood, H., 2022. Why preventing food insecurity will support the NHS and save lives [WWW Document]. NHS Confed. URL https://www.nhsconfed.org/long-reads/why-preventing-food-insecurity-will-support-nhs-and-save-lives (accessed 12.30.22).
Maares, M., Haase, H., 2020. A Guide to Human Zinc Absorption: General Overview and Recent Advances of In Vitro Intestinal Models. Nutrients 12, 762. https://doi.org/10.3390/nu12030762
Maares, M., Haase, H., 2016. Zinc and immunity: An essential interrelation. Arch. Biochem. Biophys. 611, 58–65. https://doi.org/10.1016/j.abb.2016.03.022
Mack, J., 2016. Definitions of poverty | Poverty and Social Exclusion [WWW Document]. URL https://www.poverty.ac.uk/definitions-poverty (accessed 7.18.23).
Mackley, A., McInnes, R., 2022. Coronavirus: Universal Credit during the crisis.
Maggini, S., Wenzlaff, S., Hornig, D., 2010. Essential role of vitamin C and zinc in child immunity and health. J. Int. Med. Res. 38, 386–414.
Mahabadi, N., Bhusal, A., Banks, S.W., 2021. Riboflavin Deficiency, in: StatPearls. StatPearls Publishing, Treasure Island (FL).
Mariscal-Arcas, M., Romaguera, D., Rivas, A., Feriche, B., Pons, A., Tur, J.A., Olea-Serrano, F., 2007. Diet quality of young people in southern Spain evaluated by a Mediterranean adaptation of the Diet Quality Index-International (DQI-I). Br. J. Nutr. 98, 1267–1273. https://doi.org/10.1017/S0007114507781424

Mark Nord, Cristofer Price, William Hamilton, John Cook, Gary Bickel, 2000. Guide to Measuring Household Food Security Revised 2000. United States Department of Agriculture.

Marley, A., Smith, S.C., Ahmed, R., Nightingale, P., Cooper, S.C., 2021. Vitamin A deficiency: experience from a tertiary referral UK hospital; not just a low- and middle-income country issue. Public Health Nutr. 24, 6466–6471. https://doi.org/10.1017/S1368980021003347

Marmot Review report – 'Fair Society, Healthy Lives | Local Government Association [WWW Document], 2019. URL https://www.local.gov.uk/marmot-review-report-fair-society-healthy-lives (accessed 10.31.19).

Maxfield, L., Shukla, S., Crane, J.S., 2023. Zinc Deficiency, in: StatPearls. StatPearls Publishing, Treasure Island (FL).

Maynard, M., Andrade, L., Packull-McCormick, S., Perlman, C.M., Leos-Toro, C., Kirkpatrick, S.I., 2018. Food Insecurity and Mental Health among Females in High-Income Countries. Int. J. Environ. Res. Public. Health 15, 1424. https://doi.org/10.3390/ijerph15071424

McCall, K.A., Huang, C., Fierke, C.A., 2000. Function and Mechanism of Zinc Metalloenzymes. J. Nutr. 130, 1437S-1446S. https://doi.org/10.1093/jn/130.5.1437S

McFadden, A., Green, J.M., Williams, V., McLeish, J., McCormick, F., Fox-Rushby, J., Renfrew, M.J., 2014. Can food vouchers improve nutrition and reduce health inequalities in low-income mothers and young children: a multi-method evaluation of the experiences of beneficiaries and practitioners of the Healthy Start programme in England. BMC Public Health 14, 148. https://doi.org/10.1186/1471-2458-14-148

McInnes, R., Kennedy, S., 2021. Benefits Uprating 2020.

McKevitt, F., 2020. UK online grocery growth clicks up as lockdown trends continue [WWW Document]. URL https://www.kantar.com/uki/inspiration/fmcg/uk-online-grocery-growth-clicks-up-as-lockdown-trends-continue (accessed 1.6.23).

Men, F., Tarasuk, V., 2020. Severe food insecurity associated with mortality among lower-income Canadian adults approaching eligibility for public pensions: a population cohort study. BMC Public Health 20, 1484. https://doi.org/10.1186/s12889-020-09547-y

Mensink, G., Fletcher, R., Gurinovic, M., Huybrechts, I., Lionel, L., Serra-Majem, L., Szponar, L., Tetens, I., Verkaik-Kloosterman, J., Baka, A., Stephen, A.M., 2013. Mapping low intake of micronutrients across Europe. Br. J. Nutr. 110, 1–19. https://doi.org/10.1017/S000711451200565X

Miller, R., Spiro, A., Stanner, S., 2016. Micronutrient status and intake in the UK - where might we be in 10 years' time? Nutr. Bull. 41, 14–41. https://doi.org/10.1111/nbu.12187

Miller, V., Webb, P., Cudhea, F., Shi, P., Zhang, J., Reedy, J., Erndt-Marino, J., Coates, J., Mozaffarian, D., 2022. Global dietary quality in 185 countries from 1990 to 2018 show wide differences by nation, age, education, and urbanicity. Nat. Food 3, 694–702. https://doi.org/10.1038/s43016-022-00594-9

Molitor, F., Doerr, C., Kehl, S., 2021. Unemployment, SNAP Enrollment, and Food Insecurity Before and After California's COVID-19 Shutdown. J. Nutr. Educ. Behav. 53, 1055–1059. https://doi.org/10.1016/j.jneb.2021.09.001

Moradi, S., Arghavani, H., Issah, A., Mohammadi, H., Mirzaei, K., 2018. Food insecurity and anaemia risk: a systematic review and meta-analysis. Public Health Nutr. 21, 3067–3079. https://doi.org/10.1017/S1368980018001775

MRC, 2023a. Measurement Toolkit - Nutritional biomarkers [WWW Document]. URL https://beta.measurement-toolkit.org/diet/objective-methods/biomarkers (accessed 1.24.23).

MRC, 2023b. Measurement Toolkit - Introduction to subjective measures [WWW Document]. Meas. Tool Kit. URL https://beta.measurement-toolkit.org/diet/subjective-methods/introduction (accessed 1.24.23).

MRC, 2023c. Measurement Toolkit - Estimated food diaries [WWW Document]. URL https://beta.measurement-toolkit.org/diet/subjective-methods/estimated-food-diaries (accessed 1.24.23).

MRC, 2023d. Measurement Toolkit - Weighed food diaries [WWW Document]. URL https://beta.measurement-toolkit.org/diet/subjective-methods/weighed-food-diaries (accessed 1.24.23).

MRC, 2023e. Measurement Toolkit - 24-hour dietary recalls [WWW Document]. URL https://beta.measurement-toolkit.org/diet/subjective-methods/24-hour-dietary-recall (accessed 1.24.23).

MRC, 2023f. Measurement Toolkit - Food frequency questionnaires [WWW Document]. URL https://beta.measurement-toolkit.org/diet/subjective-methods/food-frequency-questionnaire (accessed 1.24.23).

Mucavele, P., Nicholas, J., Sharp, L., 2013. Final Report compiled for the School Food Plan's Standards Panel.

Muellbauer, J., 1979. McClements on equivalence scales for children. J. Public Econ. 12, 221–231.

Nair, M., Choudhury, M.K., Choudhury, S.S., Kakoty, S.D., Sarma, U.C., Webster, P., Knight, M., 2016. Association between maternal anaemia and pregnancy outcomes: a cohort study in Assam, India. BMJ Glob. Health 1, e000026. https://doi.org/10.1136/bmjgh-2015-000026

Nelson, M., 1999. House of Commons - Education and Employment - Minutes of Evidence [WWW Document]. URL https://publications.parliament.uk/pa/cm199900/cmselect/cmeduemp/96/9111009.htm (accessed 1.21.22).

Nelson, M., Erens, B., Bates, B., Church, S., Boshier, T., 2007a. Low income diet and nutrition survey Volume 1 Background Methods Sample characteristics.

Nelson, M., Erens, B., Bates, B., Church, S., Boshier, T., 2007b. Low income diet and nutrition survey Summary of key findings.

Nelson, M., Erens, B., Bates, B., Church, S., Boshier, T., 2007c. Low income diet and nutrition survey. Food Consum. Nutr. Intake 2.

Nemeth, E., Ganz, T., 2009. The Role of Hepcidin in Iron Metabolism. Acta Haematol. 122, 78–86. https://doi.org/10.1159/000243791

Neufeld, L.M., Andrade, E.B., Suleiman, A.B., Barker, M., Beal, T., Blum, L.S., Demmler, K.M., Dogra, S., Hardy-Johnson, P., Lahiri, A., Larson, N., Roberto, C.A., Rodríguez-Ramírez, S., Sethi, V., Shamah-Levy, T., Strömmer, S., Tumilowicz, A., Weller, S., Zou, Z., 2022. Food choice in transition: adolescent autonomy, agency, and the food environment. The Lancet 399, 185–197. https://doi.org/10.1016/S0140-6736(21)01687-1

NICE, 2021. Prevalence | Background information | Anaemia - iron deficiency | CKS | NICE [WWW Document]. URL https://cks.nice.org.uk/topics/anaemia-iron-deficiency/background-information/prevalence/ (accessed 1.19.22).

Nielsen, A.L., Holm, L., Lund, T.B., 2017. Development of a survey tool to assess and monitor the influence of food budget restraint on healthy eating, food related climate impact and quality of life 36.

Niles, M.T., Bertmann, F., Belarmino, E.H., Wentworth, T., Biehl, E., Neff, R., 2020. The Early Food Insecurity Impacts of COVID-19. Nutrients 12. https://doi.org/10.3390/nu12072096

Noonan, R.J., 2020. To what extent do unhealthy behaviour indicators explain the neighbourhood deprivation gradient in overweight among 11-year-old English children? SSM - Popul. Health 10, 100541. https://doi.org/10.1016/j.ssmph.2020.100541

Novaković, R., Cavelaars, A., Geelen, A., Nikolić, M., Altaba, I.I., Viñas, B.R., Ngo, J., Golsorkhi, M., Medina, M.W., Brzozowska, A., Szczecinska, A., de Cock, D., Vansant, G., Renkema, M., Majem, L.S., Moreno, L.A., Glibetić, M., Gurinović, M., van't Veer, P., de Groot, L.C., 2014. Review Article Socio-economic determinants of micronutrient intake and status in Europe: a systematic review. Public Health Nutr. 17, 1031–1045. https://doi.org/10.1017/S1368980013001341

O'Brien, E., 2022. Cost of living crisis and sustainable food. Food Matters. URL https://www.foodmatters.org/blog/cost-of-living-crisis/ (accessed 1.6.23).

Office for National Statistics, Social Security Division, 2021. Annual Population Survey, April 2020 - March 2021. [data collection]. (5th Edition), SN: 8833. UK Data Service.

Ogundijo, D.A., Tas, A.A., Onarinde, B.A., 2021. Exploring the Impact of COVID-19 Pandemic on Eating and Purchasing Behaviours of People Living in England. Nutrients 13, 1499. https://doi.org/10.3390/nu13051499

O'Neill, J., 2020. Household income inequality, UK - Office for National Statistics [WWW Document]. URL https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/bulletins/householdincomeinequalityfinancial/financialyearending2020provisional (accessed 2.13.21).

ONS, 2022a. Coronavirus and the impact on UK households and businesses - Office for National Statistics [WWW Document]. URL https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccount

s/articles/coronavirusandtheimpactonukhouseholdsandbusinesses/2021 (accessed 1.6.23).
ONS, 2022b. The effects of taxes and benefits on household income, disposable income estimate - Office for National Statistics [WWW Document]. URL https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/datasets/householddisposableincomeandinequality (accessed 1.21.23).
Park, K., Kersey, M., Geppert, J., Story, M., Cutts, D., Himes, J.H., 2009. Household food insecurity is a risk factor for iron-deficiency anaemia in a multi-ethnic, low-income sample of infants and toddlers. Public Health Nutr. 12, 2120–2128. https://doi.org/10.1017/S1368980009005540
Patton, G.C., Sawyer, S.M., Santelli, J.S., Ross, D.A., Afifi, R., Allen, N.B., Arora, M., Azzopardi, P., Baldwin, W., Bonell, C., Kakuma, R., Kennedy, E., Mahon, J., McGovern, T., Mokdad, A.H., Patel, V., Petroni, S., Reavley, N., Taiwo, K., Waldfogel, J., Wickremarathne, D., Barroso, C., Bhutta, Z., Fatusi, A.O., Mattoo, A., Diers, J., Fang, J., Ferguson, J., Ssewamala, F., Viner, R.M., 2016. Our future: a Lancet commission on adolescent health and wellbeing. The Lancet 387, 2423–2478. https://doi.org/10.1016/S0140-6736(16)00579-1
Pavord, S., Daru, J., Prasannan, N., Robinson, S., Stanworth, S., Girling, J., 2020. UK guidelines on the management of iron deficiency in pregnancy. Br. J. Haematol. 188, 819–830. https://doi.org/10.1111/bjh.16221
Petersen, K.S., Kris-Etherton, P.M., 2021. Diet Quality Assessment and the Relationship between Diet Quality and Cardiovascular Disease Risk. Nutrients 13, 4305. https://doi.org/10.3390/nu13124305
PHE, 2021. Evaluation of the changes in dietary methodology.
PHE, 2020a. NDNS: results from years 9 to 11 (2016 to 2017 and 2018 to 2019) [WWW Document]. GOV.UK. URL https://www.gov.uk/government/statistics/ndns-results-from-years-9-to-11-2016-to-2017-and-2018-to-2019 (accessed 1.24.23).
PHE, 2020b. Impact of COVID-19 pandemic on grocery shopping behaviours. Public Health England.
PHE, 2018. England’s poorest areas are fast food hotspots [WWW Document]. GOV.UK. URL https://www.gov.uk/government/news/englands-poorest-areas-are-fast-food-hotspots (accessed 8.16.23).
PHE, 2016. From Plate to Guide: What, why and how for the eatwell model.
PHE, 2015. Composition of foods integrated dataset (CoFID) [WWW Document]. GOV.UK. URL https://www.gov.uk/government/publications/composition-of-foods-integrated-dataset-cofid (accessed 1.17.23).
Pilgrim, A., Barker, M., Jackson, A., Ntani, G., Crozier, S., Inskip, H., Godfrey, K., Cooper, C., Robinson, S., SWS Study Group, 2012. Does living in a food insecure household impact on the diets and body composition of young children? Findings from the Southampton Women’s Survey. J. Epidemiol. Community Health 66, e6. https://doi.org/10.1136/jech.2010.125476

Pollard, C.M., Booth, S., 2019. Food Insecurity and Hunger in Rich Countries—It Is Time for Action against Inequality. Int. J. Environ. Res. Public. Health 16, 1804. https://doi.org/10.3390/ijerph16101804
Pool, U., Dooris, M., 2021. Prevalence of food security in the UK measured by the Food Insecurity Experience Scale. J. Public Health fdab120. https://doi.org/10.1093/pubmed/fdab120
Power, M., Doherty, B., Pybus, K., Pickett, K., 2020. How Covid-19 has exposed inequalities in the UK food system: The case of UK food and poverty. Emerald Open Res. 2, 11. https://doi.org/10.35241/emeraldopenres.13539.1
Powers, H.J., 2021. Approaches to setting dietary reference values for micronutrients, and translation into recommendations. Proc. Nutr. Soc. 80, 365–372. https://doi.org/10.1017/S0029665121000562
Powers, H.J., 2003. Riboflavin (vitamin B-2) and health. Am. J. Clin. Nutr. 77, 1352–1360. https://doi.org/10.1093/ajcn/77.6.1352
Powers, H.J., Hill, M.H., Mushtaq, S., Dainty, J.R., Majsak-Newman, G., Williams, E.A., 2011. Correcting a marginal riboflavin deficiency improves hematologic status in young women in the United Kingdom (RIBOFEM). Am. J. Clin. Nutr. 93, 1274–1284. https://doi.org/10.3945/ajcn.110.008409
Prayogo, E., Chater, A., Chapman, S., Barker, M., Rahmawati, N., Waterfall, T., Grimble, G., 2018. Who uses foodbanks and why? Exploring the impact of financial strain and adverse life events on food insecurity. J. Public Health 40, 676–683. https://doi.org/10.1093/pubmed/fdx133
Prentice, A.M., Bates, C.J., 1981. A biochemical evaluation of the erythrocyte glutathione reductase (EC 1.6.4.2) test for riboflavin status. 2. Dose-response relationships in chronic marginal deficiency. Br. J. Nutr. 45, 53–65. https://doi.org/10.1079/bjn19810076
Radford, E., 2022. Food banks provide more than 2.1 million food parcels to people across the UK in past year, according to new figures released by the Trussell Trust. Trussell Trust. URL https://www.trusselltrust.org/2022/04/27/food-banks-provide-more-than-2-1-million-food-parcels-to-people-across-the-uk-in-past-year-according-to-new-figures-released-by-the-trussell-trust/ (accessed 12.11.22).
Raifman, J., Bor, J., Venkataramani, A., 2021. Association Between Receipt of Unemployment Insurance and Food Insecurity Among People Who Lost Employment During the COVID-19 Pandemic in the United States. JAMA Netw. Open 4, e2035884. https://doi.org/10.1001/jamanetworkopen.2020.35884
Rashid, V., Engberink, M.F., van Eijsden, M., Nicolaou, M., Dekker, L.H., Verhoeff, A.P., Weijs, P.J.M., 2018. Ethnicity and socioeconomic status are related to dietary patterns at age 5 in the Amsterdam born children and their development (ABCD) cohort. BMC Public Health 18, 115. https://doi.org/10.1186/s12889-017-5014-0
Ravelli, M.N., Schoeller, D.A., 2020. Traditional Self-Reported Dietary Instruments Are Prone to Inaccuracies and New Approaches Are Needed. Front. Nutr. 7, 90. https://doi.org/10.3389/fnut.2020.00090

Resseguier, A.-S., Guiguet-Auclair, C., Debost-Legrand, A., Serre-Sapin, A.-F., Gerbaud, L., Vendittelli, F., Ruivard, M., 2022. Prediction of Iron Deficiency Anemia in Third Trimester of Pregnancy Based on Data in the First Trimester: A Prospective Cohort Study in a High-Income Country. Nutrients 14, 4091. https://doi.org/10.3390/nu14194091

Revoredo-Giha, C., Akaichi, F., Chalmers, N., 2019. Trading on Food Quality due to Changes in Prices: Are There Any Nutritional Effects? Nutrients 12, 23. https://doi.org/10.3390/nu12010023

Rigby, C., 2020. Tesco shows how it adapted as shoppers moved online fast during the Covid-19 lockdown – and counts the costs of change [WWW Document]. Internet Retail. URL https://internetretailing.net/covid-19/tesco-shows-how-it-adapted-as-shoppers-moved-online-fast-during-the-covid-19-lockdown-and-counts-the-costs-of-change-21616/ (accessed 1.6.23).

Righettini, M.S., Bordin, E., 2022. Exploring food security as a multidimensional topic: twenty years of scientific publications and recent developments. Qual. Quant. https://doi.org/10.1007/s11135-022-01452-3

Robinson, S., Skelton, R., Barker, M., Wilman, C., 1999. Assessing the diet of adolescent girls in the UK. Public Health Nutr. 2, 571–577. https://doi.org/10.1017/S1368980099000762

Roohani, N., Hurrell, R., Kelishadi, R., Schulin, R., 2013. Zinc and its importance for human health: An integrative review. J. Res. Med. Sci. Off. J. Isfahan Univ. Med. Sci. 18, 144–157.

Rose, D., Gundersen, C., Oliveira, V., 1998. Socio-Economic Determinants of Food Insecurity in the United States: Evidence from the SIPP and CSFII Datasets [WWW Document]. URL http://www.ers.usda.gov/publications/pub-details/?pubid=47215 (accessed 7.26.23).

Rosi, A., Paolella, G., Biasini, B., Scazzina, F., Alicante, P., De Blasio, F., dello Russo, M., Paolella, G., Rendina, D., Rosi, A., Tabacchi, G., Cairella, G., Garbagnati, F., Scalfi, L., Strazzullo, P., 2019. Dietary habits of adolescents living in North America, Europe or Oceania: A review on fruit, vegetable and legume consumption, sodium intake, and adherence to the Mediterranean Diet. Nutr. Metab. Cardiovasc. Dis. 29, 544–560. https://doi.org/10.1016/j.numecd.2019.03.003

SACN, 2016. Vitamin D and Health report. Scientific Advisory Committee on Nutrition.

SACN, 2015. Carbohydrates and Health. Scientific Advisory Committee on Nutrition.

SACN, 2011. Dietary Reference Values for Energy. Scientific Advisory Committee on Nutrition.

SAITO, H., 2014. METABOLISM OF IRON STORES. Nagoya J. Med. Sci. 76, 235–254.

Samson, K.L.I., Fischer, J.A.J., Roche, M.L., 2022. Iron Status, Anemia, and Iron Interventions and Their Associations with Cognitive and Academic Performance in Adolescents: A Systematic Review. Nutrients 14, 224. https://doi.org/10.3390/nu14010224

Scheelbeek, P., Green, R., Papier, K., Knuppel, A., Alae-Carew, C., Balkwill, A., Key, T.J., Beral, V., Dangour, A.D., 2020. Health impacts and environmental footprints of diets that meet the Eatwell Guide recommendations: analyses of multiple UK studies. BMJ Open 10, e037554. https://doi.org/10.1136/bmjopen-2020-037554

School Food Matters, 2020. Food insecurity during lockdown [WWW Document]. Sch. Food Matters. URL https://www.schoolfoodmatters.org/news-views/news/food-insecurity-during-lockdown (accessed 8.16.22).

Schroeder, K., Smaldone, A., 2015. Food insecurity: A concept analysis. Nurs. Forum (Auckl.) 50, 274–284. https://doi.org/10.1111/nuf.12118

Scott, C., Sutherland, J., Taylor, A., 2018. Affordability of the UK's Eatwell Guide [WWW Document]. URL https://foodfoundation.org.uk/wp-content/uploads/2018/10/Affordability-of-the-Eatwell-Guide_Final_Web-Version.pdf (accessed 4.8.20).

Sergentanis, T.N., Chelmi, M.-E., Liampas, A., Yfanti, C.-M., Panagouli, E., Vlachopapadopoulou, E., Michalacos, S., Bacopoulou, F., Psaltopoulou, T., Tsitsika, A., 2021. Vegetarian Diets and Eating Disorders in Adolescents and Young Adults: A Systematic Review. Children 8, 12. https://doi.org/10.3390/children8010012

Sharma, S.V., 2020. Social Determinants of Health–Related Needs During COVID-19 Among Low-Income Households With Children. Prev. Chronic. Dis. 17. https://doi.org/10.5888/pcd17.200322

Shepshed, A., 2003. Inequality and Poverty. Presented at the Oxford Lecture.

Shinwell, J., Bateson, M., Nettle, D., Pepper, G.V., 2022. Food insecurity and patterns of dietary intake in a sample of UK adults. Br. J. Nutr. 128, 770–777. https://doi.org/10.1017/S0007114521003810

Shipton, M.J., Thachil, J., 2015. Vitamin B12 deficiency – A 21st century perspective. Clin. Med. 15, 145–150. https://doi.org/10.7861/clinmedicine.15-2-145

Skolmowska, D., Głąbska, D., 2019. Analysis of Heme and Non-Heme Iron Intake and Iron Dietary Sources in Adolescent Menstruating Females in a National Polish Sample. Nutrients 11, 1049. https://doi.org/10.3390/nu11051049

Sorhaindo, A., Feinstein, L., Centre for Research on the Wider Benefits of Learning (London, E., 2006. What is the relationship between child nutrition and school outcomes? Centre for Research on the Wider Benefits of Learning, London.

Spurlock, C.A., Todd-Blick, A., Wong-Parodi, G., Walker, V., 2020. Children, Income, and the Impact of Home Delivery on Household Shopping Trips. Transp. Res. Rec. 2674, 335–350. https://doi.org/10.1177/0361198120935113

Steenhuis, I.H., Waterlander, W.E., de Mul, A., 2011. Consumer food choices: the role of price and pricing strategies. Public Health Nutr. 14, 2220–2226. https://doi.org/10.1017/S1368980011001637

Stevens, G.A., Beal, T., Mbuya, M.N.N., Luo, H., Neufeld, L.M., Addo, O.Y., Adu-Afarwuah, S., Alayón, S., Bhutta, Z., Brown, K.H., Jefferds, M.E., Engle-Stone, R., Fawzi, W., Hess, S.Y., Johnston, R., Katz, J., Krasevec, J., McDonald, C.M., Mei, Z., Osendarp, S., Paciorek, C.J., Petry, N., Pfeiffer, C.M., Ramirez-Luzuriaga, M.J., Rogers, L.M., Rohner, F., Sethi, V., Suchdev, P.S., Tessema, M., Villapando, S., Wieringa, F.T., Williams, A.M., Woldeyahannes, M., Young, M.F., 2022. Micronutrient deficiencies among preschool-aged children and women of reproductive age worldwide: a pooled analysis of individual-level data from population-representative surveys. Lancet Glob. Health 10, e1590–e1599. https://doi.org/10.1016/S2214-109X(22)00367-9

Stewart, R., 2019. Voluntary National Review of progress towards the Sustainable Development Goals. HM Government.

Story, M., Neumark-sztainer, D., French, S., 2002. Individual and Environmental Influences on Adolescent Eating Behaviors. J. Am. Diet. Assoc. 102, S40–S51. https://doi.org/10.1016/S0002-8223(02)90421-9

Stringhini, S., Carmeli, C., Jokela, M., Avendaño, M., Muennig, P., Guida, F., Ricceri, F., d'Errico, A., Barros, H., Bochud, M., Chadeau-Hyam, M., Clavel-Chapelon, F., Costa, G., Delpierre, C., Fraga, S., Goldberg, M., Giles, G.G., Krogh, V., Kelly-Irving, M., Layte, R., Lasserre, A.M., Marmot, M.G., Preisig, M., Shipley, M.J., Vollenweider, P., Zins, M., Kawachi, I., Steptoe, A., Mackenbach, J.P., Vineis, P., Kivimäki, M., Alenius, H., Avendano, M., Barros, H., Bochud, M., Carmeli, C., Carra, L., Castagné, R., Chadeau-Hyam, M., Clavel-Chapelon, F., Costa, G., Courtin, E., Delpierre, C., D'Errico, A., Dugué, P.-A., Elliott, P., Fraga, S., Gares, V., Giles, G., Goldberg, M., Greco, D., Hodge, A., Irving, M.K., Karisola, P., Kivimäki, M., Krogh, V., Lang, T., Layte, R., Lepage, B., Mackenbach, J., Marmot, M., McCrory, C., Milne, R., Muennig, P., Nusselder, W., Panico, S., Petrovic, D., Polidoro, S., Preisig, M., Raitakari, O., Ribeiro, A.I., Ribeiro, A.I., Ricceri, F., Robinson, O., Valverde, J.R., Sacerdote, C., Satolli, R., Severi, G., Shipley, M.J., Stringhini, S., Tumino, R., Vineis, P., Vollenweider, P., Zins, M., 2017. Socioeconomic status and the 25 × 25 risk factors as determinants of premature mortality: a multicohort study and meta-analysis of 1·7 million men and women. The Lancet 389, 1229–1237. https://doi.org/10.1016/S0140-6736(16)32380-7

Tanumihardjo, S.A., Russell, R.M., Stephensen, C.B., Gannon, B.M., Craft, N.E., Haskell, M.J., Lietz, G., Schulze, K., Raiten, D.J., 2016. Biomarkers of Nutrition for Development (BOND)-Vitamin A Review. J. Nutr. 146, 1816S–48S. https://doi.org/10.3945/jn.115.229708

Thakur, K., Tomar, S.K., Singh, A.K., Mandal, S., Arora, S., 2017. Riboflavin and health: A review of recent human research. Crit. Rev. Food Sci. Nutr. 57, 3650–3660. https://doi.org/10.1080/10408398.2016.1145104

Thane, C.W., Bates, C.J., Prentice, A., 2004. Zinc and vitamin A intake and status in a national sample of British young people aged 4-18 y. Eur. J. Clin. Nutr. 58, 363–375. https://doi.org/10.1038/sj.ejcn.1601792

Thane, C.W., Bates, C.J., Prentice, A., 2003. Risk factors for low iron intake and poor iron status in a national sample of British young people aged 4–18 years. Public Health Nutr. 6, 485–496. https://doi.org/10.1079/PHN2002455

The Department of Health, 2013. Report on Health and Social Subjects 41 Dietary Reference Values for Food Energy and Nutrients for the United Kingdom. The Stationery Office.

The Food Foundation, 2023. NEW FOOD FOUNDATION DATA: 14% of UK families with children have experienced food insecurity in the past 6 months - Food Foundation [WWW Document]. URL https://foodfoundation.org.uk/new-food-foundation-data-sept-2020/ (accessed 10.22.20).

The Food Foundation, 2022a. Food Insecurity Tracking | Food Foundation [WWW Document]. URL https://www.foodfoundation.org.uk/initiatives/food-insecurity-tracking (accessed 1.6.23).

The Food Foundation, 2022b. Government data shows £20 uplift is likely to have protected people on Universal Credit from food insecurity | Food Foundation [WWW Document]. URL https://foodfoundation.org.uk/press-release/government-data-shows-ps20-uplift-likely-have-protected-people-universal-credit-food (accessed 8.19.22).

The Food Foundation, 2021. A CRISIS WITHIN A CRISIS: The Impact of Covid-19 on Household Food Security. [WWW Document]. Food Found. URL https://foodfoundation.org.uk/publication/crisis-within-crisis-impact-covid-19-household-food-security

Thomas, M., Eveleigh, E., Vural, Z., Rose, P., Avery, A., Coneyworth, L., Welham, S., 2022. The Impact of the COVID-19 Pandemic on the Food Security of UK Adults Aged 20-65 Years (COVID-19 Food Security and Dietary Assessment Study). Nutrients 14, 5078. https://doi.org/10.3390/nu14235078

Thurnham, D.I., McCabe, G.P., Northrop-Clewes, C.A., Nestel, P., 2003. Effects of subclinical infection on plasma retinol concentrations and assessment of prevalence of vitamin A deficiency: meta-analysis. Lancet Lond. Engl. 362, 2052–2058. https://doi.org/10.1016/s0140-6736(03)15099-4

Townsend Centre for International Poverty Research [WWW Document], 2023. URL https://www.bristol.ac.uk/poverty/definingandmeasuringpoverty.html (accessed 8.1.23).

Trussel Trust, 2021. Our new report calls for the £20 Universal Credit uplift to be extended [WWW Document]. Trussell Trust. URL https://www.trusselltrust.org/2021/02/04/our-new-report-calls-for-the-20-universal-credit-uplift-to-be-extended/ (accessed 6.22.22).

UK Parliament, 2022. Diet-related health inequalities (No. 686), POSTNOTE. UK Parliament.

UK Parliament, 2019. Sustainable Development Goals in the UK follow up: Hunger, malnutrition and food insecurity in the UK [WWW Document]. Sustain. Dev. Goals UK Follow Hunger Malnutrition Food Insecurity UK. URL https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/1491/149105.htm (accessed 10.21.20).

UKSSD, 2018. Measuring up How the UK is performing on the UN Sustainable Development Goals. UK Stakeholders for Sustainable Development.

University of Cambridge, M.E.U., NatCen Social Research, 2022. National Diet and Nutrition Survey Years 1-11, 2008-2019. [data collection].19th Edition.

University of Cambridge, MRC Epidemiology Unit, NatCen Social Research, 2021. National Diet and Nutrition Survey Years 1-11, 2008-2019. [data collection]. 19th Edition.

USDA, 2022a. Measurement [WWW Document]. URL https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-u-s/measurement/#insecurity (accessed 12.21.22).

USDA, 2022b. USDA ERS - History & Background [WWW Document]. URL https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-u-s/history-background/ (accessed 1.9.23).

USDA, 2022c. USDA ERS - Survey Tools [WWW Document]. URL https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-u-s/survey-tools/#adult (accessed 10.28.22).

Vahid, F., Hekmatdoost, A., Mirmajidi, S., Doaei, S., Rahmani, D., Faghfoori, Z., 2019. Association Between Index of Nutritional Quality and Nonalcoholic Fatty Liver Disease: The Role of Vitamin D and B Group. Am. J. Med. Sci. 358, 212–218. https://doi.org/10.1016/j.amjms.2019.06.008

Ventura, M., Melo, M., Carrilho, F., 2017. Selenium and Thyroid Disease: From Pathophysiology to Treatment. Int. J. Endocrinol. 2017. https://doi.org/10.1155/2017/1297658

Vik, F.N., Van Lippevelde, W., Øverby, N.C., 2019. Free school meals as an approach to reduce health inequalities among 10–12- year-old Norwegian children. BMC Public Health 19, 951. https://doi.org/10.1186/s12889-019-7286-z

Vitamins and minerals - B vitamins and folic acid [WWW Document], 2017. . nhs.uk. URL https://www.nhs.uk/conditions/vitamins-and-minerals/vitamin-b/ (accessed 12.13.22).

Vyncke, K., Cruz Fernandez, E., Fajó-Pascual, M., Cuenca-García, M., De Keyzer, W., Gonzalez-Gross, M., Moreno, L.A., Beghin, L., Breidenassel, C., Kersting, M., Albers, U., Diethelm, K., Mouratidou, T., Grammatikaki, E., De Vriendt, T., Marcos, A., Bammann, K., Börnhorst, C., Leclercq, C., Manios, Y., Dallongeville, J., Vereecken, C., Maes, L., Gwozdz, W., Van Winckel, M., Gottrand, F., Sjöström, M., Díaz, L.E., Geelen, A., Hallström, L., Widhalm, K., Kafatos, A., Molnar, D., De Henauw, S., Huybrechts, I., 2013. Validation of the Diet Quality Index for Adolescents by comparison with biomarkers, nutrient and food intakes: the HELENA study. Br. J. Nutr. 109, 2067–2078. https://doi.org/10.1017/S000711451200414X

Walker, R., Chawla, A., Garacci, E., Williams, J., Mendez, C., Ozieh, M., Egede, L., 2019. Assessing the Relationship between Food Insecurity and Mortality among US Adults. Ann. Epidemiol. 32, 43–48. https://doi.org/10.1016/j.annepidem.2019.01.014

Webb, P., Coates, J., Frongillo, E.A., Rogers, B.L., Swindale, A., Bilinsky, P., 2006. Measuring Household Food Insecurity: Why It's So

Important and Yet So Difficult to Do12. J. Nutr. 136, 1404S-1408S. https://doi.org/10.1093/jn/136.5.1404S

Weichselbaum, E., Buttriss, J.L., 2014. Diet, nutrition and schoolchildren: An update. Nutr. Bull. 39, 9–73. https://doi.org/10.1111/nbu.12071

WHO, 2023. WHO guidance helps detect iron deficiency and protect brain development [WWW Document]. URL https://www.who.int/news/item/20-04-2020-who-guidance-helps-detect-iron-deficiency-and-protect-brain-development (accessed 1.25.23).

WHO, 2020. WHO guideline on use of ferritin concentrations to assess iron status in individuals and populations.

WHO, 2013. Urinary iodine concentrations for determining iodine status in populations.

WHO, 2011a. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity, Vitamin and Mineral Nutrition Information System. Geneva, World Health Organization, 2011 (WHO/NMH/NHD/MNM/11.1).

WHO, 2011b. Serum ferritin concentrations for the assessment of iron status and iron deficiency in populations. Vitamin and Mineral Nutrition Information System. Geneva.

Whybrow, S., Hollis, J.L., Macdiarmid, J.I., 2018. Social deprivation is associated with poorer adherence to healthy eating dietary goals: analysis of household food purchases. J. Public Health Oxf. Engl. 40, e8–e15. https://doi.org/10.1093/pubmed/fdx007

Wirt, A., Collins, C.E., 2009. Diet quality – what is it and does it matter? Public Health Nutr. 12, 2473–2492. https://doi.org/10.1017/S136898000900531X

Wise, J., 2018. Britain's deprived areas have five times as many fast food shops as rich areas. BMJ 363, k4661. https://doi.org/10.1136/bmj.k4661

Wolfson, J.A., Leung, C.W., 2020. Food Insecurity and COVID-19: Disparities in Early Effects for US Adults. Nutrients 12. https://doi.org/10.3390/nu12061648

Yang, T.C., Sahota, P., Pickett, K.E., Bryant, M., 2018. Association of food security status with overweight and dietary intake: exploration of White British and Pakistani-origin families in the Born in Bradford cohort. Nutr. J. 17, 48. https://doi.org/10.1186/s12937-018-0349-7

Zaric, B.L., Obradovic, M., Bajic, V., Haidara, M.A., Jovanovic, M., Isenovic, E.R., 2019. Homocysteine and Hyperhomocysteinaemia. Curr. Med. Chem. 26, 2948–2961. https://doi.org/10.2174/0929867325666180313105949

Zhang, Q., Lu, X.-M., Zhang, M., Yang, C.-Y., Lv, S.-Y., Li, S.-F., Zhong, C.-Y., Geng, S.-S., 2021. Adverse effects of iron deficiency anemia on pregnancy outcome and offspring development and intervention of three iron supplements. Sci. Rep. 11, 1347. https://doi.org/10.1038/s41598-020-79971-y

Zimmermann, M.B., Jooste, P.L., Pandav, C.S., 2008. Iodine-deficiency disorders. The Lancet 372, 1251–1262. https://doi.org/10.1016/S0140-6736(08)61005-3

7 Appendices

7.1 APPPENDIX A: U.S Adult Food Security Survey Module

These next questions are about the food eaten in your household in the last 12 months, since (current month) of last year and whether you were able to afford the food, you need.		
Adult/Household questions In the last 12 months, can you tell me if these statements were true for you?		
1	"We worried whether our food would run out before we got money to buy more."	
2	"The food that we bought just didn't last, and we didn't have money to get more."	
3	"We couldn't afford to eat balanced meals."	
4a	Did (you/you or other adults in your household) ever cut the size of your meals or skip meals because there wasn't enough money for food?	
4b	If yes: How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?	Almost every day Some days but not every day Only 1 or 2 days
5	Did you ever eat less than you felt you should because there wasn't enough money for food	
6	Were you every hungry but didn't eat because there wasn't enough money for food	
7	Did you lose weight because there wasn't enough money for food?	
8a	Did (you/you or other adults in your household) ever not eat for a whole day because there wasn't enough money for food?	
8b	If yes: How often did this happen—almost every day, some days but not every day, or in only 1 or 2 days?	

7.2 APPENDIX B: Household Food Insecurity Access Scale (HFIAS) Generic Questions

No	Question	Response		
1	In the past four weeks, did you worry that your household would not have enough food?	0 = No (skip to Q2) 1 = Yes		
1a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		
2	In the past four weeks were you or any household member not able to eat the kinds of foods you preferred because of lack of resources?	0 = No (skip to Q3) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
2a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		
3	In the past four weeks, did you or any member have to eat a limited variety of foods due to lack of resources?	0 = No (skip to Q4) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
3a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		

4	In the past four weeks, did you or any household member have to eat foods that you really did not want to eat because of lack of resources to obtain other types of food?	0 = No (skip to Q5) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
4a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		
5	In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	0 = No (skip to Q6) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
5a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		
6	In the past four weeks, did you or any other member have to eat fewer meals in a day because there was not enough food?	0 = No (skip to Q7) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
6a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		
7	In the past four weeks, was there ever no food to eat of any kind in your	0 = No (skip to Q8) 1 = Yes	Lack of Money	Lack of Food available

	household because of lack of resources to get food?		(please tick)	(please tick)
7a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		
8	In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?	0 = No (skip to Q9) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
8a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		
9	In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?	0 = No (Survey finished) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
9a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		

7.3 APPENDIX C: Published manuscript 1

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ORIGINAL CONTRIBUTION

Influence of income on diet quality and daily iron and zinc intake: analysis of the National Diet and Nutrition Survey of British females aged 11–14 and 15–18 years

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Abstract

Purpose A negative socio-economic gradient exists for diet and health outcomes. Since cheaper diets are associated with increased energy and lower nutrient density, we investigated the influence of income on iron and zinc intakes and overall diet quality for adolescent (DQI-A) females aged 11–18 years.

Methods National Diet and Nutrition Survey (NDNS years 7 and 8) data for iron and zinc intake and overall diet quality was assessed by household income quintile across females aged 11–18 years.

Results Equivalised household income positively correlated with Diet quality index for adolescents (DQI-A) ($P<0.001$) Females aged 15–18 years in income quintiles (IQs) I and 2, had a greater proportion of respondents with low to intermediate DQI-A score compared to higher IQs ($P=0.002$). NDNS data showed intake was negatively influenced by income amongst females aged 11–14 years for iron ($P=0.009$) and zinc ($P=0.001$) with those from the lowest incomes consistently consuming significantly less than those from the highest. DQI-A was positively correlated with iron intakes for 11–14 ($P=0.001$) and 15–18 years ($P<0.001$). Forty-one percent of 15–18-year-olds plasma ferritin stores were below the 15 µg L^{-1} and 21% had some form of anaemia. Cereal and cereal products were the greatest contributors to iron in all groups.

Conclusion Females in the lowest income groups are at greater risk of lower overall diet quality and inadequate iron and zinc intakes. Amongst older adolescents, there is evidence of iron stores being depleted and an increased prevalence of anaemia.

Keywords Adolescent females · Iron · Zinc · Household income · Diet quality index-adolescents

Introduction

Iron and zinc are essential dietary minerals fundamental for growth and development [1, 2]. During adolescence, defined as the period spanning 10–19 years, females' physiological requirements for both minerals are increased due to the onset of puberty, [3] increased growth and energy requirements [4] and loss due to menstruation [5]. This, coupled with low dietary intakes, can result in a low iron and zinc status [6]. During the adolescent years, zinc accumulates in muscle and bone at an increased rate and sub-optimal intakes are associated with poor growth and reduced appetite [4]. However, evidence suggests that their provision remains inadequate for many. The prevalence of anaemia in non-pregnant women in the UK is currently estimated at 14% [7] and levels in adolescent girls have previously ranged between 10 and 20% [8]. Low dietary intakes of both minerals may be influenced by economic status. Children living in a household where the occupation is listed as manual are more likely to have a daily iron intake below the LRNI compared to children living in households where the occupation is managerial or professional [9]. Insufficiency of either mineral may negatively impact adolescent females' physical and cognitive development [4, 10]. Sub-optimal iron intakes have been found to limit female adolescent cognitive function and school performance, whilst an increase in iron status improved learning [8, 11]. This implies that deficiency may be felt in the economic potential of adulthood [12].

Optimal intakes of either nutrient are required to ensure an effective immune response against invading pathogens and lessen the severity and duration of illness [13–16].

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Iron and zinc deficiency has been shown to be a factor in the recurrence of childhood respiratory tract infection whilst zinc supplementation in children decreases the incidence and prevalence of pneumonia [13].

The factors which influence an adolescent female's dietary mineral intake are many and they include but are not limited to increased autonomy and decision-making around food, including frequency of eating out of home [4], dietary preference such as the adoption of vegetarian or vegan diets [17] as well as the influence of their peers [4]. Furthermore, food available in the school environment is also a factor in the diet of adolescent females and free school meals can be a way to increase the intakes of healthy foods [18] (Table 1).

However, during lockdown it was found children consumed fewer fruit and vegetables especially among poorer groups [19]. It is of concern that socioeconomic status has been shown to be positively associated with micronutrient intake [20] and there is evidence of a social gradient between diet quality and health outcome [21]. The ability to provide adolescent females with diets that align with nutritional guidelines is negatively impacted by household income. Diets more closely aligned with the government dietary guidelines may cost up to twice as much as those which are not [21, 22]. The cost of food may negatively influence the diversity of the diet and as such reduce the potential for obtaining an optimal quantity of micronutrients in low-income households. The price of food is a significant factor in determining purchasing decisions for low-income groups [21, 22], and cheaper diets are frequently associated with increased energy density and lower nutrient quality compared to higher-cost diets [23].

A recent report from Public Health England which analysed the National Diet and Nutrition Survey (NDNS) for all years found daily iron and zinc intake significantly increased with household income for children aged 1.5–3 and 4–10 years. A trend for increased iron and zinc intake with increasing household income was additionally seen for adolescents aged 11–18 years [24].

If females from poorer households consume lower intakes of iron and zinc and have an overall lower diet quality, then it is important to identify the barriers to obtaining an adequate intake of both minerals. The sources of the minerals in the diet as well as the eating occasions which are contributing to intakes, such as school meals, are required to be known for the development of interventions to reduce their risk of deficiency. In this study, we, therefore, set out to establish the extent to which iron and zinc intakes and overall diet quality amongst adolescent females are affected by household income and identify differences in types of foods consumed and eating occasions which might indicate potential routes for intervention.

Table 1 Percentage of females aged 11–14 and 15–18 years with "non-plausible" energy intakes and summary description of weight, BMI and food energy intake from the National Diet and Nutrition Survey (NDNS) by income quintile

Females		Total population		Income Quintile										P value
				1		2		3		4		5		
Number of "non-plausible" energy (kcal) reporters (%)	Age 11–14	41	(37)	11	(48)	5	(31)	12	(55)	7	(25)	6	(29)	0.156
	Age 15–18	57	(50)	11	(58)	17	(50)	5	(26)	16	(57)	8	(53)	0.252
Weight (kg) (S.E.M)	Age 11–14	52.5	(1.36)	51.3	(3.49)	50.7	(3.77)	52.3	(2.57)	52.6	(2.33)	55.1	(3.52)	0.838
	Age 15–18	64.0	(1.24)	66.8	(3.73)	62.9	(1.97)	57.7	(2.26)	65.5	(2.75)	67.9	(3.37)	0.131
BMI (S.E.M)	Age 11–14	21.1	(0.46)	21.1	(1.04)	20.6	(1.37)	21.6	(0.94)	20.7	(0.87)	21.7	(1.21)	0.631
	Age 15–18	23.8	(0.44)	24.8	(1.32)	24.1	(0.79)	21.1	(0.66)	24.2	(1.01)	24.6	(0.82)	0.052
Total energy diet only (kcal) (S.E.M)	Age 11–14	1165	(41.03)	1096	(86.12)	1238	(144.23)	1047	(80.17)	1321	(55.29)	1283	(42.38)	0.118
	Age 15–18	1225	(35.32)	1207	(83.24)	1224	(74.62)	1189	(85.76)	1250	(68.06)	1223	(87.28)	0.992

Number of respondents with a "non-plausible" total food energy (kcal) intake. Results are shown as mean and S.E.M for Total food energy (kcal) for "non-plausible" reporters. BMI and weight (kg) are shown as mean and S.E.M for the total population with valid weight and equivalised income. Number of participants included in analysis females 11–14 years ($n=110$), IQ1 $n=23$, IQ2 $n=16$, IQ3 $n=22$, IQ4 $n=28$, IQ5 $n=21$. Females 15–18 years ($n=115$), IQ1 $n=19$, IQ2 $n=34$, IQ3 $n=19$, IQ4 $n=28$, IQ5 $n=15$

Materials and methods

Data for years 7 and 8 (2014/15–2016/16) of the UK NDNS rolling programme were sourced from the UK Data Service [25]. Years 7&8 were chosen as they comprised the most recent version of the survey at the time of study and provided values of equivalised household income, in addition to indices of multiple deprivations (IMD) as quintiles from 1 'least deprived' to 5 'most deprived'.

Overall diet quality of females aged 11–18 years

NDNS food level data provides details of the type and quantity of food consumed. We used the variables 'Food name' and 'Sub food group description' to assign food groups to the categories laid out within the diet quality index for adolescent (DQI-A) as per previous studies [26, 27]. The DQI-A is a validated tool comprised of three components; dietary quality (DQ), diet diversity (DD) and dietary equilibrium (DE) and is based on food groups within the Flemish food-based dietary guidelines. These are similar to the UK food-based dietary guidelines. This tool is validated and was used in the HELENA Study which assessed the DQI of Adolescents in 10 European cities [26, 27]. Milk alternatives were placed within the milk and dairy category. Savoury sauces and pickles, nutrition powders, artificial sweeteners and dietary supplements were not included in the analysis.

Calculation of DQI-A

The diet quality index for adolescents was derived by calculating a mean score of the 3- or 4-day diet diaries for each of the participants for each of the DQI-A components: diet quality, diet diversity and dietary equilibrium and dividing by 3. Foods were allocated to either a preference group (recommended for consumption), an intermediate group or a low nutrient, energy-dense group and assigned a value of 1, 0 or – 1, respectively [26]. The diet quality component is aligned with food-based dietary guidelines and is concerned with making optimal food choices from each of the food groups [26, 27]. Food weighting values are multiplied by the quantity (physical weight) of food consumed. Results are summed and divided by the sum of total food consumed (g), then multiplied by 100. The diet diversity component represents the variety of food groups within the diet and is derived by averaging the total weight of food consumed and applying serving sizes as previously described [27]. A score of 1 is given if weight of food in the 9 recommended food groups equals or exceeds the recommended serving size for that food group, 0 if below the recommended serving size. The diet diversity score is summed, divided by 9 and multiplied by 100. Dietary equilibrium component is calculated by subtracting the results from 'dietary adequacy' (which is concerned with meeting minimum recommended intakes) from 'dietary excess' subcomponents (which is concerned with exceeding the upper limits of recommended intakes) and multiplying by 100 [26]. The higher the score the better the quality of the diet. Scores for DQI-A range from – 33 to 100. Scores of – 33 to 0 typically indicate a low diet quality, > 0 to 33 intermediate, > 33 to 66 good and > 66 very good [27]. We further condensed the values into two groups for the purpose of Chi-Square analysis. These were – 33 to 33% (low) and 33 to 100% (high).

Iron and zinc intake of females aged 11–14 and 15–18 years in the UK

Person-level estimated daily average intake of micronutrients for iron and zinc was available for children and adolescents (11–18 years of age). Mean values for iron and zinc were compared with age and gender-specific reference nutrient intakes (RNI) and lower reference nutrient intake (LRNI). Income quintiles (IQ) were created from established equivalised household income data provided by the NDNS for children aged 1–18 years in SPSS (IQ1 < £12,152.43, IQ2 ≥ £12,152.43, IQ3 ≥ 19,230.42, IQ4 ≥ £27,541.95 and IQ5 ≥ £43,402.43). We created a separate variable of daily equivalised household income by dividing equivalised household income by 365 for use in liner regression analysis to understand the relationship between income, iron and zinc intakes and DQI-A. The contribution of food groups to average iron and zinc intakes was calculated from food level data. This was completed for total intakes in addition to separate analyses which examined solely those foods consumed in school. For analysis of school intakes, only foods which comprised either hot food provision or alternative foods purchased on school premises were included.

Sensitivity analysis "plausible" reporters

"Plausible" reporters of energy intakes determined by calculating the Energy Intake/Basal Metabolic Rate (EI/BMR) and applying physical activity level (PAL) values and cut-off points (age dependent). "Plausible" reporters were participants with EI/BMR ratio within the cut-off point values as previously published [28]. Low reporters were included in the analysis but highlighted to indicate caution in the interpretation of findings.

Statistical analysis

The statistical analysis was performed using the SPSS Statistical package (Version 26.0 and 27.0. Armonk, NY: IBM Corp, Released 2020). Participant characteristics are presented as means and standard error of the mean (S.E.M). DQI-A results are presented as means ± S.E.M.

Linear regression is used to determine whether daily equivalised household income predicts DQI-A and if equivalised daily household income and DQI-A predict variance in iron and zinc intakes. Chi-square analysis was performed to understand if the representation of participants with low to intermediate (− 33 to 33) and intermediate to high DQI-A (> 33) scores varied across income quintiles and if the representation of "plausible" energy reporters differs across income quintiles. Normality of the distribution of the food data as grouped by the DQI-A tool was evaluated using Shapiro–Wilks. Results of all food groups indicated non-normally distributed data ($P < 0.05$). Non-parametric Mann–Whitney U tests were performed for comparison of the total weight of food consumed within each of the food groups for low to intermediate and intermediate to high DQI-A scorers. Results are presented as median with IQR.

Pearson's correlation was used to compare DQI-A, dietary mineral intakes with plasma ferritin, haemoglobin, and zinc levels.

The National Diet and Nutrition Survey person-level dietary data were also analysed, with descriptive statistics computed for each of the population groups for the percentage of the population meeting the RNI, percentage of the population with an intake below 90% of the RNI and percentage of the population with intakes below the lower reference nutrient intake (LRNI). Food level data were grouped as per the NDNS results for food groups.

Normality of the data was determined, and the appropriate parametric or non-parametric test conducted. Kruskal–Wallis tests were performed to determine variation between daily iron and zinc intake across different income quintiles. Participants were excluded from the analysis for income quintiles when a value for equivalised household income was not provided.

Results

Population characteristics

The NDNS data for years 7 and 8 contained dietary information for 272 females aged 11–18 years but only 231 had details of household income (mean age 14.7 ± 0.15 years), of which 11–14 olds accounted for 47.8% (12.6 ± 0.10 years)- and 15–18-year-olds 52.2% (16.6 ± 0.1 years). The largest proportion of the respondents living in the most deprived areas of the UK was from the lowest income quintile (IQ1; 36.6%), whilst the largest proportion in the least deprived areas were those with the highest income (IQ5; 32.4%). Amongst females aged 11–14, 26.1% of those in IQ1 lived in the most deprived areas of the UK and 27.3% of IQ5 lived in the least deprived areas, whilst for females aged 15–18 years these proportions rose to 47.6% and 40.0%, respectively.

Overall diet quality

All diet quality assessments varied positively with income and typically the food groups consumed in a greater quantity by those with a higher DQI-score were from the food groups associated with a higher micronutrient composition such as 'fruits' ($P < 0.001$), 'vegetables' ($P < 0.001$), 'milk products' ($P < 0.001$), 'bread and cereals' ($P = 0.002$), whilst those associated with a higher energy content such as 'snacks and candy' and 'sugared drink and fruit juice' were consumed in similar quantities in both low and high DQI-A scorers ($P = 0.871$; $P = 0.793$, respectively). The food groups remained similar when broken down by age group with 11–14-year-olds with a higher DQI-A score consuming a greater weight of food from the food groups listed above and this was mostly the same for 15–18-year-olds.

Representation of participants with low or high DQI-A between the income quintiles

The DQI-A (ranges from − 33 to 100% [27] was 38.7 ± 0.92 on average across the population. When separated into age categories, DQI-A was 39.3 ± 1.2% and 38.2 ± 1.4% for 11–14-year-olds and 15–18-year-olds, respectively. DQI-A varied considerably from -5.78 up to 72.74 and this range was present in all income quintiles. Chi-Square analysis of the data for all females found that having a low to intermediate (− 33 to 33%) or intermediate to high DQI-A (> 33%) was moderately dependent on the income quintile (Cramer's $v = 0.307$). A greater proportion of females in IQ1 and IQ2 had a DQI-A score of 33% or below (40.9% and 49.0%, respectively) compared to IQ3 (32.6%), IQ4 (25.0%) and IQ5 (5.4%; $P < 0.001$). This was predominantly driven by outcomes for 15–18-year-olds ($P = 0.002$; Cramer's $v = 0.379$) as the association was not significant for the 11–14 s ($P = 0.282$). In the older group, the proportions below DQI-A of 33% rose to 47.6% and 55.9% for IQs 1 and 2 ($P = 0.002$).

Relationship between equivalised household income and diet quality component (DQc) of DQI-A

The dietary quality component of DQI was low for both 11–14 (15.3 ± 2.85%) and 15–18-year-olds (11.6 ± 3.13; Range = − 100 to + 100). Income was directly associated with DQc ($P = 0.001$; β 0.216). For every £1 increase in weekly equivalised household income DQc increased 0.135%. Income was not a predictor of DQc for females 11–14 years ($P = 0.293$) but was for 15–18-year-olds

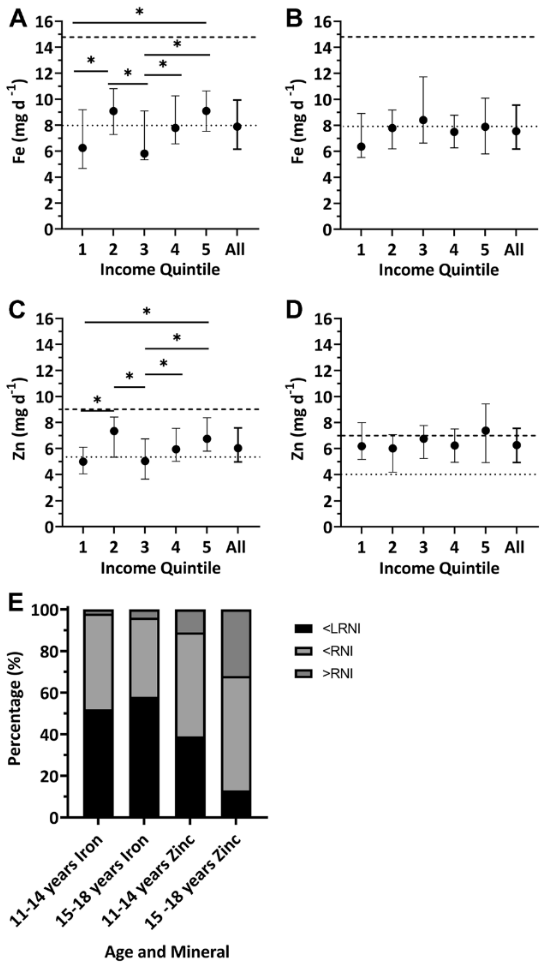

Fig. 1 **A**, **B** Median and interquartile range for daily dietary iron intake (mg day^{-1}) from food sources only: females aged 11–14 and 15–18 years across income quintiles (IQ). Kruskal—Wallis test was performed in IBM SPSSv26 to evaluate the potential influence of equivalised household income on daily iron intake, post-hoc Mann–Whitney test performed when significance detected at the Kruskal–Wallis stage. Lower bound values for income quintiles are as follows: (IQ1) < £12,152.43, (IQ2) ≥ £12,152.43, (IQ3) ≥ £19,230.42, (IQ4) ≥ £27,541.95, (IQ5) ≥ £43,402.43. Dotted line represents Lower Reference Nutrient Intake (LRNI), dashed line represents Reference Nutrient Intake (RNI). Number of participants included in the analysis with a valid income female 11–14 years IQ1 $n=23$, IQ2 $n=17$, IQ3 $n=24$, IQ4 $n=28$, IQ5 $n=22$. Females 15–18 years IQ1 $n=21$, IQ2 $n=34$, IQ3 $n=19$, IQ4 $n=28$, IQ5 $n=15$. *Significant at the $P<0.05$ level. **C**, **D** Median and interquartile ranges for daily dietary zinc intakes (mg day^{-1}) from food sources only: females aged 11–14 and 15–18 years across income quintiles (IQ). Kruskal–Wallis test was performed in IBM SPSSv26 to evaluate the potential influence of equivalised household income on daily zinc intake, post-hoc Mann–Whitney test was performed when significance detected at the Kruskal–Wallis stage. Lower bound values for income quintiles are as follows: (IQ1) < £12,152.43, (IQ2) ≥ £12,152.43, (IQ3) ≥ £19,230.42, (IQ4) ≥ £27,541.95, (IQ5) ≥ £43,402.43. Dotted line represents Lower Reference Nutrient Intake (LRNI), dashed line represents Reference Nutrient Intake (RNI). Number of participants included in the analysis with a valid income female 11–14 years IQ1 $n=23$, IQ2 $n=17$, IQ3 $n=24$, IQ4 $n=28$, IQ5 $n=22$. Females 15–18 years IQ1 $n=21$, IQ2 $n=34$, IQ3 $n=19$, IQ4 $n=28$, IQ5 $n=15$. *Significant at the $P<0.05$ level. **E** Percentage of females aged 11–14 and 15–18 years with daily iron and zinc intakes below the Lower Reference Nutrient Intake (LRNI) and above or below the Reference Nutrient Intake (RNI). Data sourced from the National Diet Nutrition Survey (NDNS) years 7 & 8 of the rolling programme. Number of participants: females, 11–14 years $n=130$ and females 15–18 years $n=142$

($P<0001$) with every £1 increase in income resulting in an increase of DQc of 0.221%.

DQI-A and weight of food consumed within food groups

For those with a low to intermediate DQI–A score ($n=73$) their diets predominantly comprised a lower weight of fruits (26.3 g, IQR 105.3 g) compared to intermediate to high DQI-A score ($n=158$; 112.3 g, IQR 149.4 g; $P<0.001$). They also consumed fewer 'vegetables' (39.1 g, IQR 54.2 g vs 84.3 g, IQR 84 g; $P<0.001$), 'milk products' (75.0 g, IQR 112.2 g vs 156.3 g, IQR 170.1 g; $P<0.001$), 'bread and cereal' (94.3 g, IQR 54.5 g vs 114.6 g IQR 83.5; $P=0.002$) and 'fats and oils' (5.3 g, IQR 9.6 g vs 9.7 g, IQR 10.5 g; $P=0.016$) compared to intermediate to high DQI-A scorers. The food groups 'sugared drinks and fruit juice', 'snacks and candy', 'potatoes and grains' 'meat, fish and substitutes were all consumed in similar amounts between the DQI-A groups ($P=0.703$; $P=0.871$; $P=0.628$; $P=0.912$, respectively). The pattern was similar for both age categories with 11–14 low DQI-A consuming lower quantities of vegetables (44% less), fruits (67% less), 'meat, fish and substitutes' (17% less) and milk products (58% less) than high DQI-A and for 15–18-year-olds these values were 59%, 72% and 39% for vegetables, fruit and milk products, respectively ($P<0.001$). It was additionally of note that 15–18-year-olds in the low DQI-A group consumed 36% more free sugars than those from the higher DQI-A group ($P=0.004$).

The influence of household income on iron, zinc and energy intake in UK female adolescents

Iron

Iron intakes of females aged 11–18 years were frequently below the RNI (Fig. 1A and B dashed line). For those between 11 and 14 years ($n=130$) 98% had an iron intake below the RNI (14.8 mg/day) with 52% being below the LRNI (8.0 mg/day), whilst for females between 15 and

18 years, ($n=142$) 58%, were below the LRNI, with 96% below the RNI (Fig. 1E).

Daily iron intakes differed significantly across income quintiles (IQ) for females aged 11–14 years ($P=0.009$) with those in IQ5 (61% of RNI) being significantly higher compared with IQ1 (just 42% of RNI; $P=0.014$) and IQ3 (39% of RNI; $P=0.005$). The IQ4 group (53% of RNI) consumed more than IQ3 ($P=0.035$) and intake in IQ2 was considerably higher than for those in the adjacent quintiles (37% higher than IQ1—$P=0.039$ and 44% higher than IQ3—$P=0.024$). Females aged 15–18 showed similar intakes across income quintiles.

Plasma ferritin concentrations were generally in the normal range (41–400 μg L^{-1}) but were 27% lower in the 15–18 years group compared with the 11–14 s ($P=0.02$; Supplementary Table 1). The proportion of 11–14 s who fell below the 15 μg L^{-1} threshold indicator of low iron stores [29] was 10% but amongst the older girls (15–18 years) this reached 41%. Haemoglobin levels exceeded 120 g L^{-1} for the majority, however, 21% of females aged 15–18 years had some form of anaemia, with 14% showing mild (haemoglobin level between 110 and 119 g L^{-1}) and 7% moderate anaemia (haemoglobin 80–109 g L^{-1}).

DQI-A scores showed a significant positive relationship with iron intakes (β 0.303, $P<0.001$) with every 1% increase in DQI-A resulting in a 0.066 mg increase in iron for all participants. This was similar for 11–14 (β 0.301, $P=0.001$; 0. 069 mg increase per 1% DQI-A) and 15–18-year-olds (β 0.306, $P=0.001$). Neither ferritin nor haemoglobin correlated with DQI-A scores in either group.

Zinc

Zinc intakes were low in both age groups (Fig. 1C and D) with 39% of females aged 11–14 years and 13% in the 15–18 years category having a zinc intake below the LRNI (5.3 mg day^{-1}; Fig. 1E). Only 11% of 11–14-year-old girls achieved the RNI for zinc (9.0 mg/day), whilst 68% of 15–18 years group were below their respective RNI (7.0 mg/day) (Fig. 1E).

The zinc intakes of females aged 11–14 years also differed with household income ($P=0.001$; Fig. 1C), with those in quintile 1 being the lowest. This group showed a lower consumption (55% of the RNI) compared with IQ2 (81% of RNI; $P=0.026$) and IQ5 (75% of RNI; $P=0.004$). Similar to the findings for iron intake, 11–14-year-old females in IQ2 consumed significantly more zinc than those in the adjacent quintiles (32% higher than IQ1—$P=0.026$ and 40% higher than IQ3—$P=0.026$). Zinc intake did not differ with income quintile in the 15–18 years group (Fig. 1D).

Daily zinc intakes were positively associated with DQI-A in all (β 0.373, $P<0.001$), with 0.061 mg (β 0.390 $P<0.001$) and 0.071 mg (β 0.306 $P<0.001$) increases for each 1% increase in DQI_A (11–14 and 15–18, respectively).

Energy intakes

Females aged 11–18 years with values for body weight and equivalised household income were included in the analysis ($n=225$) to identify "plausible" and "non-plausible" reporters of energy intakes (kcal). In total, 43.6% of females did not have a "plausible" energy intake. When analysed by age range, 37.3% of 11–14-year-olds ($n=110$) and 50% of 15–18-year-olds ($n=115$) did not have "plausible" energy intakes. There were no differences in reporting reliability across income quintiles for either age group ($P=0.156$, $P=0.252$, respectively).

Contribution of different foods to iron and zinc intake

Foods that had the greatest contribution to daily iron intakes were cereal and meat based (hereafter referred to as cereal and meat products; Supplementary tables 2 and 3), with meat contributing an increasing proportion in older groups ($P<0.001$; Supplementary tables 5 and 6). These, in addition to vegetables, vegetable products and potatoes (hereafter vegetable products) and milk products were significant contributors to zinc intakes.

Females aged 11–14 years

Iron

Most of the iron intake in females aged 11–14 years was from cereal (52%), meat (14%) and vegetable products (12%; Supplementary table 2). Flour-containing foods contributed ~ 35% of the total iron intake whilst breakfast cereals, consumed by 62% of participants, contributed 16%. Although neither the quantity nor proportion of daily iron intake from breakfast cereals differed across income quintiles ($P=0.077$ and $P=0.699$, respectively) the total quantity of cereal-based products consumed did ($P=0.001$; Supplementary Table 4). Of note, females in IQ2 consumed more than those in IQ1 ($P=0.047$) and IQ3 ($P=0.001$). Meat products were consumed by 98% of respondents and no differences in intake were observed between quintiles for either meat or vegetables. We estimated the bioavailable iron from each participant's diet by assuming that the absorption of iron from vegetable sources would be 10% of intake and that from animal sources (all assumed to be haem iron—meat and fish) would be 25% [30]. For those who met the 1.4 mg day^{-1} threshold indicated as necessary for females of 11–18 years old [31], the iron derived from meat and fish was approximately 30% higher than for those who fell short of this level ($P=0.026$).

Zinc

Meat (31%) and cereal products (31%) were the main contributors to zinc intake with milk products providing most of the remainder (16%; supplementary table 3). The percentage contributions of food groups did not vary greatly between those achieving the 9 mg RNI, however, when individuals were separated according to those who achieved 7 mg (the RNI for all older age groups) and those who did not, then milk was shown to provide a significantly higher proportion of zinc (32% higher; $P=0.013$) than for those below the 7 mg threshold.

Females aged 15–18 years

Iron

Iron in 15–18-year-old females was again predominantly derived from cereal (46%), meat (17%) and vegetable products (15%; Supplementary table 5). All participants reported consuming some form of meat. Again, 35% of daily iron intake was contributed by flour-containing foods. Just 50% reported eating breakfast cereals. This resulted in only 12% iron provision by breakfast cereals. Iron provision from meat and fish combined was similar between those achieving the predicted 1.4 mg day^{-1} threshold compared with those below this level ($P=0.485$). The proportion of iron obtained from meat was 23% greater than for the 11–14 age group ($P<0.001$).

Zinc

The largest contributor to zinc intake in 15–18-year-old females was meat (35%; Supplementary table 6). Although this did not differ overall by income, the quantity of zinc derived from burgers and kebabs did, being significantly negatively associated with income level ($P=0.026$). Cereals, milk and vegetables are provided between 11% and 18% each. Vegetable consumption was positively associated with income ($P=0.028$). Those who consumed less than the 7 mg RNI, obtained a significantly greater proportion (18% higher; $P=0.029$) of their zinc intake from cereal products compared with those whose intakes exceeded 7 mg.

Contribution of school foods to iron and zinc intakes

For many, particularly those on low incomes, school food provision would potentially contribute greatly to dietary intake of critical nutrients. We, therefore, determined the intake of iron and zinc from school-provided meals for 11–18-year-olds. Of the respondents who recorded diet diary days during school time, we found that across all ages, 45% consumed school-provided meals of which 78% were cooked. The proportions of children consuming school meals were similar across income groups. Half of the girls who consumed school meals obtained around 25% (26.2% of total; IQR 18.4–35.3%) of their daily iron intakes from them, while for zinc, this was slightly higher at 30.2% of total intake (IQR 24.3–43.9%). School meals should provide 35% of the requirements [32] and we found that this was the case for just 17% and 20% of girls for iron and zinc, respectively across all age groups.

Impact of education and gender of main food provider

Whilst higher levels of education are usually associated with higher household income and better diets, we found no evidence of a difference in the iron and zinc intakes of females 11–14 ($P=0.788$, $P=0.487$, respectively) and 15–18 years ($P=0.962$, $P=0.872$, respectively) when living in a household where the main food provider had a degree ($n=38$, $n=32$, respectively) compared to those who did not ($n=74$, $n=76$, respectively). Gender of the main food provider also was not associated with iron and zinc intakes in both age groups (11–14 years iron $P=0.397$, zinc $P=0.460$; 15–18 years iron $P=0.164$, zinc $P=0.413$).

Household income source

Very few respondents were solely dependent on benefits ($n=20$), whilst there was a number who received benefits in addition to income from employment ($n=171$). Because of the low numbers of benefits only, both age groups were combined. Whilst females living in a household with income from employment had a numerically greater iron intake (8.23 ± 024 mg day^{-1}) compared to females living in a household with income solely from non-working sources (7.78 ± 0.58 mg day^{-1}) this was not significant ($P=0.539$) and this was similar for zinc (employment 6.29 mg$\pm$0.17 mg day^{-1}, solely benefits 5.75 mg$\pm$0.36 mg day^{-1}; $P=0.289$).

Discussion

Iron and zinc deficiency continues to be of concern for many children in the UK. Our data indicated a decrease in iron and zinc from food sources amongst females aged 11–18 years compared with observations from previous years particularly amongst the older females [23]. We found, similar to previous work, [23] that income influenced iron and zinc intake with those in the lowest income quintile most frequently consuming the least. We also showed that diet diversity was compromised in those from lower incomes, particularly for older adolescents. These observations suggest that there may be a considerable number of disadvantaged children who not only consume low quantities of iron and zinc but may be further compromised by the composition of the foods that can be afforded.

Intake levels

Dietary iron and zinc intakes for females aged 11–14 and 15–18 years were low compared to the RNI and for many were below the LRNI, indicating that iron intake was insufficient to meet requirements at a time when the physiological demand to support growth and development is at its greatest [5]. The RNI is set at 14.8 mg day^{-1} for females aged 11–18 years and for non-menopausal women, to account for a typical daily iron loss of 0.8 mg day^{-1}, with an additional 0.6 mg day^{-1} due to menstruation, in the face of a bioavailability of iron from food sources of approximately 10% [33]. Therefore, for females to remain iron replete there is a requirement for 1.4 mg of iron to be absorbed from the diet daily [33]. Dietary iron intake for 11–14- and 15–18-year-olds was half of the RNI, indicating suboptimal intakes which, if sustained, could lead to depletion of iron stores and anaemia. We found that 10% of females aged 11–14 years had plasma ferritin levels below 15 µg L^{-1}, potentially indicating low iron storage, although this may be more reflective of stores being utilised to support growth and development [5] particularly since haemoglobin levels were normal in this group (Supplementary Table 1). However, a large proportion (41%) of 15–18-year-old females had plasma ferritin levels < 15 µg L^{-1} with 21% of them having haemoglobin levels indicative of anaemia. Sustained suboptimal iron intake and increased physiological requirements may have resulted in the development of anaemia in a subset of the 15–18-year-old girls in this age group. Other factors which may contribute to anaemia, including B12 and folate intake and clinical factors, such as thalassemia, inflammatory conditions and haemolysis were not considered in this study, but they represent far less frequent causes of anaemia than low iron intake. Iron deficiency in the absence of anaemia can have adverse consequences on mental capacity and immune health [34] and importantly, adolescents entering the reproductive years may not have sufficient iron stores to support the increased demand during pregnancy, estimated at 4–6 mg daily [33]. The frequency of anaemia in pregnancy has been recorded at levels as high as 46% in some UK cohorts [35, 36] representing a significant health risk for the mother and developing child [37] and it seems likely that those individuals who have been exposed to moderate iron deficiency during their teenage years, would likely comprise a significant proportion of this anaemic cohort.

The bioavailability of iron differs considerably between animal and plant-based foods. Iron from animal products is more bioavailable as it is in the form of haem iron, of which 25–30% is absorbed via the intestinal haem carrier protein 1 (HCP1 or SLC46A1). Iron from plant-based foods is predominantly in the form of Fe^{3+} which must be reduced to Fe^{2+} to enable its absorption through the divalent metal transporter 1 (DMT1 or SLC11A2). Consequently, only between 1 and 10% of the iron derived from plant sources is absorbed [11]. Zinc and iron are additionally impacted when acquired from plant-based sources, due to the presence of phytic acid which binds divalent ions, thereby inhibiting their absorption [38]. Therefore, diets high in plant material can potentially have a significant negative impact on iron and zinc status even if they contain them in relatively high concentrations. Consumption of antinutritional factors was not analysed in this report, principally due to the dearth of reliable food level data but is a factor which needs be considered in future work to help gain an understanding of the relative impact on status that this may be having in the UK population.

Zinc intake was below the RNI for a large proportion of both age groups (78.3% of all females). We found a significant negative association between intake and household income (Fig. 1), contrary to findings for previous NDNS cohorts [39] which reported no effect. Household inequality has been approximately stable over the last decade but was more volatile prior to 2010 [40], increasing sharply in non-retired households from 2002 to a peak in 2008 just before the economic downturn. The negative effect of declining household income on the ability of families to adequately feed their children is well documented [41–43]. Differences observed between income quintiles for intake in females for both age groups for both iron and zinc, therefore, may reflect a negative impact of early life exposure to inequality. Previous data which did not find an association with household income [39] is derived from individuals who were living through a period of relative stability in the level of inequality (~ 1987–1997). It is of note that children who comprised the 11–14 years cohort in the 2014–2016 NDNS survey would have ranged from 0 to 2 at the start of the steep rise in inequality. It is possible that discrepancies in consumption may link to economic challenges occurring at the very start of their lives.

Underreporting

Underreporting was widespread and was particularly high for 11–14-year-old females in IQ1 and IQ3 where 48% and 55% had "non-plausible" energy intakes. It has been shown that adolescent females are more likely to underreport energy intakes, particularly those with a higher BMI. Factors such as forgetfulness, eating meals outside of the home and being conscious of body weight and image impact reporting reliability [44] and this is particularly stark for adolescent females as up to 49% of respondents' energy intakes are low compared to estimated Basal Metabolic Rates (BMR) [45].

The underreporting will have inevitably skewed data in our study to indicate a higher proportion of individuals consuming below the RNI. However, there would remain a significant proportion of girls aged 11–18 years studied who were marginally deficient for iron. This was evident from the numbers of girls aged 15–18 years with haemoglobin levels below the cut-off point for diagnosis of anaemia. Whilst for 11–14-year-olds haemoglobin levels were above the threshold for anaemia, 10% had depleted serum ferritin stores, increasing to 41% in 15–18-year-olds. These values, whilst in themselves are not the best indicators of status, do support the outcomes of low consumption levels seen in the dietary data.

DQI-A outcomes

The results from our study found DQI-A for females aged 11–18 years overall, was 38.7% indicating average adherence to food-based dietary guidelines. The results for DQI-A in this study are slightly higher compared to a previously published study which reported DQI-A of 31.4% for adolescent females [27]. Overall females in the highest income quintile, DQI-A score was greater than those in the lowest (47.9% compared to 35.1%, respectively) and this was particularly pronounced amongst 15–18 years olds where DQI-A of females with the lowest income quintile was 16 percent lower compared to the females in the highest income quintile. Foods typically thought of as nutrient dense and low energy were consumed in lower quantities among females aged 15–18 years with a DQI-A score below 33% compared to those with a DQI-A above 33%, indicating that diets among girls in this age group in lower income quintiles are worse compared to their higher-income peers. This was supported by the observation that free sugar consumption in those with a low DQI-A was higher than in high DQI-A, and likely a consequence that these girls are making more autonomous dietary decisions.

Food contributions

The food group which contributed the greatest proportion of dietary iron was cereal products. Of these, the main single contributor was flour (~ 36% for 11–14 years and ~ 34% for 15–18 years). This would suggest that flour contributed ~ 34% of the total iron intake with breakfast cereals providing another 17%. Of the remainder, around 28% was from meat and vegetable products. This highlights the value of appropriate fortification of flour and of consuming breakfast cereals which was not universal in these cohorts. The relative contribution of breakfast cereals to iron intakes suggests that those choosing not to consume them are at significant risk of falling further short of the recommended intake levels. It should also be noted that not all breakfast cereals are fortified equivalently, so there may be some value in standardisation of cereal fortification to help ensure their ability to enable adequate iron intakes.

We noticed a higher contribution (30%) to dietary iron from meat and fish in 11–14-year-old females able to achieve their iron intake requirements compared with those who were not. The widespread consumption of meat across the whole population would suggest that provision of iron from meat sources might represent a viable strategy for increasing iron levels, particularly for those who do not consume breakfast cereals. This may be particularly pertinent for females aged 15–18 years as meat contributed a significantly higher proportion of iron for them than for the younger group. An important barrier to this would be cost. However, meals made from cheaper ingredients, whilst potentially lower in iron concentration, could still provide a cost-effective alternative. Females from lower income quintiles in the 15–18-year age group obtained proportionally more zinc from burgers and kebabs than those from the higher quintiles. A larger proportion of these teenagers may therefore be making their own dietary choices outside of the home than those from wealthier backgrounds. This is likely to impede successful interventions aimed at improving diet quality and diversity as the routes of successful communication will be more limited.

Food cost

The cost of foods influences the types purchased and diets aligned with government recommendation are more expensive than those which are not [43]. Additionally, food cost is also a factor in the food security of households, especially if available foods are not affordable [46]. Availability and affordability of foods and household food security have recently received attention due to the COVID-19 pandemic which resulted in panic buying of staple foods reducing the availability of lower-cost food items [47]. This reduced the size and quality of the diet of low-income households and increased food insecurity as they do not have the disposable income to purchase foods in bulk or to purchase higher-cost alternatives. During COVID-19 schools were closed and the safety net of school food removed, although families of children eligible for free school meals (FSM) were supported with a £15 voucher per week to provide lunch for their child. However, for many other families on a low income but not entitled to FSM, they had to bear the burden of increased food cost and increased quantities of food to be purchased to cover the meals not provided at school.

When the percentage of the population with an intake below LRNI exceeds 5% it may be a public health concern as clinically relevant deficiencies may occur [48]. This was highlighted in the SACN Iron and Health report [5], which found toddlers, girls and women of reproductive age to be at increased risk of iron deficiency anaemia. This was particularly apparent if they were from low-income groups [5]. Greater provision, therefore, needs to be made for those in low-income groups to support adequate iron and zinc nutrition during childhood with greater emphasis placed on mechanisms which allow the provision of important micronutrients. Novel mechanisms to facilitate access to and consumption of iron and zinc-rich foods in children, particularly those from lower-income households, are required with some urgency. The cost-of-living crisis has seen energy, fuel and food cost all increase in recent times (since late 2021) and disposable incomes decrease. Low-income households experience higher inflation compared to wealthy households [49] and whilst there are government strategies in place to help reduce the burden such as the cost of living support from May 2022 [50] these are one-off payments. The increase in Universal Credit during the COVID-19 pandemic provided households with a steady source of income and the removal of the uplift in October 2021 left many worried they would not be able to feed their families and rely on coping strategies such as reducing the quantity of food consumed and feeding children before adults [51], all of which may have negative impacts on the diet quality and micronutrient intakes of the most vulnerable population groups.

Conclusion

The overall diet quality of UK female adolescents in the lowest income quintiles is notably worse than for their higher-income peers and this negatively impacts the quantity of iron and zinc consumed. Furthermore, there is evidence for decreasing plasma ferritin and increasing the prevalence of anaemia as females enter their late teen years. Persistent low intakes in the face of high physiological requirements will compound the prevalence of deficiency and adverse health outcomes associated with sub-optimal micronutrient intakes often seen in lower-income groups. Interventions are required to increase iron and zinc intakes in female adolescents across all income quintiles with an emphasis on ensuring diets aligned with government dietary guidelines are accessible and affordable for all to ensure micronutrient intakes are adequate for the avoidance of 'hidden hunger' in the lowest income groups in the UK. Notably, we show that increasing income has a direct positive effect on DQI-A which in turn positively impacts iron and zinc intakes. School food is a good vehicle for the promotion of healthy diets and therefore, represents a potential avenue, outside of direct financial support, for improving health outcomes in adulthood and future generations as adolescent females enter the reproductive years.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00394-022-03000-z.

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Declarations

Conflict of interest The authors declare no conflicts of interest.

Ethics approval None required.

References

1. Anderson CP, Shen L, Eisenstein RS, Leibold EA (2012) Mammalian iron metabolism and its control by iron regulatory proteins. Biochim Biophys Acta 1823:1468–1483. https://doi.org/10.1016/j.bbamcr.2012.05.010
2. Black MM (1998) Zinc deficiency and child development. Am J Clin Nutr 68:464S-469S
3. Gibson RS, Heath A-LM, Ferguson EL (2002) Risk of suboptimal iron and zinc nutriture among adolescent girls in Australia and New Zealand: causes, consequences, and solutions: suboptimal iron and zinc nutriture among adolescent girls. Asia Pac J Clin Nutr 11:S543–S552. https://doi.org/10.1046/j.1440-6047.11.supp3.10.x
4. Langley-Evans S (2009) Nutrition: a Lifespan Approach. John Wiley & Sons, Incorporated, Hoboken
5. Great Britain, Scientific Advisory Committee on Nutrition, Jackson A (2011) Iron and health. Stationery Office, London
6. Samson KLI, Fischer JAJ, Roche ML (2022) Iron status, anemia, and iron interventions and their associations with cognitive and academic performance in adolescents: a systematic review. Nutrients 14:224. https://doi.org/10.3390/nu14010224
7. Prevalence | Background information | Anaemia—iron deficiency | CKS | NICE. https://cks.nice.org.uk/topics/anaemia-iron-deficiency/background-information/prevalence/. Accessed 19 Jan 2022
8. House of Commons—Education and Employment—Minutes of Evidence. https://publications.parliament.uk/pa/cm199900/cmselect/cmeduemp/96/9111009.htm. Accessed 21 Jan 2022
9. Gibson S, Sidnell A (2014) Nutrient adequacy and imbalance among young children aged 1–3 years in the UK. Nutr Bull 39:172–180. https://doi.org/10.1111/nbu.12087

10. Sorhaindo A, Feinstein L, Centre for Research on the Wider Benefits of Learning (London E (2006) What is the relationship between child nutrition and school outcomes? Centre for Research on the Wider Benefits of Learning, London
11. Skolmowska D, Głąbska D (2019) Analysis of heme and non-heme iron intake and iron dietary sources in adolescent menstruating females in a national polish sample. Nutrients 11:1049. https://doi.org/10.3390/nu11051049
12. Horton S, Ross J (2003) The economics of iron deficiency. Food Policy 28:51–75. https://doi.org/10.1016/S0306-9192(02)00070-2
13. Calder PC (2020) Nutrition, immunity and COVID-19. BMJ Nutr Prev Health 3:74–92. https://doi.org/10.1136/bmjnph-2020-000085
14. Calder PC (2013) Feeding the immune system. Proc Nutr Soc 72:299–309. https://doi.org/10.1017/S0029665113001286
15. Maares M, Haase H (2016) Zinc and immunity: an essential interrelation. Arch Biochem Biophys 611:58–65. https://doi.org/10.1016/j.abb.2016.03.022
16. Maggini S, Wenzlaff S, Hornig D (2010) Essential role of vitamin C and zinc in child immunity and health. J Int Med Res 38:386–414
17. Sergentanis TN, Chelmi M-E, Liampas A et al (2021) Vegetarian diets and eating disorders in adolescents and young adults: a systematic review. Children 8:12. https://doi.org/10.3390/children8010012
18. Vik FN, Van Lippevelde W, Øverby NC (2019) Free school meals as an approach to reduce health inequalities among 10–12- year-old Norwegian children. BMC Public Health 19:951. https://doi.org/10.1186/s12889-019-7286-z
19. Baraniuk C (2020) Fears grow of nutritional crisis in lockdown UK. BMJ. https://doi.org/10.1136/bmj.m3193
20. Novaković R, Cavelaars A, Geelen A et al (2014) Review Article Socio-economic determinants of micronutrient intake and status in Europe: a systematic review. Public Health Nutr 17:1031–1045. https://doi.org/10.1017/S1368980013001341
21. Darmon N, Drewnowski A (2015) Contribution of food prices and diet cost to socioeconomic disparities in diet quality and health: a systematic review and analysis. Nutr Rev 73:643–660. https://doi.org/10.1093/nutrit/nuv027
22. Steenhuis IH, Waterlander WE, de Mul A (2011) Consumer food choices: the role of price and pricing strategies. Public Health Nutr 14:2220–2226. https://doi.org/10.1017/S1368980011001637
23. Weichselbaum E, Buttriss JL (2014) Diet, nutrition and schoolchildren: an update. Nutr Bull 39:9–73. https://doi.org/10.1111/nbu.12071
24. Bates B, Collins D, Cox L, et al National Diet and Nutrition Survey: Years 1 to 9 of the rolling programme (2008/2009–2016/2017): Time trend and income analyses. 56
25. NatCen Social Research, MRC Elsie Widdowson Laboratory. (2019) National Diet and Nutrition Survey Years 1–9, 2008/09–2016/17. [data collection]. 15th Edition. UK Data Service, 2019
26. Vyncke K, Cruz Fernandez E, Fajó-Pascual M et al (2013) Validation of the Diet Quality Index for Adolescents by comparison with biomarkers, nutrient and food intakes: the HELENA study. Br J Nutr 109:2067–2078. https://doi.org/10.1017/S000711451200414X
27. Llauradó E, Albar SA, Giralt M et al (2016) The effect of snacking and eating frequency on dietary quality in British adolescents. Eur J Nutr 55:1789–1797. https://doi.org/10.1007/s00394-015-0997-8
28. EFSA (2013) Example of a protocol for identification of misreporting (under- and overreporting of energy intake) based on the PILOT-PANEU project
29. World Health Organisation Haemoglobin.pdf. https://www.who.int/vmnis/indicators/haemoglobin.pdf. Accessed 5 Jan 2021
30. Fairweather-Tait SJ (1992) Bioavailability of trace elements. Food Chem 43:213–217. https://doi.org/10.1016/0308-8146(92)90176-3
31. Great Britain (2008) Dietary reference values for food energy and nutrients for the United Kingdom: report, 18. impression. TSO, London
32. Mucavele P, Nicholas J, Sharp L Final Report compiled for the School Food Plan's Standards Panel. https://www.schoolfoodplan.com/wp-content/uploads/2014/02/School-Food-Plan-Pilot-study-EVALUATION-REPORT-Final-V3.pdf. Accessed 8 Apr 2020
33. Gibney MJ, Lanham-New SA, Cassidy A, Vorster HH Introduction to human nutrition, 2nd ed. Wiley-Blackwell
34. The Department of Health Report on Health and Social Subjects 41 Dietary Reference Values for Food Energy and Nutrients for the United Kingdom. The Stationery Office
35. Pavord S, Daru J, Prasannan N et al (2020) UK guidelines on the management of iron deficiency in pregnancy. Br J Haematol 188:819–830. https://doi.org/10.1111/bjh.16221
36. Nair M, Choudhury MK, Choudhury SS et al (2016) Association between maternal anaemia and pregnancy outcomes: a cohort study in Assam. India BMJ Glob Health 1:e000026. https://doi.org/10.1136/bmjgh-2015-000026
37. Abu-Ouf NM, Jan MM (2015) The impact of maternal iron deficiency and iron deficiency anemia on child's health. Saudi Med J 36:146–149. https://doi.org/10.15537/smj.2015.2.10289
38. Maares M, Haase H (2020) A guide to human zinc absorption: general overview and recent advances of in vitro intestinal models. Nutrients 12:762. https://doi.org/10.3390/nu12030762
39. Thane CW, Bates CJ, Prentice A (2004) Zinc and vitamin A intake and status in a national sample of British young people aged 4–18 y. Eur J Clin Nutr 58:363–375. https://doi.org/10.1038/sj.ejcn.1601792
40. Household income inequality, UK—Office for National Statistics. https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/bulletins/householdincomeinequalityfinancial/financialyearending2020provisional. Accessed 13 Feb 2021
41. French SA, Tangney CC, Crane MM et al (2019) Nutrition quality of food purchases varies by household income: the SHoPPER study. BMC Public Health 19:231. https://doi.org/10.1186/s12889-019-6546-2
42. Marmot Review report—Fair Society, Healthy Lives | Local Government Association. https://www.local.gov.uk/marmot-review-report-fair-society-healthy-lives. Accessed 31 Oct 2019
43. Scott C, Sutherland J, Taylor A (2018) Affordability of the UK's Eatwell Guide. https://foodfoundation.org.uk/wp-content/uploads/2018/10/Affordability-of-the-Eatwell-Guide_Final_Web-Version.pdf. Accessed 8 Apr 2020
44. Livingstone MB, Prentice AM, Coward WA et al (1992) Validation of estimates of energy intake by weighed dietary record and diet history in children and adolescents. Am J Clin Nutr 56:29–35. https://doi.org/10.1093/ajcn/56.1.29
45. Robinson S, Skelton R, Barker M, Wilman C (1999) Assessing the diet of adolescent girls in the UK. Public Health Nutr 2:571–577. https://doi.org/10.1017/S1368980099000762
46. Lee A, Mhurchu CN, Sacks G et al (2013) Monitoring the price and affordability of foods and diets globally. Obes Rev 14:82–95. https://doi.org/10.1111/obr.12078
47. Power M, Doherty B, Pybus K, Pickett K (2020) How COVID-19 has exposed inequalities in the UK food system: the case of UK food and poverty. Emerald Open Res 2:11. https://doi.org/10.35241/emeraldopenres.13539.1
48. Derbyshire E (2018) Micronutrient intakes of british adults across mid-life: a secondary analysis of the UK National Diet and Nutrition Survey. Front Nutr. https://doi.org/10.3389/fnut.2018.00055

49. Hourston P (2022) Cost of living crisis. In: Inst. Gov. https://www.instituteforgovernment.org.uk/explainers/cost-living-crisis. Accessed 22 Jun 2022
50. Millions of most vulnerable households will receive £1,200 of help with cost of living. In: GOV.UK. https://www.gov.uk/government/news/millions-of-most-vulnerable-households-will-receive-1200-of-help-with-cost-of-living. Accessed 22 Jun 2022
51. (2021) Our new report calls for the £20 Universal Credit uplift to be extended. In: Trussell Trust. https://www.trusselltrust.org/2021/02/04/our-new-report-calls-for-the-20-universal-credit-uplift-to-be-extended/. Accessed 22 Jun 2022

7.4 APPENDIX D: Published manuscript 2

nutrients

MDPI

Article

The Impact of the COVID-19 Pandemic on the Food Security of UK Adults Aged 20–65 Years (COVID-19 Food Security and Dietary Assessment Study)

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Abstract: The first UK lockdown greatly impacted the food security status of UK adults. This study set out to establish if food procurement was adapted differently for different income groups and if this impacted dietary intakes disproportionately. Adults (n = 515) aged 20–65 years participated in an online survey with 56 completing a 3–4 day diet diary. Food availability was a significant factor in the experience of food insecurity. Similar proportions of food secure and food insecure adapted food spend during lockdown, spending similar amounts. Food insecure (n = 85, 18.3%) had a 10.5% lower income and the money spent on food required a greater proportion of income. Access to food was the biggest driver of food insecurity but monetary constraint was a factor for the lowest income group. The relative risk of food insecurity increased by 0.07-fold for every 1% increase in the proportion of income spent on food above 10%. Micronutrient intakes were low compared to the reference nutrient intake (RNI) for most females, with riboflavin being 36% lower in food insecure groups (p = 0.03), whilst vitamin B12 was 56% lower (p = 0.057) and iodine 53.6% lower (p = 0.257) these were not significant. Coping strategies adopted by food insecure groups included altering the quantity and variety of fruit and vegetables which may have contributed to the differences in micronutrients.

Keywords: food security; micronutrients; diet; high income households; COVID-19; national lockdown; United Kingdom

check for updates

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1. Introduction

The virus "severe acute respiratory syndrome coronavirus 2" which causes the coronavirus disease (referred to in the study from here as COVID-19) led to the United Kingdom's (UK) first 'lockdown' on the 23 March 2020 until 10 May 2020, when restrictions were eased [1]. In the first 3 weeks of this lockdown more than 3 million people reported that they had gone hungry [2]. Additionally, all non-essential shops, schools (to all children whose caregivers did not work in key sector organizations), the accommodation and food sector, the arts, entertainment and recreation sector were closed to halt the spread of the disease [3]. Concerns of having to remain in the home or isolate for long periods resulted in increased demand for food from supermarkets for consumption in the home. What ensued was empty supermarket shelves, with staple food items such as pasta, rice and flour being in short supply. Whilst the UK food supply chains had adequate produce, the change in consumer behavior caused shortages as retailers were unable to keep up with the increased demand. This negatively impacted food supply to the consumer via the retail sector [4].

With the spread of the disease and closure of many sectors of UK industries, the Government introduced 'The Coronavirus Job Retention Scheme' (1 March 2020–30 September 2021). The aims of the scheme were to reduce the burden on Social Security and enable employers to retain staff and pay up to 80% of employee's usual monthly salary (capped at £2500 per month). For some, this resulted in a loss of income of 20% or more (depending on baseline income), for others, their employers topped up their wages to the full amount. Self-employed individuals received some support but this was only available to individuals if they had submitted a Self-Assessment tax return for the year 2018–2019 and had traded in the year 2019–2020 [5]. For others there was a complete loss of employment and this was particularly pronounced for younger people, who were less likely to be furloughed than those aged over 65 who were still in employment [6]. The consequence of loss of income and or employment was evident from the sharp increase in claims for Universal Credit (UC) during April and May 2020. The typical number of claims prior to COVID-19 was ~200,000 per month [7]. This increased to 1.2 million in April and 1.3 million in May 2020.

The COVID-19 pandemic had an impact on food and nutrition security both directly (food shortages) and indirectly (loss of income/purchasing power [3]). The baseline situation of communities, households and individuals (i.e., low income, living in deprived regions and limited capacity for working at home) was found to be a risk factor in the experience of food insecurity during COVID-19 [3]. As supermarkets struggled to keep pace with demand, individuals became more likely to over-purchase (defined as buying more than necessary to sustain routine practices within a household) food, toiletries and pharmacy products [8]. These individuals were more likely to be younger, female, have children living at home, and have a high income or conversely, suffering from a loss of income [8]. It has been suggested that loss of income was a factor in panic buying (defined as overbuying despite sufficient commodities within the supply chain) as individuals were concerned about future scarcity [8]. For many with a higher income, this afforded the opportunity to buy extra, to the detriment of lower income groups who did not have the equivalent purchasing power [9]. As a consequence of these factors, principle difficulties with the food supply were more a result of the many buying a little extra in times of uncertainty than from the few purchasing in excess [8].

The COVID-19 pandemic brought into sharp focus the concerns for population groups with increased vulnerability to the experience of food insecurity. Loss of income or employment increased demand for aid from food banks and the elevated general demand for food from the retail sector compromised the food security (having sustained physical and financial access to a safe and healthy varied diet that meets nutritional requirements) [10] of low income groups resulting in many experiencing food insecurity for the first time [9]. In the UK, these were typically young adults (18–24), households with children, minority ethnic groups, individuals with disabilities, and low income and unemployed households [9].

Food security can be compromised for a range of reasons which impact an individual's or a household's ability to procure food consistently to meet their dietary, nutritional and social requirements [11]. Experience of food insecurity and poor diet directly contribute to increased incidence of disease and lower life expectancy [12–14]. In addition, the experience of food insecurity can make it hard for adults to maintain stable employment [9]. A low income does not always equate to being food insecure and similarly, the anxiety around food availability is not the sole preserve of those on lower incomes [15]. The response to concerns of food security frequently results in similar dietary choices independent of background [16,17], with individuals and households experiencing food insecurity selecting high energy dense, nutrient poor, cheaper foods [18,19], which may be perceived as better value for money and more accessible under the circumstances faced [17]. Fresh fruit and vegetables are often sacrificed at the expense of high fat, high sugar alternatives such as crisps and biscuits [16,18]. Dairy products and protein rich foods may also be limited [20]. These dietary choices may negatively affect long-term health and well-being.

In this study, we assessed the impact of social isolation and movement restriction on food availability and food security in UK adults during the first COVID-19 lockdown period hypothesising that the nutrient profile of diets would change detrimentally during lockdown, resulting in the consumption of a more energy dense diet and that a significant number of people would self-classify as food insecure. We additionally set out to understand people's perceptions of their food security, their food purchasing choices and if these were reflected in their actual intakes.

2. Materials and Methods

This paper details the findings from a cross-sectional study which took place during the first UK COVID-19 pandemic lockdown between 6 May and 10 July 2020 for adults aged between 20 and 65 years who were not in education. An online survey was designed to collect general demographic information (age, gender, ethnicity, highest level of education attained, employment status, post-code), self-reported weight and height, household characteristics, whether following government guidelines on isolating and shielding, indicators of food purchasing behaviour, food security and dietary change.

2.1. Participant Recruitment

Participants were recruited to the study via social media platforms (Twitter, Facebook), radio appearances, the University communication team and word of mouth. All participants were provided with information about the study and asked to give consent before completing the survey. The study was approved by the University of Nottingham's Faculty of Medicine and Health Sciences Research Ethics Committee (Ethics Reference Number 01-0420). This research project was completed in accordance with the declaration of Helsinki and recent alterations.

2.2. Equivalised Income and Income Quintiles

Questions were adapted from the National Diet and Nutrition Survey (NDNS) [21] to determine the level of household income. Participants were asked to select an income bracket and the midpoint value of each income bracket was used in the calculation of equivalised household income (EHI), along with a household size score, adapted from the McClements scale where a value was assigned to each of the adults living in a household and, where applicable, to the children based on their ages [22–24] Household income was divided by the adapted McClements score to determine equivalised household income.

Participants were excluded from the analysis if the household size was greater than 1.5 times the inter-quartile range. As a consequence, 3 participants were excluded from the analysis. Two participants listed they had 11 children within the same age bracket and one participant was excluded as they listed, they had 11 children and 11 adults in each of the age brackets.

Income quintiles (IQ) were determined by splitting the equivalised income during lockdown into five percentiles as follows IQ1 (n = 98; 20.9%; <£25,700.47), IQ2 (n = 90; 19.1%; £25,700.47–£39,643.18), IQ3 (n = 99; 21.1%; £39,643.18–£53,277.84), IQ4 (n = 84; 17.9%; £53,277.84–£75,503.02), IQ5 (n = 99; 21.1%; >£75,503.02).

2.3. Food Security Measures

Food security was assessed with nine questions adapted from the Household Food Insecurity Access Scale (HFIAS) [25] to determine influences of monetary resources and/or food availability over the previous 4 weeks (from the date of completing the survey) on household food security. The HFIAS assesses three different but related domains of food insecurity [25]. Positive responses across the domains indicate increasing severity of food insecurity experienced. We adapted the questions to evaluate if the experience of food insecurity was because of a lack of money or lack of food.

Domain one is concerned with anxiety/worry of running out of food and asks the question (1) "Did you worry that your household would not have enough food". Domain two includes three questions to assess if there was a reduction in the quality and variety of the food consumed. These questions asked (2) "were you or any household member not able to eat the kinds of foods you preferred because of a lack of money or lack of food available?", (3) "Did you or any household member have to eat a limited variety of foods due to lack of money or food available?" and (4) "Did you or any household member have to eat same food that you really did not want to eat because of lack of money or lack of food available to obtain other types of food".

The final domain asks five questions and is concerned with reduction in the quantity of food eaten and experience of hunger. The first asks (5) "Did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?", and the second, (6) "Did you or any household member have to eat fewer meals in a day because there was not enough food?". Additional questions ask (7) "Was there ever no food to eat of any kind in your household because of a lack of money or lack of food available to get food?", (8) "Did you or any household member go to sleep at night hungry because there was not enough food?" and (9) "Did you or any household member go a whole day and night without eating anything because there was not enough food" [25].

Participants were initially categorised into the food security domains of food secure or mild, moderate, or severely food insecure. Two categories were then created comprising food secure and food insecure.

2.4. Shopping Habits and Food Spend

Participants were asked about their food shopping behaviours before and during the first UK national lockdown in reference to where food was purchased, how and how frequently (never less than once a month, 2–3 times per month, once a month, 2–4 times per week, 5–6 times per week, once a day, prefer not to say). The following question was asked with the following options for response "Which of following best describe where you purchased foods from? (Tick all that apply)": (1) Shop at one of the UK "Big Four" supermarkets (Tesco, Sainsbury's, Morrisons, Asda) (2) "In person", (3) "home delivery", (4) "Click and Collect" (5) Other supermarket (Aldi, Lidl, Iceland, Netto). (6) "Other supermarket "(Waitrose, Marks and Spencer), (7) smaller shops (e.g., Co-op, Tesco express, Sainsbury local), (8)" Corner Shops (e.g., Happy Shopper, 7-11, Spar), (9) "Markets", (10) Local independents (e.g., butchers, bakers, green grocers). In addition, participants were asked whether they were self-isolating or shielding and their level of vulnerability. Individuals were asked about usual eating behaviours, dietary choices, perception of how food availability had changed, and how their diet had changed during the lockdown. Food spend was estimated for each household from the mid-point of the monetary bracket per week (<£46, £47–£69, £70–£90, £91–£115, £116–£138, £139–£161, >£162) selected by participants.

2.5. Energy and Nutrient Intakes

Participants had the option to complete a 4-day food diary using the "Libro" app associated with professional dietary analysis software (Nutritics). Those who completed 3- or 4-day food diaries were included in the analysis (n = 56). We present the results for the total population of females and do not exclude non-plausible reporters due to the nature of the study assessing the impact of food insecurity on the energy and nutrient composition of the diet. The macronutrient and micronutrient composition of each participant's diet was calculated by the Nutritics software. Analysis of the micronutrient composition of the diet and food security status was completed for the total population. Females were stratified by age as per the reference nutrient intake (RNI) categories to enable analysis of iron intakes (19–49 and 50+ years).

2.6. Sensitivity Analysis

The plausibility of energy intake was assessed by estimating Energy Intake: Basal Metabolic Rate (EI:BMR) ratio using the Schofield equation to estimate BMR and applying the Goldberg upper and lower and cut-off points specific to physical activity level (PAL; Supplementary Tables S1 and S2) [26,27].

2.7. Data Analysis

Descriptive, parametric, and non-parametric analyses were performed using SPSS (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY,: IBM Corp). Normality of the data was assessed in SPSS using Shapiro–Wilks. Parametric data are presented as means and S.E.M (unless otherwise stated), non-parametric as medi-

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ans with 25th and 75th percentile (median [25th–75th percentile]). Chi-square was used for categorical variables to test the impact of income quintile on food security status. Relative risk was calculated for the experience of food insecurity according to employment type, adherence to government guidelines for movement restriction, household income quintiles, and food spend as a proportion of income. Dietary data were analysed for participants who completed 3 or 4 days of a food diary. Parametric and non-parametric tests were completed in SPSS to test for difference in dietary intake between individuals considered food secure and food insecure.

3. Results

This study recruited 515 participants between 20 and 65 years of age (43.3 ± 0.5 years) of which the majority were female (*n* = 435; 84%). Males (*n* = 79; 15%) had a mean age of 43.5 ± 0.6 years (Table 1). One participant did not provide their sex. The majority of participants in this study stated their ethnicity as white British (*n* = 422; (81.9%)), whilst 11.3% were white Irish or white other, 2.2% Asian, 0.4% white and black African or African, 0.2% Arab, 0.8% other and 0.2% preferred not to say. Two people did not provide details of their ethnicity. During the first lockdown, the proportion of participants in employment was 73.7% (*n* = 390) of which over half were employed full time (51.6%), 15.5% (*n* = 82) part time and 6.6% were self-employed (*n* = 35). The proportion of respondents not in paid employment was 26.4% of which retirees accounted for 6.6% (*n* = 35) and furloughed workers 9.8% (*n* = 52). Fourteen participants selected more than one option for employment type.

Table 1. Participant characteristics.

		All			Food Secure			Food Insecure			*p* Value
		n	Median	25th–75th Percentile	*n*	Median	25th–75th Percentile	*n*	Median	25th–75th Percentile	
Age (years)		515	44.0	33–52	421	45.0	33–54	94	41.0	33–50	0.031 *
Height (m)	Male	77	1.80	1.75–1.85	62	1.80	1.75–1.85	15	1.80	1.78–1.85	0.395
	Female	423	1.65	1.61–1.70	346	1.65	1.61–1.70	77	1.63	1.61–1.68	0.095
	Missing	14	n/a	n/a	12	n/a	n/a	2	n/a	n/a	
Weight (kg)	Male	78	85.1	75.0–99.5	63	84.6	76.0–96.2	15	86.0	74.0–119.0	0.506
	Female	412	66.0	59.9–78.0	336	66.0	60.0–77.4	76	67.3	58.2–81.8	0.837
	Missing	24	n/a	n/a	21	n/a	n/a	3	n/a	n/a	
BMI	Male	76	26.1	23.7–30.1	61	25.9	23.7–29.8	15	27.1	23.1–31.1	0.681
	Female	403	24.3	21.6–28.3	329	24.2	21.7–28.1	74	24.8	20.9–28.8	0.789
	Missing	35	n/a	n/a	30	n/a	n/a	5	n/a	n/a	
Equivalised income per week (£)		470	853.69	551.69–1182.20	385	853.69	580.56–1243.71	85	763.83	288.69–1123.28	0.038 *
Food spend per week (£)		468	86.51	59.74–116.33	383	86.06	60.19–115.02	85	89.32	57.13–124.14	0.582
Proportion of income (%)		466	9.9	6.4–16.3	381	9.5	5.7–15.4	85	11.04	7.3–21.7	0.011 *
Household size		512	2.0	2.0–4.0	418	2.0	2.0–4.0	94	3.0	2.0–4.0	0.140
Sex		*n*	(%)		*n*	(%)		*n*	(%)		
	Male	79	(15.3)		64	(15.2)		15	(16.0)		0.861
	Female	435	(84.5)		356	(84.6)		79	(84.0)		
	Missing	1	(0.2)		1	(0.2)		n/a	n/a		
Income quintiles	1 (<£25,700.47)	98	(20.9)		72	(18.7)		26	(30.6)		0.117
	2 (>£25,700.47)	90	(19.1)		75	(19.5)		15	(17.6)		
	3 (>£39,643.18)	99	(21.1)		80	(20.8)		19	(22.4)		
	4 (>£53,277.87)	84	(17.9)		73	(19)		11	(12.9)		
	5 (>£75,503.02)	99	(21.1)		85	(22.1)		14	(16.5)		

Comparison between food secure and food insecure groups for Age (years), height (m), weight (kg), equivalised income, food spend, and the proportion of income spent on food as well as household size and body mass index (BMI) tested with MANN Whitney U (* indicates significance at the $p < 0.05$ level). Differences in the frequency of individuals represented in food secure and food insecure groups for sex and income quintile were tested with Pearson Chi Sq (* significant at the $p < 0.05$ level). n/a = not applicable.

The study cohort was disproportionately represented by those who had successfully accessed higher education. Most participants (*n* = 405; 78.6%) had completed their education to level 6 (undergraduate degree with honours or equivalent) or above, with 35.9% having an undergraduate degree, 30.3% a post graduate degree at master level or equivalent, and 12.4% a PhD or DPhil. Only 0.4% reported having no qualifications. In the UK, by contrast, between April 2020 and March 2021, approximately 20.8% of the population reported they had a degree level qualification or above [28].

The median equivalised household income for all participants with a valid household income prior to and during lockdown (*n* = 470) decreased 5.5% from £46,969.22 [£33,783.51–£68,130.11] to £44,392.06 [£28,687.70–£61,474.59] per year. Prior to the lockdown, 81.1% of households had an income above the UK median average household income for 2020 (£29,990). This reduced to 73.8% during the first lockdown. We found 5.3% (*n* = 25) of households had an income below 60% of the UK median (£13,794.00; a level used for defining relative low income) prior to lockdown, which increased to 8.1% (*n* = 38) during the lockdown.

The largest group of households were two person (*n* = 200, 39.1%; 3, 1.5% with children) followed by 4 person (*n* = 103, 20.1%; 78, 76% with children) and 3 person (*n* = 100, 19.5%; 47, 47% with children). Single person households accounted for 14.5% (*n* = 74). Households with children comprised over a third (30.1%; *n* = 155).

Who was at risk of the experience of food insecurity?

3.1. Equivalised Household Income

Four fifths of participants in this study were food secure (81.7%). Of those who experienced some form of food insecurity (18.3%), 2.9% indicated they were severely food insecure. Participants who provided details about household income before and during lockdown (*n* = 470) were split into income quintiles (IQ; Table 1). Households in IQ1 (income < £25,700.47 per year) had the lowest proportion of food secure households (73.5%) compared to 1Q2 (83.3%), IQ3 (80.8%), IQ4 (86.9%) and IQ5, (85.9%) and the highest percentage of severely food insecure (8.2%) compared to participants in IQ2 (0%), IQ3 (2%), IQ4 (0%) and IQ5 (3.0%). Two participants who identified as severely food insecure in IQ3 (*n* = 1) and IQ5 (*n* = 1) had restricted diets due to coeliac disease. The participant in IQ3 stated,

> "I follow a gluten free diet for coeliac disease, staple food availability was limited on the 2 weeks prior to 23rd march and for several weeks after".

Additionally, one participant in IQ5 noted they were eating different brands of gluten free food available in smaller shops,

> "I have coeliac disease and have been eating different brands of gluten free food during lockdown. I do not have a car so have had to use local stores. I've mostly shopped in small stores"

Participants in IQ1 had a 60% increased risk of experiencing food insecurity (RR = 1.6, CI: 1.1–2.4) compared to those not in IQ1 (Table 2).

Table 2. Relative risk of food insecurity amongst income quintiles.

Income Quintile (per Year (£))	*n*	(%) ǂ	RR	(CI)	*p* Value
1 (<£25,700.47)	26	(30.6)	1.6	(1.1–2.4)	0.015 *
2 (>£25,700.47)	15	(17.6)	0.9	(0.5–1.5)	0.697
3 (>£39,643.18)	19	(22.4)	1.1	(0.7–1.7)	0.747
4 (>£53,277.87)	11	(12.9)	0.7	(0.4–1.2)	0.190
5 (>£75,503.02)	14	(16.5)	0.7	(0.4–1.2)	0.251

RR = Relative Risk; CI = Confidence Interval; *n* Number of people who were food insecure; ǂ Percentage who were food insecure; * Significant at the $p < 0.05$ level (Pearson Chi Sq).

3.2. Employment Type

Employment status during lockdown was associated with a relative likelihood of food insecurity. The self-employed, were significantly more likely to experience food insecurity than other groups (*p* = 0.037), whereas those in full-time employment were less vulnerable (Table 3). Whilst the numbers for several groups were too low to yield valid outcomes

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for Chi-square analysis (e.g., some expected values < 5) it is still worth noting that for those who recorded being unable to work either due to disability or being unemployed, the proportion experiencing food insecurity was very high.

Table 3. Relative risk of the experience of food insecurity by employment status.

Employment Status	Relative Risk (RR) of Food Insecurity If in Listed Employment before Lockdown RR (95% CI)						Relative Risk (RR) of Food Insecurity If in Listed Employment during Lockdown RR (95% CI)					
	n	(*n*) Ŧ	(%) ǂ	RR	CI	*p* Value	*n*	(*n*) Ŧ	(%) ǂ	RR	CI	*p* Value
Self-Employed	44	(12)	(27.3)	1.6	(0.9–2.6)	0.105	35	(11)	(31.4)	1.8	(1.1–3.1)	0.037 *
Part-time employment	93	(12)	(12.9)	0.7	(0.4–1.2)	0.140	82	(9)	(11.0)	0.6	(0.3–1.1)	0.063
Full-time employment	328	(55)	(16.8)	0.8	(0.6–1.2)	0.248	273	(45)	(16.5)	0.8	(0.6–1.2)	0.270
Unable to work due to disability	6	(3)	(50.0)	2.8	(1.2–6.4)	0.043 *,¥	8	(4)	(50.0)	2.8	(1.4–5.8)	0.019 *¥
Unable to work due to sickness	3	(3)	(100.0)	5.6	(4.7–6.8)	<0.001 *,¥	5	(3)	(60.0)	3.4	(1.6–7.0)	0.015 *¥
Unable to work as unemployed/seeking work	9	(5)	(55.6)	3.2	(1.7–5.8)	0.003 *¥	18	(8)	(44.4)	2.6	(1.5–4.5)	0.003 ¥
Homemaker/full-time parent	15	(3)	(25.0)	1.1	(0.4–3.1)	0.859 ¥	19	(5)	(26.3)	1.5	(0.7–3.2)	0.354 ¥
Furloughed worker	n/a	n/a	n/a	n/a	n/a	n/a	52	(10)	(19.2)	1.1	(0.6–1.9)	0.847
Prefer not to say	2	(1)	(50.0)	2.8	(0.7–11.2)	0.244 ¥	2	(1)	(50.0)	2.8	(0.7–11.2)	0.244 ¥

Association of employment type/status prior to and during lockdown and likelihood of food insecurity. Values for the relative risk of food insecurity (95% confidence intervals) are shown. The total number in each group (*n*) are also indicated. Values in columns headed Ŧ comprise the number of people in each group who were food insecure and values in the column headed ǂ are the proportion of the group to which they belong. 2 people recorded more than one reason for being unable to work. ¥ cells have expected count less than 5. * Significant at the $p < 0.05$ level (Pearson Chi-Square). n/a = not applicable

The numbers for most groups changed during the lockdown with reductions in the number of self-employed (20%), part-time (12%), and full-time employed (17%) and increases in the number of unemployed (33%). There were also small increases in the number of people unable to work due to sickness or disability, homemakers/full-time parents, and retired. A large number were additionally placed on furlough.

3.3. Following Government Guidelines on Isolating and Shielding

The majority of participants (n = 442, 85.81%) at the time of the study were not self-isolating but following government guidance of social distancing. People not leaving their home because they were in the high-risk category accounted for 1.7% of the study population (n = 9). Individuals not leaving their home except to get essential items such as food and medicine accounted for 5.2% (n = 27). Whilst those not leaving the home because of living with someone vulnerable to the disease was 7.4% (n = 38) Participants who were living with someone vulnerable to COVID-19 were 1.88 (CI, 1.1–3.1) times more likely to report they were food insecure (p = 0.027; Table 4).

Table 4. Relative risk of food insecurity when following government movement restriction guidelines.

QN		Relative Risk (RR) Of Food Insecurity If in Listed Government Guidelines					
		n	Ŧ (*n*)	ǂ (%)	RR	(CI)	*p* Value
1	Not self-isolating but following government guidance on social distancing	442	(72)	(16.3)	0.5	(0.4–0.8)	0.005 *
2	Self-isolating for 7 days, following symptoms	2	(1)	(50.0)	2.8	(0.7–11.2)	0.244
3	Self-isolating for longer than 7 days following symptoms, because you still have a temperature (above 37.8 °C)	1	(1)	(100.0)	5.5	(4.6–6.6)	0.034 *,¥
4	Self-isolating for LONGER than 14 days following symptoms in a member of your household, because YOU have developed symptoms during this time	0	(0)	(0.0)	n/a	n/a	0.636 ¥
5	Not leaving your home because you are at a VERY HIGH RISK of COVID-19 and have received a letter from the NHS (Shielding)	9	(1)	(11.1)	0.6	(0.1–3.9)	0.313 ¥
6	Not leaving your home except to get essential items such as food and medicine because you are at HIGH RISK of COVID-19, e.g., are 70 or older, pregnant, have diabetes, taking medication that can affect your immune system.	27	(9)	(50.0)	1.9	(1.1–3.4)	0.037 *,¥
7	Not leaving your home because someone in the household is more vulnerable to the virus (i.e., not high risk but at greater risk)	38	(12)	(31.6)	1.8	(1.1–3.1)	0.027 *
8	Status isolating or not Prefer not to say	3	(0)	(0.0)	n/a	n/a	0.412 ¥

QN = Question number; RR = Relative Risk; CI = Confidence interval; Ŧ Number of people who food were insecure; ǂPercentage of employment type food insecure; ¥ cells have an expected count of less than 5; * Significant at the $p < 0.05$ level (Pearson Chi-Square). n/a = not applicable

3.4. Concern for Food Availability

Over a quarter of all adults (27.8%) in this study said they were worried their household would not have enough food at the start of the first lockdown, of which a tenth indicated this was sometimes or often true (10.5%). Comparisons between food secure (n = 421) and food insecure (n = 94) indicated that 81.5% of food secure (n = 343) were not worried about running out of food and just 29.8% of food insecure participants (n = 28) were not worried.

3.5. Eating Preferred Food by Food Security Status and Income Quintile

Analysis by income quintiles found similar proportions of participants indicating that they were unable to eat the type of foods they preferred due to lack of food available (p = 0.624). Participants in IQ1 also reported a lack of money as a reason for not being able to eat the foods they preferred compared to IQ3 (p = 0.002), IQ4 (p = 0.016), and IQ5 (p = 0.009). Analysis by food security status indicated a greater proportion of food insecure participants (69.1%) were unable to eat the foods they preferred due to lack of foods available compared to food secure (36.1%; $p < 0.001$). Eating non-preferred foods because of a lack of money was true for some amongst the food insecure (12.8%) but not those who were food secure (0.0 %; p <0.001).

3.6. Differences in Household Income, Food Spend and Food Security Status

Most participants provided details of household income and food spend prior to and during COVID-19 (n = 468). There was an 11.1% difference in the median equivalised household income between food secure (n = 385) and food insecure (n = 85), with food secure households having on average £89.86 more per week during lockdown ($p < 0.01$). Median food spend per week during lockdown was similar for the food secure (£86.03 [£60.18–£115.02]) and food insecure (£89.32 [£57.13–£173.08]) per week; (p = 0.582). The proportion of income required for food spend in food secure respondents was 9.5% and food insecure 11.0% (Table 1).

3.7. Change in Food Spend Amount per Week during the First UK Lockdown by Food Security Status

Median food spend during the first UK lockdown was £86.51 per week. Households who increased their food spend did so on average by 44.0%, whilst households who decreased food spend did by 28.1% (Table 5). Food secure and food insecure households who increased food spend, did so by a similar proportion (43.7% and 46.7%, respectively). The percentage of income spent on food was numerically, but not significantly, greater for food insecure households compared to food secure (p = 0.151; Table 5). When households' food spend remained the same during the lockdown, food insecure households spent a greater proportion of their income on food compared to food secure (p = 0.003; Table 5).

3.8. Proportion of Income Spent on Food and Relative Risk of Food Insecurity

The proportion of household income spent on food in the UK averages 10.8% [29]. Among those participants who spent 10% or more of their household income on food and non-alcoholic beverages, we found that the relative risk of food insecurity increased by 0.07-fold for every 1% increase in the proportion of income spent (Figure 1). When the percentage of equivalised household income spent on food exceeded 13%, the relative risk of food insecurity increased by 1.6 fold (CI 1.1–2.3; p = 0.016).

3.9. Shopping Habits

As shown previously, in person shopping was reduced during the lockdown and this occurred for food secure ($p < 0.001$) and food insecure participants ($p < 0.001$), however the frequency of shopping in person during lockdown was lower for food insecure (2.98 $\pm$ 1.54) compared to food secure (3.32 $\pm$ 1.35; p = 0.05). This coincided with a slight increase in the frequency of using click and collect in both food secure ($p < 0.001$) and food insecure groups (p = 0.017). Whilst there was not a significant difference in click and collect between food

APPENDIX D

secure and food insecure groups during the lockdown, there was a clear trend, appearing higher in food insecure compared with food secure ($p = 0.067$). There was a reduction in the frequency of shopping at the big four UK supermarkets and discounter supermarkets for all households during the lockdown ($p < 0.001$).

Table 5. Change in food spend from prior to, to during lockdown by food security status.

			Food Spend Change Groups			
			Increase	**Stayed Same**	**Decrease**	***p* Value**
Total	*n*		174	209	83	0.001 **
	Percentage of income spent on food (%)		11.5 [a]	8.74 [b]	9.2 [b]	
	Percentage of group (%)		(37.3)	(44.8)	(17.8)	
	Change in food spend (£)		+33.57	0	−30.31	
	EQVINC Weekly income (£)	Median	853.69	853.69	878.11	0.380
		25th	597.11	530.07	584.1	
		75th	1297.42	1182.2	1129.32	
Food secure	*n*		144	174	63	<0.001 **
	Percentage of income spent on food (%)		11.4 [a]	7.9 [b]	9.2 [b]	
	Percentage of group (%)		(37.8)	(45.7)	(16.0)	
	Change in food spend (£)		+32.38	0	−28.88	
	EQVINC Weekly income (£)	Median	853.69	853.69	853.69	0.716
		25th	609.97	575.49	548.52	
		75th	1279.16	1269.49	1176.70	
Food insecure	*n*		30	35	20	0.047 *
	Percentage of income spent on food (%)		14.3 [a]	10.6 [a,b]	8.4 [b]	
	Percentage of group (%)		(35.3)	(41.2)	(23.5)	
	Change in food spend (£)		+39.89	0	−35.9	
	EQVINC Weekly income (£)	Median	891.17	561.51	909.56	0.028 *
		25th	520.34	225.86	629.03	
		75th	1366.22	935.85	1024.57	
p Value	Food secure v food insecure percentage of income		0.151	0.003 *	0.866	
p Value	Food secure v food insecure Change in EQVINC Weekly income (£)		0.780	0.002 *	0.802	

Kruskal–Wallis used to test for differences in the proportion of income spent between the food spend groups for food secure and food insecure, Mann–Whitney U to test for difference between food secure and food insecure EQVINC = Equivalised household income, Letters differentiate significance across the categories * Significant at the $p < 0.05$, ** Significant at the $p < 0.001$.

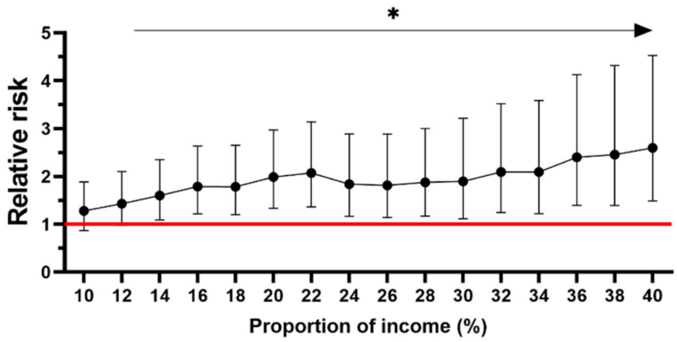

Figure 1. The relative risk of experiencing food insecurity when the proportion of income spent on food and non-alcoholic beverages exceeded 10% of income for food insecure vs. food secure. Results shown as relative risk with 95% confidence intervals. When household income spent on food exceeded 13%, the relative risk of food insecurity increased by 1.6 fold. Participants were included in the analysis if they provided details of their income and food spend ($n = 468$). * Significant at the $p < 0.05$ level (Pearson Chi-Square).

3.10. Eating Habits

Participants were asked to self-report if they thought they had eaten less than, about the same, or more than their usual diet since the 23 March 2020. Those who were classified as food insecure ($n = 94$) were 2.1 (CI 1.4–3.0) times more likely to report they thought they were eating less than usual their usual diet, however, the majority of respondents felt that their diet was as healthy as it was prior to lockdown. Despite this, food secure households reported a lower proportion of the population decreasing their fresh fruit intake (15.8%) compared to food insecure (32.3%; $p = 0.060$) as well as fresh vegetable intake (11.8% vs. 35.1%, respectively; $p = 0.001$). Consumption of breakfast cereal remained the same for all (72.4% food secure and 61.3% food insecure).

3.11. Coping Strategies

We further asked participants to indicate if they had to employ any strategies to cope with not having enough food or money to buy food. Those who were food insecure more frequently relied on less preferred or less expensive foods than the food secure ($p < 0.001$). They were also 3.1 (CI 2.2–4.4) times more likely to reduce the quantity ($p < 0.001$) and 4.1 (CI 2.8–6.2) times more likely to reduce the variety of fruit and vegetables consumed ($p < 0.001$). Access to food banks was not reported by any respondents. Six out of the 8 people who reported purchasing food on credit were in the food secure category.

3.12. Diet Diaries, Nutrient Intakes, and Food Security Status

In total 6 males and 50 females completed a 3- or 4-day diet diary using the "Libro" app (Nutritics 2021). Because of the low numbers of males, only data for females was analysed for impact of food insecurity.

3.12.1. Energy for All Participants

A non-plausible energy intake below the lower Goldberg cut off point was found in 11 participants. None exceeded the higher cut off point. One individual who was food insecure had EI: BMR below the Golberg limit, whilst 10 food secure participants were below the lower cut off.

3.12.2. Energy Intakes and BMI

Energy intake of all females aged 19-65 years was 1751 $\pm$ 50.50 kcal. Seven food secure participants (12.5%) had an EI:BMR ratio below the lower cut-off point but were not excluded from the analysis. Food secure ($n = 44$) and insecure ($n = 6$) participants had similar energy intakes (1728 $\pm$ 53.85 kcal and 1924 $\pm$ 136.37 kcal, respectively). The BMI of food secure participants was within the healthy range (23.4) whilst those for the food insecure fell within the overweight category (28.5) although there was no significant difference between the two groups.

3.12.3. Macronutrients

Carbohydrate intake provided slightly below the recommended 50% of energy for both food secure (44.0 $\pm$ 1.2%) and food insecure 42.9 $\pm$ 4.2% ($p = 0.763$), whilst energy from total fat exceeded the recommended 33% (36.5 $\pm$ 1.1% and 36.9 $\pm$ 3.2% food secure and insecure, respectively) but did not differ between the groups ($p = 0.898$). The 11% energy from saturated fat was similarly exceeded for both food secure and insecure (12.7 $\pm$ 0.7 % and 12.5 $\pm$ 1.5%, respectively; $p = 0.933$) as was protein intake (151.0% and 157.5% of DRV; $p = 0.511$). There were comparable intakes of fibre for both food secure and food insecure ~75% of the DRV (22.6 g [18.5–29.67] and 22.5 g [20.3–27.3], respectively; $p = 0.965$) and free sugar consumption was within the recommendations of $\leq$5% of energy for both groups (food secure—2.1% [1.1–5.0%] and food insecure—1.6% [0.7–5.1]; $p = 0.456$).

3.12.4. Micronutrients—Vitamins

Intakes of most vitamins were similar, but B2 (riboflavin) was significantly negatively influenced by food insecurity (Figure 2A–D). Those who were classed as food insecure, consumed 36% less riboflavin than food secure individuals with values of 0.7 mg [0.6–1.1] and 1.1 mg [0.9–1.5], respectively ($p = 0.030$; Figure 2A).

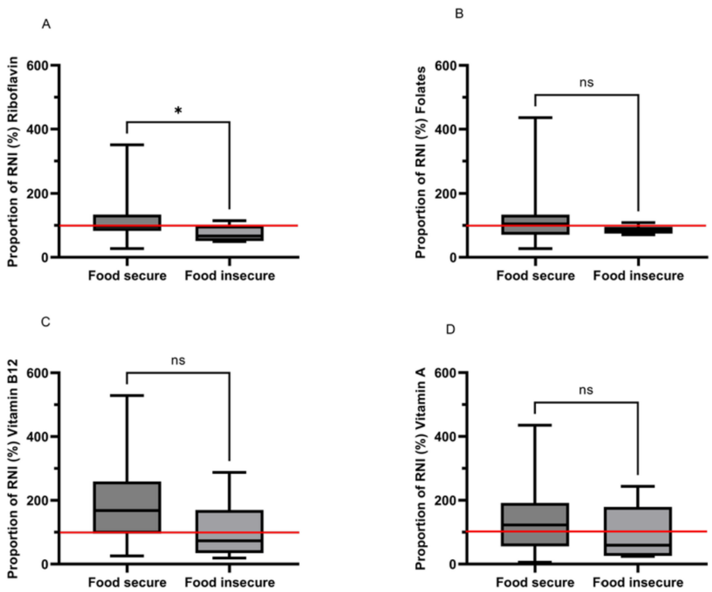

Figure 2. (**A**–**D**) The proportion of the Reference Nutrient Intake (RNI) met for vitamins amongst food secure (n = 44) and food insecure (n = 6) females aged 20–65 years. The red line indicates 100% of the RNI. * Significant at the $p < 0.05$. ns = non-significant.

Food secure females exceeded the RNI for folate (104.9% of the RNI) whilst food insecure intakes were lower than the RNI (82.6%), but no significant difference was found between groups (p = 0.222; Figure 2B).

Intakes of vitamin B12 were numerically very different between groups (2.5 µg [1.4–3.9] and 1.1 µg [0.5–2.5] for food secure and insecure, respectively), but this difference did not quite achieve significance (p = 0.057; Figure 2C). Vitamin A requirements for females 19+ in the UK are set at 600 µg d^{-1} Food insecure females had a low intake compared to the RNI (59.4% of the RNI) and consumed 51.6% less vitamin A compared to food secure individuals but again the difference, while considerable was not significant (p = 0.311; Figure 3D).

3.12.5. Micronutrients—Minerals

Mineral intakes were not seen to vary significantly, however, consumption levels for several minerals were routinely low and also showed large numerical differences indicating trends towards lower intakes amongst the food insecure group (Figure 3A–E).

Iron intakes of females 19–49 years (n = 26) were low compared to the RNI with 96.2% consuming below the RNI (14.8 mg d^{-1}) and 57.7% below the lower reference nutrient intake (LRNI; 8.0 mg d^{-1}). Amongst those who were food insecure, iron intakes were 28.9% lower but not significantly so compared to food secure (5.65 ± 1.31 mg d^{-1} vs. 7.96 ± 0.70 mg d^{-1}; p = 0.198; Figure 3A). Iron intakes were slightly higher in females over 50 years (8.37 ± 0.70 mg d^{-1}) compared to 19–49 years and, as requirements are lower in this group, the proportion below the LRNI and RNI was reduced to 12.5% and 54.2%, respectively. Only two participants were food insecure in the over 50 group, so comparisons could not be made by food security status (Figure 3B).

Zinc from dietary sources was low compared to the RNI for the majority of females 19–65 years (median 84.2% [58.1–106.1] of RNI), with 70.0% below the RNI and 24.0% below the LRNI. This did not differ with food security status (p = 0.439; Figure 3C).

Iodine intakes were also low compared to the RNI (140µg d^{-1}) for all (41.8% [23.3–66.7]) with 92.0% below the RNI and 54.0% below the LRNI (70 µg d^{-1}). Whilst intake in food insecure females was 53.6% lower (46.1 μg d^{-1} [22.0–66.2]) compared to food secure (70.8 μg d^{-1} [34.3–99.6]) this was not significant (p = 0.257).

Two females aged 19–65 years in our study had a dietary intake of selenium above the RNI (60 μg d^{-1}), with the remainder below the RNI and 74.0% were below the LRNI (40 μg d^{-1}). No differences were detected between the food security groups (p = 1.000; Figure 3E).

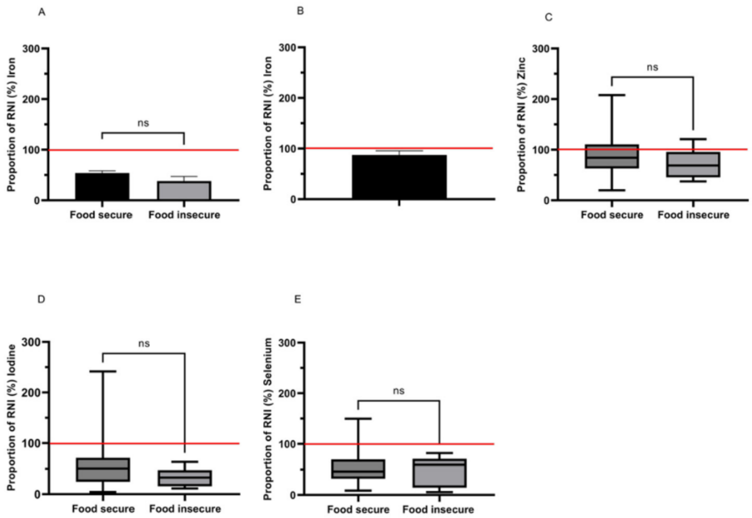

Figure 3. (**A**–**E**) The proportion of the Reference Nutrient Intake (RNI) met for minerals amongst food secure (n = 44) and food insecure (n = 6) females aged 20–65 years. The red line indicates 100% of the RNI. ns = non-significant.

4. Discussion

In this study, we found that lockdown destabilized the access to food and the perception of accessibility across all income domains, not exclusively those on lower incomes. However, those households with the lowest incomes did experience food insecurity more severely than those with higher incomes. We show that food insecurity is felt and feared in affluent groups as well as those on low incomes and that the anxiety around limited food availability drives behaviour change to ensure the security of personal acquisition. We find that the intake of a number of micronutrients is significantly below requirements and for vitamin B2 this is exacerbated by the presence of food insecurity

We found that, under lockdown conditions, having a low income, being self-employed or unemployed (for whatever reason), living with people vulnerable to disease and having children, greatly increased the likelihood of reduced food security. Notably these factors, in addition to limitations in availability, increased anxiety about household food provision. These findings are in line with previous work [30–33], but in this study, we specifically highlight the fact that these same factors are relevant to more affluent groups. Those categorised as food insecure were less able to eat preferred foods both due to availability and financial constraints and their shopping trips were reduced compared to food secure. It has been suggested that this may be because individuals with a higher level of education tend to have a more diverse diet from the outset [34]. There did not appear to be a movement to cheaper shops for the food insecure, but rather they appeared to try to replace with click and collect (albeit the association was not quite significant). We additionally saw clear trends indicating reduced intakes of important nutrients (e.g., riboflavin) in the food insecure group.

The nature of the participants, representing a relatively affluent cohort, highlighted an important aspect of the "food insecure" group. These people were, for the most part, very well educated and earning reasonable salaries, certainly to a level that would not be expected to be associated with food insecurity. Their responses, however, clearly indicated that they were either experiencing difficulties or had greater anxiety around their food security status, these findings align with a study in the US which found 19% of participants during the initial stages of COVID-19 (mid-March 2020) who had a very low food security status, had a high income (>$59,000 a year) whilst 21% with a graduate degree indicated they had a very low food security status [35]. A recent study suggested that a higher percentage of people reporting they were moderately or greatly affected during the pandemic in their shopping habits had postgraduate degrees compared with school, college or undergraduate degree holders [34]. Higher qualification levels were suggested to be associated with a more significant impact on food purchasing due to greater anxiety driving food purchases in the face of reduced variety of foods that are customarily available to them. This may have prompted our respondents to answer positively regarding worrying about running out of food, but this worry resulted in stockpiling and over-purchasing, thereby limiting further availability both for themselves and lower income households.

COVID-19 exposed fragilities in procuring food as the household income changes [9] but we found both food secure and food insecure households adjusted their shopping habits similarly. This suggested that, for this study population, the experience of food insecurity was primarily due to a lack of food availability rather than affordability, although households with the lowest incomes did indicate financial constraint was a factor in worrying about running out of food. Although income decreased in all groups, the proportional reduction was lower for food secure households, which may have afforded them the ability to still purchase food at the same level or potentially greater as a result of the reduction in extraneous costs (e.g., travel to work) [36]. Food budget modification was probably either limited or not required in this group. However, for other households, the higher percentage loss of income may have caused the food budget to be modified to pay for other household bills and costs. Limited availability of foods was the principal reason for the experience of food insecurity in this study and this was worsened by limited availability of supermarket delivery services, minimum spend and delivery cost associated with shopping online and restrictions on movement hampering access to shops [37]. During the first lockdown the infrastructure for click-and-collect and home delivery increased to cope with the demand [38,39], thereby diminishing the likelihood of limited food availability for wealthier households in subsequent lockdowns. This was probably of limited value to lower income households because of the constraint that the requirement for a minimum spend imposes [40].

The increase in food spend by wealthier households limited the availability of certain types of foods for others, such as core staple items of pasta, rice, and bread. The week before the first UK lockdown was imposed, increases in purchasing were observed across all social classes compared to the same time the previous year, however, households who were more affluent increased purchasing compared to less affluent groups [41].

Our data follows a similar trend to national data in that food insecurity was experienced at a greater level by younger individuals and those with a lower household income [42]. Furthermore, our results concur with studies researching the experience of food insecurity internationally, in that there was an increase in the experience of food insecurity during and after the initial lockdowns [43–48]. Households experiencing food insecurity spent a significantly greater proportion of their income on food. Furthermore, we found that the prevalence and severity of food insecurity was greatest for households when the proportion spent on food and non-alcoholic beverages exceeded 13% of equivalised household income. Engle's law states that the proportion of income spent on food decreases as wealth increases [49]. Here, we further show that as the proportion of income spent on food increases, the risk of food insecurity increases directly with it (Figure 1). Within this population of relatively affluent individuals, we found that, above a percentage spend of

10% on food, the relative risk of food insecurity increased by 0.07 for every 1% increase in the proportion of income spent on food. It is unclear what the proportional increase in risk might be for lower income groups, but it can be envisaged that this is likely to be higher than in this case. With current food price increases, the proportional increase in food spend has already increased [50] latest data for commonly consumed food and drink items show prices have risen by 9.8% in the previous 12 months to June 2022 [50], placing a significant burden on all, but most severely those on low incomes.

Data from DEFRA showed that the proportion of household spend on food and non-alcoholic drinks in the UK in 2018/2019 was 10.6%, whilst for those in the lowest 20% income quintile this was 14.7% [51]. So, prior to COVID, these discrepancies were already apparent [52,53] and with the increased cost of living alongside the removal of the £20 uplift in universal credit [54], the proportion for the lowest income group will either be higher or have reached a threshold spend beyond which access to food banks or simply doing without food, becomes commonplace.

A Food Foundation survey during the COVID-19 Pandemic found that 14% of adults living with children reported experiencing moderate or severe food insecurity from March to September 2020 (~4 million people including 2.3 million children). The same survey found that 12% of adults living with children said they skipped meals, whilst 4% said that they had gone without food for a whole day because they could not afford or access food [55]. The UK Food Standards Agency (FSA) previously showed that adults living with children and particularly those on low incomes are more likely to experience food insecurity. Whilst most older people are food secure, around 10–20% of those aged 55 years and above experience some level of food insecurity [56].

We evaluated the dietary intakes of participants, albeit with a relatively small sample size. Riboflavin intakes were low compared to the RNI for food insecure females (77% of the RNI) with 67% below the LRNI. Riboflavin functions in a diverse array of redox reactions critical in cell metabolism via the cofactors, flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD), respectively. These cofactors act as important electron carriers in metabolism (e.g., succinate dehydrogenase) and in fatty acid oxidation. Recent evidence indicates that riboflavin deficiency can precipitate the development of anaemia and sub-optimal intakes are known to negatively impair iron utilization and hemoglobin synthesis [57]. Other research shows riboflavin deficiency causes metabolic dysregulation in animals [58] and can impact on the utilisation of other important B vitamins such as folate, vitamin B12 and vitamin B6 [59,60]. In addition to riboflavin, a general trend showing a reduction of vitamin B12 and vitamin B6 is also reported in participants, although these changes were not statistically significant. B vitamins, including B12 and B6 are known to be important in the metabolism of phospholipids and neurotransmitters and as such, deficiencies can cause haematological and neurological problems [61]. Moreover, an adequate intake of vitamins B1, B2, B12 and B3 are associated with a lower risk of NAFLD [62] and both B6 and B12 appear important in the metabolic pathway responsible for homocysteine metabolism, a marker for cardiovascular diseases [63]. Combined, it is feasible that sub-optimal levels of B vitamins, as reported in the current study, could predispose individuals to various health related problems.

Another trend observed in the current research was a reduction in vitamin A status in participants. Vitamin A has roles in growth, and in the prevention of night blindness [64] and reduced vitamin A status increases the risk of infection [65]. Marley et al. (2021) recently demonstrated that in patients replete or having abnormal levels of vitamin A have increased rates of inflammation and C-reactive protein [66]. This study pointing to an important role of vitamin A in mitigating rates of inflammation.

4.1. Limitations and Strengths of the Study

The data is in this study is largely self-reported, however, the tools used are validated methods. Although the tools in this study have been used in previous studies (e.g., HFIAS), they were not tested for the demographic in this study. Furthermore, the overall survey itself was not piloted prior to launch. This alongside the survey being completed online meant it was not possible to ascertain if the wording of the questions was fully understood by the participants. The population who participated in the study had above average levels of education and income and as such cannot be reflective of the general population. However, it does highlight food insecurity can be felt in population groups not typically thought to experience food insecurity. Indicating the prevalence of food insecurity in the UK is likely to be higher than reported and impacting a wider demographic of the UK population.

There have been limited studies measuring actual dietary intakes in food insecure groups, so by successfully utilizing a dietary monitoring app to capture food intake in geographically or socially isolated people across the age spectrum, as in this case, we have shown that this potentially represents a feasible means of obtaining dietary intake information in groups less physically accessible. We have additionally shown that the HFIAS tool, most usually employed to measure food insecurity as a result of financial/resource constraint, can usefully be employed to assess the impact of food availability in a western population. Using these approaches we show that groups at risk of food insecurity when faced with an unreliable food supply chain, can be identified. The results may aid policy maker's decisions for the supply of funds/support for population groups at risk of the experience of food insecurity in the future.

4.2. *Conclusions*

Anyone can be food insecure or at least feel that they are. For those on higher incomes, "necessary" expenditure (e.g., debt servicing, elevated household bills) may prohibit prior freedoms of food purchasing if income is reduced or added financial burdens are placed upon them (children returning home, requirement to care for elderly relatives, energy, and mortgage cost increases). Additional drivers such as accessibility can further amplify the perception of personal food instability, all of which can result in disproportionate purchasing. These factors add to the burden of patent food insecurity amongst those with lower incomes as their ability to purchase what remains is compromised due to available choice and cost, with healthier foods in general being more expensive.

In this study, we found that despite mostly being in receipt of incomes approximating to the national average or higher, food insecurity was still experienced by nearly 20%. Those who experienced food insecurity had a lower household income (10.5% less) and were required to spend a much greater proportion of it (16% more) on food compared with food secure participants. However, food insecurity was predominantly driven by a lack of available food, although those in lower income groups indicated that financial constraint was a significant factor. Furthermore, when spend on food exceeded 13% of income the risk of experiencing food insecurity increased by 1.6 fold ($p = 0.016$).

Deficiency related diseases will be much more prevalent in those who are food insecure in the UK, and here we found that riboflavin intakes were 36% lower amongst food insecure compared to food secure individuals ($p = 0.03$). Whilst not significant, vitamin B12 intake was 56% lower and iodine, 53.6% lower in the food insecure, indicating a broader potential for deficiency in subgroups of food insecure participants. However, deficiency related diseases may still occur in people who are food secure, as deficiencies for specific nutrients, such as iron, are not uncommon (e.g., iron).

In summary, we observed a significant level of food insecurity within a population not typically considered at risk as >50% received a household income equivalent to or greater than the national average, resulting in specific nutritional intake deficits. The use of the proportion of income required to be spent on food has the potential to be an indicator for the risk of food insecurity and may help identify groups at risk when food spend equals or exceeds 13% of income.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/nu14235078/s1; Table S1: Schofield equations for estimating BMR (kcal/d) from weight (kg); Table S2: Physical Activity Level (PAL) values for category of physical activity (age dependent) and the corresponding lower and upper cut off values.

Author Contributions: Conceptualization, L.C. and S.W.; methodology, M.T., E.E., Z.V., A.A., L.C. and S.W.; formal analysis, M.T., P.R., S.W.; data curation, M.T. and S.W.; writing—original draft preparation, M.T., P.R. and S.W., writing—review and editing, M.T., E.E., A.A., L.C., P.R. and S.W.; visualization, M.T.; supervision, S.W. and L.C.; project administration, L.C. and S.W. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Prime Minister's Statement on Coronavirus (COVID-19): 10 May 2020. Available online: https://www.gov.uk/government/speeches/pm-address-to-the-nation-on-coronavirus-10-may-2020 (accessed on 21 February 2022).
2. Loopstra, R. *Vulnerability to Food Insecurity since the COVID-19 Lockdown*; The Food Foundation: London, UK, 2020.
3. Lamarche, B.; Brassard, D.; Lapointe, A.; Laramée, C.; Kearney, M.; Côté, M.; Bélanger-Gravel, A.; Desroches, S.; Lemieux, S.; Plante, C. Changes in Diet Quality and Food Security among Adults during the COVID-19–Related Early Lockdown: Results from NutriQuébec. *Am. J. Clin. Nutr.* **2021**, *113*, 984–992. [CrossRef] [PubMed]
4. COVID-19 and Food Supply: Government Response to the Committee's First Report—Environment, Food and Rural Affairs Committee-House of Commons. Available online: https://publications.parliament.uk/pa/cm5801/cmselect/cmenvfru/841/84102.htm (accessed on 8 February 2022).
5. The Ins and Outs of Government Small Business Grants. Available online: https://www.axa.co.uk/business-insurance/business-guardian-angel/government-grants-for-small-businesses-what-you-need-to-know/ (accessed on 21 February 2022).
6. Powell, A.; Francis-Devine, B.; Clark, H. *Coronavirus Job Retention Scheme: Statistics*; House of Commons Library: London, UK, 2022.
7. Mackley, A.; McInnes, R. *Coronavirus: Universal Credit during the Crisis*; House of Commons Library: London, UK, 2022.
8. Bentall, R.P.; Lloyd, A.; Bennett, K.; McKay, R.; Mason, L.; Murphy, J.; McBride, O.; Hartman, T.K.; Gibson-Miller, J.; Levita, L.; et al. Pandemic Buying: Testing a Psychological Model of over-Purchasing and Panic Buying Using Data from the United Kingdom and the Republic of Ireland during the Early Phase of the COVID-19 Pandemic. *PLoS ONE* **2021**, *16*, e0246339. [CrossRef]
9. Power, M.; Doherty, B.; Pybus, K.; Pickett, K. How Covid-19 Has Exposed Inequalities in the UK Food System: The Case of UK Food and Poverty. *Emerald Open Res.* **2020**, *2*, 11. [CrossRef]
10. Jones, A.D.; Ngure, F.M.; Pelto, G.; Young, S.L. What Are We Assessing When We Measure Food Security? A Compendium and Review of Current Metrics. *Adv. Nutr.* **2013**, *4*, 481–505. [CrossRef]
11. What Is Household Food Insecurity? | ENUF. Available online: https://enuf.org.uk/what-household-food-insecurity (accessed on 21 February 2022).
12. Liu, Y.; Eicher-Miller, H.A. Food Insecurity and Cardiovascular Disease Risk. *Curr. Atheroscler. Rep.* **2021**, *23*, 24. [CrossRef] [PubMed]
13. Eicher-Miller, H.A. A Review of the Food Security, Diet and Health Outcomes of Food Pantry Clients and the Potential for Their Improvement through Food Pantry Interventions in the United States. *Physiol. Behav.* **2020**, *220*, 112871. [CrossRef]
14. Gundersen, C.; Ziliak, J.P. Food Insecurity and Health Outcomes. *Health Aff.* **2015**, *34*, 1830–1839. [CrossRef]
15. Nord, M.; Brent, C.P. *Food Insecurity in Higher Income Households*; US Department of Agriculture, Economic Research Service: Washington, DC, USA, 2002; p. 50.
16. Litton, M.M.; Beavers, A.W. The Relationship between Food Security Status and Fruit and Vegetable Intake during the COVID-19 Pandemic. *Nutrients* **2021**, *13*, 712. [CrossRef]
17. Butcher, L.M.; Ryan, M.M.; O'Sullivan, T.A.; Lo, J.; Devine, A. Food-Insecure Household's Self-Reported Perceptions of Food Labels, Product Attributes and Consumption Behaviours. *Nutrients* **2019**, *11*, 828. [CrossRef]

18. Morales, M.E.; Berkowitz, S.A. The Relationship between Food Insecurity, Dietary Patterns, and Obesity. *Curr. Nutr. Rep.* **2016**, *5*, 54–60. [CrossRef]
19. Mello, J.A.; Gans, K.M.; Risica, P.M.; Kirtania, U.; Strolla, L.O.; Fournier, L. How Is Food Insecurity Associated with Dietary Behaviors? An Analysis with Low Income, Ethnically Diverse Participants in a Nutrition Intervention Study. *J. Am. Diet. Assoc.* **2010**, *110*, 1906–1911. [CrossRef] [PubMed]
20. Avery, A. Food Insecurity and Malnutrition. *Kompass Nutr. Diet.* **2021**, *1*, 41–43. [CrossRef]
21. University of Cambridge, M.E.U. *NatCen Social Research National Diet and Nutrition Survey Years 1–11, 2008–2019. [Data Collection]*, 19th ed.; University of Cambridge: Cambridge, UK, 2022.
22. Household below Average Income Series: Quality and Methodology Information Report FYE 2020. Available online: https://www.gov.uk/government/statistics/households-below-average-income-for-financial-years-ending-1995-to-2020/household-below-average-income-series-quality-and-methodology-information-report-fye-2020 (accessed on 9 February 2022).
23. Muellbauer, J. McClements on Equivalence Scales for Children. *J. Public Econ.* **1979**, *12*, 221–231. [CrossRef]
24. Shepshed, A. *Inequality and Poverty*; The Institute for Fiscal Studies: London, UK, 2003.
25. Coates, J.; Swindale, A.; Bilinsky, P. *Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide: Version 3: (576842013-001)*; American Psychological Association: Washington, DC, USA, 2007.
26. EFSA. Example of a Protocol for Identification of Misreporting (under- and Overreporting of Energy Intake) Based on the PILOT-PANEU Project. *EFSA J.* **2013**, *11*, 1–17.
27. Dutch, D.C.; Golley, R.K.; Johnson, B.J. Diet Quality of Australian Children and Adolescents on Weekdays versus Weekend Days: A Secondary Analysis of the National Nutrition and Physical Activity Survey 2011–2012. *Nutrients* **2021**, *13*, 4128. [CrossRef]
28. Office for National Statistics. *Social Survey Division Annual Population Survey, April 2020–March 2021. [Data Collection]*, 2nd ed.; Office for National Statistics: London, UK, 2021.
29. Department for Environment Food and Rural Affairs National Statistics Family Food 2019/20. Available online: https://www.gov.uk/government/statistics/family-food-201920/family-food-201920 (accessed on 15 August 2022).
30. Sharma, S.V. Social Determinants of Health–Related Needs During COVID-19 Among Low-Income Households With Children. *Prev. Chronic. Dis.* **2020**, *17*, 33006541. [CrossRef] [PubMed]
31. Clay, L.A.; Rogus, S. Impact of Employment, Essential Work, and Risk Factors on Food Access during the COVID-19 Pandemic in New York State. *Int. J. Environ. Res. Public. Health* **2021**, *18*, 1451. [CrossRef]
32. Raifman, J.; Bor, J.; Venkataramani, A. Association Between Receipt of Unemployment Insurance and Food Insecurity Among People Who Lost Employment During the COVID-19 Pandemic in the United States. *JAMA Netw. Open* **2021**, *4*, e2035884. [CrossRef]
33. Molitor, F.; Doerr, C.; Kehl, S. Unemployment, SNAP Enrollment, and Food Insecurity Before and After California's COVID-19 Shutdown. *J. Nutr. Educ. Behav.* **2021**, *53*, 1055–1059. [CrossRef] [PubMed]
34. Ogundijo, D.A.; Tas, A.A.; Onarinde, B.A. Exploring the Impact of COVID-19 Pandemic on Eating and Purchasing Behaviours of People Living in England. *Nutrients* **2021**, *13*, 1499. [CrossRef]
35. Wolfson, J.A.; Leung, C.W. Food Insecurity and COVID-19: Disparities in Early Effects for US Adults. *Nutrients* **2020**, *12*, 1648. [CrossRef]
36. Coronavirus and the Impact on UK Households and Businesses—Office for National Statistics. Available online: https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/articles/coronavirusandtheimpactonukhouseholdsandbusinesses/2021 (accessed on 16 August 2022).
37. House of Commons Environment, Food and Rural Affairs Committee. *COVID-19 and the Issues of Security in Food Supply*; House of Commons Environment, Food and Rural Affairs Committee: London, UK, 2021; p. 32.
38. Tesco Shows How It Adapted as Shoppers Moved Online Fast during the Covid-19 Lockdown—And Counts the Costs of Change. Available online: https://internetretailing.net/covid-19/covid-19/tesco-shows-how-it-adapted-as-shoppers-moved-online-fast-during-the-covid-19-lockdown--and-counts-the-costs-of-change-21616 (accessed on 12 May 2022).
39. UK Online Grocery Growth Clicks up as Lockdown Trends Continue. Available online: https://www.kantar.com/uki/inspiration/fmcg/uk-online-grocery-growth-clicks-up-as-lockdown-trends-continue (accessed on 12 May 2022).
40. Spurlock, C.A.; Todd-Blick, A.; Wong-Parodi, G.; Walker, V. Children, Income, and the Impact of Home Delivery on Household Shopping Trips. *Transp. Res. Rec.* **2020**, *2674*, 335–350. [CrossRef]
41. Public Health England. *Impact of COVID-19 Pandemic on Grocery Shopping Behaviours*; Public Health England: London, UK, 2022; p. 38.
42. Department for Environment, Food and Rural Affairs United Kingdom Food Security Report 2021: Contents. Available online: https://www.gov.uk/government/statistics/united-kingdom-food-security-report-2021/united-kingdom-food-security-report-2021-contents (accessed on 16 August 2022).
43. Kent, K.; Murray, S.; Penrose, B.; Auckland, S.; Horton, E.; Lester, E.; Visentin, D. The New Normal for Food Insecurity? A Repeated Cross-Sectional Survey over 1 Year during the COVID-19 Pandemic in Australia. *Int. J. Behav. Nutr. Phys. Act.* **2022**, *19*, 115. [CrossRef] [PubMed]
44. Kang, Y.; Baidya, A.; Aaron, A.; Wang, J.; Chan, C.; Wetzler, E. Differences in the Early Impact of COVID-19 on Food Security and Livelihoods in Rural and Urban Areas in the Asia Pacific Region. *Glob. Food Secur.* **2021**, *31*, 100580. [CrossRef]

45. Benites-Zapata, V.A.; Urrunaga-Pastor, D.; Solorzano-Vargas, M.L.; Herrera-Añazco, P.; Uyen-Cateriano, A.; Bendezu-Quispe, G.; Toro-Huamanchumo, C.J.; Hernandez, A.V. Prevalence and Factors Associated with Food Insecurity in Latin America and the Caribbean during the First Wave of the COVID-19 Pandemic. *Heliyon* **2021**, *7*, e08091. [CrossRef] [PubMed]
46. Niles, M.T.; Bertmann, F.; Belarmino, E.H.; Wentworth, T.; Biehl, E.; Neff, R. The Early Food Insecurity Impacts of COVID-19. *Nutrients* **2020**, *12*, 2096. [CrossRef]
47. Gaitán-Rossi, P.; Vilar-Compte, M.; Teruel, G.; Pérez-Escamilla, R. Food Insecurity Measurement and Prevalence Estimates during the COVID-19 Pandemic in a Repeated Cross-Sectional Survey in Mexico. *Public Health Nutr.* **2021**, *24*, 412–421. [CrossRef] [PubMed]
48. Dondi, A.; Candela, E.; Morigi, F.; Lenzi, J.; Pierantoni, L.; Lanari, M. Parents' Perception of Food Insecurity and of Its Effects on Their Children in Italy Six Months after the COVID-19 Pandemic Outbreak. *Nutrients* **2021**, *13*, 121. [CrossRef]
49. Drewnowski, A. Fat and Sugar: An Economic Analysis. *J. Nutr.* **2003**, *133*, 838S–840S. [CrossRef] [PubMed]
50. Food Prices Tracking: July Update | Food Foundation. Available online: https://foodfoundation.org.uk/news/food-prices-tracking-july-update (accessed on 16 August 2022).
51. Department for Environment Food and Rural Affairs Data for Chart 2.2: Trend in Share of Spend Going on Food and Non-Alcoholic Beverages in Low Income and All UK Households, 2003-04 to 2018-19-GOV.UK. Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/908880/foodstatisticspocketbook-shareofspendonfood-13aug20.csv/preview (accessed on 4 October 2021).
52. Connors, C.; Malan, L.; Canavan, S.; Sissoko, F.; Carmo, M.; Sheppard, C.; Cook, F. The Lived Experience of Food Insecurity under Covid-19. In *A Bright Harbour Collective Report for the Food Standards Agency*; Food Standard Agency: London, UK, 2020; p. 41.
53. Thompson, E.; Jitendra, A.; Rabindrakumar, S. *5 Weeks Too Long: Why We Need to End the Wait for Universal Credit*; The Trussell Trust: Salisbury, UK, 2019; p. 44.
54. The Food Foundation Government Data Shows £20 Uplift Is Likely to Have Protected People on Universal Credit from Food Insecurity | Food Foundation. Available online: https://foodfoundation.org.uk/press-release/government-data-shows-ps20-uplift-likely-have-protected-people-universal-credit-food (accessed on 19 August 2022).
55. School Food Matters Food Insecurity during Lockdown. Available online: https://www.schoolfoodmatters.org/news-views/news/food-insecurity-during-lockdown (accessed on 16 August 2022).
56. Fuller, E.; Urszula, B.; Davies, B.; Mandalia, D.; Stocker, B. *The Food and You Survey—Wave 5*; Food Standard Agency: London, UK, 2019; p. 96.
57. Powers, H.J.; Hill, M.H.; Mushtaq, S.; Dainty, J.R.; Majsak-Newman, G.; Williams, E.A. Correcting a Marginal Riboflavin Deficiency Improves Hematologic Status in Young Women in the United Kingdom (RIBOFEM). *Am. J. Clin. Nutr.* **2011**, *93*, 1274–1284. [CrossRef]
58. Prentice, A.M.; Bates, C.J. A Biochemical Evaluation of the Erythrocyte Glutathione Reductase (EC 1.6.4.2) Test for Riboflavin Status. 2. Dose-Response Relationships in Chronic Marginal Deficiency. *Br. J. Nutr.* **1981**, *45*, 53–65. [CrossRef]
59. Thakur, K.; Tomar, S.K.; Singh, A.K.; Mandal, S.; Arora, S. Riboflavin and Health: A Review of Recent Human Research. *Crit. Rev. Food Sci. Nutr.* **2017**, *57*, 3650–3660. [CrossRef]
60. Powers, H.J. Riboflavin (Vitamin B-2) and Health. *Am. J. Clin. Nutr.* **2003**, *77*, 1352–1360. [CrossRef]
61. Shipton, M.J.; Thachil, J. Vitamin B12 Deficiency—A 21st Century Perspective. *Clin. Med.* **2015**, *15*, 145–150. [CrossRef]
62. Vahid, F.; Hekmatdoost, A.; Mirmajidi, S.; Doaei, S.; Rahmani, D.; Faghfoori, Z. Association Between Index of Nutritional Quality and Nonalcoholic Fatty Liver Disease: The Role of Vitamin D and B Group. *Am. J. Med. Sci.* **2019**, *358*, 212–218. [CrossRef]
63. Zaric, B.L.; Obradovic, M.; Bajic, V.; Haidara, M.A.; Jovanovic, M.; Isenovic, E.R. Homocysteine and Hyperhomocysteinaemia. *Curr. Med. Chem.* **2019**, *26*, 2948–2961. [CrossRef]
64. Tanumihardjo, S.A.; Russell, R.M.; Stephensen, C.B.; Gannon, B.M.; Craft, N.E.; Haskell, M.J.; Lietz, G.; Schulze, K.; Raiten, D.J. Biomarkers of Nutrition for Development (BOND)-Vitamin A Review. *J. Nutr.* **2016**, *146*, 1816S–1848S. [CrossRef] [PubMed]
65. Thurnham, D.I.; McCabe, G.P.; Northrop-Clewes, C.A.; Nestel, P. Effects of Subclinical Infection on Plasma Retinol Concentrations and Assessment of Prevalence of Vitamin A Deficiency: Meta-Analysis. *Lancet Lond. Engl.* **2003**, *362*, 2052–2058. [CrossRef]
66. Marley, A.; Smith, S.C.; Ahmed, R.; Nightingale, P.; Cooper, S.C. Vitamin A Deficiency: Experience from a Tertiary Referral UK Hospital; Not Just a Low- and Middle-Income Country Issue. *Public Health Nutr.* **2021**, *24*, 6466–6471. [CrossRef]

7.5 APPENDIX E: Covid-19 Dietary assessment study survey.

PAGE 1

Welcome to the **Covid-19 Food Security and Dietary Assessment** Study

We would like to invite you to take part in our research study exploring the potential impact of Covid-19 related social isolation and movement restriction on dietary intake and access to food. Firstly, we would like you to understand why the research is being done and what it would involve for you. Please take some time to read the **participant information sheet which can be accessed by following this link (ADD LINK TO PDF OF P.I.S ONCE APPROVED)** before joining the survey and completing the consent questions.

This research has been approved by the School of Biosciences Research Ethics Committee (SBRECXXXXXXX)

If you have any questions please contact lisa.coneyworth@nottingham.ac.uk or simon.welham@nottingham.ac.uk

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Consent

The following questions confirm that you consent to taking part in this online survey. Your individual identities will be anonymised prior to analysis. Your participation in this survey and subsequent dietary analysis is voluntary and you may withdraw at any time by simply not completing or submitting the survey. Data will be stored in accordance with the General Data Protection Regulation (GDPR). Cookies, personal data stored by your Web browser, are not used in this survey. However, as an online participant in this research, there is always the minimal risk of intrusion by outside agents and therefore the possibility of being identified.

I confirm that I have read the participant information sheet and I understand all information provided about the online survey.

True False

I understand that my individual identity will be anonymised prior to analysis.

True False

I understand that my participation in the online survey is voluntary and that I may withdraw at any time by exiting the survey.

True False

I agree that data collected in the online survey may be used for academic publication and conference presentations.

True False

I understand that relevant sections of data collected in the survey may be looked at by authorised individuals from the University of Nottingham, the research group and regulatory authorities where it is relevant to my taking part in this survey. I give permission for these individuals to have access to these records and collect, store, analyse and publish information obtained from my participation in this survey.

True False

I understand that anonymous direct quotes from the survey may be used in study reports.

True False

I agree to take part in the online survey.

True False

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Please tell us a little bit about yourself

Questions on this page will ask you to provide information about yourself.

1. What is your sex?
   - ❑ Male
   - ❑ Female
   - ❑ Prefer not to say
   - ❑ Other

2. What is your age in years and months?

(yy/mm)

3. Please state your height and weight

Body Weight	
Kg	
Lbs	

Stones and Pounds	
Height	
Feet and inches	
Centimetres	

4. Please state your ethnicity (INCLUDE AS A DROP DOWN BOX)
   White

   - ❑ English/Welsh/Scottish/Northern Irish/British
   - ❑ Irish
   - ❑ Gypsy or Irish Traveller
   - ❑ Any other White Background

   Mixed/Multiple Ethnic groups

   - ❑ White and Black Caribbean
   - ❑ White and Black African
   - ❑ White and Asian
   - ❑ Any other Mixed / Multiple ethnic background

   Asian / Asian British

   - ❑ Indian
   - ❑ Pakistani
   - ❑ Bangladeshi
   - ❑ Chinese
   - ❑ Any other Asian background

   Black / African / Caribbean / Black British

   - ❑ African
   - ❑ Caribbean
   - ❑ Any other Black / African / Caribbean background

   Other ethnic group

   - ❑ Arab
   - ❑ Any other ethnic group

5. What is your highest level of education? *Please select one option*
   - ❑ No qualifications
   - ❑ Completed GCSE/CSE/O-levels, NVQ 2, or equivalent
   - ❑ AS Level, A levels, Access to Higher Education, NVQ 3 or equivalent
   - ❑ Certificate of Higher Education (CertHE) ,Higher apprenticeship, Higher National Certificate (HNC), NVQ level 4 or equivalent
   - ❑ Diploma of Higher education (DipHE), Foundation Degree, Higher National Diploma (HND) or equivalent
   - ❑ Undergraduate degree or equivalent
   - ❑ Postgraduate degree (e.g., MEng, MA, MSc, PGCE)
   - ❑ Postgraduate degree (PhD or DPhil)

6. Please enter your Post Code below. Post code information will help us to complete regional analysis of the data we collect.

7. Are you currently:
   - ❑ Self-isolating following symptoms
   - ❑ High risk
   - ❑ Self-isolating following symptoms in a member of your household
   - ❑ Not applicable

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Food security

We would like to ask you some question related to your household food access.

8. Please complete the table below

Resources = lack of money or lack of food available

If you have any concerns about access to food or would like further support, please visit

https://www.trusselltrust.org/get-help/emergency-food/

No	Question	Response		
1	In the past four weeks, did you worry that your household would not have enough food?	0 = No (skip to Q2) 1 = Yes		
1a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		
2	In the past four weeks were you or any household member not able to eat the kinds of foods you preferred because of lack of resources?	0 = No (skip to Q3) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
2a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks)		

		3 = Often (more than ten times in the past four weeks		
3	In the past four weeks, did you or any member have to eat a limited variety of foods due to lack of resources?	0 = No (skip to Q4) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
3a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		
4	In the past four weeks, did you or any household member have to eat foods that you really did not want to eat because of lack of resources to obtain other types of food?	0 = No (skip to Q5) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
4a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		
5	In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	0 = No (skip to Q6) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
5a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		
6	In the past four weeks, did you or any other member have to eat fewer meals in a day because there was not enough food?	0 = No (skip to Q7) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
6a	How often did this happen	1 = Rarely (once or twice in the past four weeks)		

		2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		
7	In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?	0 = No (skip to Q8) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
7a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		
8	In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?	0 = No (skip to Q9) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
8a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		
9	In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?	0 = No (Survey finished) 1 = Yes	Lack of Money (please tick)	Lack of Food available (please tick)
9a	How often did this happen	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks		

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How have you been coping during the Covid 19 self-isolation and movement restrictions?

9. In the past 7 days, if there have been times when you did not have enough food or money to buy food, how many days has your household had to:

Behaviours:	Frequency: Number of days out of the past seven: (Use numbers 0 – 7 to answer number of days; Use NA for not applicable)
a) Rely on less preferred and less expensive foods? (switching from branded to non-branded food items or using cheaper cuts of meat, e.g., beef mince instead of beef steak or switching from 5% fat beef mince to higher percentage fat mince)	
b) Reduce the amount of fruit and vegetable intake? c) Reduce the variety of fruit and vegetable intake?	
d) Borrow food, or rely on help from a friend or relative?	
e) Access the Food Bank	
f) Purchase food on credit?	
g) Send household members to eat elsewhere?	
h) Limit portion size at mealtimes?	
i) Restrict consumption by adults in order for small children to eat?	
j) Feed working members of HH at the expense of non-working members?	
k) Reduce number of meals eaten in a day?	
l) Reduce food variation in meals? (eat the same foods at each meal occasion or eat the same foods for consecutive days)	
m) Skip entire days without eating?	

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Food purchasing habits – sourcing of food

10. Prior to the Covid-19 social isolation and movement restrictions which of following best describe where you purchased foods from? (Tick all that apply)

		Never, less than once a month	2-3 times per month	Once a week	2-4 times per week	5-6 times per week	Once a day	Prefer not to say

1	Shop at one of the UK "Big Four supermarkets" (Tesco, Sainsbury's, Morrisons, Asda)							
a	In person							
b	Home delivery							
c	Click and collect							
2	Other Supermarket (Aldi, Lidl, Iceland, Netto)							
3	Other Supermarket (Waitrose, Marks and Spencer)							
4	Smaller shops (e.g., Co-op, Tesco express, Sainsbury local)							
5	Corner shops (e.g., Happy Shopper, 7-11, Spar)							
6	Markets							
7	Local independents (e.g., butchers, bakers, green grocers)							
8	Subscription delivery fruit and vegetables (e.g., Able & Cole, Riverford Organic, Wonky veg boxes)							
9	Subscription Delivery meal boxes (e.g., Hello fresh, Mindful Chef, Gousto)							
10	Foodbank and other charity organisations							

11. Since the Covid-19 social isolation and movement restrictions, which of following best describes where you now purchase foods from? (Tick all that apply)

		Never, less than once a month	2-3 times per month	Once a week	2-4 times per week	5-6 times per week	Once a day	Prefer not to say
1	Shop at one of the UK "Big Four supermarkets" (Tesco,							

	Sainsbury's, Morrisons, Asda)							
a	In person							
b	Home delivery							
c	Click and collect							
2	Other Supermarket (Aldi, Lidl, Iceland, Netto)							
3	Other Supermarket (Waitrose, Marks and Spencer)							
4	Smaller shops (e.g., Co-op, Tesco express, Sainsbury local)							
5	Corner shops (e.g., Happy Shopper, 7-11, Spar)							
6	Markets							
7	Local independents (e.g., butchers, bakers, green grocers)							
8	Subscription delivery fruit and vegetables (e.g., Able & Cole, Riverford Organic, Wonky veg boxes)							
9	Subscription Delivery meal boxes (e.g., Hello fresh, Mindful Chef, Gousto)							
10	Foodbank and other charity organisations							

12. Since Covid-19 movement restriction, which of the following best describes how you are purchasing food?
    - ❑ I am able to shop in person
    - ❑ I am purchasing food online for home delivery
    - ❑ Partner/spouse/adult child who lives with me is going food shopping in person
    - ❑ I am reliant on family or friends who do not live with me to purchase food
    - ❑ I am in receipt of food parcels delivered to those who were identified as critically vulnerable

13. Prior to the Covid-19 social isolation and movement restrictions, how often did you eat out or consume take-away?
    - ❑ Never less than once a week
    - ❑ Once a week
    - ❑ 2-4 times per week
    - ❑ 5-6 times per week
    - ❑ Once a day
    - ❑ 2-3 times per day

Diet

The following questions will ask you about your typical diet. This data will help us to understand how your diet may have changed during the recent period of Covid-19 social isolation and movement restrictions.

14. Do you usually eat meat (including bacon, ham, poultry, game, meat pies, and sausages)?'

- ❑ Yes
- ❑ No

15. Do you usually eat fish?' (Including shellfish)

- ❑ Yes
- ❑ No

16. Do you usually eat dairy products (including milk, cheese, butter, yoghurt)?

- ❑ Yes
- ❑ No

17. Do you usually eat eggs (including eggs in cakes and other baked foods)?

- ❑ Yes
- ❑ No

18. Consider your diet over the last 7 days. Do you think that you have eaten.....
    - ❑ Less than your usual diet
    - ❑ About the same as your usual diet
    - ❑ More than your usual diet

19. Consider your diet over the last 7 days. Do you think that your diet has been....
    - ❑ Less healthy than your usual diet
    - ❑ About the same as your usual diet
    - ❑ More healthy than your usual diet

20. Consider your diet over the last 7 days. Compared to your diet before the Covid-19 related social isolation and movement restrictions, do you think your diet has changed?
    - ❑ I think that my diet has changed a little
    - ❑ I think that my diet is the same as usual
    - ❑ I think that my diet has changed a lot

21. Has your consumption of the following foods changed since the covid-19 social isolation and movement restrictions were introduced?

	Increased	**No change**	**Decreased**	**I do not know**	**I prefer not to say**	**Not applicable**
Fruits						
Vegetables						
Pulses (beans, lentils, chickpeas)						
Fish						
Meat						
Sugary drinks						
Alcohol						
Pastries, cakes, chocolates						
Pre-prepared bought meals						
Home-cooked meals						
Snacks						
Dietary supplements						

22. Are you currently taking any supplements? This includes over the counter and prescribed supplements (e.g., multivitamins, iron, fish oil etc)

- ❑ Yes
- ❑ No
- ❑ Prefer not to say

If yes, please can you describe any supplementation you are taking, TABLE OF OPTIONS WITH RADIO BUTTONS

- ❑ Combined multivitamins and minerals
- ❑ Combined multivitamins and minerals with iodine/iodide
- ❑ Vitamin B complex
- ❑ Folic acid
- ❑ Vitamin B12
- ❑ Vitamin C
- ❑ Vitamin D
- ❑ Vitamin E
- ❑ Iron tablets prescribe for the treatment of iron deficiency/Anaemia.
- ❑ Cod liver oil / fish oil
- ❑ Prefer not to say

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Household

The following questions will ask you about your households

23. Are you currently
    - ❑ Living with parents/guardians
    - ❑ Renting (council tenant)
    - ❑ Renting (private landlord)
    - ❑ Renting (university accommodation)
    - ❑ Home owner (paying mortgage)
    - ❑ Home owner (no mortgage)
    - ❑ Away from home in quarantine?
    - ❑ Prefer not to say
    - ❑ Other

24. How many adults are currently in the household (including yourself)
    - ❑ 19-64 years
    - ❑ 65 years and over
    - ❑ Prefer not to say

25. How many children are currently living with you in the household?
    - ❑ 0 – 17 months
    - ❑ 1.5 – 3 years
    - ❑ 4-10 years
    - ❑ 11-18 years
    - ❑ Prefer not to say

26. Has the number of people in your household changed since the Covid-19 movement restrictions and self-isolation requirements were introduced?
- ❑ Yes
- ❑ No
- ❑ Prefer not to say

If yes, please state how many adults (including yourself) and children are usually in your household (pre covid-19)?

XX Adults and XX Children (X=drop down box)

27. What is your **usual** total household income (prior to covid-19)?
    - ❑ Prefer not to say
    - ❑ Less than £5,000 a year (£96 a week)
    - ❑ £5,000- £9,999 a year (£96-£191 a week)
    - ❑ £10,000-£14,999 a year (£192 - £287 a week)
    - ❑ £15,000-£19,999 a year (£288 - £384 a week)
    - ❑ £20,000-£24,999 a year (£385 - £480 a week
    - ❑ £25,000-£29,999 a year (£481 - £576 a week)
    - ❑ £30,000-£34,999 a year (£577 - £673 a week)
    - ❑ £35,000-£39,999 a year (£674 - £769 a week)
    - ❑ £40,000-£44,999 a year (£770 - £865 a week)
    - ❑ £45,000-£49,999 a year (£866 - £961 a week)
    - ❑ £50,000-£74,999 a year (£962 - £1442 a week)
    - ❑ £75,000-£99,999 a year (£1443 - £1922 a week)
    - ❑ More than £100,000 a year (£1923 a week)

28. What is your **usual** monthly expenditure on food (excluding toiletries, household items and alcohol) prior to Covid-19
    - ❑ Prefer not to say
    - ❑ Less than £200 a month (£46 a week)
    - ❑ £200-£300 a month (£47-£69 a week)
    - ❑ £300-£400 a month (£70-£90 a week)
    - ❑ £400-£500 a month (£91-£115 a week)
    - ❑ £500-£600 a month (£116-£138 a week)
    - ❑ £600-£700 a month (£139-£161 a week)
    - ❑ More than £700 a month (£162 a week)
29. What is your **current** total household income (since Covid-19 self-isolation and movement restrictions have been introduced)?
    - ❑ Prefer not to say
    - ❑ Less than £5,000 a year (£96 a week)
    - ❑ £5,000- £9,999 a year (£96-£191 a week)
    - ❑ £10,000-£14,999 a year (£192 - £287 a week)
    - ❑ £15,000-£19,999 a year (£288 - £384 a week)
    - ❑ £20,000-£24,999 a year (£385 - £480 a week
    - ❑ £25,000-£29,999 a year (£481 - £576 a week)
    - ❑ £30,000-£34,999 a year (£577 - £673 a week)
    - ❑ £35,000-£39,999 a year (£674 - £769 a week)

- ❑ £40,000-£44,999 a year (£770 - £865 a week)
- ❑ £45,000-£49,999 a year (£866 - £961 a week)
- ❑ £50,000-£74,999 a year (£962 - £1442 a week)
- ❑ £75,000-£99,999 a year (£1443 - £1922 a week)
- ❑ More than £100,000 a year (£1923 a week)

30. What is your **current** monthly expenditure on food (excluding toiletries, household items and alcohol) (since Covid-19 self-isolation and movement restrictions have been introduced)

- ❑ Prefer not to say
- ❑ Less than £200 a month (£46 a week)
- ❑ £200-£300 a month (£47-£69 a week)
- ❑ £300-£400 a month (£70-£90 a week)
- ❑ £400-£500 a month (£91-£115 a week)
- ❑ £500-£600 a month (£116-£138 a week)
- ❑ £600-£700 a month (£139-£161 a week)
- ❑ More than £700 a month (£162 a week)

Page 9.

Work

The following questions will ask you about your employment status

31. What was your employment status prior to the Covid-19 pandemic? Tick all that apply
- ❑ At university or college
- ❑ Self Employed
- ❑ In part time employment
- ❑ In full-time employment
- ❑ Unable to work due to disability
- ❑ Unable to work due to sickness
- ❑ Homemaker/full-time parent
- ❑ Unemployed and seeking work
- ❑ Retired
- ❑ Prefer not to say

32. What is your current employment status? Tick all that apply
- ❑ At university or college
- ❑ Self Employed
- ❑ In part-time employment
- ❑ In full-time employment
- ❑ Unable to work due to disability
- ❑ Unable to work due to sickness
- ❑ Homemaker / full-time parent
- ❑ Unemployed and seeking work
- ❑ Furloughed worker

- ❑ Retired
- ❑ Prefer not to say

33. What is your usual employment type?

- ❑ **A large organisation, with higher managerial or professional capacity** (e.g., lawyers, Architects, Medical doctors, Chief executives, Economist)

- ❑ **Lower managerial, administrative & professional occupations** (e.g., Social workers, Nurses, Journalists, Teachers)

- ❑ **Intermediate occupations** (e.g., Armed forces up to sergeant, Paramedics, Nursery Nurses, Police up to sergeant, Bank staff)

- ❑ **Small employers and own account workers** (e.g., Farmers, Shopkeepers, Taxi drivers, Driving instructors, Window cleaners)

- ❑ **Lower supervisory and technical occupations (**e.g., Mechanics, Chefs, Train drivers, Plumbers, Electricians)

- ❑ **Semi-routine occupations** (e.g., Traffic wardens, Receptionists, Supermarket workers, Care workers, Telephone Salespersons)

- ❑ **Routine occupations** (e.g., Bar staff, cleaners, labourers, Bus drivers, Lorry drivers)

- ❑ **Never worked and long term unemployed**

- ❑ **Full time student**
- ❑ **Prefer not to say**

34. Are you a key worker currently working in one of the sectors identified as critical to the Covid-19 response?
    - ❑ Health and social care (e.g., doctors, nurses, midwives, social care staff)
    - ❑ Education and childcare (e.g., teachers, support worker, specialist education professional)
    - ❑ Key public services worker (e.g., justice staff, religious staff)
    - ❑ Local or national government (e.g., staff essential for delivering Covid-19 response or delivering essential public services)

- ❑ Food and other necessary goods (e.g., workers involved in food production, distribution, sale and delivery or workers supplying other key goods such as medicines or protective equipment)
- ❑ Public safety or national security (e.g., police and support staff, fire and rescue service)
- ❑ Transport (e.g., people who are responsible for keeping rail, road, air and sea networks operating during Covid-19)
- ❑ Utility, communication and financial services (e.g., bank and building society staff, energy, water, gas or sewerage workers or those employed in the postal service)
- ❑ None of above

35. Do you or any member of your household receive or access food assistance programmes from any of the following (please tick all that apply)
    - ❑ Healthy Start Vouchers
    - ❑ Free school meals
        - ❑ If yes, are you receiving the £15 voucher or gift card for your child/ren
    - ❑ Local food bank
    - ❑ Food parcel from the government (Delivered to persons identified as clinically vulnerable)
    - ❑ Prefer not to say.
    - ❑ Other

Final Page

Thank you.

We would like to thank you for taking time to complete this survey. Your participation is greatly appreciated and the data you have shared will help us to understand the impact of the Covid-19 related social isolation and movement restriction on food availability in the UK population.

We would now like to invite you to take part in a 4 consecutive day online food diary (using the online Libro mobile app) to help us assess the impact of these social restrictions on dietary intake.

If you would like to complete a food diary, receive updates about the results of this study or be contacted in the future for potential follow up, please provide your email address in the text box below. (optional). If you do not wish to provide your email address, please leave this text box blank. This email address will not be shared with any third parties.

ADD TEXT BOX HERE

36. I agree that researchers may use this email address to (please tick all that apply)
- ❑ Send further information to enable a 4-day food diary to be provided using the online Libro mobile app
- ❑ Send updates about the study findings and results
- ❑ Contact me in the future about further data collection once the social isolation and movement restrictions are lifted
- ❑ No, I do not agree. I do not want to be contacted further by the research team.

If no, automatically go to final screen to exit survey.

If you have agreed to take part in the food diary, one of our researchers will contact you directly using the email address you have provided above. You will be provided with a link to download the free Libro dietary assessment app and some instructions to help you complete your food diary. However, before we can complete your Libro profile we need to ask you two more questions.

37. Which of the following best describes your **current** physical activity level?
   - ❑ None: Little or no regular exercise
   - ❑ Light: e.g., walking, etc for 1-3 days per week
   - ❑ Moderate: e.g., brisk walking or riding a bike 3 or more days per week
   - ❑ Very active: e.g., exercising at a vigorous intensity 6 or more days per week
   - ❑ Ultra-active: Training twice daily

38. Has your physical activity level increased or decreased since the Covid-19 movement restrictions were implemented
- ❑ Increased
- ❑ Decreased
- ❑ No change
- ❑ Prefer not to say

7.6 APPENDIX F: Report written for Chef's in Schools (PIPs placement.)

Chefs in Schools:

Engagement Strategy and Evaluation Methods

Michelle Thomas

April 2021

Polly Praill, Naomi Duncan, Nicole Pisani and Michael Nelson

Contents

Figures

Acronyms

CiS	**Chefs in Schools**
KCL	**Kings College London**
PHN	**Public Health Nutrition Research**
FSM	**Free School Meals**
CEO	**Chef Executive Officer**
UoN	**University of Nottingham**
MN	**Michael Nelson**
PP	**Polly Prail**
ND	**Naomi Duncan**
NP	**Nicole Pisani**
MT	**Michelle Thomas**

Background

Chefs in Schools (CiS) was launched in April 2018 by Nicole Pisani (Co-founder), previous Executive Chef at Gayhurst Community School and former head chef of London restaurant NOPI, Louise Nichols (Co-founder and Executive Head teacher of the Leap Federation of Schools, Hackney) and Henry Dimbleby (Co-founder and Chair of Chefs in Schools and Co-author of the School Food Plan)[1]. Nicole is responsible for development of the CiS Model[1], the model is based on the 'whole school approach' which aims to improve the health of pupils by connecting the food served in the dining hall to the classroom whilst promoting good a school food culture. The whole school approach was developed from 1998 definition of a Health Promoting School[2] defined as "a school that is constantly strengthening its capacity as a healthy setting for living, learning and working"[3].

The model developed by CiS is tailored to each school needs and circumstances. The main elements of the model are 1) training of existing kitchen teams to develop and improve food preparation and cooking techniques to restaurant standards. 2) support schools in the recruitment of restaurant chefs, this is achieved by reviewing potential applicants CVs and providing consultation during the interview process. 3) support and training for restaurant chefs to improve school food. This is achieved by providing onsite support during launch and a comprehensive Chefs Pack which includes expert advice and guidance on transforming school food. This includes requiring the Chefs to lead by example when running a kitchen and guidance and practical advice on training their kitchen teams to ensure the food served is meeting School Food Standards as well as guidance on the financial aspects of running a kitchen.

The mission of Chefs in Schools is to serve great and creative food and to engage and develop children's knowledge of diet and health whilst at the same time teaching food preparation and cooking skills. Chefs in Schools primary focus is on reducing the inequality of diet related disease and all forms of malnutrition including hidden hunger and disease associated with overweight and obesity for children living in areas with high socio-economic deprivation. To date, 35 schools predominantly based in London have adopted the Chefs in Schools model and transformed their school food provision. Evaluation of the work of Chefs in Schools is required to gather the evidence on the impact the model has on the transformation of school food and children's health and to further expand the reach of Chefs in Schools.

Engagement strategy: overview

The engagement strategy was developed with Michael Nelson (PHN Research and KCL), Naomi Duncan (CEO, CiS), Polly Praill (Head of Development), CiS and Michelle Thomas (Ph.D. Student, UoN) in consultation with Nicole Pisani (Co- founder, CiS). The remit was to consider the evidence headteachers would require, persuading them of the benefits of changing their catering arrangements.' We considered the types of tools suitable for evaluating the evidence. Additionally, we reviewed Chefs in Schools current auditing processes and tools for data collection.

The objective of the strategy is to develop an evidence base which will aid to increase the uptake of the Chefs in Schools model and develop Chefs in Schools as an authoritative voice on school food. Additional outputs include background information on the reasons why headteachers/schools sought to change their catering arrangements and work with Chefs in Schools and evidence on where typical costs were derived from when changing catering arrangements.

Chefs in Schools Model

Research Plan

The engagement strategy questions:

- What are the reasons head teachers/schools, changed their catering arrangement?
- Are there stakeholders' groups who may be resistance to change?
- What is the cost associated with changing catering arrangements?
- Does cooking from scratch have an impact on the cost to produce a school meal?
- Does changing the food served in schools' impact on the uptake of school meals? (to include FSM, Non-FSM, and packed lunch consumption).
- Does changing the food served in schools have an impact on pupil behaviour, concentration, and educational attainment?
- What is the impact of changing catering arrangements and working with CiS on catering teams levels of engagement and their health and wellbeing?
- What is the impact of working with Chefs in Schools on absences and retention rate of chefs and the wider kitchen team?

The study will investigate the above questions using a mixed method approach including qualitative and quantitative assessments. During the first wave of data collection, schools already working with CiS were invited to participate, as such data collected regarding previous catering arrangement is retrospective and reliant on memory. Part 1 of this document will report on the development of the head teachers survey and the results. Part 2 will focus on the review of Chefs in Schools current data collection process and tools.

Part 1

Head teachers survey

Background

In consultation with Michael Nelson and CiS, a flow diagram for the type of evidence a head teacher and school manger may find persuasive, and the tools required to evaluate the evidence was constructed (Figure 1). A search of the literature was carried out between January and March 2021 to identify studies which had developed tools to evaluate the following areas (1) pupils and parent satisfaction levels of school food, (2) studies evaluating the cost to implement a Breakfast Club and its impact on pupil's attainment, cognition, and behaviour (3) studies which assessed the school food environment, (4) studies which developed tools to measure food literacy.

Methods

The Head teachers and School Business Manager survey questions were developed in consultation with PP, ND and MN (Appendix 1 and 2). The surveys are a mix of qualitative (e.g., Likert scale) and quantitative (e.g., number of pupils enrolled in school) questions. Additionally, the surveys comprised free text answer options to key questions.

Questions on why schools wanted to change their catering arrangements, impact on pupil behaviour and concentration and the cost associated with changing catering arrangements were adapted from the evaluation survey carried out by Magic Breakfast[4]

Schools who already changed their catering arrangement with CiS between 2018 and 2020 were eligible to participate in the study (n = 32). The surveys were hosted on Survey Monkey and a link to the survey was sent by PP to the schools for completion. The survey ran from the 18th - 24th March 2021 and a reminder email was sent on 23rd March 2021. The aim was to receive responses from 50% head teachers currently working with CiS.

Data analysis

Data from the head teachers was coded and entered SPSS, Analysis was completed between school type and for all schools together. Descriptive statistics calculated to understand respondent characteristics. The normality of the data was assessed for respondents' levels of satisfaction with previous and current catering arrangements, where results were not normally distributed a Wilcoxon test was performed to test for significance between satisfaction levels before and after working with CiS. Where the data was normally distributed a paired samples T Test was performed. All analysis completed in SPSS version 27. Free text questions were coded and key themes identified as per the phases of thematic analysis listed by Braun and Clarke[5] .

Results

Respondent characteristics

In total 32 schools were contacted to participate in the survey. Responses were received from 62.5% of participants of which 100% were in a leadership role within the schools, sixty five percent (n = 13) listed their role as Head teacher, fifteen percent (n = 3) as Executive head teacher, ten percent (n =2) as Director and five percent (n = 1) as either Head of school or Principal.

The main type of schools, respondents was employed by was primary schools (70%) (n = 14). Twenty percent of respondent listed their school type as 'Other', of which three schools stated they were 'All through schools' and one listed their school as a private early year's nursery (10 months -5 years). Ten percent of respondent listed their school type as a Secondary school (n = 2). Majority of primary schools were within the two local authority catchments, these were Haringey (n = 5) and Hackney (n = 4) (figure 2).

Figure 1. School type and local authority's catchment areas schools are located within

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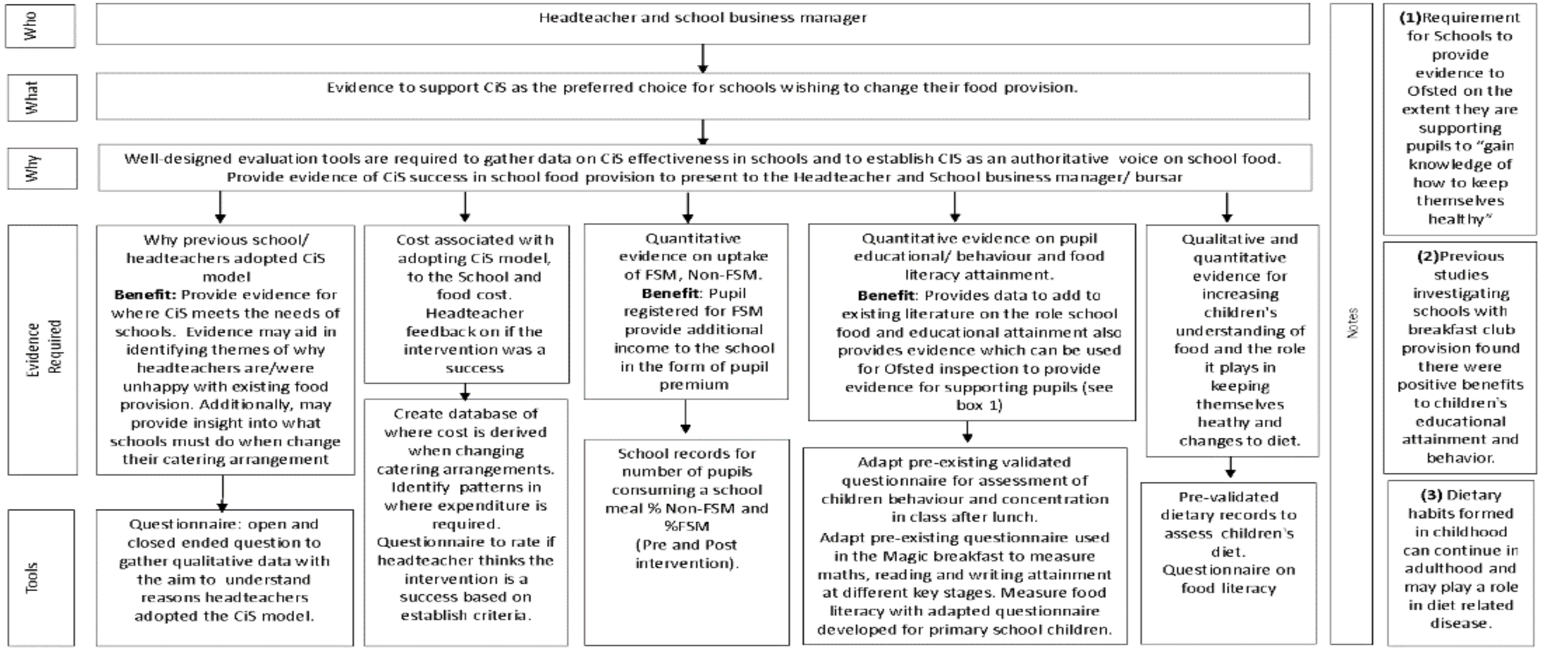

Figure 2 The types of evidence a head teacher and school business manager may find persuasive for changing their catering arrangements

School size, pupil numbers.

The number of pupils enrolled in schools varied from a minimum of 46 to a maximum of 1506 pupils. Analysis by school type found primary schools had on average 70% fewer pupils (range 430: min 170-max 600) compared to secondary schools (range 1396: min 110 - max 1506), whilst schools listed as 'other 'their mean number of pupils was similar to primary schools there was a greater range in pupil numbers (range 1234: min 46 - max 1280) (Figure 3).

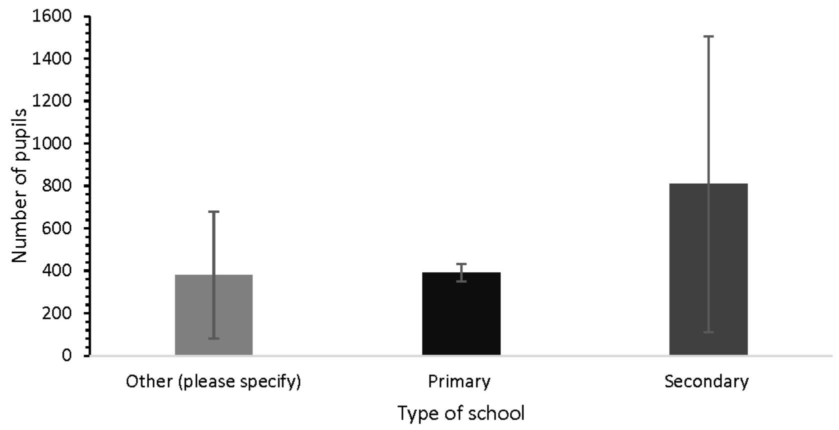

Figure 3. Average number of pupils per school type

Values are mean and errors bars represent standard error of the mean (S.E.M). Other (n = 4), Primary (n = 14) Secondary (n = 2)

Food vision and school food discussion with the governing body

When asked if their schools had a food vision 100% of respondents employed in 'Other' school types answered yes. Eleven primary schools had a food vision, two did not (Figure 4) one school had a food vision but was not in use, whilst another was working on a food vison.

Respondent 16

'We have had one in the past but needs revisiting'.

Respondent 14

'Currently working on this with new team'

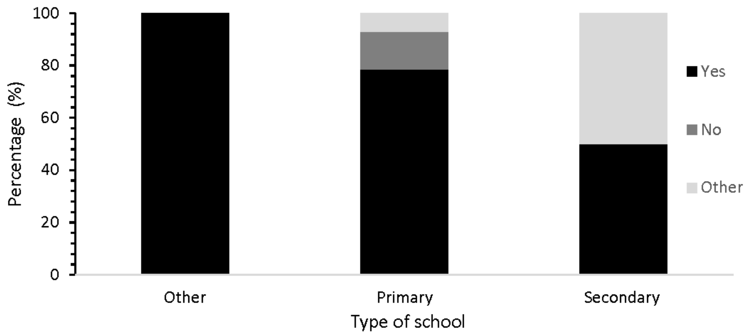

Figure 4. Percentage of schools with a food vision by school type

Other (n = 4), Primary (n = 14) Secondary (n = 2)

Discussion on school food with the governing body varied between the school types, 100% of secondary schools reported it was a regular item on the agenda, whilst only 21% of primary schools discussed school food regularly (Figure 5).

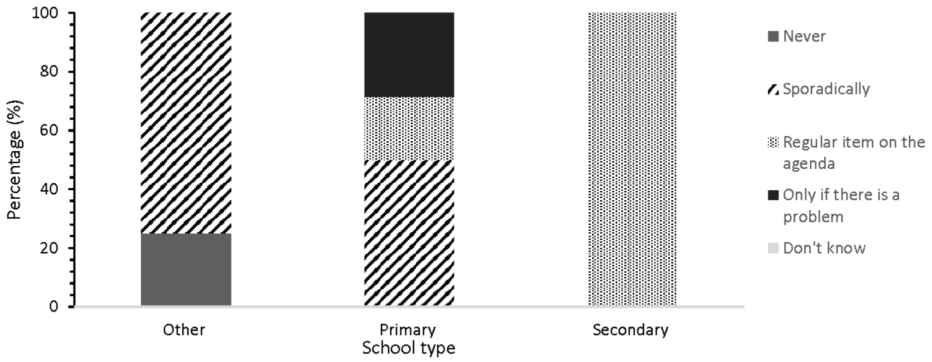

Figure 5 Frequency and reason for when school food is discussed with the governing body, by school type.

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Reasons for changing catering arrangements and resistance to change

The results indicate main the reason schools wanted to change their catering arrangement was for the heath of their pupils and not academic attainment. Eighty percent of respondents wanted to change their catering arrangement to improve pupil health and wellbeing and to improve food education. Only 25% listed they wanted to change their catering arrangement to improve pupil concentration after lunch and to improve academic attainment (Figure 6). Where respondents answered 'other' answers included reference to developing a food culture

Respondent 15

'Build a food culture in line with our approach with young children and their families'

Another reason for changing catering arrangements was for developing pupil's life skills to support them in adulthood.

Respondent 20

'To better meet the needs of students with complex dietary needs and especially those students with Profound and Multiple Learning Difficulties. To enhance students' life skills. The major focus of curriculum pathways is about preparing students for adult life, to have a voice, to make choices and to do as much for themselves as possible'.

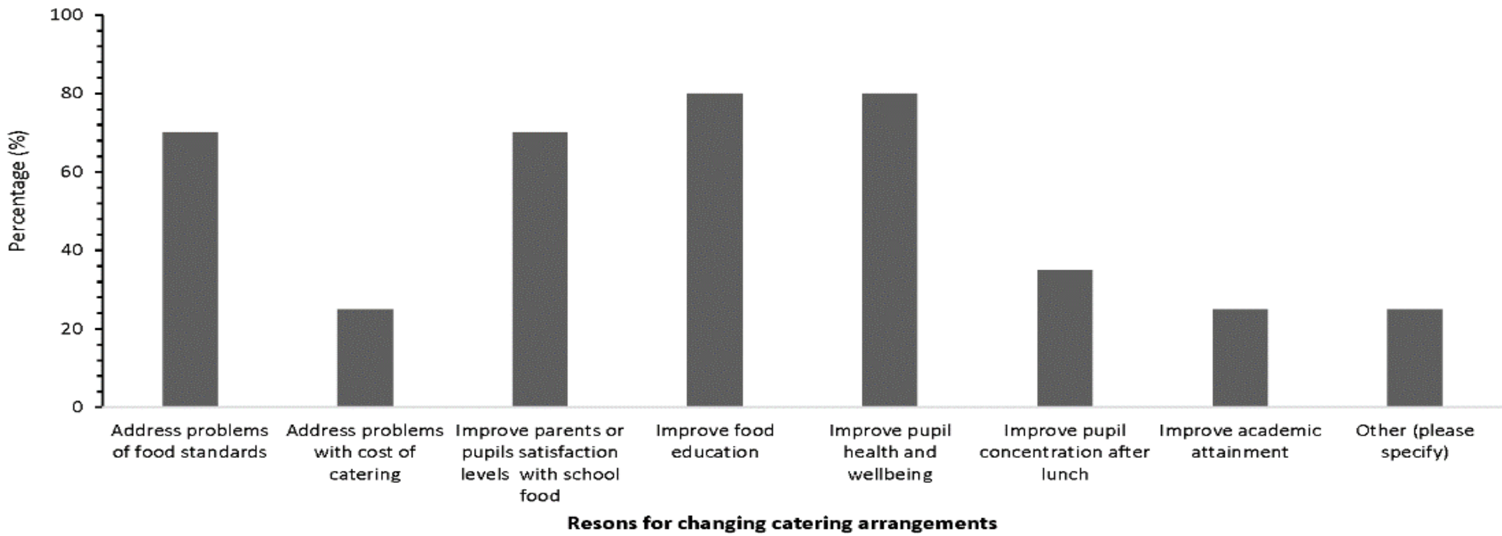

Figure 6. The reasons for wanting to change catering arrangements

Overall, the schools experienced resistance to change from 3 main stakeholder groups, parents (45%), pupils (40%) and the kitchen team (35%), none of the schools reported resistance to change from the governing body. Analysis by school type revelled primary schools experienced the greatest resistance to change from the three main groups (Figure 8). One school reported resistance to changing their catering arrangement came from the local authority. Whilst secondary and 'Other' schools did not report resistance to change from the kitchen team, they did make comments regarding difficulties with kitchen team members and that to improve the situation it required a change of personal.

Respondent 15

'yes, and I needed to change staff to move forward'

Respondent 14

'Not as a whole. But poor communication by previous chef led to conflict with kitchen team, staff and pupils. This is now resolved with new lead and SLT line management'.

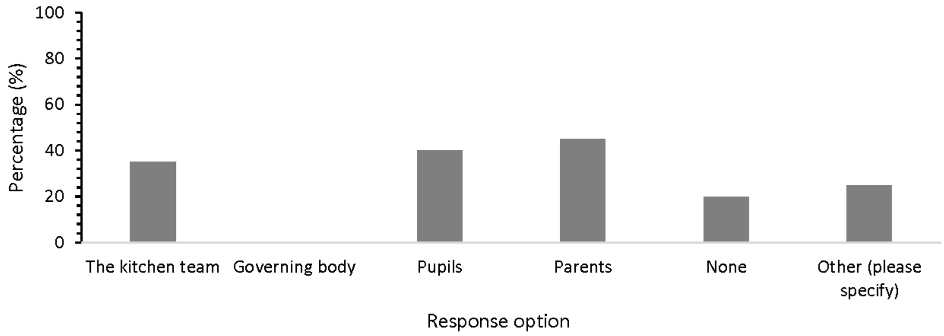

Figure 7. Stakeholder groups reported as being resistant when changing the schools catering arrangements

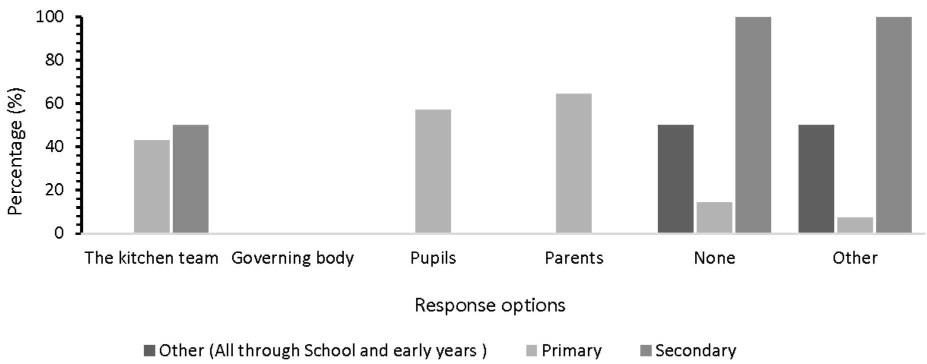

Figure 8. Stakeholder groups reported as being resistant when changing the schools catering arrangements (by school type)

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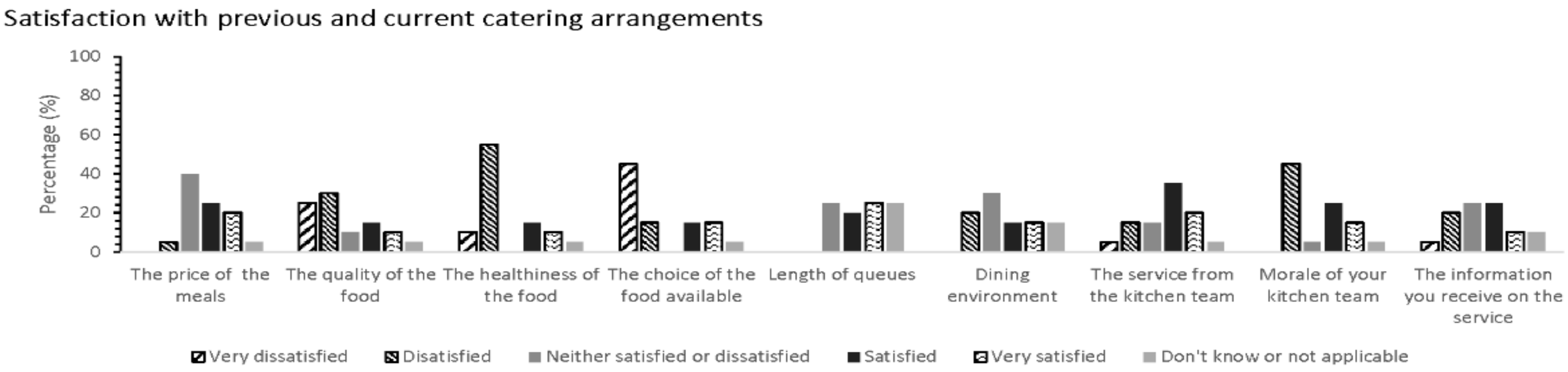

Figure 9. Satisfaction levels with previous catering arrangements. Number of participants (n=19)

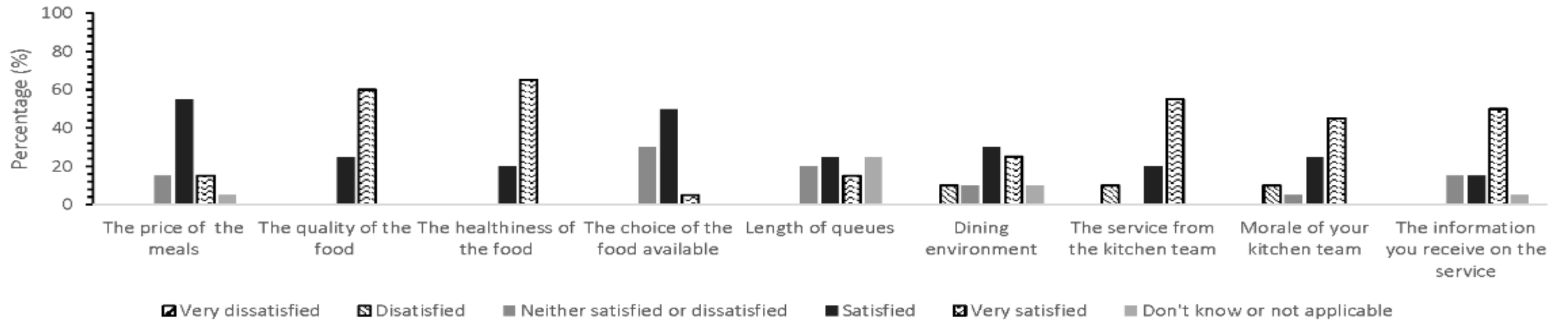

Figure 10. Satisfaction levels since working with Chefs in Schools (n =17)

Satisfaction levels

In total 19 people responded to the question on level of satisfaction with previous catering arrangement and 17 people respond when asked about their satisfaction levels since changing their catering arrangements and working with CiS (Figure 9 and 10). Predominantly schools were dissatisfied with their previous catering arrangement due of the healthiness of the food, 65% of respondents reported they were very dissatisfied or dissatisfied whilst only 25% said they were either very satisfied or satisfied. Sixty percent of respondents said they were very dissatisfied or dissatisfied with the quality of the food, and the choice of the food available, whilst 45% were dissatisfied with the morale of their kitchen team (Figure 9).

Overall satisfaction levels for all the variables have increased since working with CiS apart from length of ques which had a slightly lower satisfaction score although this was not significant ($P = 1.00$). The greatest increase in satisfaction levels was seen for the quality of the food, this increased 66% from a mean score of 2.37 ± 0.34 (S.E.M) to 4.71 ± 0.11 ($P = 0.002$). Satisfaction levels with the healthiness of school food increased by 65% from a mean score of 2.42 ± 0.31 (S.E.M) to 4.76 ± 0.11 ($P < 0.001$). Whilst satisfaction with the choice of food available increased by 42% from a mean score of 2.84 ± 0.31(S.E.M) to 4.35 ± 0.30 (S.E.M) ($P = 0.002$). Overall school's satisfaction level on the service they received from their kitchen team increased by 27% from 3.37 ± 0.33 to 4.41 ± 0.24 (S.E.M) ($P = 0.012$). Furthermore, schools reported an increase in morale of their kitchen teams (36% increase from mean score of 2.95 ± 0.32 to 4.24 ± 0.25, $P = 0.06$).

Whilst majority of the respondents reported they were satisfied with their catering provision it is of note two schools reported that there were concerns with the kitchen team but that they are aware off the issues.

Respondent 18

'Our kitchen team is still not functioning well. We need a key member of staff to move on'.

Respondent 4

'The kitchen team are not serving the food with love or encouraging children to try different elements of the meal. This is an issue the school is aware of and trying to work on'.

Where there was dissatisfaction with the dining environment, the schools were working to address these problems

Respondent 14

'Poor environment which is being addressed via new build'.

Respondent 20

'The school dining hall needs repainting and re-imagining. We hope to fund raise to achieve this in the next 12 months. During the summer holidays we had the kitchen re-decorated. It looked and felt so much better and symbolized the beginning of our new food adventure'.

Impact on pupil's behaviour

Thirty five percent of respondents reported they thought the change in catering arrangements had improved their pupil behaviour a bit, 30% thought it had stayed the same, whist 20% were not sure. Seven of the respondents made further comments, of note is the respondents perceive behaviour at a lunchtime to have improved, but they were unable to directly link this to the change in catering arrangements due to other factors such as covid or other interventions coinciding with the change of catering arrangements

Respondent 13

'Behaviour at lunch in primary has improved - more engaged in lunch time as an experience. It is hard to validate with data as so much of the last year has been impacted by the pandemic. Secondary pupils were often complaining about food with previous catering team (not enough, raw bread in pizza etc) and we would have parental complaints too - that has significantly dropped'.

Respondent 17

'Fewer lunchtime incidents. This is partly due to a new restorative behaviour approach but also coincides with the new lunch service'.

Other respondents noted children were less irritable after lunch or parent careers have noticed their young people are not as hungry when returning home from school

Respondent 12

'Teachers report that children are less irritable and able to sustain concentration for longer'.

Respondent 20

'The majority of students have complex behavioural needs as a part of their learning disability, so this is a difficult question to answer. Students are noticeably more satisfied after eating lunch and this helps them to remain calmer and more focused during the afternoon. Parents/Carers report that their young person is no longer ravenous on return home at the end of the school day, and this helps them with managing their young person's behaviour more effectively'.

Consumption of food

Seventy percent of respondents thought pupil consumption of fruit and vegetables had increased, only 5% thought it had decreased whilst 45% thought the amount of food consumed at a lunch had increased (Figure 11 and 12)

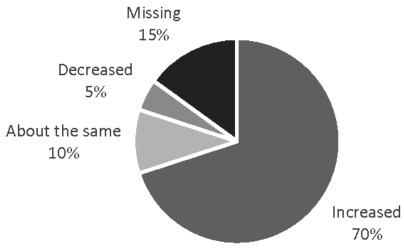

Figure 11. What do you think has happened to pupil consumption of fruit and vegetables?

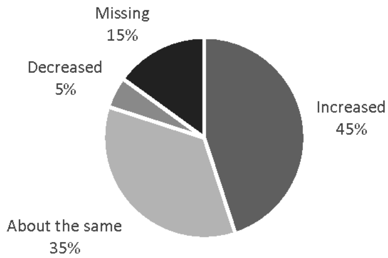

Figure 12 What do you think has happened to the amount of food consumed at a lunch time (are pupils eating more or less on their plate)

Discussion

Chefs in Schools support schools to change their catering arrangements from nursery through to secondary schools. As such the nutritional requirements of pupils are varied. Physiological requirements for nutrients are greater during the preschool years to support growth and development and again during the teenage years when pupils transition through puberty and have increased requirement to support growth and development at this life stage. Furthermore, Chefs in Schools operate in schools with high proportions of pupils who are eligible for Free School Meals as such pupils may experience lower quality diet due to household economic constraints. Previous studies have found children from lower income households to be disproportional impacted by overweight and obesity[6] and consume lower quantities of some micronutrients [7].

As such the work of Chefs in Schools and School food provision is important for addressing dietary inequalities. Children are exposed to a potentially greater diversity of food within the school setting which may not be available in the home setting, as such this may provide children with a greater diversity of foods within their diet. Studies have shown dietary habits formed in childhood track into adulthood[8] as such improved diet in childhood may prevent disease in adulthood, furthermore deficiencies in zinc, iron and iodine have been linked impaired cognition[9] and this may impact on a child's educational attainment

Satisfaction

The results of the survey indicate Chefs in Schools have successfully increased school's satisfaction levels with the quality, variety, and healthiness of food. It is suggested further research is required to gather quantitative data on the quality, variety and healthfulness of foods served. Suggested methods for assessing food quality, variety and healthfulness included theoretical analysis of menus before and after changing catering arrangements and to assess compliance with school food standards. It is also suggested to collect samples of food and meals to assess the change in the nutritional composition when changing ingredients e.g., using fresh mince as opposed to frozen.

Behaviour

Thirty five percent of respondents reported they felt pupil behaviour had improved since changing catering arrangements. The results provide a rationale for further research to validate the link between lunch consumption and pupil behaviour. A previous study investigating school breakfast provision found behaviour did improve in schools who offered a breakfast club[4]. There are already plans in place to complete a systematic review of the available evidence on the impact of school food provision on pupil's behaviour, concentration, attainment, and wellbeing. The results of this study will be a basis for recommendations for further research once the gaps have been identified.

Consumption

Respondents reported pupil's consumption of fruit and vegetables had increased since changing catering arrangements. It is suggested further research is required to quantify the increase inf fruit and vegetable consumption. This can be achieved via assess pupils' diets at baseline and follow up or by asking pupils to complete a shore survey on fruit and vegetable consumption at baseline and follow up. The results of this study indicate respondents perceived that their pupils were consuming more food on their plates, this is further supported by respondents also noticing children where less hungry on the return home from school. It is suggested research is completed to assess children hunger levels after lunch at baseline and follow up. It is also suggested to assess the portion sizes served and quantity of food consumed by pupils at base line and follow up.

Conclusion

Chefs in Schools have successful improved schools' satisfaction with the quality, quantity and healthiness of food served in schools. The results indicate pupils are consuming more food on their plates at a lunchtime and are consuming more fruit and vegetables and are also likely or very likely to try new foods.

References

1. Chefs In Schools. *Chefs In Schools* https://www.chefsinschools.org.uk.
2. Goldberg, J. M. *et al.* Effectiveness of interventions adopting a whole school approach to enhancing social and emotional development: a meta-analysis. *Eur. J. Psychol. Educ.* **34**, 755–782 (2019).
3. Global Standards for Health Promoting Schools and their implementation guidance. https://www.who.int/publications-detail-redirect/9789240011069.
4. Magic_Breakfast_report.pdf.
5. Braun, V. & Clarke, V. Using thematic analysis in psychology. *Qual. Res. Psychol.* **3**, 77–101 (2006).
6. Noonan, R. J. Poverty, Weight Status, and Dietary Intake among UK Adolescents. *Int. J. Environ. Res. Public. Health* **15**, (2018).
7. Knez, M. *et al.* The influence of food consumption and socio-economic factors on the relationship between zinc and iron intake and status in a healthy population. *Public Health Nutr.* **20**, 2486–2498 (2017).
8. Movassagh, E. Z., Baxter-Jones, A. D. G., Kontulainen, S., Whiting, S. J. & Vatanparast, H. Tracking Dietary Patterns over 20 Years from Childhood through Adolescence into Young Adulthood: The Saskatchewan Pediatric Bone Mineral Accrual Study. *Nutrients* **9**, (2017).
9. Sorhaindo, A., Feinstein, L. & Centre for Research on the Wider Benefits of Learning (London, E. *What is the relationship between child nutrition and school outcomes?* (2006).

Part 2

Review of Chefs in Schools current audits

A review of CiS current auditing practices was carried out to identify potential data collection points during the first year of a school changing their catering arrangements (Part 2, figure 13) the process of schools changing their catering arrangements first starts with the Headteacher or another person in leadership at a school contacting Chefs in Schools via their webpage. This starts a cascade of events including a quality audit of current kitchen practices and a skills test of the kitchen team. This data is used as a basis to identify the level of support which would be best suited to the schools to enable them to successfully change their catering arrangements.

During the one-day assessment, a food service check in and a food service audit is performed by the Chef Trainers. It is suggested the food service check in and food service audit be merged and renamed as a 'quality audit' (Appendix 3) and that the scoring system is 1= yes, meets the criteria and 0 = no, does not meet criteria. If scores are to be incremental between 0 and 1 than a criteria standard is advised to be established to ensure consistency throughout the audits to enable conclusions to be drawn during analysis of the results.

Data collection point 1

Initial contact is made by the school via the website with Chefs in Schools or via recommendation from a school to another school

Key Information collected at this stage:
1) Why the person made contact
2) Number of pupils at the school
3) Current uptake of school meals

Data collection point 2

One day assessment of the kitchen and team
Key information collected at this stage:
1) General: Number of kitchen staff, number of meals cooked per day , number of meals served , number of sittings, time allocated to eat, cost of meals as advertised (Non and FSM, teachers' prices)
2) Self completion surveys for catering team: Engagement index questions (qualitative), Assessment of nutrition knowledge, Allergen test.
3) Observations of catering team: Skills test
4) Kitchen and dining environment: School Food Environment Assessment Tool (SFEAT) (including images of dining environment and if healthy eating messages displayed etc.)
5) Food/ingredient procurement: Food supplier details, Images of dry stores, fridge, freezers etc. (samples of food collected for nutrient analysis)
6) Quality assurance:
a) Menu compliance & Service (images taken, menus collected for analysis), is the correct menu week on display, are menu boards clean and full (if available), all dishes advertised are on offer, recipe file followed, water freely on offer, Selection of fruit is available, plates or trays, cups and cutlery clean, customers served quickly, service starts & finishes on time. Sufficient food available throughout service, service well organised, number of staff washing up, portion control measures in place?
b) Kitchen hygiene/health & safety
c) Food preparation
d) Food delivery and temperatures
e) Food presentation & taste: Is colour of food appealing. Is smell of food appealing. Is the food fit for service, including vegetables. Does the cook taste the food. Are the portion sizes correct. Is the whole plate approach adopted. Are children encouraged to take vegetables. Is there a salad bar, does it contain minimum selection of 5 items (suggestion is to collect sample of meals and foods for nutrient analysis, images of food on the plate when served and image of a pupils finished plate (same child)
f) Unit paperwork up to date
g) Staff appearance (uniforms, etc)
h) Customer service
i) Training (have kitchen teams received training?)

Interview with the School leadership team
(Headteacher / School Business Manager)
Information collected at this stage:

Headteachers survey and structured interview
1) What motivated you to contact Chefs in Schools?
e.g., Complaints from, parents, pupils, staff about the provision of food?, Contract about to end etc.
2) Please describe the food served at a lunch time?
3) Why would you like to change your catering arrangement?
4) What changes would you like to see happen as a result of changing your catering arrangement ?
5) Do teachers, teaching assistants and other employees of the school eat with the children?
6) Does the school have a Breakfast club?

School Business Mangers interview and survey

1) Percentage of pupils eligible for Free School Meals
2) Cost of food procurement,
3) Budget for school meal per person

Proposal sent to schools with financial forecast. Feed back sent to School with professional opinion on kitchen team structure:

School agree to proposal

Data collection point 3,4,5

3 month follow up:
Same as data point 2 for Assessment of kitchen and team and % of meals and costs

6 month follow up:
Same as data point 2 for Assessment of kitchen and team and % of meals and costs

12 month follow up:
Same as data point 2 for Assessment of kitchen and team and % of meals and costs

Figure 13. Diagram of key information suggested to be collected at different collection point during schools first year of working with Chefs in Schools

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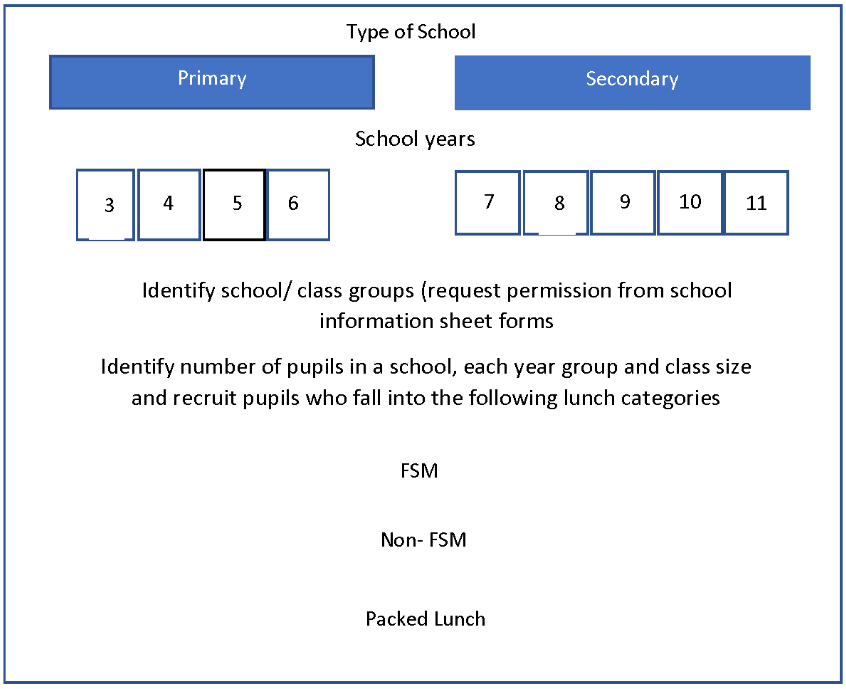
Pupil and parent surveys

Chefs in Schools operate within state primary and secondary schools within Greater London and are expanding to other areas of the country. An analysis of the proposal's sent to schools (n=16) revealed 12.5%, had as part of their package, CiS directly engaging with parents and pupils for feedback. It is suggested this may provide an opportunity to recruit pupils to follow through from baseline when CiS begins operation to when the pupil leaves the schools with regular follow ups in the in between period to assess food literacy defined as, cooking skills and impact on the household of the child.

Figure 1 displays a potential method for recruiting volunteers to participate in a study evaluation survey of the service It is suggested to recruit a subset of the school population by random sampling and ensure a balance in the numbers of pupil recruited who are eligible and non-eligible for free-school meals. It is also suggested to recruit pupils who are non-consumer of school meals to understand their perception, and reason for opting for a packed lunch.



In schools with a higher uptake of FSM it is suggested to over sample non-free school meal and vice versa to ensure an equal number of responses.

Parent satisfaction surveys

Systematic review: School food and learning outcomes of pupils, impact on pupil behaviour and their concentration/attention

Discussion with MN, ND and MT on the evidence available for the impact of school lunch on pupil's academic achievement, behaviour and cognition resulted in the submission of a project idea for a systematic review of the available evidence relevant to the work of Chefs in Schools to King's College London. Emily Kier a MSc student with King's has agreed to complete the review and will work with Michelle Thomas and Michael Nelson to explore issues relevant to the work of Chefs in Schools. The initial focus will be as follows: Breakfast and Lunch consumption and impact on learning outcomes of children in high income countries. The purpose of the project is to write a comprehensive, in-depth review of the evidence base for the impact of school food on academic outcomes, health, and well-being. If of sufficient quality, the aim would be to submit the review for publication*.

*Details of the systematic review are adapted from King's College London Department of Nutrition and Dietetics, research projects: MsC Nutrition 2020-2021

Appendix 1: Headteachers survey

Chefs in Schools: Headteacher Survey (February 2021).

We are coming up to our three-year anniversary and are reflecting on all that we have achieved in this time. We have supported over 30 schools like yours to improve their food and support their food education. We have big ambitions to support many more schools across the country to do the same and we need your help to do so.
We want to understand more about the impact our work has had on your school community and so your answers will be invaluable to the future success of our work.
Thank you for taking the time to complete this survey. Please be honest and share as much information as you can.
This survey will take approximately 15 minutes to complete. All responses to this survey will be anonymised.
If you would like further information on this survey, please email polly@chefsinschools.org.uk

Question number	Question	Response	Code
1	Do you consent to participating in the survey?	Yes No	1 2
2	Would you like to be contacted in the future to discuss the results of this survey?	Yes No	1 2
3	Please confirm your work email address	Free text	
4	What is the name of your school?	Free text	
5	What local authority is your school in?	Free text	
6	How long have you worked at this school?	Less than one year One to two years Two to five years Five to ten years More than ten years Prefer not to say	1 2 3 4 5 6
7	What is your job role?		
8	Please tell us the type of school you are employed in	Free school Special school Faith school Academies Private school Grammar school State School	1 2 3 4 5 6 7

		Other (please specify)	.00
9	Please indicate if your school is	Primary Secondary Other (please specify)	1 2 .00
10	How many pupils are enrolled in your school?	Free text	
11	Does the school have a school food vision?	Yes No Don't know Other (please specify)	1 2 3 .00
12	Do you discuss school food regularly with the governing body?	Never Sporadically Regular item on the agenda Only if there is a problem Don't know	1 2 3 4 5
13	Were you heavily involved in deciding to change the schools catering arrangement?	Yes No	1 2
14	What were the reasons for changing your catering arrangements and working with Chefs in Schools? (please select all that apply)	Address problems of food standards Address problems with cost of catering Improve parents or pupil's satisfaction levels with school food Improve food education Improve pupil health and wellbeing Improve pupil concentration after lunch Improve academic attainment Other (please specify)	1
15	In general, did you experience any resistance to changing the schools catering arrangements from any of the following (please select all that apply)	The kitchen team Governing body Pupils Parents None Other (please specify)	1
16	How satisfied were you with each of the following aspects of the school lunch service? Please select one answer for each row	Very dissatisfied Dissatisfied Neither satisfied nor dissatisfied Satisfied Very satisfied Don't know/not applicable	1 2 3 4 5 .00
17	If you have answered very dissatisfied or dissatisfied to any of the above questions, please can you	Free text	

	provide some more information on why you were dissatisfied. Please state the question in your answer. (e.g., I was dissatisfied with the choice of food available because....)		
18	If you have answered very satisfied or satisfied to any of the above questions, please can you provide some more information on why you were satisfied. Please state the question in your answer. (e.g., I was satisfied with the choice of food available because....)	Free text	
19	What impact did the food provided have on behaviour and classroom engagement of your pupils?	Positive impact Negative impact No impact	1 2 3
20	How satisfied are you with each of the following aspects of the school lunch service? Please select one answer for each row	Very dissatisfied Dissatisfied Neither satisfied nor dissatisfied Satisfied Very satisfied Don't know/not applicable	1 2 3 4 5 .00
21	If you have answered very dissatisfied or dissatisfied to any of the above questions, please can you provide some more information on why you were dissatisfied stating the question in your answer. (e.g., I was dissatisfied with the choice of food available because....)	Free text	
22	If you have answered very satisfied or satisfied to any of the above questions, please can you provide some more information on why you were satisfied	Free text	

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	stating the question in your answer. (e.g., I was satisfied with the choice of food available because....)		
23	Since changing your catering arrangements, what impact have you seen on Pupil behaviour?	Improved a lot Improved a bit Stayed the same Got a little worse Got a lot worse Not sure	1 2 3 4 5 6
24	Since changing your catering arrangements, what impact have you seen on Pupil concentration?	Improved a lot Improved a bit Stayed the same Got a little worse Got a lot worse Not sure	1 2 3 4 5 6
25	Since changing your catering arrangements, what impact have you seen on the schools catering or dining area?	Improved a lot Improved a bit Stayed the same Got a little worse Got a lot worse Not sure	1 2 3 4 5 6
26	Since changing your catering arrangements, what do you think has happened to pupil consumption of fruit and vegetables?	Increased About the same Decreased	1 2 3
27	Since changing your catering arrangements, what do you think has happened to the amount of food consumed at a lunch time (are pupils eating more or less food on their plate)?	Increased About the same Decreased	1 2 3
28	Since changing your catering arrangements, in your view how likely are pupils to try new foods?	Very likely Likely Neither likely nor unlikely Unlikely Very unlikely	1 2 3 4 5
29	What did you find to be the most useful elements of Chefs in Schools programme? (Please select all that apply).	Chef recruitment Menu development Setting up new suppliers Budgeting Sourcing food	

		Staff training Food curriculum Engaging with pupils and parents	
30	Since working with Chefs in Schools, have you developed your food education?	Yes No	1 2
31	Is your chef involved in delivering the food curriculum?	Yes No	1 2
32	Please rate your overall experience of working with Chefs in Schools	Positive Neutral Negative	1 2 3
33	Please share any other comments you have below:	Free text	
34	Will you consent to Chefs in Schools being listed as a partner on our website and other publications?	Yes No	1 2

Appendix 2: School Business Managers Survey

School finance survey

We are coming up to our three-year anniversary and are reflecting on all that we have achieved in this time. We have supported over 30 schools like yours to improve their food and support their food education. We have big ambitions to support many more schools across the country to do the same and we need your help to do so.

A vital part of this is understanding the financial impact on schools of bringing catering in-house.

This survey will take approximately 10 minutes to complete. The data collected will be anonymised. Your participation in this survey is voluntary.

If you would like further information on this survey, please email Chefs in Schools: polly@chefsinschools.org.uk

Question Number	Question	Response	Code
1	Do you consent to participating in this survey?	Yes No	1 2
2	Would you like to be contacted to in future to discuss the results of this survey?	Yes No	1 2
3	Please confirm your work email address	Free text	
4	What is the name of your school?	Free text	
5	What local authority is your school in?	Free text	
6	How long have you worked at the school?	Less than one year One to two years Two to five years Five to ten years More than ten years Prefer not to say	1 2 3 4 5 -9
7	What is your job role?	Free text	
8	Please tell us the type of school you are employed in	Free school Special school Faith school Academies	1 2 3 4

		Private school Grammar school State School Other (please specify)	5 6 7 -8
9	Please indicate if your school is	Primary Secondary Other -8	1 2
10	How many pupils are enrolled in your school?	Free text	
11	Are pupils required to register for school lunches at the beginning of term?	Yes No Don't know Other	1 2 -7 -8
12	Prior to the pandemic, what percentage of pupils were regularly taking up a school lunch?	Free text	
13	What percentage of your pupils are eligible for Free School meals	Free text	
14	When bringing your catering in- house, did the school carry out any of the following? (Please select all that apply)	Make improvements to the dining environment Increase the number of staff/ adjust hours to cover lunch delivery Training of kitchen staff Upgrade/additions of kitchen equipment Make improvements to storage facilities Access additional funding Other (please specify) Please expand on the above (free text)	1 2 3 4 5 6 -8
15	Which of the following did the school spend money on when implementing the new in-house catering programme?	Kitchen structures (e.g., replace damaged tiles lights) Large kitchen equipment Smaller kitchen equipment Service facilities Serving equipment Signage and branding New uniforms for catering team Improvements to the dining environment Don't know not applicable	1 2 3 4 5 6 7 8 -7
16	Please estimate the cost (£) of changing or replacing any of the following	<£250 £250-£2499 £2500 -£4999 £5000-£7499	1 2 3 4

	Kitchen structures (e.g., replace damaged tiles lights) Large kitchen equipment Smaller kitchen equipment Service facilities Serving equipment Signage and branding New uniforms for catering team Improvements to the dining environment Don't know not applicable	£7500-£9999 >£10000 Don't know/not applicable	5 6 -7
17	Did you have to spend additional money on staff recruitment and training to successfully change your catering arrangement	Yes No Don't know	1 2 -7
18	Please estimate approximately how much you spent on staff recruitment and training to successfully change your catering arrangement	Free text	
19	Since changing your catering arrangement, has the cost to produce lunches increased?	Yes No Don't know	1 2 -7
20	Have your food costs changed since bringing your catering in-house	Increased Decreased No change	1 2 3
21	What are your average costs per meal?	Free text	

22	Since changing your catering arrangement, has the total cost of your catering provision increased	Yes No	1 2
23	Please estimate as a percentage the increase in pupils eating a school lunch since changing your catering arrangements (this question was reworded on Survey Monkey)	Free text	
24	Please rate your overall experience of working with Chefs in Schools	Positive Neutral Negative	1 2 3
25	In your own words, is there anything we could have done differently to improve your experience of working with Chefs in Schools and brining your catering in house?	Free text	
26	Please share any other comments you have below	Free text	

Appendix 3 Skills test (observations)

Skill	Includes	Criteria	Score (0 or 1)
Attention to detail	Heat control	0 = did not adjust cooking temperatures, items were overcooked/undercooked 1= adjusted cooking temperatures to suit ingredients being cooked	
	Measuring	0 = did not use measuring equipment 1 = evidence of use of weighing scales and measuring spoons	
	Portion sizing	0 = inconsistent portion sizing not compliant with school food standards 1 = consistent portion sizes compliant with school food standards	
	Presentation	0 = no garnish, plates not clean, inconsistent presentation of food on counter or plate. 1 = Food garnished, plates cleaned, consistent presentation of food.	
	Quality of Food	0 = taste, texture and appearance of food not as expected for the dish 1 = taste, texture and appearance of food as expected for the dish produced	
		Total score	
Creativity	Experimenting	0 = no evidence of trying new dishes/ suggesting new dishes to include on the menu 1 = evidence of trying new dishes/ suggesting new dishes to include on the menu	
	Menu Design	0 = menus are designed at head office level; kitchen team have little or no input. 1 = Chef creates own menus, seeks input from kitchen team	
	Recipe Design	0 = if recipe not used 1 = if recipe used and modified to some degree	
		Total score	
Skill	**Criteria**	**Observation notes**	**Score 0 = not observed 1 = observed**
Culinary Expertise/ food awareness	Baking		
	Baking Techniques		

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	Food Preparation		
	Grilling		
	Ingredient Selection		
	Knife Control		
	Knife Cuts		
	Pastry		
		Total score	
Skill	**Includes**	**Criteria**	**Score (0 or 1)**
Cleanliness	Health and Safety	0 = no evidence of HACCP training 1 = evidence of HACCP training completed in the previous 3 years 0 = no evidence of Allergen training 1 = evidence of Allergen training in the previous 3 years	
	Hygiene	0 = not working in a hygienic manner e.g., hair not tied back, in appropriate jewellery, apron not worn, raw and cook foods prepped at the same time, vegetable peelings on the same board peeled vegetables 1 = worked in a hygienic manner, e.g., hair tied back, jewellery removed, clean apron, cross contamination minimised	
	Sanitary Practices	0 = no evidence of hand washing or limited handwashing 1=Evidence of handwashing at expected stages e.g., when starting work, when taking the bin out, after touching raw meat, when returning from a break	
		Total score	

Skill	Criteria	Observation notes	Score 0 = not observed 1 = observed
Organisation/time management	Efficiency		
	Planning		
	Multitasking		
		Total score	
Team Player	Accepts Feedback		
	Collaborates		
	Shows Compassion		
	Emotional Intelligence		
	Has a Sense of Humour?		
		Total score	
Other	Motivation and engagement		
	Eagerness to learn		
	Service trained		
		Total score	

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Appendix 4

Engagement index questions

1 "I am proud to work for [Company]"

2 "I would recommend [Company] as a great place to work"

3 "I rarely think about looking for a job at another company"

4 "I see myself still working at [company] in two years' time"

5 "[Company] motivates me to go beyond what I would in a similar role elsewhere"

Answers

Strongly disagree

Disagree

Neither agree nor disagree

Agree

Strongly agree

7.7 APPENDIX G: Report written for Henley Grub Hub

THE ROLE OF SOCIAL SUPERMARKETS AND REDISTRIBUTION OF SURPLUS FOOD IN THE CONTRIBUTION TO THE DIET OF LOW-INCOME POPULATION GROUPS: COULD THIS FACILITATE A 'RIGHT TO FOOD' AND ADDRESS DIET AND HEALTH INEQUALITIES?

Abstract

In this report we examine the nutritional composition of Henley Grub Hub Food Bags and estimate the contribution of fruit and vegetables, energy, and micronutrients to the diets of their members

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Summary

In this report we examine the nutritional composition of Henley Grub Hub Food Bags and estimate the contribution of fruit and vegetables, energy, and micronutrients to the diets of their members

In the UK it is recognised there is a social gradient in health with the poorest communities having the worse health and lower life expectancy (1). It is estimated that 8.4 million people in the UK are unable to afford enough food to eat (2)(3). Coventry adult population (18-65+)in mid-2019 was 291,756 residents (4) and recent data suggest up to 17% of the adult population struggled to obtain sufficient food in January 2021 (5). The Covid-19 pandemic highlighted the vulnerability of low-income populations and their limited capacity to purchase sufficient food of adequate quality (6). The pandemic brought with it 'panic buying' resulting in low-cost staple items such as pasta and rice as well toilet rolls disappearing from supermarket shelves and leaving those without the capability of buying in bulk to make the best of what remained (7). At the same time food bank use doubled during the pandemic, not because the UK didn't have enough food but rather due to a lack of sufficient income and social support (8).

During the pandemic the City of Coventry saw 14 social supermarkets open in deprived areas (Dianne Williams, Henley Grub Hub). The growth of Social Supermarkets in the UK is partly driven by the increasing prevalence of food insecurity (9). Henley Grub Hub provides its members with £20 worth of food for £4 (75% discount) the contents of the bags are designed for a household of three people. The core food offering (see appendix 1) is constructed around food groups and includes fruit and vegetables, breakfast cereal, milk, tinned products, and dried goods such as pasta, rice, noodles, or instant mash, plus there is uncooked meat items, dairy, and other chilled items when available. The nutritional contribution (all nutrients) from 3 separate weeks of food provision was calculated and used to determine the average contribution of one week's bag of shopping to a household's fruit and vegetable, energy, and micronutrient intake.

Key Points

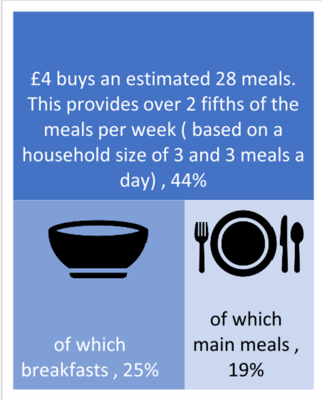

Figure 1 Estimated percentage contribution of bags of food to a household of 3 people meals per week. Based on 3 meals per day for 7 days.

£0.14

Average cost of a meal.

One portion of fruit and veg per day, per person for 7 days (based on household size of 3 people)

49599

Estimated number of people in Coventry who struggled to obtain sufficient food in January 2021.

Social Supermarkets in the UK operate with different models and target different needs. Social supermarkets with an 'open model' are open to the public, do not require membership and are driven by the desire to reduce food waste because of the environmental impacts, whilst SSMs with a 'closed model' require membership, although they are not means tested, they are instead targeted to people living in low income areas (10).

Across the age spectrum low-income population groups have been found to have an increased prevalence of overweight and obesity compared to higher income groups (13)(14)(15)(16). It has been shown that individuals who are obese are more likely to have lower paid jobs (17) and that lower income groups exhibit increased incidence of other diseases directly related to diet and nutrition such as diabetes, cardiovascular disease and some types of cancer (16). Furthermore the Low Income Diet and Nutrition Study (LDNS) found iron intakes were lower in women compared to the general population (18). All these conditions have a detrimental impact on health across the life course and negatively impact an individual's ability to reach their full economic potential, which perpetuates the cycle of poverty and ill health.

Consuming a diet aligned with the government Eatwell Guide recommendations is mostly too expensive for lower income populations (19)(20). When people are able to more closely match recommended intakes they show a very significantly reduced risk of total mortality compared with those who do not (21) consuming a varied diet aligned with government recommendations in theory should provide adequate micronutrients in the diet, due to the variety of food within food groups providing different quantities and types of micronutrients.

Micronutrients include minerals, such as iron and zinc as well as vitamins. Vitamins are sub-divided into water soluble (C and B vitamins) and fat-soluble vitamins (A, D, E, and K vitamin). Minerals are sub divided into macro-minerals (calcium, phosphorus, magnesium, sodium, and potassium) and trace minerals (iron, iodine, zinc, selenium and copper). It is essential for health to have adequate intakes of vitamins and minerals derived from the diet as the body is unable to synthesise these. Micronutrient deficiencies are a recognised Public Health problem and recent results from the NDNS found that for some vitamins and minerals, more than 10% of adolescents had dietary intakes below the lowest recommended intake levels (lower reference nutrient intake – LRNI; Table 1).

Table 1 Proportion of children, adolescents, and adults in the UK with dietary micronutrient
Intake below the Lower Reference Nutrient Intake (age and sex specific)

	Children		**Males**			**Females**			
	Percentage (%) below the Lower Reference Nutrient Intake								
Age in years	**1.5-3**	**4-10**	**11-18**	**19-64**	**65+**	**4-10**	**11-18**	**19-64**	**65**
Vitamin A	9	9	**18**	**12**	**10**	**13**	**18**	8	7
Riboflavin	0	1	**13**	4	5	2	**22**	**13**	**10**
Folates	0	1	9	2	2	1	10	7	4
Iron	**11**	1	**11**	2	1	2	**49**	**25**	5
Calcium	1	1	**14**	4	5	1	**16**	9	7
Magnesium	0	1	**33**	**12**	**14**	3	**47**	**11**	**11**
Potassium	0	0	**22**	**10**	8	1	**37**	**24**	**20**
Iodine	4	6	**19**	8	4	8	**28**	**12**	7
Selenium	0	1	**24**	**26**	**34**	2	**41**	**46**	**59**
Zinc	8	8	**20**	6	9	15	**16**	**7**	**4**

Table adapted from the National Diet and Nutrition Survey Rolling Programme Years 9 to 11 (2016/2017 to 2018/2019) (22)
Figures in bold indicated vitamins and minerals where greater than 10% of the population have a dietary intake below the Lower Reference Nutrient Intake

The LRNI represents an intake level sufficient to meet the requirements of just 2.5% of the population. The remaining 97.5% of the population will require more than this at a minimum level. Recent data showing that 52% of females aged 11-14 years and 58% of those aged 15-18 years consumed below the LRNI for iron (M Thomas et al under review) as did 27% of women aged 19-64 years (22) Indicates the considerable prevalence of iron deficiency both in the UK and globally (23). For women, deficiency of iron is suggested to be the top cause of years lived with a disability (24). When Iron Deficiency Anaemia (IDA) is present there is a decrease in red blood cell production(25), cognitive function is impaired and for women of child bearing age, deficiency of iron during pregnancy can adversely affect offspring neurodevelopment (25). This clearly represents a significant public health challenge for women, adolescent girls and developing infants.

Deficiency of micronutrients such as magnesium and cobalt, have additionally been observed in the development of diseases such as diabetes (26) and clear links between micronutrient deficiency and obesity have been identified (27) (28). The Covid-19 pandemic also highlighted the importance of having an adequate micronutrient status to help fight infectious disease (29). Iodine intake is low in girls aged 11-18 years (75% of the RNI) and even mild deficiency has been found to negatively impair mental capacity (30) motor skills and IQ (31). Furthermore, the possibility of eating disorders was found to increase as income decreased for adults in the UK(32).

Foods which are good sources of micronutrients have been found to cost three time as much per calorie compared to less healthy food (20), exacerbating the sub optimal micronutrient intakes and prevalence of chronic and acute conditions amongst low income population groups. The probability of low income groups experiencing food insecurity has risen from 27.7% in 2004 to 45.8% in 2016 whilst during the Covid-19 pandemic food insecurity as recorded in May 2020 was 250% higher than pre-covid levels (33).

Due to the nature of how food is sourced this may lead to variability in the types and quantity of food available to customers for purchase. Although all food sold via SSM's is of good quality and in date, if the products which are available are highly processed or convenience products high in fat, sugar or salt or there is limited supply and variety of fruit and vegetables this may exacerbate further the inequalities observed in diet and health between low income and higher income households in the UK.

As such it is suggested that Social Supermarkets with a hybrid model of providing food items to customers (mix of preselected food items and the opportunity for customer to purchase additional food items) represent a robust and reliable method to provide continuity in the availability of micronutrients in the diet of low-income population groups by suppling customers with a shopping basket of pre-selected food items at a discounted cost which are varied and from across different food groups.

In order to demonstrate this, we set out to establish the precise nutrient profile of the foods provided by the Grub Hub over a period of three weeks and determine the proportion of required nutrients that these would provide for different household types.

Methods

The nutritional content of the core food items (See appendix 1) provided by "The Grub Hub" Social Supermarket in Coventry was estimated using nutritional analysis software (Nutritics 2021). The nutritional contribution (all nutrients) from 3 separate weeks of food provision was calculated and used to determine the average contribution of one week's bag of shopping to a household's micronutrient intake. Provision was calculated for a household (HH) of 3 people which comprised either one adult and two children aged 11-14 years (male and female; HH1) or two adults and one child aged 11-14 years (female only; HH2; Appendix 3). The UK Government Dietary Reference Values for Food Energy and Nutrients were used to calculate household micronutrient requirements based on age and gender as per the household composition detailed above. The decision to calculate the households' nutritional requirements on household types with children aged 11-14 years was based on the fact that children between 11-14 years typical have higher micronutrient requirements due to the onset of puberty and the growth and development which takes place during this stage of life.

The nutritional content of shopping baskets was determined based on weights and type of food supplied. In some instances, photographs of fruit and vegetables were used to determine weekly provision. On pack weights were used to help establish the nutrient composition of ambient and chilled products. Where a direct match was not possible an item of similar type and nutritional composition was used.

Key Findings

- **Food products contained within the core shopping bags constructed for 3 person households were estimated to provide at least 28 meals (cost £0.14 per meal).**
- **On average 21 (80g) portions of fruit and vegetables were available in the shopping bags for £4.**
- **A substantial contribution towards daily recommended nutrient intakes (RNI) for vitamins (ranging from 37% to >100% depending on the vitamin) and minerals (ranging from 16% to 36%).**
- **Vitamin C content of shopping bags completely met household requirements (>100% of the RNI).**
- **Free sugars (43% of RNI), total fat (19% of food energy) and sodium (29% of RNI) were within recommended limits.**

Results

The shopping basket of pre-selected food items cost £4 and on average had 21 portions of fruit and vegetables per week which equated to 1 portion (80g) per person, per day for the two household types. The breakfast cereals comprised sixteen 30g servings and provided 5.5 portions per person, per week. We then estimated the number of main meals (excluding breakfast) which could be made from the core items in the basket by using the weights of food as recommended for a portion size where possible. It is suggested 4 different meal types each serving 3 people could be made from the core items basket (12 meals) (Appendix 2). In total it is suggested the shopping basket provides approximately 28 meals per week (16 breakfast and 12 main meals) which permits 9 meals per person per week or 1.3 meals per person per day). The average cost of a meal based on 16 portions of breakfast and 12 main meals is £0.14.

Energy and nutrient content of the shopping basket and contribution to daily intakes by household type.

The nutritional content of the shopping basket is reported as a daily contribution in a 7-day period. The main source of energy in the shopping basket was derived from carbohydrates (62%), followed by protein (20%) of energy and fat (19%) of energy. On average the shopping basket of core food items contributed 1075 kcal per day (16% of HH1 and 18% of HH2 Estimated Average Requirements (EAR), 18g of fibre (21% and 22% of dietary Reference Value (DRV) for HH1 and HH2), 39g of free sugars (43% of HH1 and HH2 DRV) and 54g of protein per day (38% of HH1 and 42% of HH2 Reference Nutrient Intake (RNI)).

Vitamins

When considering the micronutrient contribution, we found that there was a significant contribution to daily recommended nutrient intakes for vitamins (ranging from 37% to >100%; Figure 2 A). The food groups contributing the greatest to vitamin content of the basket were cereal and cereal products, fruit and vegetables and animal products in the case of Vitamin B12 (Figure 3, F-I).

The shopping basket easily met HH1 and HH2 requirements for vitamin C and was close to 100% for Vitamin B12 (Figure 2 A). Fruit and vegetables contributed 80% of the vitamin C in the shopping basket with vegetables being the primary contributor (Figure 3 F) whilst vitamin B12 was primarily derived from animal products (75%; Figure 3 I). Folate provided 2/3 of the RNI for HH1 and HH2, the primary source of which was cereal products.

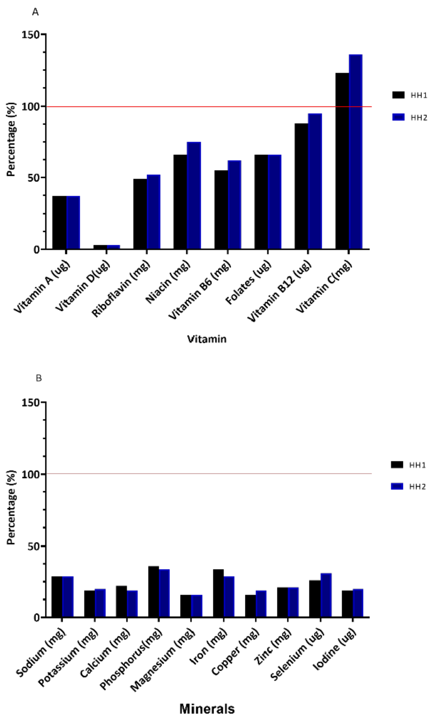

Figure 2 A and B Percentage contribution of core food items in shopping basket to household Recommended Nutrient Intake (RNI) for vitamins.

HH1 = 1 adult, 2 children household
HH2 = 2 adult, 1 child household
Red line indicates 100% of Reference Nutrient Intake

Minerals

The contribution of the shopping basket to mineral requirements for both household types ranged from 16% for Magnesium and Copper to 36% for Phosphorus (Figure 2 B). One third of the RNI for iron for HH1 was provided, with cereal products contributing the most (meat products provided approximately 10%). Over half the zinc (54%) in the shopping basket was derived from meat products and contributed 20% towards the HH1 and HH2 requirements. Selenium was provided by a range of food types whilst the vast majority of iodine was provided by milk products.

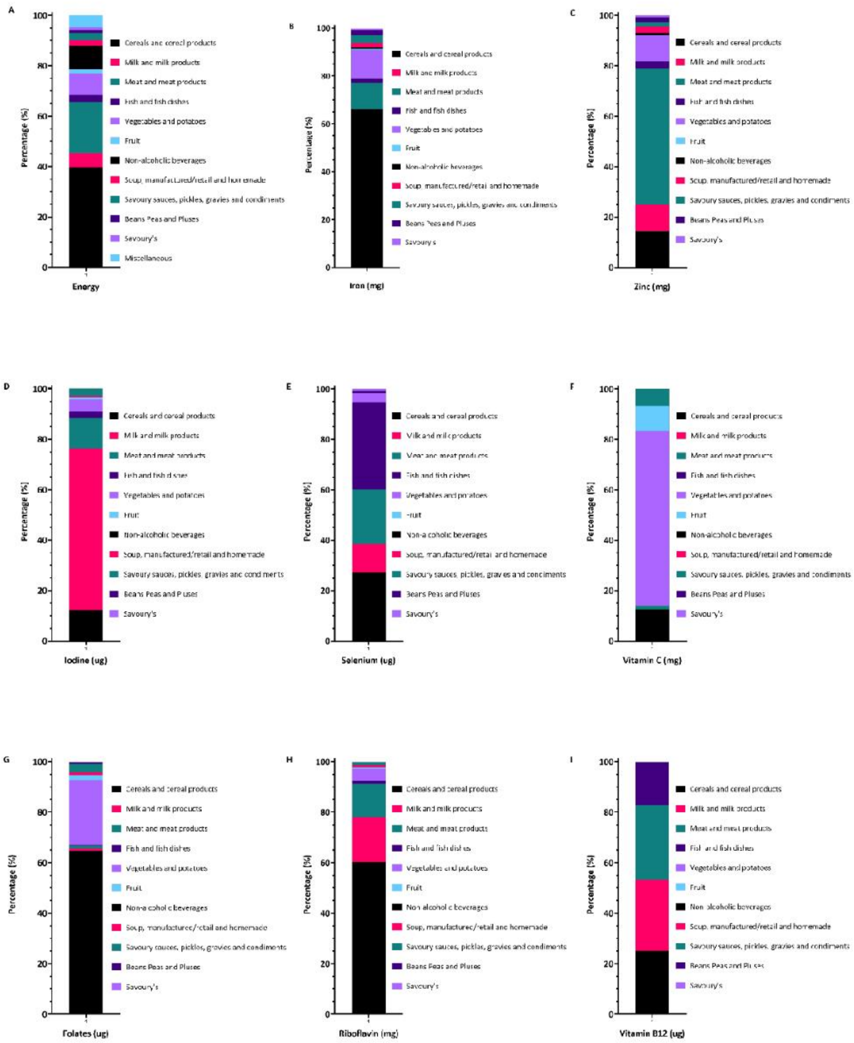

Figure 3 Percentage contribution of food groups of energy, mineral and vitamins.

A= energy (kcal), B = Iron (mg), C = Zinc (mg), D = Iodine (µg), E = Selenium (µg), F = Vitamin C (mg), G= Folates (mg), F= Riboflavin (mg), I = Vitamin B12 (µg*)*

Discussion

In this study we examined the nutrient provision from a predefined shopping basket costing £4 provided by "Henley Grub Hub" a social supermarket located within the premises of Henley Primary School, Wyken Croft, Coventry. We found the food items included in the shopping basket contributed significantly to the micronutrient intake of low-income populations, whilst the amount of energy, fat, or salt was within recommended limits. This was in part because the contents of the shopping basket were assembled to include a variety of food items from different food groups. The knowledge of the team running the social supermarket, enabled the combination of food items supplied each week to comprise items suitable for making composite meals e.g., pasta sauce was supplied with spaghetti or fusilli. The team also included items with the aim of building a stock of items for customers e.g., tea, coffee, squash, and sugar by rotating the supply over a four-week period.

A social supermarket with a predefined shopping basket which perhaps could be akin to subscription boxes for fruit and vegetables or recipe boxes, has the potential to address the dietary inequality observed in the UK for population groups who can access them, by providing foods in the diet such as fruit and vegetables which are consumed with a lower frequency in low income groups However, the vulnerability of the food supply could undermine the nutritional content of the baskets if those foods which are a good source of nutrients are in short supply. Therefore, the ability for Social Supermarkets to top up their stock is imperative, and it is suggested that funding could be usefully put in place to enable the purchase of items such as fruit and vegetables and other nutrient dense, but energy low products. This could address the low intakes of fruit and vegetable intakes observed amongst low-income groups in the UK and contribute positively to health in this population.

It is estimated that 8.4 million people in the UK are unable to afford enough food to eat (2)(3) with recent data suggesting 17% of adults in Coventry struggled to have food in January 2021 (5). Furthermore, the number of people in the UK living in a 'food desert' exceeded one million (3). Although the neighbourhood where Henley Grub Hub is located doesn't meet the definition per say of a food desert as there are greater than two supermarkets(34) within a 2 miles radius (Appendix 4), residents without access to private or public transport may find foods shops are not accessible easily.

Part of the Government's Covid-19 response was the provision of £16 million funding from DEFRA to support third sector organisations in providing food to vulnerable communities (8). Social Supermarkets were a recipient of this funding and have a pivotal role in the redistribution of surplus food whilst enabling individuals to access food in an affordable and dignified way. Furthermore, Social Supermarkets seek to bring other organisations to them to create a one stop shop as it were for individuals to be able to shop and get welfare advice or skills development training if required, plus other forms of support, this is often termed the wrap around services (35). Henley Grub Hub offer welfare advice, opportunity to gain advice on training and CV building to increase employment prospects, customers are also made aware of what is available to them and their families e.g., The Holiday Activity Programme and sign up is made easy with support from activity leaders. The Grub Hub additionally offers informal support from volunteers and staff by providing advice on how to prepare and cook foods and there is a café located at another site where people can come together and build relationships. This all works towards strengthening and building resilient individuals and communities by removing barriers to communities traditionally thought of as being hard to reach.

We currently have in the UK an abundance of good quality surplus food going to waste at the same time as large groups of people are going hungry. Surplus food is derived from a range of areas including food retailers buying additional stock to meet demands of seasonal events, and changes in branding or labelling. As such good quality foods become surplus to requirements and organisations like Fare Share redistribute this food to organisations to feed those in need.

The structure and aim of how social supermarkets operate influences their method of food redistribution. The Henley Grub Hub, located in the grounds of Henley Green primary school, Coventry where some 47.4% of pupils are eligible for free school meals (36) model around providing food bags comprising items from different food groups sufficient for a household of 3 people. They provide this for a weekly membership fee of £4. The core offering of ambient products on a rotating basis includes pasta, rice, noodles, pasta sauce, tuna, breakfast cereals and UHT milk. In addition, there is a bag of fruit and vegetables with a variety of different produce and a chilled bag which has meat and/or dairy products with additional items added such as pate or ready meals depending on availability.

The Henley Grub Hub provides its customers with the facility to purchase foods which their budget may not otherwise allow. It has been suggested that shopping at a social supermarket can save up to £212 a month on food bills for a household (37). The other benefits of shopping at a social supermarket are the building and strengthening of communities. The wrap around services provided by Social Supermarkets help to build and maintain relationships between customers, volunteers and employed members of staff and external organisations, such as benefit advisors or job shops offering training and CV support.

Food Insecurity and a Right to Food

In the UK food insecurity and food waste exist. There is a need to prevent food waste from occurring and redistribution of surplus foods via organisations is a method utilised to prevent the food becoming waste (38). The use of surplus food will not solve food insecurity as the experience of food insecurity is an issue of monetary resource rather than availability of food. However, Social Supermarkets fulfil the need to be able to purchase food affordably, using surplus foods. This has been a method utilised as a strategy to get food to low income groups, although it doesn't tackle the root causes of food insecurity (39).

A Public Health priority in the UK is improving food and nutrition security (39). Food insecurity is defined by the US Department of Agriculture (USDA) in two levels 1) low food security and 2) very low food security. Low food security is indicative of reduced quality and variety of foods in the diet as well as consuming foods which are not preferred. Whilst very low food security includes fluctuations in eating patterns, reducing the quantity of food eaten or missing meals(40). The Food and Agriculture Organization (FAO) defines food insecurity as a "lack of secure access to adequate quantities of food which is safe to eat, nutritious and meets the requirement for normal growth and development and for an active healthy life(41)(42) Individuals can experience transient or chronic food insecurity and many factors influence this and include income level including from benefits, employment type (for example zero-hour contracts, seasonal work, disability, household size, and race/ethnicity

The 'Right to Food' is a human right focused approach to address the systematic differences between socio-economic groups health(43) and is bound in international law in Article 25.1(39) . The UK has signed up to International Covenant on Economic, Social and Cultural Right (ICESCR) Article 11 and is ratified(39). It is thought Social Supermarkets could be a tool in the ensuring people have a right to food as food sold is affordable. However, there maybe limitations on culturally acceptable food for the different communities Social Supermarkets are serving and it is suggested monetary resources are available to organisation for the purchase of relevant foods to help prevent further inequalities in diet and health between different ethnic groups in the UK.

Micronutrient Intakes in the UK for population groups at risk of sub-optimal intakes

The foods we eat, our diet and nutritional status are a factor in health and the development of non-communicable diseases such as heart disease, diabetes, obesity and some cancers. Furthermore, suboptimal intakes of micronutrients such as iron can lead to the development of anaemia and impair physical and mental capacity whilst deficiency of iodine can manifest in a spectrum of disorders across the life span from severe goitre in adults and children and congenital hypothyroidism if mothers are deficient during pregnancy to mild iodine deficiency which impairs mental capacity in adults and children alike. Whilst deficiency of zinc can compromise immune function it is also essential for optimal growth and development in children and adolescents.

Population groups at risk of micronutrient deficiencies are women and children due to their higher physiological requirements. In the UK, recent data from the National Diet and Nutrition survey indicate children aged 1.5-3 years, 11-18 years and women aged 19-64 years greater than 5% of these population groups had an iron intake below the lower reference nutrient intake (LRNI; 11%, 30% and 25% respectively). Furthermore, for 24% of children aged 11-18 years and 12% of women aged 19-64 years iodine intakes were below the LRNI, whilst 32% and 46%, respectively were reported to have a selenium intake below the LRNI. Additionally, 18% of children aged 11-18 years had zinc and vitamin A intakes below the LRNI whilst for women aged 19-64 years this number was around 8%. Micronutrients such as iron, zinc, selenium, iodine and vitamin are involved with many physiological processes and are also required concurrently to ensure biological process can take place (18)

Physiological role of micronutrients impact to health

Deficiency of iron can impair cognitive ability in children and adults and iron deficiency anaemia is a global nutrient deficiency disease (44). Zinc is required for growth and development in children and adolescents and deficiency can impair immune function, whilst selenium is an antioxidant and is a core component of enzymes required in the function of thyroid hormones. Thyroid hormone synthesis requires iodine, iron, zinc and selenium and mild deficiencies, particularly of iodine have been found to impair cognition in children and adults.

Minerals such as iron, zinc and selenium are required to produce antioxidant enzymes (29)are involved in protecting cells from damaging chemicals (reactive oxygen species) that are generated during normal cellular metabolism (45) and also when immune cells are fighting a virus (46) . Deficiency of selenium impairs the immune response by limiting the production of T Cells(47) which are involved in attacking infected cells (48)deficiency of zinc can increase susceptibility to infection as it is required in some viruses for proliferation (29). Zinc is also required for many other functions of the immune system including maintaining T and B cell numbers (29), important components for antibody production, helping to protect the body from infection.

Overall, it is apparent that the foods contributed by the Grub Hub provide critical nutrients for general life, but also to enable longer term good health by supporting normal cellular processes and robust immune function. Without this contribution, people struggling to make ends meet are very likely to become deficient in a number of nutrients, in particular the micronutrients discussed above which will make them far more prone to chronic, long-term disease and also susceptibility to infection.

Suggestion for future work.

Future studies are required investigating the shopping and food purchasing habits of customers shopping at Social Supermarkets and how this influences the type of foods in the diet, food security status and health of individuals.

Studies on how the shopping baskets are utilized by customers and if there are any barriers to using the food products in the bags and methods to alleviate them e.g., knowledge on the preparation and cooking of vegetables or how to create meals with limited ingredients?

It will be important to examine the profile of food provision to groups over a longer time-period and also to track the health of recipients to confirm progressive improvement so that the model of the social supermarket may be established as a viable intervention that could be usefully supported at both local and national levels.

References

1. Darmon N, Drewnowski A. Contribution of food prices and diet cost to socioeconomic disparities in diet quality and health: a systematic review and analysis. Nutr Rev. 2015 Oct;73(10):643–60.

2. 8.4m in UK too poor to eat | Sustain [Internet]. [cited 2022 Jan 12]. Available from: https://www.sustainweb.org/news/voicesofthehungry/

3. Ferrando DT, Dalmeny K. A UK right to food law could tackle food poverty and environmental degradation. 2018;2.

4. Team I. About Coventry [Internet]. Coventry City Council. [cited 2022 Feb 3]. Available from: https://www.coventry.gov.uk/facts-coventry/coventry-72

5. UK local food insecurity of Adults Jan 2021 [Internet]. [cited 2022 Jan 12]. Available from: https://shefuni.maps.arcgis.com/apps/instant/interactivelegend/index.html?appid=8be0cd9e18904c258afd3c959d6fc4d7

6. Loopstra DR, Bryant DM. A crisis within a crisis: The impact of Covid-19 on houseold food security. 2021 Jan;30.

7. New study identifies who is most likely to 'panic buy' in times of crisis [Internet]. 2021 [cited 2022 Jan 25]. Available from: https://www.sheffield.ac.uk/news/new-study-identifies-who-most-likely-panic-buy-times-crisis

8. COVID-19 and food supply: Government Response to the Committee's First Report. :26.

9. Saxena LP. How social supermarkets are filling a gap in austerity Britain [Internet]. The Conversation. [cited 2022 Jan 4]. Available from: http://theconversation.com/how-social-supermarkets-are-filling-a-gap-in-austerity-britain-99705

10. Redistribution of food surplus, social supermarkets, and food insecurity [Internet]. Redistribution of food surplus, social supermarkets, and food insecurity. [cited 2022 Jan 2]. Available from: https://www.foodaidnetwork.org.uk/blog/redistribution-of-food-surplus-social-supermarkets-and-food-insecurity

11. FareShare. FareShare, Fighting hunger, tackling food waste. [Internet]. FareShare. [cited 2021 Dec 31]. Available from: https://fareshare.org.uk/

12. Franco S, Cicatiello C. Levering waste taxes to increase surplus food redistribution at supermarkets: Gains and scenarios in Italian municipalities. Waste Manag. 2021 Feb 15;121:286–95.

13. Adult obesity [Internet]. [cited 2021 Dec 31]. Available from: http://healthsurvey.hscic.gov.uk/support-guidance/public-health/health-survey-for-england-2015/adult-overweight-and-obesity.aspx

14. Holmes J. Tackling obesity: the role of the NHS in a whole-system approach. 2021 Jul p. 38.

15. Moody A. HEALTH SURVEY FOR ENGLAND. LONDON: NATCEN SOCIAL RESEARCH; 2016.

16. Darmon N, Drewnowski A. Does social class predict diet quality? Am J Clin Nutr. 2008 May;87(5):1107–17.

17. Kim TJ. Income and obesity: what is the direction of the relationship? A systematic review and meta-analysis. Open Access. :13.

18. Miller R, Spiro A, Stanner S. Micronutrient status and intake in the UK – where might we be in 10 years' time? Nutr Bull. 2016;41(1):14–41.

19. Scott C, Sutherland J, Taylor A. Affordability of the UK's Eatwell Guide. p. 16.

20. Tobi R, Goudie S, Hughes I. FOOD FOUNDATION AUTHORS. 2021 p. 21.

21. Scheelbeek P, Green R, Papier K, Knuppel A, Alae-Carew C, Balkwill A, et al. Health impacts and environmental footprints of diets that meet the Eatwell Guide recommendations: analyses of multiple UK studies. BMJ Open. 2020 Aug;10(8):e037554.

22. NDNS: results from years 9 to 11 (2016 to 2017 and 2018 to 2019) [Internet]. GOV.UK. [cited 2022 Jan 11]. Available from: https://www.gov.uk/government/statistics/ndns-results-from-years-9-to-11-2016-to-2017-and-2018-to-2019

23. Domellöf M, Braegger C, Campoy C, Colomb V, Decsi T, Fewtrell M, et al. Iron Requirements of Infants and Toddlers. J Pediatr Gastroenterol Nutr. 2014 Jan;58(1):119–29.

24. Cappellini MD, Musallam KM, Taher AT. Iron deficiency anaemia revisited. J Intern Med. 2020;287(2):153–70.

25. McCann S, Perapoch Amadó M, Moore SE. The Role of Iron in Brain Development: A Systematic Review. Nutrients. 2020 Jul 5;12(7):2001.

26. Dubey P, Thakur V, Chattopadhyay M. Role of Minerals and Trace Elements in Diabetes and Insulin Resistance. Nutrients. 2020 Jun;12(6):1864.

27. García O, Long K, Rosado J. Impact of micronutrient deficiencies on obesity. Nutr Rev. 2009 Oct 1;67:559–72.

28. McKay J, Ho S, Jane M, Pal S. Overweight & obese Australian adults and micronutrient deficiency. BMC Nutr. 2020 May 1;6:12.

29. Calder PC. Nutrition, immunity and COVID-19. BMJ Nutr Prev Health. 2020 May 20;3(1):74–92.

30. Bath SC, Rayman MP. Iodine deficiency in the U.K.: an overlooked cause of impaired neurodevelopment? Proc Nutr Soc. 2013 May;72(2):226–35.

31. Vanderpump M. Thyroid and iodine nutritional status: a UK perspective. Clin Med Lond Engl. 2014 Dec;14 Suppl 6:s7-11.

32. Health Survey for England 2019 [NS] [Internet]. NHS Digital. [cited 2022 Feb 2]. Available from: https://digital.nhs.uk/data-and-information/publications/statistical/health-survey-for-england/2019

33. Connors C, Malan L, Canavan S, Sissoko F, Carmo M, Sheppard C, et al. The lived experience of food insecurity under Covid-19. 2020 Jul.

34. Kelloggs_Food_Desert_Brochure.pdf [Internet]. [cited 2022 Jan 12]. Available from: https://www.kelloggs.co.uk/content/dam/europe/kelloggs_gb/pdf/Kelloggs_Food_Desert_Brochure.pdf

35. Saxena LP. How social supermarkets are filling a gap in austerity Britain [Internet]. The Conversation. [cited 2022 Feb 1]. Available from: http://theconversation.com/how-social-supermarkets-are-filling-a-gap-in-austerity-britain-99705

36. Henley Green Primary - GOV.UK [Internet]. [cited 2022 Jan 12]. Available from: https://www.get-information-schools.service.gov.uk/Establishments/Establishment/Details/133476

37. Rayner J. The rise of social supermarkets: "It's not about selling cheap food, but building strong communities." The Observer [Internet]. 2019 May 19 [cited 2022 Jan 31]; Available from: https://www.theguardian.com/society/2019/may/19/social-supermarkets-food-poverty-jay-rayner

38. Surplus food redistribution in the UK 2015 to 2020 | WRAP [Internet]. [cited 2022 Feb 1]. Available from: https://wrap.org.uk/resources/report/surplus-food-redistribution-uk-2015-2020

39. Pollard CM, Booth S. Food Insecurity and Hunger in Rich Countries—It Is Time for Action against Inequality. Int J Environ Res Public Health. 2019 Jan;16(10):1804.

40. Banks AR, Bell BA, Ngendahimana D, Embaye M, Freedman DA, Chisolm DJ. Identification of factors related to food insecurity and the implications for social determinants of health screenings. BMC Public Health. 2021 Jul 16;21(1):1410.

41. Event summary: Food insecurity and children's health. 2021 Sep 23 [cited 2022 Jan 24]; Available from: https://post.parliament.uk/event-summary-food-insecurity-and-childrens-health/

42. Hunger [Internet]. Food and Agriculture Organization of the United Nations. [cited 2022 Jan 24]. Available from: http://www.fao.org/hunger/en/

43. Whitehead M, Dahlgren G. Concepts and principles for tackling social inequities in health: :45.

44. Zhang D-L, Ghosh MC, Rouault TA. The physiological functions of iron regulatory proteins in iron homeostasis - an update. Front Pharmacol. 2014;5:124.

45. Weydert CJ, Cullen JJ. MEASUREMENT OF SUPEROXIDE DISMUTASE, CATALASE, AND GLUTATHIONE PEROXIDASE IN CULTURED CELLS AND TISSUE. Nat Protoc. 2010;5(1):51–66.

46. Shields HJ, Traa A, Van Raamsdonk JM. Beneficial and Detrimental Effects of Reactive Oxygen Species on Lifespan: A Comprehensive Review of Comparative and Experimental Studies. Front Cell Dev Biol. 2021;9:181.

47. Fedele D, De Francesco A, Riso S, Collo A. Obesity, malnutrition, and trace element deficiency in the coronavirus disease (COVID-19) pandemic: An overview. Nutrition. 2021 Jan 1;81:111016.

48. T cell immunity: What is it and how does it help to protect us from COVID-19? | Imperial News | Imperial College London [Internet]. Imperial News. [cited 2022 Jan 7]. Available from: https://www.imperial.ac.uk/news/201833/cell-immunity-what-does-help-protect/

Appendix 1: Core food offering

Supplies change weekly but include, as a minimum; c£20 (in value) with items on rotation from each product group:

· 1 x sundry item e.g., condiments; cooking sauces

· 1 x 1L milk Long-life/Fresh as available

· 1 x 'drink' tea or coffee or hot chocolate or sugar or squash/juice

· 3 x cans 1 x meat or fish; plus 2 x others e.g., peas, beans, soup, tomatoes

· 1 x carb: pasta or rice or packet mash or noodles

· 1 x cereal: porridge or cornflakes or Weetabix (or others as available)

· 1 x portion fresh meat or fish as available (c1kg)

· Apples, bananas,

· 1 x chilled item e.g., yogurt or cook-chill or spread (as available)

Appendix 2: Meal ideas using core food items in shopping basket

Tuna Pasta Bake serves 3 people

225g Dried pasta
1 Tin of Tuna
3/4 jar of pasta sauce

Chicken pot pie serves 3 people

1 tin of chicken in white wine sauce (400g)
1 tin of chicken soup (400g)
1 carrot diced
3 potatoes (boiled and sliced thinly)
Served with Red cabbage.

Pork balls with ramen style noodles serves 3

375g pork mince
100g spring onions sliced
138g noodles and flavourings
Shredded kale
Water

Pork Bolognese style pasta bake serves 3

375g pork mince
100g spring onions sliced
1 carrot diced
6 tomatoes
225g Dried pasta
¼ jar pasta sauce

Remaining items

50g pasta
1 tin chicken soup (with bread serves 2)
1 tin spaghetti in tomato sauce (on toast serves 2)
250g pork mince (2 portions can be cooked and frozen for a different meal)

2 oranges (eaten at breakfast or as a snack?)

Appendix 3: Recommended Nutrient intakes for males and females aged 11-50 years and nutrient requirement for household by type (age and gender specific)

	Female 19-50 years	Males 19-50 years	Female 11-14 years	Male 11-14 years	Household type: 2 adult and 1 child	Household type: 1 adult and 2 children
Energy(kcal)	1940	2550	1845	2200	6690	5985
Fibre(g)	30	30	25	25	85	80
Free Sugars(g)	30	30	30	30	90	90
Vitamin A (ug)	600	600	600	600	1800	1800
Vitamin D(ug)	10	10	10	10	30	30
Vitamin E(mg)	3	4	-	-	7	3
Riboflavin (B2)(mg)	1.1	1.3	1.1	1.2	3.6	3.4
Niacin (Total NE)(mg)	13	17	12	15	45	40
Vitamin B6 (mg)	1.2	1.4	1	1.2	3.8	3.4
Folates Total(ug)	200	200	200	200	600	600
Vitamin B12 (ug)	1.5	1.5	1.2	1.2	4.2	3.9
Vitamin C(mg)	40	40	30	30	110	100
Sodium (mg)	1600	1600	1600	1600	4800	4800
Potassium (mg)	3500	3500	3100	3100	10100	9700
Calcium (mg)	700	700	1000	800	2200	2500
Phosphorus (mg)	550	550	625	775	1875	1950
Magnesium (mg)	270	300	280	280	850	830
Iron (mg)	14.8	8.7	14.8	11.3	34.8	40.9
Copper (mg)	1.2	1.2	0.8	0.8	3.2	2.8
Zinc (mg)	7	9.5	9	9	25.5	25
Chloride (mg)	2500	2500			5000	2500
Selenium (ug)	60	75	45	45	180	150
Iodine (ug)	140	140	130	130	410	400

Appendix 4: Groceries stores within the vicinity of Henley Grub Hub

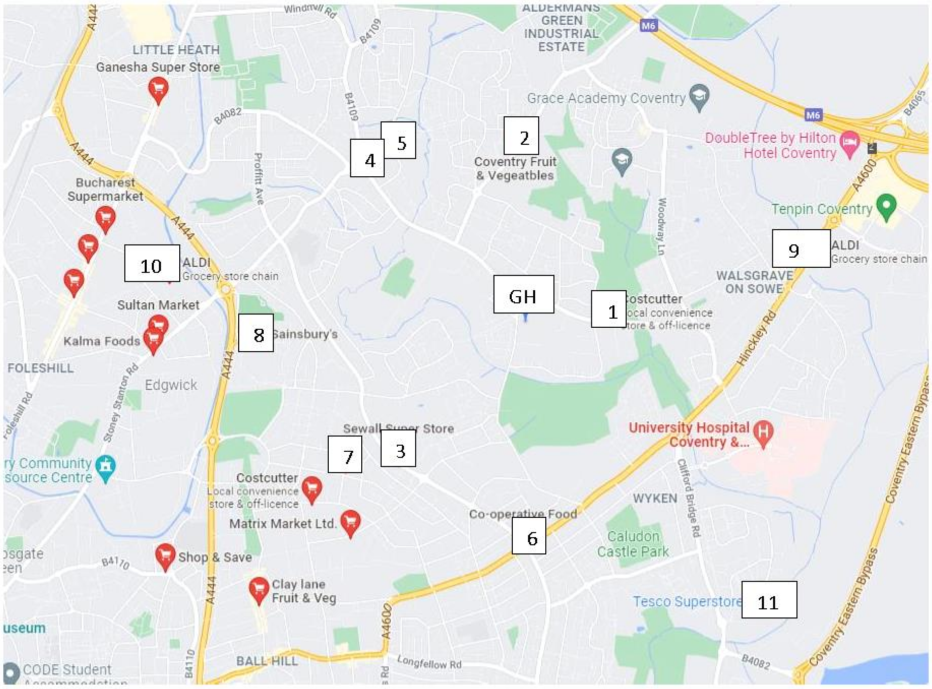

Table 2 Type of groceries stores and distance from Henley Grub Hub

Number	Shop Name	Type of shop	Distance from Henley Grub Hub (Miles)	Time to get there by foot (minutes)
1	Cost Cutter	Convenience store	0.4	8
2	Coventry Fruit and Vegetables	Small Grocery store	0.8	17
3	Sewall Superstore	Corner Shop	0.8	15
4	Kasia FoodPlus	Polish Deli	0.9	17
5	Kaneshie Market	Corner Shop	0.9	19
6	Co-op Food	Small Grocery store	1.0	20
7	Wyken Stores	Corner shop	1.0	21
8	Sainsburys	Supermarket	1.4	28
9	Aldi	Supermarket	1.4	28
10	Aldi	Supermarket	1.7	35
11	Tesco	Supermarket	1.8	35

GH= Grub Hub