Whole grain intake, diet quality and cardio-metabolic health in two UK cohorts

A thesis submitted for the degree of Doctor of Philosophy

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Declaration

I hereby declare that the contents of this thesis are my own, have not been submitted or accepted in any previous application for a degree or other qualification, and are a true record of the work carried out by myself unless stated otherwise. All quotations have been distinguished by quotation marks and all sources of information are referenced.

Kay D Mann
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Abstract

Processed grains that retain all three component parts - bran, germ and endosperm are known as whole grains. Epidemiological evidence suggests an inverse association between whole grain (WG) consumption and the risk of non-communicable diseases, such as cardio-vascular disease, type 2 diabetes, obesity and some cancers. The USA and Denmark have quantity-specific WG dietary recommendations, but other countries, including the UK, do not. Despite recognition that WG is an important component of a healthy diet, monitoring of WG intake in the UK is poor. Thus, there is a need to assess WG intake and its consequences in the UK population.

The purpose of this work was to calculate WG intake and investigate potential associations with cardio-metabolic measures, nutrient intakes and intakes of other foods in the most recent UK National Diet and Nutrition Survey (NDNS) data and in the Newcastle Thousand Families Study (NTFS), a birth cohort from Newcastle upon Tyne.

The estimated WG content of whole-grain foods identified in 3073 four-day food diaries was used to calculate WG intake of adults and children from the NDNS 2008-2011. A cereal food frequency questionnaire was developed with estimated portion sizes to estimate WG intake. WG intake was also calculated in the NTFS at 50- and 60-year follow-up.

WG intake, which came mainly from breads and breakfast cereals, was low with an average of 20g/d in adults and 13 g/d in children of the NDNS and 19, 21 and 33g/d in the NTFS at ages 50, 60 and 67 years, respectively. In both studies WG was inversely associated with some, but not all, cardio-metabolic measures, after adjustment for confounding factors. Associations were small, but significant, suggesting that WG may have an important role in disease prevention. For example, a significant decrease in NDNS white blood cell counts were seen across tertiles of increasing WG intake, after adjustment for age, sex and total energy intake. In the NTFS members at 50-year follow-up, each 10g/d increase in WG intake was associated with a 0.1mmol/L reduction in total and LDL cholesterol concentrations, after adjustment for confounders such as sex, SES, medication use and smoking status. WG consumers also had overall better dietary profiles, with higher intakes of fibre, iron and magnesium and lower intakes of fats.

The recent UK recommendation to increase dietary fibre intake will require a greater emphasis on consuming more WG. Specific recommendations on WG intake in the UK are warranted as is the development of a public health policy to promote the consumption of these important foods.

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Contributions to PhD thesis

Kay Mann compiled and wrote this thesis with guidance and advice from the supervisors.

NDNS data were collected by the NDNS team (see acknowledgements) and obtained from the UK data service. The whole grain contents of UK foods file was established by Dr Angela Jones. Kay Mann added to this file by identifying and calculating the whole grain contents of foods reported in 4-day diet diary data from the NDNS rolling programme years 1-3 (Appendix A). Estimation of whole grain intake and statistical analysis of associations with diet and cardio-metabolic markers was performed and interpreted by Kay Mann (Chapter 3). Funding of Kay Mann's time during this analysis from Cereal Partners Worldwide is gratefully acknowledged.

Fifty and 60-year NTFS data were obtained from the study database at Newcastle University. Calculation of nutrient and food intakes from food frequency questionnaires was performed by Kay Mann using the FETA software. Socio-economic classification and achieved education level coding was previously done by the study team and checked by Kay Mann. Data on medication use, reported at both 50- and 60-year follow-up, were cleaned and coded by Kay Mann. Clinical data from the 50-year follow-up had been previously cleaned and were checked by Kay Mann. Clinical data from the 60-year follow-up was, cleaned and cross-checked with physical records, where appropriate, by Kay Mann.

Ethical application for new data collection was prepared by Kay Mann. The Cereal Food Questionnaire was developed and distributed by Kay Mann. Data entry was done by Emma Thompson and Katharine Kirton and was cross-checked by Kay Mann. The online version of the questionnaire was programmed by Steven Hall (Appendix D). Online data were received and stored by Kay Mann. Food portion size estimation for the Cereal Food Questionnaire was conducted by Kay Mann (Appendix E). Estimation of whole grain intake and statistical analysis of associations with diet and cardio-metabolic markers was performed and interpreted by Kay Mann (Chapter 4).

Publications

The following journal articles have been published from work presented in this thesis:

Mann, K.D., Pearce, M.S., McKevith, B., Thielecke, F. and Seal, C.J. (2015). Low whole grain intake in the UK: results from the National Diet and Nutrition Survey rolling programme 2008-11. *British Journal of Nutrition*, 113(10), pp. 1643-1651

Mann, K.D., Pearce, M.S., McKevith, B., Thielecke, F. and Seal, C.J. (2015). Whole grain intake and its association with intakes of other foods, nutrients and markers of health in the National Diet and Nutrition Survey rolling programme 2008-11. *British Journal of Nutrition*, 113(10), pp.1595-1602

Mann, K.D., Pearce, M.S. and Seal, C.J. (2016). Providing evidence to support the development of whole grain dietary recommendations in the United Kingdom. *Proceedings of the Nutrition Society*, pp.1–9.

Jones, A.R., **Mann, K.D.**, Kuznesof, S.A., Richardson, D.P. and Seal, C.J. (2017). The whole grain content of foods consumed in the UK. *Food Chemistry*, 214, pp.453-459

The whole grain databased produced from the work in this thesis was also applied to data from a study on whole grain intake in Singaporean infants:

Neo, J.E., Binte Mohamed Salleh, S., Toh, Y.X., How, K.Y.L., Tee, M., **Mann, K.**, Hopkins, S., Thielecke, F., Seal, C.J. and Brownlee, I. A. (2016). Whole-grain food consumption in Singaporean children aged 6–12 years. J*ournal of Nutritional Science*, 5, e33.

Peer reviewed abstracts presented at scientific meetings by Kay Mann.

Healthgrain Forum Autumn Workshop 2013, VTT Technical Research Centre, Finland

Mann, K.D. and Seal, C.J. Whole grain intake in the UK - The National Diet and Nutrition Survey 2008-2011.

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Mann, K.D., Pearce, M.S., McKevith, B., Thielecke, F. and Seal, C.J. Whole grain intake remains low: results from the National Diet and Nutrition Survey rolling programme years 1, 2 and 3. Nutrition Society Summer meeting Glasgow 2014

Mann, K.D., Pearce, M.S., McKevith, B., Thielecke, F. and Seal, C.J. Whole grain intake is associated with intakes of other foods and nutrients and some markers of health in the National Diet and Nutrition Survey rolling programme years 1, 2 and 3.

Human Nutrition Research Centre Annual Research Day, 2014, Newcastle University, UK

Mann, K.D., Pearce, M.S., McKevith, B., Thielecke, F. and Seal, C.J. Whole grain intake is associated with intakes of other foods, nutrients and markers of health in the National Diet and Nutrition Survey rolling programme 2008-2011.

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Human Nutrition Research Centre Annual Research Day, 2015, Newcastle University, UK

Jones, A.R., **Mann, K.D.**, Kuznesof, S.A., Richardson, D.P. and Seal, C.J. The whole grain content of foods consumed in the UK.

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Mann, K.D., Pearce, M.S. and Seal, C.J. Providing evidence to support the development of whole grain dietary recommendations in the United Kingdom.

Abbreviations

AACC: American Association of Cereal Chemists

ALSPAC: Avon Longitudinal Study of Parents and Children

AOAC: Association of Official Analytical Chemists

ASN: American Society for Nutrition

BMI: Body Mass Index

BNF: British National Formulary

CAFÉ: Compositional Analyses from Frequency Estimates

CAPI: Computer-assisted Personal Interviewing

CFQ: Cereal Foods Questionnaire

CHD: Coronary Heart Disease

CRP: C-reactive Protein

CVD: Cardio-vascular Disease

DINO: Diet In Nutrients Out

DoH: Department of Health

DONALD: Dortmund Nutritional and Anthropometric Longitudinally Designed

EPIC: European Prospective Investigation into Cancer and Nutrition

EU: European Union

FDA: Food and Drug Administration

FETA: FFQ EPIC Tool of Analysis

FFQ: Food Frequency Questionnaire

FSA-FPSB: Foods Standard Agency's Food Portion Sizes Book

HDL: High-density Lipoprotein

HNR: Human Nutrition Research

HOMA-IR: Homeostasis Model Assessment of Insulin Resistance

HOMA-β: Homeostasis Model Assessment of Beta Cell Function

HRP: Household Reference Person

IGD: Institute of Grocery Distribution

IHD: Ischaemic Heart Disease

IQR: Interquartile Range

LDL: Low-density Lipoprotein

MRC: Medical Research Council

MUFA: Monounsaturated Fatty Acids

NDNS: National Diet and Nutrition Survey

NHANES: National Health and Nutrition Examination Survey

NME: Non-milk Extrinsic

NS-SEC: National Statistics Socio-economic Classification

NTFS: Newcastle Thousand Families Study

PAI-1: Plasminogen Activator Inhibitor 1

PREDIMED: PREvención con Dieta MEDiterránea

PUFA: Polyunsaturated Fatty Acids

QUID: Quantitative Ingredient Declaration

RACC: Reference Amount Customarily Consumed

RTEBC: Ready to Eat Breakfast Cereal

SACN: Scientific Advisory Committee on Nutrition

SD: Standard Deviation

SES: Socio-economic Status

SFA: Saturated Fatty Acids

SOC: Standard Occupational Classification

T: Tertile

T2D: Type 2 Diabetes

UK: United Kingdom

US: United States (of America)

USDA: United States Department of Agriculture

WG: Whole grain

WGC: Whole Grains Council

WHO: World Health Organisation

Terminology

Throughout this thesis the term 'whole grain' has been used to denote grains that are whole (i.e. contain all three component parts of the grain). The term 'whole-grain' has be used to describe foods, products or ingredients that contain whole grains.

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1.1 What are whole grains and whole-grain foods?

Whole grains and their definition

Cereal grains are the seeds of the Gramineae family of grasses and have been cultivated as a staple food in the human diet for thousands of years. The Gramineae family consist of barley, maize (corn), millet, oats, rice, rye, sorghum, triticale and wheat (Seal *et al.*, 2006). There are also the pseudo-cereals; amaranth, buckwheat, psyllium, quinoa and wild rice which are seeds from non-Gramineae families that function, from a nutritional perspective, as cereals since their anatomical structure is similar to that of a grain (Harris and Kris-Etherton, 2010; van der Kamp *et al.*, 2014). Whole grains are important dietary sources of carbohydrate and protein which also provide nutrients, vitamins and minerals to the diet. A whole grain has three principal components of outer bran (also known as the aleurone layer), endosperm and germ (Figure 1.1) and the proportions of these vary by the type of grain (Seal *et al.*, 2006).

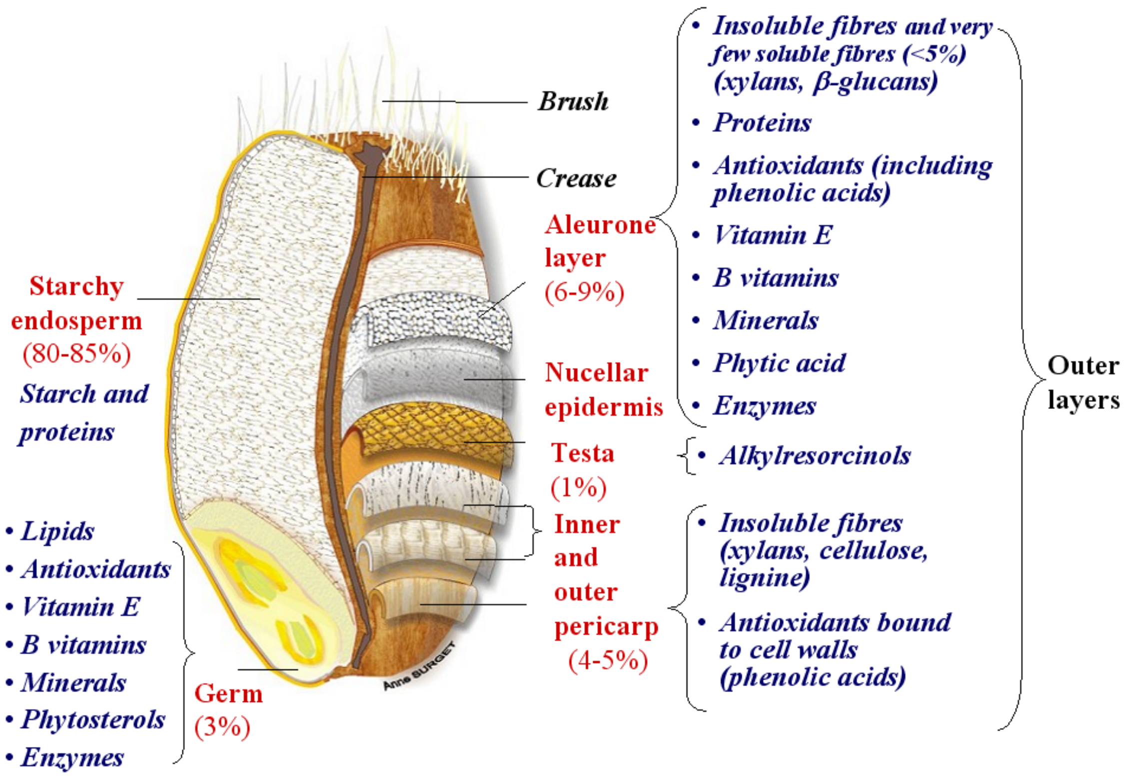


Figure 1.1 Anatomical structure of a whole wheat grain

(Surget and Barron, 2005; Hemery *et al.*, 2007; Fardet, 2010; Seal *et al.*, 2016)

Generally, grains consist of around 80-85% endosperm 10-15% bran and 2-3% germ (Fardet, 2010). In addition to this, grains have a further outer layer usually known as the hull or husk which is a protective barrier from sun damage, pests and disease. Inedible hulls or husks are removed from grains via processing leaving the grain's tough, natural protective bran shell. The largest component of the grain, the endosperm, is carbohydrate in the form of starches with smaller amounts of oligosaccharides such as fructans and arabinoxylans (Seal *et al.*, 2016). As well as starch, the endosperm also contains storage proteins and cell wall polymers. The germ is the plant embryo and is the sprouting portion of the grain that has a high lipid and protein content. The outer bran layers and germ fractions of whole grains are high in dietary fibre (both soluble and insoluble) and contain the majority of the bioactive compounds in the grain. The bioactive compounds include B-vitamins (thaimin, niacin, riboflavin and pantothenic acid), vitamin E, minerals (calcium, magnesium, potassium, phosphorus, sodium and iron) and phytochemicals such as phenolic and phytic acids that give whole grains their high in vitro antioxidant capacity (Hemery *et al.*, 2007). Whole grains need to be processed in order for human consumption and, after removal of hulls and husks, are often milled or ground into flours. Other grain processing techniques include steaming, followed by rolling or flaking, pearling and toasting. Milling whole grains allows for separation of the bran, germ and endosperm components which gives the opportunity to improve flavour, colour, palatability, appearance and cooking characteristics (Seal *et al.*, 2006). Removal of the bran and germ fractions through processing is known as refining and thus refined grains and the foods made from them have lower fibre, protein, vitamin and mineral compounds in comparison to whole grain versions (Smith *et al.*, 2003). In some countries refined grain flours have mandatory refortification to compensate for these nutrient losses. For example, in the UK, brown and white flours are fortified with iron, thaimin, niacin and nicotinic acid (*The Bread and Flour Regulations 1998, No. 141*, 1998). However, there are no commonly used processes to replace the loss of fibre from refining grains.

In 1999, the first officially approved whole grain definition was produced by the American Association of Cereal Chemists (AACC) International for the benefit of consumers and food manufacturers (American Association of Cereal Chemists, 1999). The approved definition *"Whole grains shall consist of the intact, ground, cracked or flaked caryopsis, whose principal anatomical components – the starchy endosperm, germ and bran - are present in the same relative proportions as they exists in the intact caryopsis"* was adopted and included in the United States Food and Drug Administration (US FDA) guidelines on what the term 'whole grain' may include (U.S. Food and Drug Administration, 2006). To make this definition clear to consumers, the Whole Grains Council (WGC), a US based non-profit consumer advocacy group of millers, manufacturers, scientists and chefs, later approved an endorsed the definition "*Whole grains or foods made from them contain all the essential parts and naturally-occurring nutrients of the entire grain seed in their original proportions. If the grain has been processed (e.g., cracked, crushed, rolled, extruded and/or cooked), the food product should deliver the same rich balance of nutrients that are found in the original grain seed."* (Oldways Whole Grains Council, 2004). The Healthgrain forum, a consortium of European academic and industry bodies, set about to develop a unified EU definition of a whole grain such that it was more comprehensive than current EU country specific definitions, reflective of manufacturing processes and be used in the context of nutrition guidelines for food labelling. Subsequently, in 2010, the first presentation of the definition followed, which was finally published in 2014: *"Whole grains shall consist of the ground, cracked or flaked kernel after the removal of inedible parts such as the hull and husk. The principal anatomical components - the starchy endosperm, germ and bran - are present in the same relative proportions as they exist in the intact kernel. Small losses of components - that is, less than 2% of the grain/10% of the bran - that occur through processing methods consistent with safety and quality are allowed."* (van der Kamp *et al.*, 2014). This definition, and that of the AACC International, are now widely accepted definitions and are adopted in most research studies and country specific reports (Mejborn *et al.*, 2008; Health Promotion Board Singapore, 2012; Food Standards Australia New Zealand, 2015). Therefore, there is now a current consensus among scientists, public and private organisations on what constitutes a whole grain. Currently there is representation across Europe, led by the Healthgrain forum for the European commission to formally adopt this definition as a legal entity.

Whole-grain foods and their definition

Whole-grain foods are foods made from whole cereals such as corn, rice and barley, and whole-grain ingredients, such as flours (wholemeal, oatmeal), flaked or rolled whole grain cereals. Typically, flours are roller milled where the three component parts of the whole cereal grain are ground and separated by sieving and sifting and reconstituted to reform the whole-grain flour (Seal *et al.*, 2006). In traditional milling methods, such as stone grinding, whole cereal grains are crushed into flour and thus the three component parts are not separated into fractions. Foods that contain whole grains or whole-grain ingredients should make this clear on food package labelling. Generally speaking, if a grain ingredient is prefixed by 'whole', 'whole grain' or 'whole-grain', for example wholemeal flour;

wholewheat; whole-grain rice, then the ingredient must comply with the whole grain definition. However, there are other ingredients such as oats, rolled oats, flaked oats, brown rice, popcorn and rye which are all whole grain, but are not always listed using the ‘whole’ pre-fix which can cause confusion as to whether a food containing these ingredients is whole grain or not. In addition, the term ‘whole’ is not regularly used to describe whole pseudo-cereal foods such as amaranth, buckwheat and quinoa. In the UK, currently the only protected and regulated whole grain label is wholemeal in which manufacturers must include the three relative proportions of a whole wheat grain in the flour (*The Bread and Flour Regulations 1998, No. 141*, 1998).

At present the labelling of a food as ‘whole grain’ or a product as a ‘whole-grain food’ is not protected, as there is no legal or agreed definition of the minimum quantity of whole grains or whole-grain ingredients required for a food to be defined as ‘whole-grain’. In 1999, General Mills, a food manufacturer, submitted a notification to the US FDA to use a health claim on whole-grain foods. The claim *“Diets high in plant foods--i.e., fruits, vegetables, legumes, and whole-grain cereals--are associated with a lower occurrence of coronary heart disease and cancers of the lung, colon, esophagus, and stomach."* was permitted for use (U.S. Food and Drug Administration, 1999). To use the claim on food products, manufacturers must comply with the definition that whole-grain foods contain 51% or more whole-grain ingredient(s) by weight per reference amount customarily consumed (RACC). Compliance may be assessed with reference to the dietary fibre level of whole wheat (11g dietary fibre per 100g) and thus to use the claim foods must have 11g x 51% x RACC/100 (U.S. Food and Drug Administration, 1999). In addition, a similar whole grain health claim on foods was submitted to the US FDA from Kraft foods for approval in 2003. This claim *“Diets rich in whole grain foods and other plant foods, and low in saturated fat and cholesterol, may help reduce the risk of heart disease”* again defined whole-grain foods as foods that contain 51% or more whole-grain ingredient(s) by weight per RACC. Additionally, foods using this claim must also meet regulatory definitions for low saturated fat and cholesterol, label the quantity of trans-fat and contain less than 6.5g total fat as well as 0.5g or less trans-fat per RACC (U.S. Food and Drug Administration, 2003). Previously, in 2002, the UK also had a health claim that was allowed for the use on foods containing at least 51% whole grain. “*People with a healthy heart tend to eat more whole-grain foods as part of a healthy lifestyle*” (Joint Health Claims Initiative, 2002). However, this claim is no longer permitted for use, since in 2010, the European Foods Standard Agency rejected the use of all whole grain health claims in Europe on the basis that whole grain was "insufficiently characterised" (EFSA Panel on Dietetic Products and Nutrition Allergies, 2010).

Despite these health claims being a useful tool for manufacturers to use on products, they have not been universally adopted, since the 51% whole-grain ingredient and fibre content limitations mean that many whole grain containing foods, such as brown rice, would not be able to use the health claim. Other countries define whole-grain foods as part of their dietary guidelines which differ by food type. In Denmark, flours, grains and rice must contain 100% whole grain, breakfast cereals 60% and bread 50% whole grain and in Germany pasta must contain 100% whole grain, whereas wheat and rye breads must contain 90% whole grain (Ferruzzi *et al.*, 2014). In the UK, in 2007, the Institute of Grocery Distribution (IGD) working group recognised the need for a recommendation on minimum level of whole grain content in foods for its presence to be communicated (Institute of Grocery Distribution, 2007). The IGD recommended a minimum level of whole grain to be 8g per serving based on the AACC International's recommendation of this quantity being a 'dietary significant level' which was later approved (American Association of Cereal Chemists International, 2013). This recommendation falls in line with EU labelling legislation 2, that any foods declaring whole grain ('with whole grain', 'made with whole grain') are required to provide quantitative ingredient declaration (QUID) on the packaging. However, since this minimum level is a recommendation and not intended to support a health claim, it is not currently legally imposed in the UK. Similar to the AACC International, a roundtable of experts from academic and industry, have also suggests a minimum whole grain content of 8g per 30g serve (~27%) for a food to be labelled as whole grain (Ferruzzi *et al.*, 2014). Ferruzzi *et al.* (2014) based their definition on the scientific evidence for disease risk reduction as well as considering whole grain intake recommendations in the US and making this definition meaningful to the consumer to be able to meet intake recommendations. Furthermore, the Healthgrain forum have recently proposed that a whole-grain food should contain at least 30% whole grain content on a dry matter basis with more whole-grain ingredients than refined grain ingredients in the final product (Ross *et al.*, 2017). This is in addition to compliance with country-specific fat, salt and sugar limitations. A universal consensus on the minimum level of whole grain content required in foods to be labelled as whole-grain would provide clear guidance to manufacturers and consumers and may help to increase whole-grain food availability and consumption.

1.2 Whole grain intake recommendation

At present, there is a general consensus from a public health perspective that we should consume more whole grains and, as such, there are some recommendations to consume whole grains across the globe. These vary by country with some offering generic advice and others providing quantity-specific daily target intakes (Seal *et al.*, 2016). For example in the US and Canada advice to "*make one-half of your grains whole grains*" is followed by a quantity recommendation of a minimum 3-5 ounce-equivalents (servings) per day (48-80g/d) (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015-2020). Similarly, quantity-specific dietary guidance is given in Denmark, however with a higher target to consume 75g/d whole grain per 10MJ/2400kcal diet (approximately 4 portions a day). Semi-quantity specific intake targets are advised in Singapore where advice for adults is to consume sufficient amount of grains, especially whole grains with at least one serving of rice and alternatives from whole-grain foods (Health Promotion Board Singapore, 2012). In the UK, generic advice in the Eatwell Guide, is to *"choose wholegrain or higher fibre versions with less added fat, salt and sugar"* (Public Health England, 2016). In the majority of other countries with food-based dietary public guidance (including Australia, China, France, Germany and Ireland) generic advice to choose or include whole grain and consume more whole grain is given (Ferruzzi *et al.*, 2014; Seal *et al.*, 2016). The variety of whole grain recommendations across many countries could be confusing, particularly where quantity-specifics do not match. Target intakes are largely based on meeting dietary fibre recommendations and endorsing whole grains as a source of fibre. Clearly targets need to reflect country specific cultural and traditional diets, however some consistency between countries based on scientific evidence would be useful. In addition, in consideration of cultural and traditional diets, a whole grain intake recommendation also needs to consider the amount likely achievable within a healthy diet. Intake targets should carefully consider the availability and quantity of foods required to be consumed. This has recently been highlighted by the British Nutrition Foundation in relation to the recently updated UK dietary fibre recommendation from 23-24g/d to 30g/d (AOAC) for adults (Buttriss, 2015; Hooper *et al.*, 2015). Buttriss (2015) noted through an example dietary model that achieving these recommendations is possible, but would require substantial changes to dietary patterns for many. Interestingly, in an example weekly meal planned by the British Nutrition Foundation, many of the foods contributing to total fibre intake were whole-grain foods in addition to fruits, vegetables, beans and pulses needed to meet the adult target fibre intake (British Nutrition Foundation, 2015).

The justification behind whole grain intake recommendations and the promotion of whole-grain foods in healthy diets come from epidemiological studies that have suggested higher whole grain intakes are associated with reduced risk of disease. Many large scale prospective cohort studies have found links by comparing people that consume the highest amounts, to those that consume no or very little, whole grain with risk reductions for cardiovascular disease (CVD), type 2 diabetes (T2D), obesity, some types of cancer and mortality (Aune et al 2016, Li et al 2016, Ye et al 2012, Aune et al 2011, Aune et al 2013, Thieleke et al 201). Further detail on the summaries of the observational and intervention study literature is reviewed in the following chapter. The majority of the observational evidence comes from US and Scandinavian populations, where there are quantity-specific whole grain intake recommendations. There is a lack of evidence from studies on UK populations as well as poor monitoring of whole grain intake in the UK.

1.3 Whole grain consumption

As with whole grain recommendations, whole grain intake varies across countries. Assessing intake of whole grains is challenging for many reasons. In addition to universal issues of self-reported dietary intake from either food frequency questionnaire or diet records, further difficulties arise for whole grains since the identification of these partly rely on participant knowledge, manufacturer information and standardised databases on the content of whole grains in foods. Such databases are publicly available in the US through the United States Department of Agriculture (USDA) Patterns Equivalents Database (U.S. Department of Agriculture - Agricultural Research Service, 2014) and as such whole grain intake has been routinely estimated and reported in the US National Health and Nutrition Examination Survey (NHANES) for over 10 years (McGill *et al.*, 2015). Whole-grain food data are also recently publicly available for whole-grain foods consumed in Australia (Galea *et al.*, 2016), however published data on whole grain intakes seem to be scarce. In some reports, such as the Danish and Irish surveys, they use in house methods and food market data to estimate the average whole grain content of foods consumed and base estimated intakes on that data (Devlin *et al.*, 2013; Mejborn *et al.*, 2014). In other countries, such as the UK, France and Italy, there is a lack of publicly available data on the whole-grain foods consumed and used to estimate whole grain intakes.

Despite the difficulties in assessing and measuring whole grain intake, the available data show that consumption and intake of whole grains in the majority of countries are low (Table 1.1). Average whole grain intakes for adults range from as little as 4g/d in Italy, measured in 2005-06, and 5g/d in France measured in 2009-10, to as high as 58g/d (63g/d/10MJ) in Denmark measured in 2011-13 (Bellisle *et al.*, 2014; Mejborn *et al.*, 2014; Sette *et al.*, 2015). In children (including teenagers), average intakes are typically lower and in some countries, such as Singapore, negligible (Neo *et al.*, 2016). One reason for the low level of whole grain intake across many countries is the level of non-consumption in the populations. In Italy and France, around 70% of the populations surveyed did not consume any whole grain. This does not imply that these populations are not consuming cereals, but that they are choosing refined grain cereal products over whole grain or perhaps a lack in the availability and desirability of whole-grain foods. The higher reported whole grain intakes in the Danish population are attributed to a combination of traditional diets that include whole-grain foods, such as rye bread, and the recent success of the Danish whole-grain campaign. The campaign, a public and private company partnership, aimed to increase accessibility and awareness of whole grains and the associated health benefits, has seen a substantial increase of 75% in average Danish whole grain intakes (Danish Whole Grain Partnership, 2014).

Whole grain intakes from the US NHANES are reported in ounce-equivalents to be consistent with their dietary guidelines. Ounce-equivalents cannot meaningfully be converted into grams per day for comparison, since an ounce-equivalent can be either 16 or 28.35g depending on the food source. Nevertheless, whole grain intakes in the US are low with less than 10% of Americans meeting their dietary intake recommendation (Albertson *et al.*, 2016). Scandinavian countries, fair slightly better in meeting their higher dietary intake recommendation with around 30% of adults achieving 75g/10MJ/d and more than 95% of these populations consuming some whole grain (Table 1.1). In the UK, whole grain intake from foods with at least 10% whole grain content was reported to be 7g/d for children and 14g/d for adults from the 2000-01 and 1997 National Diet and Nutrition Survey (NDNS), respectively (Table 1.1, (Thane *et al.*, 2005; Thane *et al.*, 2007)). Although there are no quantity-specific recommendations, 16% of adults consumed at least 48g/d, the suggested minimum amount for reduced risk of disease. Since the last assessment of whole grain intake in the UK, in 2001, there has been an increase in the whole-grain food products available in the consumer market and consumer awareness of whole grains is increasing. From 2008, the UK NDNS has been run as a rolling programme and therefore presents an opportunity to update and assess more recent whole grain consumption in this population.

Table 1.1 Country specific whole grain intakes from national dietary surveys or nationally representative dietary surveys

Country; *Study*	Age range (n)	Whole grain intake (g/d unless otherwise stated)			
		Mean (SD/SE)	Median (5th - 95th percentile)	% non-consumers	% meet target intake (target)
Italy; *INRAN-SCAI (Italian food consumption database) 2005-06 (Sette et al., 2015)*	18 - 65 years (TP:2313, M:1068, F:1245)	TP: 4 (12) M: 3 (12) F: 5 (13)	TP: 0 (34*) M: 0 (30*) F: 0 (38*)	TP: 76% M: 84% F: 69%	1% (48g/d)
France; *Comportements et Consommations Alimentries en France 2010 Survey (Bellisle et al., 2014)*	18+ years (TP:1389, M:588, F:801)	TP: 5 (0.3) M: 4 (0.5) F: 5 (0.5)	TP: 0 (26†) M: 0 (25†) F: 0 (27†)	TP: 68% M: 72% F: 63%	7% (48g/d)
UK; *National Diet and Nutrition Survey 2000-01 (Thane et al., 2007)*	19 - 64 years (TP:1692, M:758, F:934)	TP: 23 (28)	TP: 14 (0 – 98)	TP: 29% M: 31% F: 27%	16% (48g/d)
USA; *National Health and Nutrition Examination Survey 2011-12 (Albertson et al., 2016)*	19+ years (TP:4878)	TP: 0.97 (0.05) oz eq/d‡	-	TP: 46%	8% (3 oz eq/d‡)
Singapore; *National Nutrition Survey 2010 (Health Promotion Board Singapore, 2010)*	18 - 69 years (TP:739, M:377, F:368)	TP: 26 (-) M: 22 (-) F: 31 (-)	-	-	27% (1 serve)
Australia; *Australian Grain and Legumes Consumption and Attitudinal Study 2014 (Grain & Legumes Nutrition Council (GLNC), 2014a)*	2 - 70 years (TP:3031, M:1194, F:1837)	TP: 28 (-)	-	TP: 25%	Adults only: 30% (3 serves/d ~48g/d)
Ireland; *National Adult Nutrition Survey 2008-10 (Burns et al., 2013)*	18 - 90 years (TP:1051, M:523, F:528)	TP: 29 (37) M: 33 (45) F: 26 (27)	-	TP: 20% M: 21% F: 19%	21% (48g/d)
Norway; *Norwegian Women and Cancer Cohort 1992-98 (Kyrø et al., 2012)*	30 - 60 years (F:1797)	F: 51 (36)	F: 44 (0 – 120)	F: ~5%	F: 35% (75g/d/10MJ)
Sweden; *Northern Sweden Health and Disease Study Cohort 1992-98 (Kyrø et al., 2012)*	30 - 60 years (TP:2989, M:1372, F:1617)	M: 58 (50) F: 41 (32)	M: 49 (0 – 149) F: 35 (0 – 102)	TP: ~5%	M: 29%, F: 27% (75g/d/10MJ)
Denmark; *Danish National Survey of Diet and Physical Activity 2011-13 (Mejborn et al., 2014)*	15 - 75 years (TP:3189, M:1546, F:1643)	TP: 58 (-) M: 65 (-) F: 51 (-)	-	TP: 0%	30% (75g/d/10MJ)

SE: Standard Error; SD: Standard Deviation; TP: Total population; M: Male; F: Female; *Median and 97.5th percentile; †Median and 95th percentile; ‡ ounce-equivalents (one ounce-equivalent can be either 16g or 28.35g depending on the food source hence is not converted in grams (Albertson *et al.*, 2016)).

1.4 The aim of this thesis

Whole grain intake in the UK population was last assessed in 1986/7 and 2000/01, where it was shown to be low and declining (Thane *et al.*, 2005; Thane *et al.*, 2007). Since then there remains no UK quantity-specific whole grain recommendations. There has also been an increase in whole-grain foods on the UK market perhaps due to influences on manufacturing companies that sell products in the US and around the world. Observationally, whole grain intake in the UK has not been investigated to assess if intakes are associated with markers of cardio-metabolic health. Since whole grain intakes have been previously reported to be low in the UK, it is important to understand if, even at such low levels, the potential beneficial effects of whole grain consumption are seen in cardio-metabolic markers. It is also important to examine nutrient and other food intakes across differing whole grain consumption levels, since these may help to explain significant associations with cardio-metabolic health markers. Recent data from the UK NDNS rolling programme are available and allow for the estimation of more recent levels of whole grain intake. Additionally, this cross-sectional survey collected data on some markers of cardio-metabolic health. Thus, the survey gives the opportunity to assess if differing whole grain intake levels are associated with such markers. Whole grain intake increases with age and since whole grain intakes in the UK have been shown to be previously low, an older population has been studied. Further exploration of whole grain intake and the association with cardio-metabolic health markers is also possible in a longitudinal cohort from Northern England, the 1947 Newcastle Thousand Families Study (NTFS), a birth cohort that was retraced and followed up when the study members were aged 49-51 years, 62-63 years and more recently when they were aged 67 years (Pearce *et al.*, 2009b).

The aim of this thesis was to investigate the level of whole grain consumption and whether whole grain intake was related to markers of cardio-metabolic risk in the UK population and a cohort of older people based in Newcastle upon Tyne.

The objectives of this aim were:

1. To update a database of whole grain content of foods consumed in the UK.
2. To calculate whole grain intake in a nationally-representative sample of adults and children using data from the first three years of the NDNS rolling programme 2008-2011.
3. To investigate the relationship between whole grain intake and diet composition and markers of cardio-metabolic risk in participants from the NDNS rolling programme 2008-2011.
4. To develop a cereal food consumption questionnaire to implement in the NTFS to accurately estimate whole grain intake at age 67 years.
5. To quantify whole grain intake in follow-up studies of the NTFS at ages 50 and 60 years.
6. To investigate associations between whole grain intake and dietary intake and health markers in participants in the NTFS at age 50 and 60 years.

The following chapter in this thesis, presents a review of the available literature on the associated health benefits of increased whole grain intake. The third Chapter, addresses objectives one, two and three, and presents the investigation of whole grain intake in the UK population, the association of whole grain intake with diet composition and if increasing levels of intake are associated with markers of cardio-metabolic health. Chapter four, addresses objectives four, five and six, and presents the assessment of whole grain intake in the NTFS. In order for a detailed estimate of whole grain intake to be made in this population, Chapter four begins with details of the development of a new cereal food questionnaire (objective four), before whole grain intake is estimated and associated with dietary intake and cardio-metabolic health markers. The final Chapter of this thesis discusses the results of whole grain intake in both UK populations, the differences in intakes of nutrient and other foods across whole grain consumption and the potential association with cardio-metabolic markers.

Chapter 2 Literature Review

Intake of whole grains and whole-grain foods is advised as part of a healthy diet. Whole grains have been and continue to be a staple part of the human diet providing complex carbohydrates, proteins, vitamins and minerals. They are included in dietary patterns, such as the Mediterranean diet, which are suggested to be cardio-protective and aid the prevention of diabetes (Koloverou *et al.*, 2016). There are many prospective cohort, cross-sectional and intervention studies that have investigated the potential association between whole grain consumption and non-communicable disease risk. These studies have been reviewed with several meta-analyses conducted to summarise the potential effects of increased whole grain consumption on disease risks such as CVD, T2D, obesity and some types of cancer (Aune *et al.*, 2011; Ye *et al.*, 2012; Aune *et al.*, 2013; Thielecke and Jonnalagadda, 2014; Scientific Advisory Committee on Nutrition, 2015; Aune *et al.*, 2016; Zong *et al.*, 2016). To further detail the potential health benefits of whole grain consumption on non-communicable disease, this literature review summarises the available review and meta-analysis publications focusing on CVD, T2D and obesity outcomes. More recent whole grain studies, not included in the review publications, are also detailed. This review is not a systematic review however, the literature was initially searched systematically with newer articles, of relevance, added once published.

2.1 Health benefits of whole grain consumption - Observational evidence

2.1.1 Cardio-vascular disease

CVD is the number one cause of death globally, which equated to 31% of all global deaths in 2012 (World Health Organization, 2014). It accounts for 27% of all deaths in the UK and is currently the 2nd biggest killer in the UK, after cancer (Townsend *et al.*, 2015). It is estimated that there are 7 million people living with CVD in the UK (British Heart Foundation, 2016). CVD is a general term used to describe a disease of the heart or blood vessels which include coronary heart disease (CHD), cerebrovascular disease, peripheral arterial (or vascular) disease and aortic disease. Cardiovascular events such as strokes and heart attacks are usually acute episodes where the flow of blood is blocked to the brain and heart, respectively. Risk factors of CVD are indicated in the body as high blood pressure (hypertension), raised blood glucose, hyperlipidaemia (high levels of blood lipids) and measures of obesity such as high body mass index (BMI), adiposity and fat mass. Prevention or reduction of such risk factors will aid to lower the prevalence of CVD globally, of which whole grains as part of a healthy diet may have a role to play.

There are many epidemiological studies that have observationally investigated the association between whole grain intake and CVDs, including CHD, coronary artery disease and ischemic heart disease as well as cardiovascular events such a strokes, myocardial infarction and heart failure. The majority of prospective cohort studies observe an inverse association between whole grain consumption and CVD with higher intakes reducing the estimated risks of disease occurrence (Table 2.1). One of the first reviews and meta-analyses of these studies focused on the link between fibre consumption, including cereal fibre and whole grains, and heart disease risk from publications over a 20 year period (Anderson *et al.*, 2000). This was later updated with a focus on whole grain vs refined grain intakes and atherosclerotic CVD risk (Anderson, 2003). These reviews indicated that fibre and whole grain consumption was consistently linked with protection from CHD and atherosclerotic CVD, and that whole grains had a stronger protection from CHD events than intakes of cereal fibre, vegetables or fruits alone. It was suggested that regular intake of whole grain was associated with a 26% CHD adjusted risk reduction when comparing the lowest with the highest quintiles of whole grain consumers. In the updated review, which included one additional study compared with the first review, the adjusted risk reduction was increased to 29% comparing the lowest to the highest quintile of whole grain consumption (Anderson, 2003). Other reviews have shown similar associations, with many of the prospective cohort and case-control studies indicating that the highest whole grain or whole-grain food consumers had reduced risk estimates for CVD occurrence, outcome and mortality, in comparison to never, rare or low habitual whole grain consumers (Table 2.1). It has been suggested that even small whole grain intakes may be important as pointed out by Richardson (2000), that across over 9-years of follow-up in the Iowa women's health study, women who reported consuming at least one whole-grain food serving per day had a substantially lower risk of mortality from CVD compared to women consuming almost no whole-grain foods at all (Jacobs *et al.*, 1999). Slightly higher intakes of 2.5 whole grain servings per day were suggested to be associated with a 21% lower risk of CVD events in comparison to 0.2 servings per day in a meta-analysis by Mellen *et al.* (2008). This led to one of the more definitive meta-analysis conclusions of a consistent, inverse association between whole grains and incident CVD and the suggestion that policy-makers, scientist and clinicians should enhance efforts to promote the beneficial effects of whole grain consumption to the public. Similar conclusions have been made in review studies advising that health claims or supportive statements may be valid for plant-based diets including whole grains as the main source of carbohydrates or whole grain foods and oatmeal (or bran) as protective of CVD, CHD or stroke, although the evidence for stroke alone is not particularly consistent (Truswell, 2002; Hu, 2003; Flight and Clifton, 2006). A more recent meta-analysis on stroke risk, including the cohorts reviewed by Flight and Clifton (2006), a stricter classification of whole grain intake and three additional studies, reported a 14% reduction in stroke risk for the highest whole grain consumers compared with the lowest (Fang *et al.*, 2015). Similar to the review by Mellen *et al.* (2008), comparisons between low or rare whole grain consumers to whole grain intakes of 3-5 servings per day were associated with ~21% lower risk of CVD (Ye *et al.*, 2012) in cohort studies. Another more recent study has also reported a 22% risk reduction of CHD comparing the lowest to highest whole grain intakes in cohort studies, however this was not significant for the three case-control studies alone (Tang *et al.*, 2015). This result may be due to the low number of case-control studies meeting the review criteria.

Table 2.1 Summary of the review studies and meta-analyses on the observational evidence of whole grain intake and cardiovascular disease

Publication	Type of study	Exposure of interest	Outcome	Number of studies reviewed [region]	Studies published	Summary of the review
Anderson *et al.* (2000)	Meta-analysis	WG, cereal fibre or WGF intake	CHD events or mortality	29 in the review (7 WG), 12 in meta-analysis (4 WG) [IT 1, US 6]	1966-1999	5 out of 7 studies reported significant negative effects of WG intake on CHD. Strongest inverse association was between WG intake and CHD risk reduction. H vs L WG consumers had a 26% adjusted risk reduction for CHD (RR 0.74 95%CI 0.64, 0.84).
Anderson (2003)	Meta-analysis		Atherosclerotic CVD	Update to the 29 above including 1 more USA study	1966-2000	6 out of 8 studies reported significant negative effects of WG intake on CHD. H vs L WG consumers had an adjusted risk reduction of 29% for CHD (RR 0.71 95%CI 0.48, 0.94). Cereal fibre alone was not associated with CHD events.
Richardson (2000)	Review	WGF or total fibre intake	CHD	5 cohort studies [All US]	1996-1999	Indicates that at least 1 serving of WGF per day is associated with a reduced risk of CHD.
Truswell (2002)	Review	Cereal-fibre including WG	CHD events	7 cohort studies [FI 1, NO 1, US 6]	1996-1999	It appears valid to make a health claim that WG cereal foods and oat meal or bran may reduce the risk of CHD.
Hu (2003)	Review	WG intake	CVD	4 cohort studies [All US]	1992-2000	Substantial evidence indicates that plant-based diets including WGs as the main form of carbohydrate have an important role in the prevention of CVD.
Jacobs and Gallaher (2004)	Review	WGF intake	CVD risk & mortality	13 cohort studies [FI 1, GB 1, NO 1, US 10]	1992-2003	Studies uniformly showed an inverse association of WG on CHD, stroke, or CVD incidence or mortality. Risk reductions were 20 – 40% for habitual vs rare WG consumers.
Flight and Clifton (2006)	Review	WG intake	CHD & stroke	10 cohort studies (CVD) [NO 1, US 9] 4 cohort studies (stroke) [All US]	1992-2004	WGF intake clearly protects against heart disease and stroke but the exact mechanism is not clear. Mixed results are seen for the studies on stroke included but trends were strongly suggestive of a protective effect of WGs on stroke risk.
Seal (2006)	Review	WG intake	CVD	7 cohort studies [NO 1, US 6]	1999-2004	All studies showed CVD risk reductions, not all significant, but after adjustment factors were accounted for they are supportive of CVD risk reductions for increased WG intake.
Mellen *et al.* (2008)	Meta-analysis	WG intake	Clinical CVD events	8 cohort studies [All US]	1966-2006	2.5 WG servings vs 0.2 WG servings per day were associated with 21% lower risk of CVD events (RR 0.79 95%CI 0.73, 0.85)
Seal and Brownlee (2010)	Review	WG intake	CVD	6 cohort studies [All US]	1998-2006	Repeated meta-analyses showed CVD risk is reduced by ~30% comparing H vs L WG consumers but these studies do not demonstrate causality.
Ye *et al.* (2012)	Meta-analysis	WG & fibre intake	CVD risk & mortality	45 cohort studies (10 WG) [All US]	1966-2012	Compared to never/rare consumers, WG intakes of 48-80g/d (3-5 servings) had ~21% reduction in CVD risk (RR 0.79 95%CI 0.74, 0.85). Findings provide evidence to support beneficial effects of WG intake on CVD prevention.
Cho *et al.* (2013)	Systematic review	Mix of WG & bran intake, WG intake	CVD & hypertension	22 cohort, 12 cross-sectional studies [All US]	1965-2010	A risk reduction of 7-52% of CVD for studies on mixtures of WG and bran. The association for WG on CVD risk was non-significant after adjustment for dietary factors, evidence is 'limited'
Lillioja *et al.* (2013)	Review	WG intake	CHD & hypertension	4 cohort studies (CVD), 2 cohort studies (hypertension) [All US]	1999-2007	The collective regression slope from ANCOVA resulted in a 25% reduction (95%CI 19-33%) in CHD incidence for a 20g/d increase in WG intake and a 36% reduction (95%CI 27-45%) in CHD incidence for a 30g/d increase in WG intake. In men an increase of 30g/d WG intake reduced hypertension incidence by 4 cases per 1000 person years (95%CI 2.9-5.2) and an increase of 40g/d WG intake reduced hypertension incidence by 5.4 cases per 1000 person years (95%CI 3.8, 6.9)
Fang *et al.* (2015)	Meta-analysis	WG intake	Stroke	6 cohort studies [FI 1, US 5]	1999-2009	One study out of 6 reported an inverse association between WG intake and risk of stroke. Pooled results suggested H vs L WG intake was significantly associated with a 14% stroke risk reduction (RR 0.86 95%CI 0.73-0.99).

Tang *et al.* (2015)	Meta-analysis	WG intake	CHD	15 cohort, 3 case-control studies [IT 1, NO 3, PT 1, SE 1, US 12]	1998-2012	Pooled results showed a significant risk reduction comparing H vs L WG consumers of 22% for CHD (RR 0.787 95%CI 0.734, 0.833). This association was significant for cohort studies but not for case-control studies.
Scientific Advisory Committee on Nutrition (2015)	Meta-analysis	WG Intake	CVD & stroke	5 cohort studies(CVD) [All US] 3 cohort studies(stroke)[All US]	2000-2007	Higher WG consumption associated with a 5% reduced incidence of CVD (RR 0.95 95%CI 0.92, 0.97) for each 0.5 serving/day. Higher WG consumption associated with a 4% reduced incidence of stroke (RR 0.96 95%CI 0.93, 0.99) for each 0.5 serving/day.
Aune *et al.* (2016)	Meta-analysis	WG intake	CVD, CHD & Stroke	10 cohort studies (CVD) [CN 1, ES 1, SCAN 1, SE 1, US 6] 7 cohort studies (CHD) [CN 1, SCAN 1, SE 1, US 4] 6 cohort studies (stroke) [CN 1, FI 1, SCAN 1, US 3]	1999-2016	H vs L WG intakes associated with 16% CVD risk reduction (RR 0.84 95%CI 0.8, 0.87), 21% CHD risk reduction (RR 0.79 95%CI 0.73, 0.86) and 13% stroke risk reduction (RR 0.87 95%CI 0.72, 1.05), and per 90g/d increase in WGF intake risk were reduced by 22% for CVD (RR 0.78 95%CI 0.73, 0.85), 19% for CHD (RR 0.81 95%CI 0.75, 0.87) and 12% for stroke (RR 0.88 95%CI 0.75, 1.03).
Chen *et al.* (2016a)	Meta-analysis	WG & WGF intake	CVD mortality	11 cohort, 1 case-control studies [ES 1, FI 1, NL 1, NO 1, SCAN 1, SG 1, UK 1, US 5]	1996-2015	H vs L WGF intake associated with 18% CVD mortality risk reduction (RR 0.82 95%CI 0.78, 0.85) and for each 50g/d or WG CVD mortality risk was 30% lower (RR 0.70 95%CI 0.61, 0.79). Evidence for a nonlinear association seen, steeper curves for WG intakes of <35g/d
Chen *et al.* (2016b)	Meta-analysis	WG intake	Stroke	5 cohort studies [FI 2, US 3]	2000-2013	Stroke risk was 8% lower (RR 0.92 95%CI 0.72, 1.17) and Ischemic stroke risk was 25% lower (RR 0.75 95%CI 0.6, 0.95) comparing H vs L WG intake.
Li *et al.* (2016a)	Meta-analysis	WG intake	CVD, CHD & stroke mortality	9 cohort studies (CVD) [ES 1, SCAN 2, US 5] 3 cohort studies (CHD & stroke) [SCAN 1, US 2]	2003-2015	Pooled results showed for an increment of WG serving (30g/d) risk reductions of 5% for CVD mortality (RR 0.95 95%CI 0.92, 0.98), 8% for CHD mortality (RR 0.92 95%CI 0.88, 0.97) and 4% for stroke mortality RR (0.96 95%CI 0.91, 1.01).
Wei *et al.* (2016)	Meta-analysis	WG intake	CVD mortality	9 cohort studies [ES 1, SCAN 1, US 7]	2001-2015	H vs L WG intakes associated with 19% reduction in CVD mortality (RR 0.81 95%CI 0.75-0.89) and 26% reduction in CVD mortality per 90g/d increase in WG (RR 0.74 95%CI 0.66, 0.83).
Zong *et al.* (2016)	Meta-analysis	WG & WGF intake	CVD mortality	11 cohort studies [SCAN 3, UK 1, US 7]	1992-2015	Pooled results showed a reduction of 18% for CVD mortality (RR 0.82 95%CI 0.79, 0.85) comparing H vs L WG intake and a reduction in CVD mortality of 8% per 10g/d WG (RR 0.92 95%CI 0.88, 0.96), 19% per 30g/d WG (RR 0.81 95%CI 0.75, 0.89), 22% per 50g/d WG (RR 0.78 95%CI 0.72, 0.84) & 23% per 70g/d WG (RR 95%CI 0.68, 0.87).

WG: Whole grain; WGF: Whole-grain food; CHD: Coronary heart disease; CVD: Cardiovascular disease; CN: China; ES: Spain; FI: Finland; GB: Great Britain; IT: Italy; NL: The Netherlands; NO: Norway; PT: Portugal; SCAN: Scandinavia; SE: Sweden; SG: Singapore; UK: United Kingdom; US: United States of America; RR: Relative risk; 95%CI: 95% Confidence interval; H: High; L: Low;

More recent cohort studies that have not yet been included in a review or meta-analysis include an examination of the PREvención con Dieta MEDiterránea (PREDIMED) trial. The PREDIMED study was a large, parallel-group, multi-centre, randomised, controlled field clinical trial conducted in Spain on adults (55-80 years) to assess the effects of the Mediterranean diet on the prevention of CVD. Participants, who had either T2D or at least three CHD risk factors but free of CVD, were given advice to follow either one of two interventions (Mediterranean diet enriched with olive oil or mixed nuts) or a control low-fat diet (Martínez-González *et al.*, 2012). In participants, followed up two years and six months post intervention for CVD death, myocardial infarction and stroke events, no association was seen between whole-grain product intake at baseline as well as a cumulative measure of whole-grain food intake and combined CVD outcomes (Buil-Cosiales *et al.*, 2016). It is noted in this study that whole-grain food intakes were low at median of 5g/d which may be one reason for the lack of significant association. Similarly in a Chinese intervention trial of vitamin or mineral supplements or placebo, with subsequent six year follow-up, no significant association was seen with increasing whole-grain food consumption by once a day and heart disease or stroke risk (Wang *et al.*, 2016). Again, this may be due to the low average whole-grain food intake in this population and the low variation in foods included in their whole-grain classification (cornmeal porridge, bread, cakes, dumplings and sorghum). In contrast, beneficial effects of whole grain consumption has been seen in a population with higher average whole grain intakes from a greater variety of foods. A study of the Danish Diet, Cancer and Health cohort recently reported after 13.6 years follow-up of 54,871 men and women, that higher whole grain and whole-grain food intakes were associated with lower risk of myocardial infarction (Helnæs *et al.*, 2016). They assessed both dietary whole-grain food (product) and absolute whole grain intakes adhering to the AACC International definition of whole grains and no limit on the amount of whole grain content in foods. Using these classifications, they showed, after adjustment for confounding factors, those in the highest quartile of whole-grain food intake per day had a 23% and 29% significant lower risk of myocardial infarction for men and women, respectively. Similarly, men and women in the highest quartile of whole grain intake per day had a 25% and 27% significant lower risk of myocardial infarction, respectively. It was also reported, through linear analysis, that per 50g increase in whole-grain food intake a significant 6% and 10% lower risk of myocardial infarction was seen in men and women, respectively, and per 25g increase in whole grain intake a significant 12% and 13% lower myocardial infarction risk was seen in men and women, respectively. Further investigation into specific whole grain and whole-grain product types indicated that rye and oat cereals may especially hold a beneficial effect.

2.1.2 Type 2 diabetes and obesity

One of the risk factors for CVD or a CVD event is T2D which may be on the causal pathway to CVD occurrence. Diabetes, indicated by high circulating concentrations of glucose in the blood, is a disease caused by low levels of insulin which regulate blood glucose. Untreated high blood glucose, hyperglycaemia, is associated with long term complications such as heart disease among others and is therefore a considered a risk factor for CVD. Similarly, metabolic syndrome a combination of insulin resistance or glucose intolerance, high blood pressure and obesity is also major risk factor for CVD.

There are many reviews of the observational evidence for a protective effect of whole grains on T2D incidence and metabolic syndrome occurrence (Table 2.2). Murtaugh *et al.* (2003) reviewed 3 US cohort studies, the Iowa women's study (Meyer *et al.*, 2000), the Nurses' Health Study (Salmerón *et al.*, 1997b; Liu *et al.*, 2000b) and the Health Professionals Study (Salmerón *et al.*, 1997a) for whole grain or cereal fibre intakes and the risk of T2D. Overall risk for incident T2D was 21-27% lower for those in the highest quintile of whole grain intake and 30-36% lower in the highest quintile of cereal fibre intake both of which persisted after adjustment for healthier lifestyle factors among habitual whole grain consumers. This review highlighted the differences in whole grain intake assessment and lack of whole grain definition but since the amount of cereal fibre in whole grain and bran enriched products is higher than in refined grain products they suggest that cereal fibre is closely reflective of whole grain intake and they are both measuring the same entity. They also highlighted that cereal fibre and magnesium may be the operable components of whole grain responsible for the association with T2D since when cereal fibre and magnesium were adjusted for in the Iowa women's health study the association with whole grain was attenuated and non-significant. However, fibre is high in the bran faction of whole grains and highly correlated as well as the nutrient correlations so it hard to tell whether it is the fibre and magnesium per se or whether they are both simply markers of the phytochemicals found in whole grains. These three US cohort studies were also included in a Cochrane review of 11 cohort studies which found consistent associations between high intakes of whole-grain foods with between 28-37% reduced risk of T2D (Priebe *et al.*, 2008). Despite this large apparent reduction in risk the authors suggested that the evidence for a protective effect coming from prospective cohort studies should be considered as weak, since no cause and effect relationship can be established from such studies. Other review studies have also suggested that there is moderate or limited evidence for the inverse association between whole grain intake and T2D risk (Cho *et al.*, 2013; Scientific Advisory Committee on Nutrition, 2015; Yamini and Trumbo, 2016). Two earlier meta-analyses have both reported pooled T2D risk reductions of 26% with seven out of a total nine of the cohort studies reporting significant risk reductions, comparing the highest with lowest whole grain consumers (Ye *et al.*, 2012; Aune *et al.*, 2013). The moderate or limited evidence conclusions of the more recent reviews are formed on the basis that no consistent definition of whole grain or whole-grain food intake is used in the meta-analyses and across the cohort studies.

One of the major risk factors for CVD and T2D is obesity, which has become a global health concern as the rate has more than doubled since the 1980s (World Health Organization, 2016). In the health survey for England 41% of men and 31% of women were overweight and around a quarter of adults were obese (Craig *et al.*, 2015). Intake of whole grains may have a beneficial role in weight management or maintenance (Thielecke and Jonnalagadda, 2014). A meta-analysis of three prospective cohort studies with a total of 119,054 participants, concluded that 3-5 daily servings of whole grains was associated with consistently less weight gained during 8-13 years of follow-up, compared with never/rare consumers (Ye *et al.*, 2012). These three cohort studies were conducted in US populations and the data are supported by a recent examination of trends in national data over 12 years which confirmed that whole-grain foods may contribute to weight management (Albertson *et al.*, 2016). A previous meta-analysis has also shown reductions in body weight measures with weighted mean differences of 0.63kg/m^2 lower BMI, 2.7cm lower waist circumferences and 0.023 lower waist to hip ratio measures comparing the lowest with the highest whole grain consumers from across 15 cohort studies (Harland and Garton, 2008). It is however, difficult to disentangle the potential confounding effect of body weight in such studies since higher whole grain consumers tend to have lower body weight measures and thus are less likely to be obese. In the case of the association of weight management or less weight gain with higher whole grain intake, intervention studies may provide more conclusive results.

Table 2.2 Summary of the review studies and meta-analyses on the observational evidence of whole grain intake and type 2 diabetes or obesity

Publication	**Type of study**	**Exposure of interest**	**Outcome**	**Number of studies reviewed [region]**	**Year studies published**	**Summary of the review**
Murtaugh *et al.* (2003)	Review	Total grain, WG & cereal fibre intake	T2D	4 cohort studies [All US]	1997-2000	The risk for incident T2D was 21-27% comparing H vs L WG intake and was 30-36% lower comparing H v L cereal-fibre intake.
Liu (2003)	Meta-analysis	High fibre & WGF intake	T2D	7 cohort studies [FI 1, US 6]	1996-2002	Pooled results showed a 30% reduction in T2D occurrence comparing H vs L intakes of high fibre and WGFs
de Munter *et al.* (2007)	Meta-analysis	WG or WGF intake	T2D	6 cohort studies [FI 1, US 5]	2000-2007	A 2 serving increment per day of WG was associated with 21% decreased risk of T2D (RR 0.79 95%CI 0.72, 0.87), after adjustment for confounders and BMI. The association was stronger for bran than for germ.
Gaesser (2007)	Review	Carbohydrate intake (including WG)	BMI	9 cohort studies [FI1, IR 1, US 7]	1998-2006	WG, but not refined grain, intake is consistently associated with lower BMI. Public health recommendations to increase consumption of whole-grain, fibre-rich foods should have multiple positive health benefits, facilitate weight control efforts and possibly reduce prevalence of overweight and obesity.
Harland and Garton (2008)	Meta-analysis	WG intake	BMI, WC & WHR	15 cohort studies [FI 1, IR 1, NO 1, SE 1, UK 1, US 10]	1998-2007	The combined weighted mean difference, in BMI was 0.63kg/m^2 lower (95% CI 0.46, 0.80kg/m^2), in WC was 2.7cm lower (95%CI 0.2, 5,2cm) and in WHR was 0.023 lower (95%CI 0.02, 0.03) comparing H vs L WG intake.
Priebe *et al.* (2008)	Systematic review	WG & cereal fibre intake	T2D, weight gain & obesity	11 cohort studies [FI 1, US 11]	1997-2006	H vs L WG intake was associated with 21-30% T2D risk reduction in 4 studies and H vs L cereal fibre intake was associated with 21-63% T2D risk reduction in 6 studies. Increased WG intake was associated with small reductions in weight gain (0.3-0.5kg) and reduced risk of becoming obese.
Williams *et al.* (2008)	Review	Diet pattern 'prudent' high in WG & legumes Grain food intake Cereal & legume intake	Overweight & Obesity BMI, WC & weight status Weight gain	11 cohort studies (diet pattern) [AU 1, BR 1, DK 1, SE 1, UK 2, US 5] 16 cross-sectional studies (grain foods) [ES 1, GR 1, IR 3, PT 1, US 10] 8 cohort studies (cereals & legumes) [DE 1, DK 1, US 6]	1997-2005	Most studies found an association between a prudent dietary pattern (including higher levels of WG cereals) and lower obesity. Cross-sectional and longitudinal studies were quite consistent reporting higher intakes of WG cereals and legumes associated with lower BMI, WC, risk of overweight and weight gain.
Giacco *et al.* (2011)	Review	WG intake	BMI & WC	3 cohort studies [All US] 12 cross-sectional studies [SE 1, US 11]	2002-2009	Higher WG intake was associated with lower BMI and WC. In all cross-sectional studies BMI was 1-2.5kg/m^2 lower comparing H vs L WG intake, in cohort studies 0.39kg less weight was gained over 12 years of follow-up.
Ye *et al.* (2012)	Meta-analysis	WG intake	T2D & weight gain	6 cohort studies (T2D) [FI 1, US 5] 3 cohort studies (weight gain) [All US]	2000-2007	There was an overall multi-variable adjusted 26% reduction in T2D risk (RR 0.74 95%CI 0.69, 0.80) and consistently less weight gained (1.27 vs 1.64kg) over 8-13 years of follow-up comparing never/rare to highest WG consumers (48-80g/d)
Lillioja *et al.* (2013)	Review	WG intake	T2D	5 cohort studies [All US]	2000-2010	The studies that showed a WG effect on T2D became stronger in subsequent years. The common ANCOVA slope was -0.039 (+-0.005) cases per 1000 person years per 1g increase in WG intake. For a T2D incidence of 3.87, this equates to a 30% reduction (95%CI 22, 39) in T2D incidence for a 30g/d increase in WG intake and a 40% reduction (95%CI 29, 52) for a 40g/d increase in WG intake.

Aune *et al.* (2013)	Meta-analysis	WG & WGF intake	T2D	10 cohort studies [DE 1, FI 1, SE 2, US 6]	2000-2013	Pooled results showed a 26% reduction in T2D risk (RR 0.74 95%CI 0.71, 0.78) comparing H vs L WG intake and a 32% reduction in T2D risk (RR 0.68 95%CI 0.58, 0.81) per 3 WG servings per day. Evidence of a nonlinear association was seen with a steeper reduction in T2D risk when increasing WG intake from low levels up to 2 servings per day.
Cho *et al.* (2013)	Systematic review	Mix of WG & bran intake, WG intake	T2D & obesity	8 cohort studies (T2D) [FI 1, US 7] 5 cohort studies (weight status) [All US]	1997-2010	There is moderate evidence for reduced T2D risk with high intakes from mixtures of WG and bran (21-40%) and the evidence for WG alone is limited. There is moderate to limited evidence for an inverse association between high intakes from mixtures of WG and bran or WG alone on body weight measures.
Thielecke and Jonnalagadda (2014)	Systematic review	WG intake	Obesity	10 cohort & 21 cross-sectional studies [No detail given]	1989-2011	There is a moderate body of evidence from epidemiological studies clearly demonstrating that increased WG intake is associated with lower BMI, WC, abdominal adiposity and weight gain. Generally, a ~1 unit difference in BMI was observed between H vs L WG intake.
Chanson-Rolle *et al.* (2015)	Meta-analysis	WG & WGF intake	T2D	7 cohort studies [FI 1, SE 1, US 5] 1 cross-sectional study [Iran 1]	2000-2013	Quantitative meta-regression showed an inverse linear association between WG intake and T2D with an absolute reduction of 0.3% (95%CI 0.0.2, 0.4%) in T2D rate for each 10g/d WG.
Scientific Advisory Committee on Nutrition (2015)	Meta-analysis	WG and whole-grain bread intake	T2D	11 cohort studies (WG intake) [DE 1, FI 1, SE 2, US 7] 4 cohort studies (whole-grain bread) [AU 1, DE 1, UK 1, US 1]	2000-2013	There was moderate evidence for an association between higher WG intake and reduced T2D risk but due to difference in WG definitions and serving sizes no risk reduction was estimated. An association was indicated between higher whole-grain bread intake and reduced T2D incidence with a 7% T2D risk reduction for each 0.5 serving per day (RR 0.93 95%CI 0.90, 0.96).
Yamini and Trumbo (2016)	Review	WG and brown rice intake	T2D	3 cohort studies [All US] 6 intervention studies [DK 1, IT 1, SE 1, UK 2, US 1]	2001-2010	The results of 6 analyses of 3 cohort studies from which scientific conclusions could be drawn were mixed. There is limited evidence to support a health claim relationship between intake of WG and reduced risk of T2D.

WG: Whole grain; WGF: Whole-grain food; T2D; Type 2 diabetes; BMI: Body mass index; WC: Waist circumference; WHR: Waist to hip ratio; AU: Australia; BR: Brazil; DK: Denmark; DE: Germany; FI: Finland; GR: Greece; IR: Iran; NO: Norway; PT: Portugal; SCAN: Scandinavia; SE: Sweden; UK: United Kingdom; US: United States of America; RR: Relative risk; 95%CI: 95% Confidence interval; H: High; L: Low;

2.1.3 How much whole grain?

Much of the observational studies and meta-analyses have concluded that increased whole grain intakes are associated with CVD and T2D risk reduction (Table 2.1 and Table 2.2). Often these studies have compared low whole grain consumers with the highest whole grain consumers which often equate to 3-5 servings of whole grain per day (Ye *et al.*, 2012). A series of recent meta-analyses, detailed in Table 2.1 and Table 2.2, have set out to investigate if there is a specific amount of whole grain which would provide a disease risk reduction and if the associations seen are linear or indeed reach a plateau (Aune *et al.*, 2011; Aune *et al.*, 2013; Chanson-Rolle *et al.*, 2015; Aune *et al.*, 2016; Chen *et al.*, 2016a; Li *et al.*, 2016a; Wei *et al.*, 2016; Zong *et al.*, 2016). The most recent dose-response meta-analyses, including 45 cohort studies from 64 publications, found relative risk reductions of 19%, 22%, 15% and 17% per 3 servings of whole-grain foods a day (90g/d) for CHD, CVD, total cancer and all-cause mortality, respectively (Aune *et al.*, 2016). Although there was some evidence for non-linear associations between whole grain intakes and these disease outcomes, most of the analyses showed clear dose-response relationships with additional reductions up to 7-7.5 whole grain servings per day (210-255g/d). This study, and a second on T2D risk, also reported in non-linear dose-response analyses that whole grain intakes of one or two servings per day reduced risk for these disease outcomes (Aune *et al.*, 2013). A quantitative meta-regression analysis has also shown a 0.3% risk reduction in T2D risk per 10g/d whole grain intake (Chanson-Rolle *et al.*, 2015). These results are promising since it has been shown that only a small proportion of populations consume 3 servings of whole grain per day (Kyrø and Tjønneland, 2016) and thus even moderate increases in whole grain intakes may reduce the risk of disease or mortality.

2.2 Appraisal of the observational evidence

2.2.1 Confounding factors

Confounding is a limitation of all the observational evidence suggesting disease risk reductions with higher whole grain intake. In many of the population studies those that consume the highest amount of whole grains are also those that are older, less likely to smoke and drink alcohol, more likely to be physically active, consume higher amounts of fruit and vegetables and, in general, have healthier lifestyle habits. However, many studies and the reviews of these studies attempt to control for the measurable confounding factors. For example, in Anderson (2003) the authors attempted to control for potential confounding factors such as age, sex, smoking, BMI, hypertension or blood pressure, total energy intake, other dietary intakes, physical activity, history of heart disease and education level to name a few. Another review of the studies on whole grain intake and CVD that has considered adjustment for confounding factors indicated that the data do provide evidence to support an inverse association of whole grain intake on CVD risk, independent of known CVD risk factors such as history of hypertension, T2D and high cholesterol as well as lifestyle behaviours such as smoking, alcohol and physical activity. This comprehensive meta-analysis of the available US cohort studies concluded that, compared with those that rarely or never ate whole grains, consumption of 3-5 servings of whole grain per day (48-80g/d) resulted in a 21% risk reduction in CVD risk (Ye *et al.*, 2012).

Including adjustment in meta-analyses, to control for potential factors that may explain the inverse significant associations reported, is clearly important, but it should be noted that the detail of confounding information relies on the original studies included in the analyses and the consistency in the use of each confounding factor between studies. As detailed in Seal (2006), adjustments in full models for demographic, dietary and non-dietary factors reduce the significance of hazard ratios and relative risks for the associations between whole grain intake and CVD risk when compared with unadjusted data. However, the data from the six large-scale observational studies considered (Fraser, 1999; Jacobs *et al.*, 1999; Liu *et al.*, 2000a; Jacobs *et al.*, 2001; Steffen *et al.*, 2003; Jensen *et al.*, 2004) still support the overall risk reduction in CVD with higher whole grain intakes event after adjustment. A more recent meta-analysis on CVD mortality reported an age and sex adjusted hazard ratio of 0.61 (95%CI 0.59 – 0.62) which was attenuated to 0.77 (95%CI 0.75 – 0.79) after adjustment for smoking and further attenuated to 0.83 (95%CI 0.81 – 0.86) after additional adjustments for race/ethnicity, alcohol intake, education, marital status, health status, obesity, physical activity, red meat, fruit, vegetable and total energy intakes and hormone use (Huang *et al.*, 2015). These results again showing that there is evidence of confounding, but the reported significant 17% reduction in all-cause mortality hazard ratio, for the highest whole grain consumers compared with the lowest, appears be independent of the confounders tested.

2.2.2 Measurement of whole grain intake

In addition to confounding, another important consideration of meta-analyses and the observational studies included, is the dietary assessment method used to estimate whole grain intake and indeed the criteria used for identifying whole-grain foods. The majority of the observational studies estimated whole grain intake from a food frequency questionnaire (FFQ) in one form or another (e.g. semi-quantitative, 128 item) but other studies have used 24-hour dietary recalls, food diaries (weighed and estimated), interviewer-led questionnaires and dietary histories (Anderson *et al.*, 2000). Jacobs and Gallaher (2004) have suggested that imprecision in whole grain intake assessment could under estimate the inverse association between whole grain intake and CVD and imprecision in measurement of potential confounders, or failure to measure relevant confounders, could overstate the inverse association. In which case, Jacobs and Gallaher's 20% to 40% risk reduction summary of 13 prospective studies, assessing the impact of whole grain foods on CVD or diabetes, may be a reasonable working estimate. The differences in whole grain intake assessment have also been highlighted in the recent UK Scientific Advisory Committee on Nutrition's (SACN) report on carbohydrates and health (Scientific Advisory Committee on Nutrition, 2015). Despite this, their meta-analysis of the consumption of carbohydrates from whole grain sources in five studies of CVD and three studies of stroke risk showed a 5% risk reduction (95%CI 0.92 – 0.97) in CVD incidence and a 4% risk reduction (95%CI 0.93 – 0.99) in stroke incidence for each whole grain consumption event every two days.

2.2.3 Definitions of whole grain and whole-grain foods

One issue with the earlier reviews and meta-analyses, mentioned above, is that their study inclusion criteria did not restrict the classification of whole grain or whole-grain foods in the studies that they reviewed to a strict whole grain definition. Instead some of the studies, including three large US cohorts (Jacobs *et al.*, 1998; Jacobs *et al.*, 1999; Liu *et al.*, 1999), encompassed bran-enriched foods which do not meet the current definition of whole grains. In order to more clearly summarise the studies the American Society for Nutrition (ASN) conducted a systematic review separating studies that included cereal fibre alone, studies that included mixtures of whole grains and bran and studies that met the FDA's whole grain definition criteria (Cho *et al.*, 2013). This defined whole-grain foods as foods that contain at least 51% whole grain per RACC, in line with a US approved health claim. Following this, the ASN position on whole grains and CVD concluded that there was moderate evidence for an inverse association between consumption of foods rich in cereal fibre or mixtures of whole grains and bran and CVD risk, but the inverse association between consumption of whole grains alone and CVD risk was limited. It was concluded that since inverse associations of whole grain intake on CVD risks were attenuated or disappeared after adjustment from cereal fibre, magnesium, bran and other dietary components, that the associations seen may be due to the cereal fibre and bran in whole grains. One limitation of their review was that only three studies met the strict definition for whole-grain foods, each of which observed different disease outcomes (CHD, CVD mortality and hypertension) and in two differing populations (men from the Health Professionals Follow-up study (Jensen *et al.*, 2004; Flint *et al.*, 2009) and women in the Nurses' Health Study with T2D (He *et al.*, 2010)). Interestingly in these studies, average whole grain intakes ranged from 3.3 to 4.8g/d in the lowest consumers and from 32.6 to 46.0g/d in the highest consumers, all of which fell below the previously noted intakes (48-60g/d) associated with CVD risk reduction. It is possible that the intakes in these three studies are not high enough to be able to detect a significant CVD risk reduction when adjusted for potential confounding factors.

The inclusion of bran-enriched foods was borne from the notion that cereal-fibre may be responsible for the associated whole grain and disease risk reductions. However, Anderson *et al.* (2000) highlighted that the associated risk reductions for CHD were stronger for whole grain intake than for intakes from cereal fibre, vegetables or fruits alone. This was interesting since much of the beneficial effect of whole grain intake was thought to be due to the increased fibre content of whole grains, particularly in the bran fraction, in comparison with refined grains. This was also noted in the review by Jacobs and Gallaher (2004) which suggested that fibre is only one constituent of whole grains in addition to accompanying phytochemicals. High fibre cereal intake in most populations is most likely to be a marker of habitual whole grain intake. Therefore, separating the effects of fibre intake from other whole grain components may be difficult to study. This was highlighted in one of the studies included in Jacobs and Gallaher's review, the Iowa women's health study by Jacobs *et al.* (1998). This study of 34,492 postmenopausal women who were followed for 9 years for occurrences of ischaemic heart disease (IHD) death found a clear inverse associations between whole grain intake and risk of IHD death. They estimated that the risk of death from IHD was reduced by 30% comparing the highest quintile of whole grain consumption (18.5-84.5 whole-grain food servings per week) with the lowest (0-3.5 whole-grain food servings per week) which was adjusted for 19 potentially confounding variables. In a further model, dietary fibre intake was controlled for and the risk reduction for the highest quintile of whole grain intake compared with the lowest was attenuated to 23% which was not significant. It has been more recently stated that there was high correlation between whole grain and cereal-fibre (rho=0.7) in this cohort and this purely statistical adjustment does not encompass the biology of cereal fibre (Jacobs, 2015). It has, therefore, been argued that the associated risk reduction of whole grain intake may be due to more than just the fibre component in whole grains (Andersson *et al.*, 2014).

2.2.4 Location of studies

The majority of the cohort studies included in the review studies and meta-analyses come from US and Scandinavian populations with a small number of studies from European cohorts and a very few from middle or far-Eastern population. Therefore, the applicability of the findings to populations with differing dietary patterns and cultural habits should be further investigated. In the UK, there have been very few studies investigating the association between whole grains (exclusively) and CVD. One explanation for this is the lack of recognition and separation of whole-grain foods from refined grain foods in FFQ. Instead, studies on cereal-fibre intake, which may be a potential marker of whole grain intake, have shown beneficial effects on CVD risks. One early study on UK men reported fewer cases of CHD in those who consumed the highest cereal-fibre intakes compared with the lowest (Morris *et al.*, 1977). This was not the case for fibre intake from other sources (fruits or vegetables, pulses and nuts). In a UK study of dietary fibre intake and CVD mortality in women, cereal-fibre was suggested to lower the risk of stroke in women with higher BMI (Threapleton *et al.*, 2013; Threapleton *et al.*, 2015). However, the evidence suggested that total dietary fibre intake did not have any additional CVD benefit in already health-conscious women. In another early UK study, it was shown that mortality was reduced in male and female vegetarian and health conscious people who consumed wholemeal bread daily, but this was not significant after the adjustment for fruit intakes (Key *et al.*, 1996). These studies highlight that careful consideration must be made when reviewing the observational evidence since many of those that consume the highest amount of whole grain are those that are generally healthier. They tend to have overall better diets, consuming higher amounts of fruits and vegetables and lower amounts of meat, which have been shown to be associated with reduced disease risks. Whole grain consumers, as seen in UK populations, are less likely to smoke or excessively drink alcohol and are more physically active. In addition, whole grain consumers are generally well educated and come from more advantaged socio-economic backgrounds (Morris *et al.*, 1977; Key *et al.*, 1996; Lang and Jebb, 2003; Lang *et al.*, 2003; Thane *et al.*, 2007; Threapleton *et al.*, 2013). In a recently published British study, men with the highest scores on a dietary pattern characterised by high intakes of white bread, butter, lard, chips, sugar sweetened beverages and processed meat and lower intakes of whole-grain bread, were more likely to smoke, be in a manual occupation and have low dietary intakes of fruit, fibre and vegetables (Mertens *et al.*, 2017). After adjustment for such factors, it was also shown in these middle-aged men that those with the highest scores for the dietary pattern had a higher risk of developing incident CVD and stroke, compared with those that had the lowest scores. In addition, another dietary pattern characterised by higher intakes of sweet puddings, biscuits, whole-grain breakfast cereals and dairy (excluding butter and cheese) and low alcohol intake was associated with a decreased risk of developing CVD, CHD and stroke events (Mertens *et al.*, 2017). A second UK cohort study has also suggested that lower intakes of whole grains as part of a dietary pattern also including high intakes of red and processed meat, peas, legumes and fried foods was associated with higher inflammatory markers and accelerated cognitive decline at older ages (Ozawa *et al.*, 2016). These results perhaps indicating that the inclusion of whole-grain foods within certain dietary patterns in UK populations may have a role in CVD prevention. In addition to CVD, whole grains may have a role in T2D and obesity prevention in UK populations. Of the few studies conducted, low-fibre dietary pattern (including low intakes of whole grain cereals) in women and a dietary pattern including low intakes of medium-/high-fibre breakfast cereals and wholemeal bread has been associated with an increased risk of T2D (McNaughton *et al.*, 2008; Pastorino *et al.*, 2016). It has also been suggested that and one or more daily portions of wholemeal bread may be associated with a reduction in T2D risk (Simmons *et al.*, 2007). One cross-sectional study of adults from the 1986-7 and 2000-1 UK NDNS reported that whole grain intake was inversely associated with the percentage of men classified as obese (Thane *et al.*, 2009). However, this was not the case for women and whole grain intake was not associated with body weight measures or prevalence of overweight in this population.

2.3 Health benefits of whole grain consumption - Intervention evidence

The results of intervention studies do not consistently corroborate the findings from observational studies. Some interventions show beneficial effects of consuming whole grains on health markers, whereas others fail to find significant results (Table 2.3). For example, obese participants with metabolic syndrome who were given a 12 week dietary advice intervention to obtain all grain servings from whole grains, showed a reduction in plasma C-reactive protein concentrations and percentage body fat in the abdominal region compared with a whole grain avoidance group (refined grain group) (Katcher *et al.*, 2008). In another randomised controlled trial, markers of inflammation were reduced in overweight and obese but otherwise healthy participants, with suboptimal diets, following a whole-grain wheat intervention vs a refined grain control group for 8 weeks. However, no significant variations in body composition, plasma lipids or glycaemia were found in these participants or between intervention and the refined grain control (Vitaglione *et al.*, 2015). Similarly, in a 16 week whole grain intervention on overweight or obese UK men and women, no changes in CVD markers between intervention groups and controls were seen (Brownlee *et al.*, 2010). In contrast, after a four week run in period followed by a 12 week whole grain intervention, healthy weight UK men and women in the intervention group had significantly reduced systolic and pulse pressures in comparison to the refined grain control group (Tighe *et al.*, 2010). Additionally, a controlled cross-over trial in overweight and obese adults, of an eight week whole grain vs an eight week refined grain diet with a 10 week washout period between diets, recorded a 3-fold greater improvement in diastolic blood pressure after the whole grain diet compared to the refined grain diet (Kirwan *et al.*, 2016).

Table 2.3 Summary of whole grain intervention studies and cardio-metabolic measures

Publication	Trial design and length[1]	Population, health status, age (mean ± SE or range)	The WG intervention (n in groups if not crossover)	Comparison diet/group (n in groups if not crossover)	Cardio-metabolic outcomes measured	Significant results reported	
Ampatzoglou *et al.* (2015a); (Ampatzoglou *et al.*, 2015b)	WG vs RG diet, crossover, 2wk run in followed by 2x6wk diets with 4 wk washout	33 M&W Healthy* Age 49 ± 1y	Advised to achieve >80g/d (actual 168g/d) based on WG pasta, brown rice, WG snacks and WG RTEBC	RG diet (low WG <16g/d) with RG equivalents to WG products	Weight, BMI, %BF, WC, BP, TC, LDL, HDL, TG, glucose	None	†
Andersson (2007)	WG vs RG diet, crossover, 2x6wk of diets with 6-8wk washout	30 M&W Features of MetS Age 59 ± 5y	112g WG/d based on a mixture of whole wheat, rye, oats and rice foods	RG equivalent foods	Weight, BMI, BP, TC, LDL, HDL, TC, TG, FFA, insulin, glucose, IS, PAI-1, hsCRP, IL-6, 8-iso-PGF	None	
Azadbakht *et al.* (2005)	2 DASH diets (with WG) vs usual diet, parallel, 4wk run in followed by 6 month of diet	116 M&W MetS & OW Age 41 ± 12y	1) 500kcal diet with 3 WG servings (n=38), 2) 500kcal DASH diet with 4WG servings (n=38)	Eat as usual (control diet n=40)	Weight, WC, BP, HDL, TG, glucose	Higher HDL-C and lower weight, WC, SBP, DBP, TG and fasting glucose concentrations were seen in the DASH diet group in comparison with control group.	
Behall *et al.* (2006)	AHA diet vs 3 WG diets, crossover, 2wk AHA diet followed by 3x5wk WG diets	25 M&W Healthy* & high TC Age 38-53y	20% of energy replaced with 1) WW/brown rice 2) WG barley 3) 50:50 mix.	AHA diet for 2wks (control)	Weight, BP, MAP	SBP was reduced in WW/brown rice and 50:50 die and weight, DBP and MAP reduced in all WG diets compared with AHA diet.	†
Bodinham *et al.* (2011)	WG vs RG diet, crossover, 2x3wk diets with 3wk washout	14 M&W Healthy Age 26 ± 1y	Two WG bread rolls providing 48g WG/d	Two RG bread rolls per day	Weight, %BF, WC, BP	SBP decreased in WG and increased in control group.	†
Brownlee *et al.* (2010)	2 WG dose diets vs habitual low WG diet, parallel, 16wk	266 M&W OW/OB Age 45 ± 10y	1) Mix of WG foods-wheat bread & pasta, oat porridge, brown rice, RTEBC, providing 60g WG/d (n=85) 2) Mix of WG foods providing 60g (8wk) and 120g (8wk) WG/d (n=81)	Habitual diet (n=100)	Weight, BMI, WC, %BF, BP, TC, LDL, HDL, TG, FA, glucose, insulin, IS, PAI-1, hsCRP, sialic aid, IL-6, fibrinogen, ICAM-1, VCAM-1, E-selectin.	None	
Chang *et al.* (2013)	Oat vs placebo diet, parallel, double-blind, 12wk	34 subjects OW Age 18-65y	37.5g oat cereal/d mixed with hot water (n=16)	37.5g non-oat (placebo) cereal/d mixed with hot water (n=18)	Weight, BMI, %BF, W/H, TC, LDL, HDL, TG, FFA	Weight and BMI were decreased in oat group and, %BF, TC and LDL concentrations were lower in oat group compared with control.	†
Cooper *et al.* (2017)	WG vs RG free living diets, parallel, 6wk	46 M&W Healthy Age 26 ± 1y	WG market basket based on individual caloric need -WW bread, RTEBC, cookies, cous cous, crackers, pasta, tortilla four, brown rice and whole cornmeal muffins (n=35)	RG market basket based on individual caloric need -RG equivalent foods (n=11)	BMI, FM, FFM, TC, LDL, HDL, non-HDL, TG, glucose	LDL and non-HDL sign decreased after WG diet but not after RG diet.	†
Costabile *et al.* (2008)	WW vs wheat bran diets, crossover, double-blind, 2wk run in followed by 2x3wk diets with 2wk washout	31 M&W Healthy Age 18-50y	WW RTEBC 48g WG/d	Wheat bran RTEBC (placebo) 48g/d	TC, HDL, TG, glucose, insulin, NEFA	Participants with the highest TC concentrations prior to diets had a sign reduction in TC after both WW and WG diet periods.	†
Davy *et al.* (2002)	WG oat vs WG wheat diets, parallel, 12 wk	36 M OW Age 50-75y	WG oats (soluble fibre) - 60g oatmeal porridge, 76goat bran RTEBC (n=18)	WG wheat - 60g WW porridge, 81g WW RTEBC (n=18)	Weight, BMI, skin fold thickness, WC, TC, LDL, HDL, TG, lipid particle sizes, glucose, insulin, IS, AIR, SG	The WG oat compared with WG wheat diet produced lower concentrations of small, dense LDL and LDL particle numbers without any adverse changes in TG or HDL.	

de Mello *et al.* (2011); Lankinen *et al.* (2011)	Healthy diet (incl WG) & WG enriched diet vs control diet, parallel, 12wk	104/106 M&W Impaired glucose metabolism and features of MetS Age 59 ± 7y	Healthy diet (n=36): replace usual cereal foods with 50% WG, consume fish 3 times/w, use vegetable oil, consume 3 portions of bilberries/d. WG enriched diet (n=34): replace usual cereal foods with 50% WG plus 1 WG oat snack/d	Control diet (n=34): avoid WG and choose RG foods, fatty fish once/w, no bilberries	Weight, BMI, WC, BP, TC, LDL, HDL, TG, glucose, 2-hour glucose, insulin, 2-hour insulin, IR, IS, E-selectin, hsCRP, IL-6, TNF-α, FA, ICAM-1, ADMA, vWF, CCL5, MIF-1	E-selectin and 2-hour glucose was decreased in healthy diet group and did not change in other diets. hsCRP levels decreased in WG enriched diet group but did not change in other diets.	
Foerster *et al.* (2014)	WG vs red meat diets, crossover, 2wk run in (usual diet) followed by 2x3wk diets with 3wk washout	20 M&W Healthy Age 40 ± 3y	WG diet: high amounts of WG >40g/d dietary fibre from WG breads and muesli and < 30g/d red meat intake	Red meat diet: 200g/d and minimal amounts of fibre, isocaloric	Weight, BMI, W/H, WC, %BF, TC, LDL, HDL, TG, CRP	Weight, BMI and %BF was reduced following the WG diet but did not change following the red meat diet.	†
Giacco *et al.* (2010)	WG wheat vs RG diets, crossover, 2 wk run in followed by 2x3 wk diets, no washout	15 M&W Healthy* Age 55 ± 8y	WG wheat-bread, pasta rusks and crackers included as main CHO for each meal, isoenergetic	Same as WG products but in RG form, isoenergetic	Weight, BP, TC, LDL, HDL, APOA1, APOB, TG, glucose, insulin, c-pep, FA, IR, hsCRP, leptin, adiponectin, ghrelin	TC and LDL were sign lower after the WG diet period compared with RG diet period.	†
Giacco *et al.* (2013); Giacco *et al.* (2014)	WG vs RG diet, parallel, 2-4wk run in followed by 12wk diet	123 M&W Met S Age 57 ± 8y	Cereal products 60-80% of total CHO intake. Italy: WW bread/pasta, barley kernels, WG oat biscuits, RTEBC. Finland: WG rye bread, endosperm rye bread, sourdough WW bread, WW pasta, WG oat biscuits. (n=62)	Italy: RG products including wheat bread, rice, pizza, cornmeal porridge, RTEBC. Finland: RG wheat breads, allowed 1-2 small portions of rye bread/d. (n=61)	Weight, BMI, WC, SBP, DBP, TC, LDL HDL, TG, glucose, insulin, IS, hsCRP, IL-6, IL-1ra, TNF-α	None	
Hajihashemi *et al.* (2014)	WG vs RG diets, crossover, 2 wk run in followed by 6wk diets with 4wk washout	44 W OW/OB Age 11 ± 1y	Given list of WG foods and asked to consume half grains as WG. Achieved an average of 98g/d during intervention period	Asked to avoid all WG foods	Weight, BMI, WC, hsCRP, glucose, insulin, ICAM-1, VCAM-1, amyloid A, leptin	Reduction in hsCRP after WG diet whereas not after RG diet, greater reduction in serum amyloid A after WG diet and leptin decreased in WG period but rose in control period.	
Harris Jackson *et al.* (2014)	WG vs RG weight loss diets, parallel, 12wk	50 M&W Features of MetS Age 46 ± 6y	WG wheat, rice and oats top 3 grains. Intake based on energy intake, ranging from 163g/d (1600 kcal diet) to 301g/d (3600 kcal diet)	RG counterpart to WG food, wheat, rice and corn top 3 grains.	Weight, BMI, adipose tissue, TC, HDL, LDL, TG, glucose, insulin, IR, hsCRP, adiponectin, leptin, IL-6, TNF-α	Both WG and RG groups lost weight and SBP was reduced. There were higher reduction in glucose in those in WG group compared with RG group.	
Jang *et al.* (2001)	WG powder vs refined rice, parallel, 4wk run in followed by 16 wk diet	76 M CAD Age 59 ± 2y	70g WG (66%-rice, barley) and legume (beans 22.2%) powder (with 5.6% seeds and 5.6% vegetables) dissolved in water (n=38)	Isocaloric refined rice (n=38)	Weight, BMI, BP, TC, HDL, LDL, TG, glucose, insulin, IR	DBP decreased and HDL increased in WG group but not in refined rice group, greater decline in glucose concentrations in WG group compared with refined rice group.	†
Juntunen *et al.* (2003)	WG vs RG diets, crossover, 2-3 wk run in followed by 2x8 wk diets with 8wk washout	20 W Healthy* age 59 ± 6y	High fibre rye bread, 4-5 portions/d	White wheat bread , 4-5 portions/d	Weight, BMI, BP, TC, HDL, LDL, TG, glucose, insulin	Greater increases in acute insulin responses after WG diet compare with RG diet.	†
Karl *et al.* (2017) Vanegas *et al.* (2017)	WG vs RG weight maintenance diets, parallel, 2wk run in followed by 6wk diet	81 M&W Healthy Age 55 ± 6y	All grain intake from WG wheat, oats and brown rice (n=41)	All grain intake from RG foods (n=40)	Weight, BMI, WC, W/H, TC, HDL, LDL, TG, glucose, insulin, IR, IS, resting metabolic rate	Favourable energetic effects of WG diet resulted in a 92-kcal/d higher daily energy loss compared with RG diet.	†
Karmally *et al.* (2005)	WG oat vs cornflake RTEBC, parallel, 5wk run in weight maintenance diet followed by 6wk	152 M&W Healthy* Age 30-70y	2 packets WG oat RTEBC/d (Cheerios) (=73)	2 packets cornflake RTEBC/d (n=79)	Weight, BMI, TC, LDL, HDL, TG, APO-A1, APOB	TC and LDL concentrations reduced in the WG RTEBC group whereas no change in corn RTEBC group.	
Katcher *et al.* (2008)	WG vs RG diets, parallel arm, 12 wk	47 M&W MetS Age 45 ± 8y	Reduced energy diet containing WG, ~5 servings/d (n=24)	Reduced energy diet avoiding WG, <0.2 servings/d (n=23)	Weight, BMI, WC, %BF, BP, TC, HDL, LDL, TG, PAI-1, APOA1, APOB, glucose, insulin, hsCRP, IL-6, TNF-α	Greater decrease in abdominal %BF in WG group compared with RG group. Reduction in CRP, independent of weight loss, in WG group whereas no change in RG group.	

Keenan *et al.* (2007)	Oat vs low fibre cereal diet, parallel, 6wk	18 M&W Hypertensive/ hyperinsulinemia Age 44y	137g Oat cereal, isocaloric diet	146g low fibre cereal, isocaloric diet	BP, TC, HDL, LDL, TG, glucose, insulin, IS	SBP, DBP, TC and LDL decreased in the oat cereal group whereas there was no change in the low fibre cereal group.
Kirwan *et al.* (2016)	WG vs RG diet, crossover, double-blind, 2x8 wk of diets with 10 wk washout	33 M&W OW/OB Age 39 ± 7y	Macronutrient matched isocaloric diet with WG (RTEBC, cereal bars)	Macronutrient matched isocaloric diet with RG	Weight, BMI, FM, %BF, WC, BP, MAP, PP, IR, TC, HDL, LDL, glucose, insulin, hsCRP, MetS z-score, HbA1c	DBP decreases were greater after WG diet compared with RG.
Kristensen and Bugel (2011)	Low fibre vs oat bran diets, crossover, double-blind, 2x2 wk of diets with 4 wk washout	24 M&W Healthy Age 25 ± 3y	Low fibre diet plus 102g oat bran/d given in breads	Low fibre standardised diet based on participant energy requirement (control diet)	Weight, TC, HDH, LDL, TG, PAI-1, factor VII	Reductions in TC, non-HDL-C, TG very-LDL-TG, PAI-1 and factor VII were greater following the added oat bran diet compared with control diet. †
Kristensen *et al.* (2012)	WW vs RW weight loss diets, parallel, 2wk run in followed by 12 wk	72 W OW/OB Age 60 ± 5y	62g WW bread, 60 g WW pasta, 28g WW biscuits providing 105g WG/d (n=38)	62g RW bread, 60 g RW pasta, 28g RW biscuits /d (n=34)	Weight, BMI, WC, FM, BP, TC, LDL, HDL, TG, glucose, insulin, IR, HbA1c, hsCRP, IL-6	Reduction in %FM tended to be greater in the WW group compared with RW group, TC and LDL-C increased in the RW group but did not change in WW group.
Kristensen *et al.* (2017)	WG vs RG weight maintenance diets, parallel, 8wk weight loss diet followed 1 wk RG run in and 12 wk diet	179 W with habitual <16WGg/d intake OW/OB Age 20-50y	Ad libitum diet with 80g/d WG foods - bread, RTEBC, pasta, rice, cous cous, muesli bar (n=81)	Equivalent RG foods (n=88)	Weight, BMI, WC, W/H, %BF, BP, TC, LDL, HDL, TG, glucose, insulin, PAI-1, hsCRP, HbA1C, leptin, adiponectin	Abdominal %FM increased more in WG group compared with RG group but poor compliance in WG group.
Landberg *et al.* (2010)	WG vs RG diet, crossover, 2x6 wk of diet with 2wk washout	17 M prostate cancer Age 74 ± 5y	Replace cereal foods with 300g/d WG soft bread, 100g/d WG crisp bread, 50g/d WG breakfast cereals, 35 g/d WG porridge.	Replace cereal foods with 300g/d soft bread, 100g/d crispbread, 50g/d RTEBC, 35 g/d porridge plus wheat cellulose to balance fibre.	Weight, BMI, glucose, insulin, hsCRP, FA, c-pep, α-tocopherol, γ-tocopherol,	Insulin, hsCRP and c-pep lower after WG diet compared with RG diet. †
Leinonen *et al.* (2000)	WG rye bread vs white wheat bread, crossover, 2x4 wk of diets with 4wk washout	40 M&W elevated TC Age 43 ± 2y	Usual diet but with WG rye breads for a minimum of 20% daily energy intake	Usual diet with white wheat breads for a minimum of 20% daily energy	Weight, TC, HDL, LDL, TG, glucose, insulin	TC and LDL concentrations decreased in M after the rye bread diet but no changes after white wheat diet.
Li *et al.* (2016b)	WG oat diets vs healthy diet vs no intervention, parallel, 1wk run in followed by 30d diet & 1y follow-up	298 M&W T2D & OW Age 59 ± 7y	1) Healthy diet plus 50g WG oats/d (n=80) 2)Healthy diet plus 100g WG oats/d (n=79)	1) Usual diet group (n=60) 2) Healthy diet group: low-fat high-fibre diet (n=79)	Weight, BMI, WC, %BF, BP, TC, LDL, HDL, TG, glucose, insulin, IR, HbA1c	The WG oat groups had sign bigger reduction in postprandial glucose and TC compared with the usual diet group. The 100g WG oat group also have sign bigger reduction in IR and LDL compared with the usual diet group. After 1 y follow-up the 100g WG oat group had bigger weight loss and lower HbA1c.
MacKay *et al.* (2012)	WG wheat bread vs white bread diets, crossover, 2x6wk with 4-5 wk washout	28 M&W Normal or impaired carbohydrate metabolism Age 50-70y	6 slices WG bread/d for women, 7 slices WG bread/d for men	4 slices wheat bread/d for women, 5 slices wheat bread/d for men	Weight, BMI, WC, %BF, BMP, glucose, insulin, IR, PAI-1	Glucose area under the curve was lower after WG wheat bread diet compared with white wheat bread diet.
Maki *et al.* (2010)	WG Oat RTEBC vs low fibre, parallel, 1wk run in followed by 12wk	144 M&W OW/OB Age 20-65y	2 portions WG Oat RTEBC providing 3g/d β-glucan (n=77)	Low fibre breakfast/snack foods providing similar energy and macronutrient content (n=67)	Weight, BMI, WC, BP, TC, LDL, HDL, TG, hsCRP	WC decreased sign more and, TC and LDL reduced sign more in WG group compared with low fibre group.
McIntosh *et al.* (2003)	2 WG vs RG diets, crossover, 3x4 wk diets with no washout	28 M OW Age 40-65yrs	1) WG wheat diet - 140g WW bread, 40g WW crispbread, 50g WW RTEBC. 2) WG rye diet - 40g WG rye bread, 40g WG rye crispbread, 50g WG rye RTEBC	Low fibre RG diet - 140 white bread, 40g RG crispbreads, 50g rice RTEBC	Insulin, glucose	Postprandial glucose and insulin were sign lower after both WG diets compared to low fibre diet. †

Pereira *et al.* (2002)	WG vs RG diets, crossover, 2x6 wk diets with 6-9wk washout	11 M&W OW/OB & hyperinsulinaemic Age 42 ± 3y	6 to 10 servings of WG/d	RG equivalents	Fasting insulin, glucose, weight	Fasting insulin 10% lower after WG diet compared with after RG diet.	
Nilsson *et al.* (2015)	Barley bread vs white bread diet, crossover, 2x3d diet with 2-5 wk washout	20 M&W Healthy* Age 64 ± 6y	Barley kernel based bread	White wheat bread	Glucose, insulin, IR, IS, SCFA, NEFA, IL-6, IL-18	Glucose and insulin concentrations and IS were lower after the barley bread diet.	†
Rave *et al.* (2007)	WG diet vs meal replacement, crossover, 2x4wk with 2 wk washout	31 M&W OB with elevated fasting glucose 51 ± 13y	Hypocaloric diet with WG dietary product with reduced starch content derived from double-fermented wheat	Nutrient dense meal replacement, same people	Weight, BMI, W/H, WC, BP, TC, LDL, HDL, TG, glucose, insulin, IR,	Weight loss and lower TC, BP, fasting glucose, IR in both groups but after correcting for weight loss, fasting serum insulin and IR 'improved better' during WG consumption but not meal replacement.	†
Ross *et al.* (2011)	WG vs RG diet, crossover, 2x3wk diets with 5 wk washout	17 M&W Healthy Age 36 ± 4yrs	7-day menus repeated twice in each intervention period; range of WG foods providing 150 g WG/d 64% wheat, 13% oats, 9% brown rice remainder barley and rye. 277g total cereal intake/d.	Menus with refined grain matched to WG wherever possible; 66% wheat, 27% white rice, 8% refined maize. 277g total cereal intake/d.	Glucose, TC, LDL	TG sign higher on WG diet after 1 week only.	†
Suhr *et al.* (2017)	2 WG vs RG diets, parallel, 6wk	75 M&W OW/OB Age 30-65y	1) Given a selection of WG rye foods to replace all cereal consumption (n=24) 2) Given a selection of WG wheat foods to replace all cereal consumption (n=24)	Given a selection of RG wheat foods to replace all cereal consumption (n=25)	Weight, BMI, WC, FM, FFM, insulin, glucose	Body weight and fat mass sign decreased in WGR group compared with RG group.	†
Tighe *et al.* (2010); Tighe *et al.* (2013)	2 WG diets vs habitual RG diet, single-blind, controlled, parallel, 16 wk	206 M&W OW signs of metabolic syndrome Age 52 ± 1y	1) WW group -3 servings/d WG (48g/d) as: 70-80g WG wheat bread, 30-40 g WG RTE cereals/d (n=73). 2) WW & oat group - 1 serving of WG wheat, 2 servings WG oats (n=70).	RG group: habitual diet with 3 servings/d RG cereals and white bread (n=63).	Weight, BMI, WC, BP, PP, TC, LDL, HDL, TG, glucose, insulin, IR, IS, hsCRP, IL-6	SBP and PP sign reduced in WG groups compared with RG group.	
Zhang *et al.* (2011)	Brown rice vs white rice diet, parallel, 16wk	202 M&W T2D Age 49 ± 7y	Ad libitum brown rice (n=101).	Ad libitum white rice (polished from same batch of brown rice used in the intervention, n=101)).	Weight, BMI, BP, TC, LDL, HDL, TG, insulin glucose, IR, HbA1c	Weight fell sign in BR group but no differences between groups. SBP and DBP fell sign in both groups but no difference between groups.	
Zhang *et al.* (2012)	WG Oat vs RG noodles, parallel, 6wk	166 M&W Hypercholesterolemia 35 -70y	100g instant oat cereal/d	100g RG wheat noodles/d	Weight, BMI, WC, BP, TC, LDL, HDL, TG, glucose, ApoA1, ApoB	TC, LDL and WC sign decreased in oat group compared with noodle group.	

1-all studies were randomised and non-blinded unless otherwise stated; *participants were classified as healthy but some participants may have had overweight BMI; †studies also assessed other (non-cardio metabolic) outcome measures including gastrointestinal symptoms, satiety measures, liver function and microbiome profile

WG: Whole grain; RG: Refined grain; wk: week; d:day; AHA: American Heart Association step 1 diet: M: Men W:Women; MetS: Metabolic syndrome; OW: overweight; OB: obese; CAD: Coronary Artery Disease; T2D: Type 2 diabetes; RTEBC: Ready-to-eat breakfast cereals; sign: significant

Outcome measures - BMI: Body Mass Index; WC: Waist Circumference; W/H: Waist to Hip ratio; FM: Fat Mass; %BF: Percentage Body Fat; BP: Blood Pressure; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; PP: Pulse Pressure; MAP: Mean Arterial Pressure; TC: Total Cholesterol; HDL: High-density Lipoprotein; LDL: Low-density Lipoprotein; TG: Triglyceride/Triacylglycerol; FA: Fatty Acids; FFA: Free Fatty Acids; SCFA: Short Chain Fatty Acids; PAI-1: Plasminogen Activator Inhibitor-1; IR: Insulin Resistance; IS: Insulin Secretion; AIR: Insulin response to glucose; SG: glucose effectiveness;; vWF: von Willebrand Factor; CCL5: hemokine (C-C motif) ligand 5; MIF-1: Macrophage migration inhibatory Factor; hsCRP: high sensitivity C-Reactive Protein; IL: Interleukin; c-pep: c-peptide; ICAM-1: Intercellular adhesion molecule 1; VCAM-1: vascular cell adhesion molecule; HbA1c: glycated haemoglobin; TNF-α: Tumor necrosis factor; ADMA: asytmmetric dimethylarginine, A systematic review and meta-analysis of randomised controlled studies investigating changes in blood lipids has recently reported overall 0.09mmol/L (95%CI -0.15, -0.03) and 0.12mmol/L (95%CI -0.19, -0.05) lower weighted differences in low-density lipoprotein (LDL) and total cholesterol concentrations for the varying whole grain intervention diets vs non-whole grain control diets (Hollaender *et al.*, 2015). However, these reductions differed when studies were separated by the type of whole-grain food prescribed in the whole grain diets, e.g. oat, wheat, rye, barley, rice or mixed. Meta-analyses separated by whole-grain food type indicated that whole-grain oat interventions had the greatest effect on total and LDL cholesterol reductions in comparison with control diets. A meta-analysis of randomized controlled whole grain intervention studies on body weight and body composition concluded that the trials did not support the role of whole grain in body weight management. However, beneficial effects of whole grain on body weight may be more apparent for body fat percentage or abdominal adiposity which may be mediated through decreased inflammatory responses (Pol *et al.*, 2013). A review by the US FDA aiming to define a health claim statement on whole grain intake and the risk of T2D, reviewed six intervention studies that met the FDAs whole grain definition alongside three observational studies (Yamini and Trumbo, 2016). Amongst the six intervention studies reviewed, only one found a significant reduction in insulin resistance following a four week randomised trial. The remaining interventions reported no differences between the whole grain and control groups for fasting blood glucose, glucose tolerance and insulin resistance measures.

On the basis of these results, the US FDA did not support a significant scientific agreement health claim, instead opting for a qualified health claim (based on less scientific evidence but with an accompanying statement on the level of evidence). They issued a letter of enforcement discretion for the following claim “Whole grains may reduce the risk of T2D, although the FDA has concluded that there is very limited scientific evidence for this claim” (Yamini and Trumbo, 2016)

Explanations for the differing findings of interventions studies to those of observation studies are thought to be due mainly to the differences in study design. Intervention studies are time-restricted with no reported trial lasting longer than 4 months which may not be long enough for sustained health benefits to be seen. Sample sizes are often small, although usually authors claim that they are powered to be able to detect any significant meaningful changes in disease markers resulting from the intervention. The type, variety and quantity of whole grains used in intervention studies differ and this may be another reason for inconsistent results. Some whole grains, such as oats, rye and barley, contain higher fibre, particularly soluble fibre, than wheat and rice. Therefore, the physiological effects on the body may differ between grain types and if one grain type or a mix of grains are included in the diet.

The outcomes of intervention studies are reported as the outcome on risk markers for disease, not the occurrence of a disease as this would not be possible within the time-frame of an intervention study. Therefore, comparison with observational studies where a particular disease or event has occurred may not be appropriate. Interestingly observational studies that report on markers for disease risk also have varying results (Seal and Brownlee, 2010). For example, in a cross-sectional cohort of German men and women, a significant association was reported between consumers in the highest quintile of whole-grain bread intake and circulating oxidative stress levels, fat accumulation measures and C-reactive protein concentrations in comparison to those in the lowest tertile of intake. However, no such association was seen for insulin sensitivity, high-density lipoprotein (HDL) cholesterol, triglyceride or HbA1c concentrations (Montonen *et al.*, 2013). This suggests that intervention studies and observational studies that report biomarkers of disease risk are more aligned in the inconsistency of their results compared with those that only report disease outcomes. Finally, intervention studies that report no changes in disease markers are most often carried out in healthy or overweight but otherwise 'healthy' volunteers. This raises the question, whether improvement in disease risk markers should be expected if the participants are otherwise healthy. Some of the largest effects are seen in intervention studies with 'at risk' participants with dyslipidaemia or obesity (Azadbakht *et al.*, 2005; Behall *et al.*, 2006; Katcher *et al.*, 2008; de Mello *et al.*, 2011). Furthermore, it is known that as we age our health and health markers in general decline. It has been suggested that we should re-consider the pharmacological paradigm approach to nutrition research which suggests that short-term dietary intervention with whole grains should improve or reduce disease risk, in favour of a longer-term model which suggests that increased whole grain intake in the longer-term reduces age-related declines in health.

Despite the inconsistent results from whole grain interventions, to my knowledge, no study has shown or reported negative effects or outcomes of increasing whole grain intake on health markers. Therefore, advice to consume more whole grains could be a low risk public health strategy. Of course, it is important to note that for a small proportion of the population with a gluten intolerance, caution must be made when consuming whole grains containing gluten. However, gluten free whole grain alternatives such as amaranth, brown rice, buckwheat and quinoa are available and their consumption by those with gluten intolerance can be encouraged. Whole grain oats do not contain gluten but are sometimes cross-contaminated with wheat during harvesting or factory processing. Thus, consumers should always check product labels for gluten-free oat ingredients for clarification. For those that do not have coeliac disease or a major gluten intolerance, caution should be made for unnecessary exclusion of gluten from the diet since it has recently been shown that gluten free diets may increase the risk of T2D in women from the Nurses Health Study (American Heart Association, 2017). The increased risk may not be attributed to the exclusion of gluten itself but potentially to the higher fat, salt and sugar and lower fibre, vitamins, minerals and overall nutrient profiles of gluten-free foods (Staudacher and Gibson, 2015; Wu *et al.*, 2015a).

2.4 Health benefits of whole grains - Mechanisms of action

There is no single clear mechanism identified for which whole grains benefit the body, instead it seems there are a combination of several processes suggested which may also interact with one another. Essentially the accepted pathways in which whole grains have an effect on chronic diseases can be split into two; those associated with dietary fibre and those associated with possible bioactive components (Figure 2.1, Table 2.4).

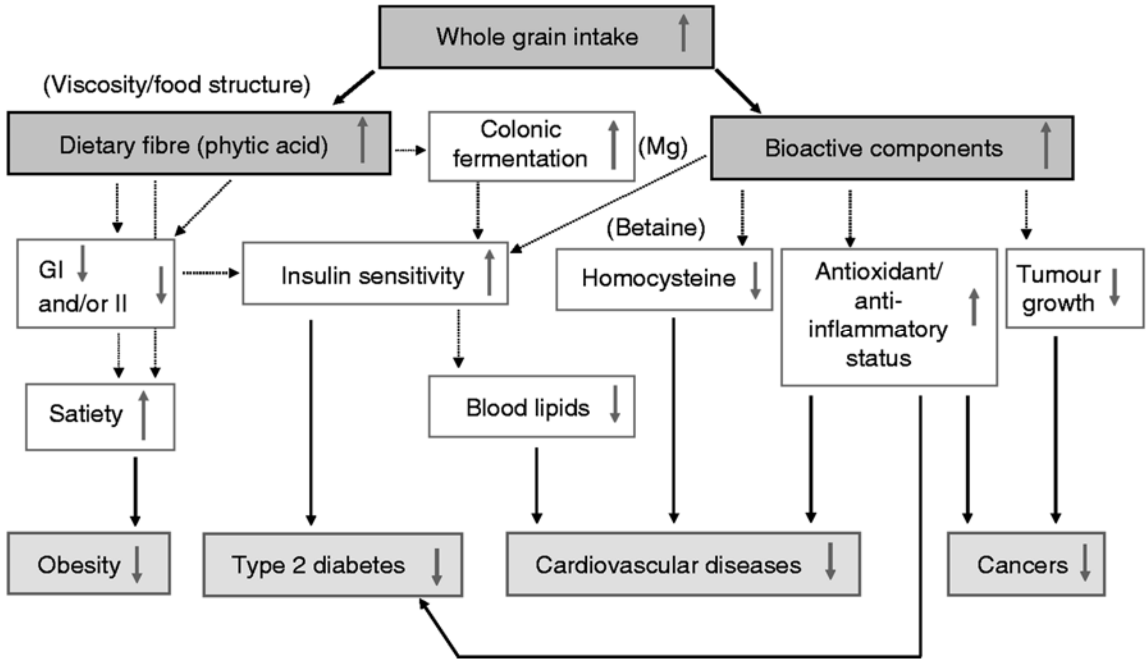


Figure 2.1 Accepted mechanisms for effects of whole grain on chronic disease (Fardet *et al.,* 2010)
GI, glycaemic index; II, insulinaemic index.

Whole grains are a good dietary source of cereal fibre and have increased amounts compared with refined grain counterparts. For example, the Association of Official Analytical Chemists (AOAC) dietary fibre content of wholemeal bread is more than twice as high at 7g per 100g whereas for white bread it is 2.9g per 100g (Public Health England, 2015). Insoluble and soluble dietary fibres improve digestive health through a range of effects such as stool bulking, altered intestinal transit time as well as increased colonic fermentation which induces the production of short chain fatty acids (Slavin, 2010). Soluble dietary fibres found in whole grains delay gastric emptying and decreas intestinal absorption and digestion of carbohydrates, hence slows rate of glucose absorption and favourably enhances postprandial glucose and insulin response (Kaline *et al.*, 2007; Rave *et al.*, 2007; McRae, 2017). Beta-glucan, a soluble fibre found in higher concentrations in oats and barley, has been shown to lower blood cholesterol concentrations and improve post prandial insulin and glucose responses (Lattimer and Haub, 2010; Tiwari and Cummins, 2011).

Table 2.4 Suggested beneficial components of whole grains and potential mechanisms for benefits on cardio-metabolic health

Whole Grain component	Comparison with refined grain	Potential health benefits and mechanism
Fibre	Higher levels of soluble and insoluble fibre, non-digestible oligosaccharides and resistant starch	• Modulate absorption of nutrients either by affecting digesta flow rate or by direct interaction between cereal components and individual nutrients • Reduced inflammatory status – exact mechanism unclear • Improved blood pressure and vascular function – exact mechanism unclear • Affect enterohepatic circulation of bile and lower cholesterol by sequestration of bile salts with soluble fibre preventing reabsorption • Possible effects on satiety/gastric emptying affecting satiety mechanisms • Reduces energy density of foods and lowers total energy intake, possibly linked to satiety effects • Reduction in body weight and body weight gain over time, possibly linked to satiety effects • Altered gut microbiota and fermentation products, increase faecal bulk- exact mechanism unclear
Vitamins and Minerals	Higher macro- and micronutrient content e.g. fat soluble vitamins, magnesium, selenium, folic acid.	• Help to maintain normal glucose and insulin metabolism as some nutrients, e.g. magnesium, are cofactors for insulin receptor kinase and chromodulin. • Improved blood pressure and vascular function - exact mechanism unclear • Antioxidant activity, scavenging for free radicals to prevent oxidative damage. Trace minerals, e.g. selenium, zinc, copper, and manganese, are cofactors for enzymes that conduct antioxidant functions (NB: mandatory fortification of foods in some countries may replace macro- and micronutrient losses from refinement, e.g. mandatory calcium fortification of white bread in the UK)
Phytochemicals	Higher non-nutrient and phytochemical content e.g, polyphenols (phenolic acids, flavonoids and lignans, phytosterols, phytic acids)	• Lower cholesterol levels by competing with cholesterol for absorption by the small intestine hence increasing cholesterol excretion • Possible effects on vascular endothelium by promoting vasodilation, which leads to a reduction in blood pressure • Antioxidant activity, polyphenols neutralise carcinogenic compounds thus prevent oxidative damage to DNA • Reduced inflammatory status – exact mechanism unclear • Altered gut microbiota - exact mechanism unclear
Glycaemic index	May have a lower glycaemic index – depending on cereal type and degree of processing	• Possible effects on satiety/gastric emptying affecting satiety mechanisms • Reduced insulin and glucose responses that favour the oxidation and lipolysis of fat rather than its storage (NB: Not all whole-grain foods have a low glycaemic index)

In addition, the physiological effects of both soluble and insoluble fibre, whole grains may also have satiating effects on appetite which may have a role in weight management (Jonnalagadda *et al.*, 2011). Cereal fibre, in particular, has been highlighted as one fibre source that may reduce CHD risk (Wu *et al.*, 2015b), and the need for trials investigating the effects of cereal fibre on T2D risk has been emphasised (Whincup and Donin, 2015).

It is also important to consider that the associated benefits of whole grains are above and beyond those of just the cereal fibre. Whole grains also contain a large amount of bioactive components such as phenolic acids, lignans, plant sterols, tocotrienols, benzoxazinoids and alkylresorcinols as well as a variety of vitamins and minerals, as also show in Table 2.4 (Borneo and Leon, 2012; Andersson *et al.*, 2014). Many of these have anti-oxidant and anti-inflammatory properties as well as providing essential nutrients into the diet of whole grain consumers which could lead to protection from later disease (Kris-Etherton *et al.*, 2002; Slavin, 2003; Fardet, 2010). Similar to the effects of fibre, vitamins such as magnesium and chromium may aid to regulate glucose and insulin metabolism because they are cofactors (aids of biological activities) of insulin receptor kinase and chromodulin (Dong *et al.*, 2011; McRae, 2017).
The compounds of vitamin E are associated with antioxidant activity, for example alpha-tocopherol, has the ability to scavenge free radicals and prevent oxidative damage. In addition, it has been suggested that alpha-tocopherol has the potential to be a gene regulator (Borneo and Leon, 2012; Joshi and Praticò, 2012). Phytochemical contents of whole grains can have an effect on the vascular endothelium by aiding the dilation of blood vessels, leading to reduction in blood pressure (Biesinger *et al.*, 2016). New and emerging research into the gut microbiome suggests that whole grains may influence the type of bacteria that make up the gut microbiota which has beneficial effects on the host gut health (Rose, 2014; Zhong *et al.*, 2015; Zhou *et al.*, 2015). In a human trial it was shown that a mixture of whole grain types, a combination of whole grain barley and brown rice, increased gut microbial diversity which induced some beneficial changes on the profile of bacterial populations in the host; evidence that in the short term, increased intake from a mixture of whole grains alters the gut environment and results in improvements in systematic inflammation (Walter *et al.*, 2013). Finally, some whole grains, but not all, have a low glycaemic index, depending on the grain type and degree of processing. Low glycaemic foods promote satiety, slow digestion and absorption leading to relatively lower insulin and glucose responses (Williams *et al.*, 2008).

2.5 Summary

Overall reviews and meta-analyses on the observational evidence of CVD, T2D and obesity outcomes, consistently promote the intake of whole grain. Significant risk reductions from studies range from 19 - 40% for CVD and 21 - 40% for T2D occurrence, and measures of body weight are lower when comparing the highest with the lowest whole grain consumers. There is also evidence for a dose-response effect of increased whole grain intake with varying quantities specified, for example per 10g/d of whole grain, per serving (~15g of whole grain) and per 90g/d of whole-grain food (3 servings). All studies have attempted to control for potential confounding factors such as age, sex, smoking status, socioeconomic status and those indicative of a general healthy lifestyle, however the full effect of potential confounders cannot be completely ruled out. Therefore, it is not possible to conclude a cause and effect of whole grain intake on disease outcomes from observational studies. The majority of studies have been conducted in US and Scandinavian populations and there is a need for further investigation in UK populations that follow the consensus whole grain definition and detailing the whole grain contents of foods consumed. Furthermore, future studies on whole grain intake should also consider the intakes of other foods and nutrients since whole-grain foods are not consumed alone but as part of an overall diet. In addition, whole-grain foods are likely to be consumed instead of refined grain foods and such substitution may also confound the associated disease risk reductions.

Chapter 3 Whole grain intake in the UK National Diet and Nutrition Survey and the association with health markers

3.1 Introduction

As described in chapter 2, there is observational evidence to suggest that whole grain intake reduces the risk of several chronic diseases notably CVD, T2D, some cancers and has beneficial effects on obesity (Seal and Brownlee, 2010; Ye *et al.*, 2012; Kyrø *et al.*, 2013; Chanson-Rolle *et al.*, 2015). As a results of this, some countries, e.g. USA and Denmark, have quantity-specific whole grain intake recommendations. Currently there are no specific dietary recommendations for whole grain in the UK, other than suggesting *"choose wholegrain or higher fibre versions with less added fat, salt and sugar"* (Public Health England, 2016). Previous studies of the UK diet have shown that whole grain intake is low and declining (Thane *et al.*, 2005; Thane *et al.*, 2007). However, since these assessments, there has been an increase in whole-grain food products available in the consumer market and consumer awareness of whole grain is increasing, although barriers to their consumption still remain (McMackin *et al.*, 2013; Nicklas *et al.*, 2013; Kamar *et al.*, 2016). The last assessment of whole grain intake in the UK undertaken by Thane *et al.* (2007) presented results of information collected in 1986-7 and 2000-1. National dietary information from the UK has now been published from a collection period from 2008 to 2011 in the NDNS (Bates *et al.*, 2012a).

3.2 Aim

The aim of this work was to quantify whole grain intake in the more recent diet of the UK population using data from the most recent NDNS rolling programme and to associate estimated intake with markers of cardio-vascular health and body mass. To address this aim, types of whole grains and whole-grain foods consumed will be detailed as well as calculation of the whole grain content of the foods consumed. Whole grain intake will be described for the total population and by population demographics (age, sex, and social classification) and for different cut-off levels for the whole grain content of foods. Detail on whole grain consumption day, location and who was present during consumption will also be reported. Intakes of other foods, nutrients and averages of health markers will be described with differences and trends across increasing levels of whole grain intake.

The following sections of this chapter describe the survey data and methodology used to estimate whole grain intakes (section 3.3), present the results of the objectives described above (section 3.5) and summarises these results (section 3.6).

3.3 Methodology

3.3.1 The National Diet and Nutrition Survey (NDNS)

The NDNS is a programme of surveys designed to assess the diet, nutrient intake and nutritional status of the general population aged 1.5 years and older living in private households in the UK (Bates *et al.*, 2012a). Since 2008 the NDNS has been conducted as an annual rolling programme. Between April 2008 and March 2011, 9990 addresses from 370 postcode sectors were drawn from the UK postcode Address File. Where there were multiple households at an address, a single household was selected at random. Within each household, either one adult and one child, or one child only, were selected for inclusion. Adults and children selected were invited to complete a four-day food diary, an interview and to provide blood and urine samples. The interview collected information on dietary habits, socio-economic status and lifestyle in the form of computer-assisted personal interviewing (CAPI) and self-completion questionnaires.

The response rate for completion of the diary was 55% in year 1 and year 2 and 52% in year 3 (Bates *et al.*, 2012a). The diet diary and interview information was administered and collected over three visits to the household. After this first stage of the survey, the second stage, requiring further participant permission, involved a nurse visit. Some participants declined the nurse visit and a further number declined to give a blood sample during the nurse visit. For the 2008-2011 cohort, 50% of adults aged 19-64 years (582) and 38% of children aged 11 to 18 years (256) who completed the diet diary also provided a blood sample (Bates *et al.*, 2012a).

3.3.2 Dietary data

Diet data were collected between April 2008 and April 2011 using a four-day food diary, from 3073 individuals aged 1.5 years and over. The four-day food diary was explained and given to participants by a trained interviewer during the first visit to the household. In the explanation, details of how to describe food, drink and portion sizes (with picture references for adults only and some young people in the survey year 3) were given. These details were also included in an instructions page within the diary (Bates *et al.*, 2012b). Diet diaries for participants aged 11 years and younger were completed by a parent/carer with help from the child. Participants were asked to record all food and drinks consumed both at home and away from home for four consecutive days. Leftover food was not recorded separately, instead participants were asked to take this into account when recording their consumption which was prompted for within the diary. Food packaging and branding information was requested along with details of cooking method. For homemade dishes, the recipe, ingredients, quantities and cooking method were recorded separately within the diary. In addition to the food and drink record, information on where they were and who they were eating with was recorded. In a second visit by the interviewer, the diaries were checked for compliance, reviewed and edited for completion and any questions answered. The third and final visit by the interviewer reviewed and collected the completed diet diary.

Across year 1 of the rolling survey (2008/09) diet diaries were designed to be recorded over two week and two weekend days. From year 2 onwards (2009+) the design was changed to record diet equally over all days of the week due to potential oversampling of weekend days. Therefore in year 2 (2009/10), diet diaries were designed to over-represent weekdays and under-represent weekend day and in year 3 (2010/11) diet diaries were designed so that all days of the week were evenly represented.

Processing of the diet diary data was done by trained coders and editors. Food intakes were entered into the Medical Research Council, Human Nutrition Research's (MRC HNR's) dietary assessment system, DINO (Diet In Nutrients Out) (Fitt *et al.*, 2015). The food composition data used was the Department of Health's (DoH) NDNS Nutrient Databank. Data coders matched each food/drink item recorded in the diary with a food code and portion code from DINO. Composite items (for example sandwiches) and homemade meals were split into their component parts and assigned individual food codes. Where appropriate, foods that could not be matched and assigned food codes (for example new food products), were sourced and product information added into DINO and the databank. Further details of data coding and editing are outlined in published documents by the NDNS team (Lennox *et al.*, 2012).

3.3.3 Health and lifestyle information

Socio-economic and health-related lifestyle data were collected during the CAPI interviews. Social class was determined by the National Statistics Socio-economic Classification (NS-SEC) of the household reference person (HRP), defined as the householder (a person whose name the property is owned or rented) with the highest income (Rose *et al.*, 2005). If there was more than one householder and they had equal income, the oldest was selected as the HRP. The NS-SEC classification is based on employment status of the HRP at the time of the interview. The NS-SEC has eight categories (known as the 'analytical' scale); Higher managerial and professional occupations; lower managerial, administrative and professional occupations; Intermediate occupations; Small employers and own account workers; Lower supervisory and technical occupations; Semi-routine occupations; Routine occupations; Never worked and long-term unemployed. To derive the NS-SEC category the HRP is first allocated to an occupational category using the Standard Occupational Classification 2000 (Office for National Statistics, 2000). This occupational category along with size of the establishment worked at and employment status are cross-referenced on a lookup table to obtain the NS-SEC category. The eight categories of the NS-SEC can be further collapsed in four classes: Higher managerial, administrative and professional occupations; Intermediate occupations; routine and manual occupations; Never worked.

Height and weight were measured at the first visit to the household, using a portable stadiometer and weighting scales. BMI was calculated by the CAPI program as weight (kg) divided by height (m) squared. For participants whose height could not be measured, estimated height based on demispan was used to calculate BMI.

Waist and hip circumferences were measured during the nurse visit to the household using a tape measure on all participants age 11 years and over. All measurements were taken twice and a third taken if a discrepancy between the two measurements was at or above a given value (height ≥ 0.5cm, weight ≥ 0.2kg, waist and hip circumference ≥ 3cm). For the purpose of analysis the mean of the two closest measurements is used. Blood pressure, collected during the second stage nurse visit of the survey, was measured in the sitting position using an automated, validated machine (Omron HEM907), after five minutes rest. Blood pressure was only collected for participants aged 4 years and over. The mean of three blood pressure readings taken at one minute intervals in participants who had not eaten, drunk alcohol, exercised or smoked in the preceding 30 minutes was used. If three readings were not obtained the mean of two valid readings was used instead. If an individual did not have two or more valid blood pressure readings they were excluded. Hypertension derived from blood pressure readings was defined as a systolic blood pressure reading of 140mmHg or above and/or a diastolic blood pressure of 90mmHg or above and/or taking medication to reduce blood pressure.

Written consent for blood sampling was obtained and samples collected during the second stage nurse visit. Overnight fasting blood samples were obtained from those age 4 years and over and non-diabetics, otherwise non-fasting samples were obtained. Blood samples were analysed for a range of blood analytes and lipids including: haemoglobin (g/L), white blood cell count ($x10^9$/L), plasma creatinine (µmol/L), high sensitivity C-reactive protein (CRP, mg/L), total cholesterol (mmol/L), HDL cholesterol (mmol/L), LDL cholesterol (mmol/L) and serum triglycerides (mmol/L). Full details for the analysis of blood analytes are given in the in published documents by the NDNS team (Nicholson *et al.*, 2012). All data used from the NDNS were accessed through the UK Data Service (www.ukdataservice.ac.uk), a publically accessible database library of major UK surveys (National Centre for Social Research *et al.*, 2013).

3.3.4 Identification of whole-grain foods

From a total of 3073 diet diaries, 61 main food groups containing 150 sub divisions were checked for the presence of foods containing cereal grains. The following food groups were eliminated on the basis of having no cereal grain ingredients: Milk and milk products (whole, semi-skimmed, 1% and skimmed milk and cream) ; cheese; fat spreads (butter, polyunsaturated margarine, other non-polyunsaturated margarine, low fat and reduced fat spread) ; vegetables (salad and raw vegetables, cooked vegetables); fruit; fruit juice; sugar, preserves and sweet spread; diet and non-diet soft drinks; tea, coffee and water; spirits and liqueurs; wine; beer, larger, cider and perry; dietary supplements; artificial sweeteners. Cereal grains identified in the remaining food groups were categorised into whole grain or non-whole grain using Table 3.1.

Table 3.1 Food ingredients commonly found on food packaging[1]

Grain	Whole grain ingredient	Non-whole grain ingredient
Barley	Hulled barely Whole barley	Barley flakes Barley flour Pearl barley Toasted/Malted barley flakes
Maize	Popcorn Whole/whole-grain corn	Cornmeal Sweet corn
Oat	Oat flakes Oatmeal Pinhead oats Rolled oats Stabilized oats Whole oats	Oat flour Toasted/Malted oat flakes
Rice	Brown rice Red rice Whole-grain rice Wild rice	Rice flour
Rye	Malted rye Rye Rye flakes Whole rye flour Wholemeal rye	
Wheat	Cracked wheat Graham Flour Kibbled wheat Wheat flakes Whole-grain wheat Whole kamut flour Wholemeal flour Whole spelt Whole wheat	Buckwheat Bulgur wheat Cous cous Puffed wheat Toasted/Malted wheat flakes Wheat flour
Others	Whole millet Whole amaranth Whole psyllium Whole quinoa Whole sorghum Whole teff Whole triticale	Millet flour

[1] Classification of ingredients taken from Seal *et al.* (2006)

3.3.5 Calculations of whole grain percentage in foods - assumptions made

For each of the foods identified as whole-grain, whole grain dry matter percentage content was obtained. Firstly the whole-grain foods identified were cross-checked with a list of food codes and names for which whole grain dry matter percent had been previously calculated by Jones (2007) . Where foods could not be identically matched to a product in this list, a second check matched identified foods to products that were very similar. Finally, foods that were not matched (including new food products) were sourced for product information (ingredients list) in order to calculate whole grain dry matter percentage manually. Branded and supermarket own-brand food product information was sourced via branding website if available, supermarket grocery website (Sainsbury's, Waitrose, Tesco and Asda) if available or sourced from the supermarket and recorded directly from food product labelling. Non-branded food products were matched to a variety of similar own-brand and brand foods and an average percentage whole grain of these foods was calculated.

3.3.6 Dry matter percentage whole grain calculation

Calculation of whole grain dry matter percentage of foods that could not be matched, followed the formulation outlined in Jones *et al.* (2017) (Equation 3.1). This calculation was designed to accurately estimate the whole grain content of a food as commonly consumed, meaning that the proportion of whole grain dry matter of the food took into account the water/moisture remaining in the product when eaten. However, each whole grain has a different water content. To account for this difference the whole grain content calculation applied a factor to remove the water percentage depending on the type of whole grain ingredient, hence dry matter (Equation 3.1). Water content (%) and the subsequent dry matter whole grain content (%) of whole-grain ingredients were established from Holland *et al.* (1988) and the USDA agricultural research service online national nutrient database (U.S. Department of Agriculture - Agricultural Research Service, 2012), as shown in Table 3.2.

$$\text{Whole Grain (dry matter) \%} = \frac{\text{Weight of whole grain ingredient(s)} \times \text{\% dry matter of whole grain ingredient(s)}}{\text{Total weight of food recipe} - \text{Losses during cooking}} \times 100$$

Equation 3.1 Calculation for whole grain dry matter percentage of a whole-grain food

Table 3.2 Water and dry matter content of whole grain ingredients (adapted from Jones *et al.* (2017))

Ingredient	% water content	% dry matter
Amaranth, uncooked*	11.3	88.7
Amaranth, cooked*	75.2	24.8
Barley, pearl, boiled	69.6	30.4
Barley, whole grain, raw	11.7	88.3
Brown rice (boiled)	66.0	34.0
Brown rice (raw)	13.9	86.1
Maize (cornmeal)	12.2	87.8
Millet, raw*	8.7	91.3
Oatmeal (quick cook raw)	8.2	91.8
Oatmeal (raw)	8.9	91.1
Quinoa, uncooked*	13.3	86.7
Quinoa, cooked*	71.6	28.4
Red rice, raw*	13.2	86.8
Red rice (boiled)*	78.8	21.2
Rye flour (whole)	15.0	85.0
Spaghetti, wholemeal, boiled	69.1	30.9
Spaghetti, wholemeal, raw	10.5	89.5
Spelt raw, uncooked*	11.0	89.0
Wholemeal flour	14.0	86.0

* Data obtained from U.S. Department of Agriculture - Agricultural Research Service (2012)

The percentage of each whole grain ingredient, taken from product information, was converted into dry matter per 100g. The total of all dry matter whole-grain ingredients per 100g gave percentage whole grain of that food. For example: Nestlé, Oats and More cereal: almond (Table 3.3, product information taken from the Cereal Partners UK website (Cereal Partners Worldwide-Nestlé and General Mills, 2013).

Table 3.3 Example of whole grain dry matter calculation for Nestlé Oats and More cereal

Ingredients	Weight per 100g	Whole grain dry matter per 100g
Whole grain oat-59.2%	59.2	59.2 x 0.911* = 53.9
Whole grain wheat-5.5%	5.5	5.5 x 0.86† = 4.7
Others (non-whole grain)	35.3	
Total per 100g	100	58.7
Dry matter whole grain percent	58.7 %	

* Percent dry matter of oats, † Percent dry matter of whole grain wheat (see Table 3.2 above)

Where product information was unclear and did not include detailed percentage amounts of each grain type when more than one grain was present, equal quantities of each identified grain was assumed e.g. 33% cereals (wheat, whole wheat, oats) was assumed to contain 11% of each grain type. Since detail on weight loss during cooking/baking and on the cooking/baking process was not available on product information, this could not be accounted for in the whole grain dry matter percent calculation. A full list detailing whole grain dry matter percentage calculation for all whole-grain foods reported as being consumed in the NDNS is included in appendix A.

3.3.7 Individual whole grain intake

Whole grain intake for each participant of the NDNS was calculated by identifying each whole-grain food product consumed over the duration of the diet diary. The total grams of each whole-grain product identified was then multiplied by the food specific dry matter whole grain percentage to give grams of whole grain for each whole-grain food product consumed. The grams whole grain consumed were then totalled for all whole-grain foods eaten during the diet diary and divided by the number of diet diary recording days (four) to give average daily whole grain intake. Day specific whole grain intake was calculated by summing the grams of whole grain eaten for each diary day. Energy-adjusted whole grain intake was calculated by dividing individual whole grain intake (grams per day) by total energy consumed over the diet diary (MJ per day).

3.4 Statistical Analysis

3.4.1 Weighting the data

Data used in the analysis were weighted in order to remove any potential selection bias in the observed results arising from non-response bias in the NDNS data. Selection bias may occur due to differences in the probability of households and individuals being selected to take part; for example, non-response to the individual questionnaire, the follow-up nurse visit and providing a blood sample are all possible. Full details of weighting computation which was done by the NDNS team are described in the published documents by the NDNS team (Tipping, 2012). Three sets of weighting were utilised on results presented in this report: Individual, nurse and blood weighting. Individual weighting accounted for any bias in household, main food provider and individual selection, seasonality and for the age/sex and regional profiles of participating individuals. Nurse weighting adjusted for unequal selection, non-response to the household and individual interviews and non-response to the nurse visit. Blood weighting, in addition to that accounted for by the nurse weighting, also accounted for non-response to giving a blood sample.

For the purpose of this study, analyses of whole grain intake, nutrient intakes, weight and BMI were estimated using the individual weighting. Waist hip ratio and blood pressure results were estimated using nurse weighting and analyses of the blood analytes were estimated using blood weighting.

3.4.2 Data Handling and analysis

Whole grain intake, energy-adjusted whole grain intake, other food intake, nutrient intake, weight, BMI, blood pressure and all blood analytes were treated as continuous variables. Age, sex, social classification, whole grain serving, consumption day, consumption location and who whole-grain foods were consumed with were treated as categorical variables. Whole grain intake was also categorised into tertiles of intake (consumers only) and number of servings, where one serving was defined as 16g/d. Whole grain intake is reported as a median g/d or median g/MJ/d with corresponding interquartile ranges (IQR) because data were not normally distributed.

The following statistical techniques were used to test for differences, trends or associations with whole grain intake. A linear trend of whole grain intake by age was tested using linear regression. The Mann-Whitney ranks sum test was used to test differences by sex in whole grain intake (raw and energy-adjusted), and the Kruskal-Wallis test was used to ascertain significant differences in whole grain intake by social classification. The Wilcoxon sign-rank test was used to test for the differences between weekday and weekend whole grain consumption. The non-parametric test for trend was utilised to test for trends of food groups (milk, cheese, meat, fish, etc.) and health outcomes (blood pressure, weight, etc.) across whole grain servings. Spearman's correlation co-efficient (rho) assessed correlation between food groups and nutrient intakes with whole grain intake.

Linear regression analysis is used to investigate associations between variables.
The simplest form of regression analysis relates one dependent (also known as the outcome) variable, y, to and one independent (also known as an explanatory or predictor) variable, x, using a straight line which takes the form;

$$y = \alpha + \beta x + \varepsilon ,$$

where α, the constant, is the intercept of the straight line along the y-axis when y=0 and β, the regression co-efficient, is the gradient of the regression line and ε is the model error/residual. This simple linear regression form is also referred to as univariate analysis, where one independent variable at a time is associated with the outcome. A regression line is estimated using a least squares approach which aims to fit a line in such a place that minimises the sum of the squared distances of the observed responses from the regression line, that is $\sum_{i=1}^{n}(\widehat{y_i} - y_i)^2$.

This simplest form of regression can be extended to a multiple regression model which relates y to a number of continuous or categorical independent variables. This model would take the form;

$$y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots + \varepsilon \ ,$$

where α is the intercept, β_1, β_2, β_3 are the regression co-efficients corresponding to x_1, x_2, x_3 (the independent predictor variables), and ε is the model error/residual.

Multiple (or multivariable) regression models can also be interpreted as an adjustment to an association between an outcome variable and one independent predictor variable. That is, an association between outcome, y, and predictor, x_1, is adjusted for any effect of x_2 or x_3 on the association between y and x_1. It may be stated that x_2 and x_3 are potential confounders of any association between y and x_1.

The assumptions of linear regression are

- There is a linear relationship between the predictor variables and the outcome
- The residuals/errors of the regression model are normally distributed and identically and independently distributed.
- The residuals/errors of the regression model are homoscedastic (i.e. the error variance should be constant)

Other considerations in regression models include outlying observations, which can be identified by a large residual/error, may also have a high leverage (how far the observation deviates from the mean of the outcome) and thus may be influential in the regression model. Regression diagnostics were used to check regression model assumption and investigate potential outliers.

The Mann-Whitney ranks sum test is a non-parametric (i.e. does not assume a specific distribution of the data) test for comparing the rank of observations in one group to the rank of observations in another group (the non-parametric equivalent to a Student’s t-test, which assumes a normal distribution of observations). The null hypothesis is that there is no systematic difference in the ranks of observations between the two groups. The alternative hypothesis tests against the null (i.e. there is a systematic/distribution difference in the ranks).

The assumptions of the Mann-Whitney test that must be met are:

- Independence of the two groups/samples (not related or paired data)
- The sample drawn from the population is random
- The measurement to be ranked is on an ordinal scale

The Kruskal-Wallis test is an extension to the Mann-Whitney test (following the same assumptions) where more than two groups can be compared, as is the non-parametric test for trend across ordered groups (which is analogous). The Wilcoxon sign-rank test follows a similar procedure as the Mann-Whitney test but allows for differences in paired observations (from the same participants) to be ranked and tested for systematic/distributional differences between two time points.

Spearman's correlation co-efficient (the non-parametric equivalent of Pearson's correlation coefficient) assesses the statistical dependence between the rankings of two variables. The co-efficient (rho) indicates the direction of association between two variables. If one variable, Y, increases as the other variable, X, increases, rho will be positive, with a value of 1 denoting perfect positive correlation. If Y decreases as X increases, rho will be negative, with -1 denoting perfect negative correlation. A rho of 0 denotes there is no correlation between the two variables.

3.4.3 Associations with nutrients, foods and health markers

Means and standard deviations (SD) of food and nutrient intakes were calculated for non-consumers of whole grain and by tertile of intake for consumers. In order to account for potential confounding of energy intake macro nutrient intakes are reported as a percentage of energy intake and micro nutrient intakes are reported per 10MJ of energy intake. Means and standard deviations of health outcomes were also calculated for non-consumers of whole grain and by tertile of intake for consumers. Associations across whole grain intakes (non-consumers and tertile groups) and intakes of other foods, nutrients and health markers were investigated using linear regression, with adjustment for age and sex as potential confounders in multivariable models; the dependent variable was the outcome of interest (e.g. sodium intake or blood pressure) and the independent predictor was whole grain intake group (non-consumer, tertile 1, tertile 2 and tertile 3). To eliminate potential confounding by sex, age and total energy intake (for health markers only), any significant associations were then adjusted for sex and, if the association remained significant, further adjusted for age and, finally for health marker outcomes, if the association remained significant it was further adjusted for total energy intake (MJ per day). Differences between non-consumers and tertiles of whole grain intake were assessed using independent t-tests, adjusting for sex (and age if required), within regression modelling. $P<0.05$ was used to denote significance throughout all statistical analysis. All analysis was done in Stata version 13 (StataCorp, 2013) utilising the complex survey functions.

3.5 Results

3.5.1 Terminology

For the purpose of this chapter, results presented are stratified into three cut-off points of whole grain content; foods containing any whole grain, foods containing 10% or more whole grain and foods containing 51% or more whole grain, in order for comparison with previously published studies. For ease of reporting, the following terminology is used throughout the results chapter.

Absolute (non-)consumers	Participants that (do not) consume foods with any whole-grain content
(Non-)consumers-10	Participants that (do not) consume foods with 10% or more whole-grain content
(Non-)consumers-51	Participants that (do not) consume foods with 51% or more whole-grain content

In addition to these terms, any use of the phrase "all whole-grain foods" refers to all the whole-grain foods identified with any whole grain content.

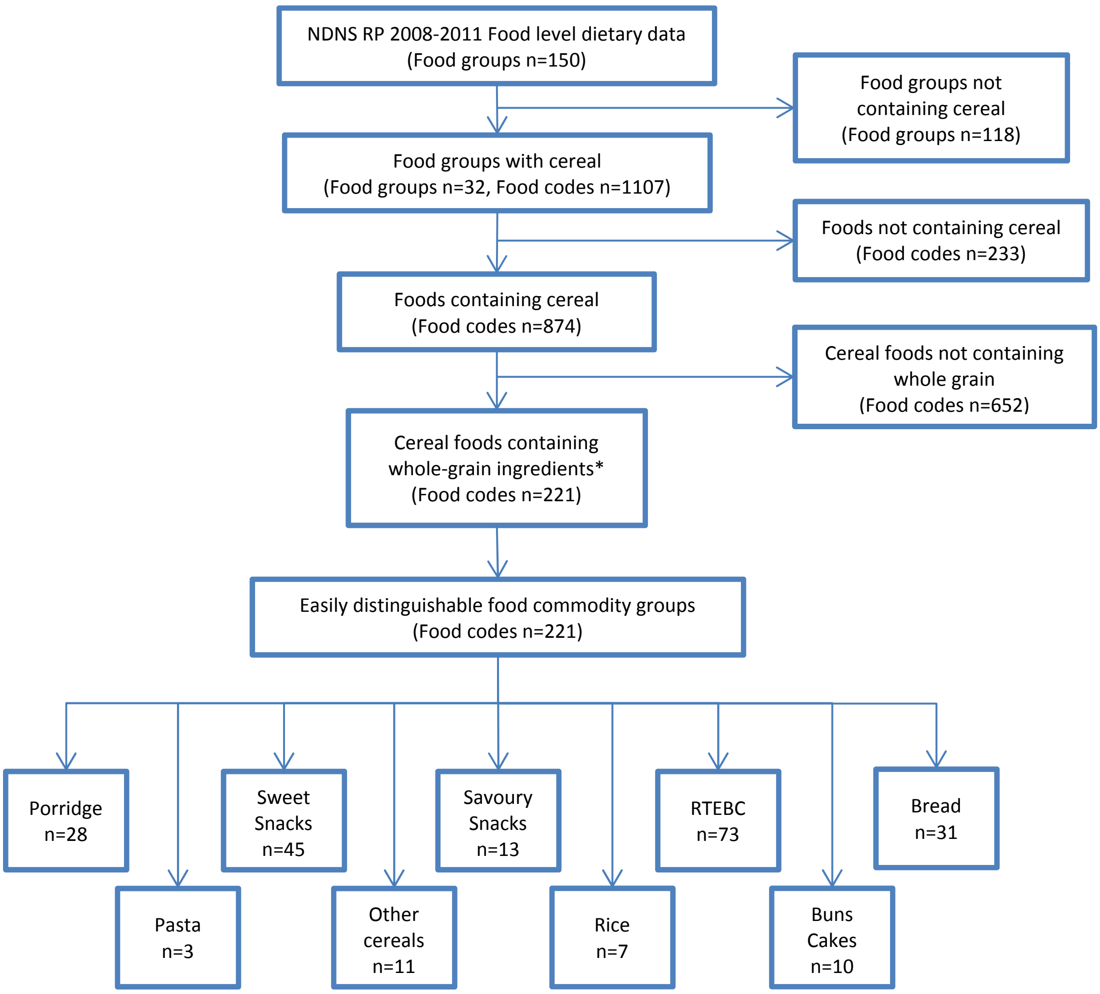
3.5.2 Descriptive details of the NDNS

During years 1-3 of the NDNS rolling programme 3073 individuals completed diet diaries. The participants' ages ranged from 1.5 to 94 years, with 48% male and 52% female. 16% of the total population were absolute non-consumers over the 4 days recorded, 18% were non-consumers-10 and 37% were non-consumers-51.

The absolute non-consumers of whole grain (across all age groups) were 54% male and 46% female. Absolute non-consumer adults (18 years+) were 49% male and non-consumer children/teenagers (1.5-17 years) were 51% male. Of the whole population, 18% of adults and 15% of children/teenagers were absolute non-consumers, with zero whole grain intake. At the higher cut-offs, 19% of adults and 17% of children/teenagers were classified as non-consumers-10 and 35% of adults and 40% of children/teenagers were classified as non-consumers-51.

3.5.3 Food categories for whole grain sources

A total of 221 different whole-grain foods were identified and sorted into nine food groups (Figure 3.1); Ready to Eat Breakfast Cereals (RTBEC), Sweet Snacks, Bread, Porridge, Savoury Snacks, Other Cereals, Bakes, Rice and Pasta. Descriptions of the foods contained in these food groups are given in Table 3.4 along with the number of different food product varieties in each food group. Note that varieties may be very similar within a food group, such as a food with a particular flavour and the same food with no or a different flavour. Each variety was counted separately; a complete list of all whole-grain foods encountered in the NDNS is presented in appendix B.



Food groups relate to the subsidiary food groups of the NDNS RP and food codes relate to the unique food code given to each food consumed assigned by the NDNS coders. *Whole grain ingredients as defined in Seal *et al.* (2006).

Figure 3.1 Flow diagram for the identification of whole-grain foods and whole-grain food groups.

Table 3.4 Description of whole-grain foods in the 9 food groups identified.

Food Group	Description of foods	Number of varieties
RTEBCs	All brand and own brand varieties of whole grain containing ready to eat breakfast cereals, muesli and granolas	73
Sweet snacks	Biscuits, cereal bars, flapjack, popcorn and yoghurts with whole grain cereals	45
Bread	All breads, rolls, pittas, chapatis, parathas and tortilla wraps made with wholemeal flour, rye flour, oatmeal or granary	31
Porridge	Branded (Ready Brek, Quaker) and own brand porridges	28
Savoury snacks	Crisp breads and crackers, tortilla chips and crisp-like snacks	13
Other cereals	Whole grain barley, millet, oats, quinoa and whole grain flours (wholemeal, rye, oatmeal)	11
Bakes	Whole grain malt loaf, scones, dumplings, fruit buns, jam tart, sponge, fruit cake and oatcakes	10
Rice	All brown rice varieties, wild rice and red rice	7
Pasta	All wholemeal/whole wheat pastas any shape	3
	Total	221

RTEBC: Ready to eat breakfast cereal

Of the 221 whole-grain foods identified, whole grain dry matter percentage for 112 foods were identically matched and 31 were matched to similar foods outlined in Jones *et al.* (2017). Product information (ingredients list) for the remaining 78 foods was collected via a range of sources (websites and supermarkets) as described in section 3.3.5.

3.5.4 Whole-grain food consumption

Over the duration of the diet diaries (a total of 12,239 days) there were 6,419 and 5,561 whole-grain food-eating occasions for adults and children/teenagers, respectively (Table 3.5). The most frequently consumed whole-grain foods were RTEBC (36%) in children/teenagers and whole-grain breads (44%) in adults. Sub-dividing the children/teenagers into smaller age groups (Table 3.5) showed that the most frequently consumed whole-grain foods were RTEBC in young children 1.5-5 years, whereas whole-grain bread was more frequently consumed by 5-17 year olds. The contribution of RTEBC to whole grain consumption declined with age. Sweet and savoury snack consumption was most prevalent in the teenagers (13-17 years), porridge consumption was favoured more by the oldest (over 65's) and whole-grain rice, pasta and bakes contributed to less than 3% of all whole-grain foods consumed.

Table 3.5 Percentage contribution of different food groups containing whole-grain foods to whole grain eating occasions by age

Food group / Age group years	Children/Teenagers			Adults						Total population
	1.5 to 5	5 to 12	13 to 17	18 to 24	25 to 34	35 to 44	45 to 54	55 to 64	65+	
RTEBC	38.7	34.7	32.3	33.6	28.1	26.8	27.7	26.3	24.5	31
Bread	35.6	35.2	35.1	41.1	42.7	44.7	44.5	46.3	41.1	39.7
Sweet snacks	11.7	19.8	21.0	10.9	15.8	12.5	11.1	10.7	13.7	14.6
Porridge	7.0	4.0	2.4	2.9	3.0	5.4	5.8	7.4	10.6	5.8
Savoury snacks	1.8	2.5	5.5	7.1	3.6	4.4	5.2	3.2	4.3	3.7
Other Cereals	3.2	1.8	1.5	1.5	2.6	3.9	3.6	4.0	4.4	3.0
Rice	0.9	0.6	1.6	1.5	3.7	1.5	1.0	1.0	0.7	1.2
Pasta	1.0	1.3	0.6	0.6	0.1	0.7	0.5	0.9	0.2	0.8
Bakes	0.1	0.1	0	0.8	0.4	0.1	0.6	0.2	0.5	0.2
n, consumers	426	514	335	143	167	263	233	218	270	
	Total 1275			*Total 1294*						2569
Total number of WG eating occasions	2109	2232	1220	479	727	1196	1166	1197	1654	
	Total 5561			*Total 6419*						11980

RTEBC: Ready to eat breakfast cereal; WG: Whole grain

3.5.5 10% and 51% cut off points for whole grain content of whole-grain foods

In total there were 11,980 whole-grain food eating occasions (Table 3.5, Table 3.6), 11,406 (95%) of these were of foods with 10% or more whole grain content and 6,673 (56%) of these were of foods with 51% or more whole grain content. Restricting the inclusion of whole-grain foods to foods containing 10% or more whole grain eliminated some porridge varieties and some sweet snacks such as biscuits, yoghurts and cereal bars. Restricting the inclusion of whole-grain foods to foods containing 51% or more whole grain eliminated foods across all food groups (Table 3.6).

Table 3.6 Percentage contribution of food groups containing whole-grain foods to whole grain eating occasions by whole grain content cut-off point

Whole grain food group	All whole grain foods	Foods containing ≥10% whole grain	Foods containing ≥51% whole grain
RTEBC	31.0	32.6	41.2
Bread	39.7	41.7	41.9
Sweet snacks	14.6	10.4	3.1
Porridge	5.8	6.0	2.4
Savoury snacks	3.7	3.9	6.0
Other cereals	3.0	3.2	5.2
Rice	1.2	1.2	0.07
Pasta	0.8	0.8	0.03
Bakes	0.2	0.3	0.2
Total number of eating occasions	11980	11406	6673
n, consumers	*2569*	*2518*	*1941*

RTEBC: Ready to eat breakfast cereal

3.5.6 Main grain type consumed

Across all foods identified the main whole grain consumed was wheat, accounting for 77% of the overall whole grain consumption (Figure 3.2) coming from a variety of foods, mainly bread (63%) and RTEBCs (32%). Oats accounted for 15% of all foods consumed coming from porridge (32%), RTEBCs (26%), other cereals (25%) and sweet snacks (15%). Maize consumption (3% of total) came from savoury snacks (47%), sweet snacks (33%) and RTEBCs (20%). The remaining grains rice, rye, barley, quinoa and millet cumulatively accounted for 2% or less each of overall whole grain consumption. When considering only foods with 10% or more whole grain, the relative proportions of the grain types consumed were not altered. When considering only foods with 51% or more whole grain content, the proportion of grain types consumed were 81% wheat, 12% oat, 4% maize, 2% rye, 0.7% barley and 0.3% rice.

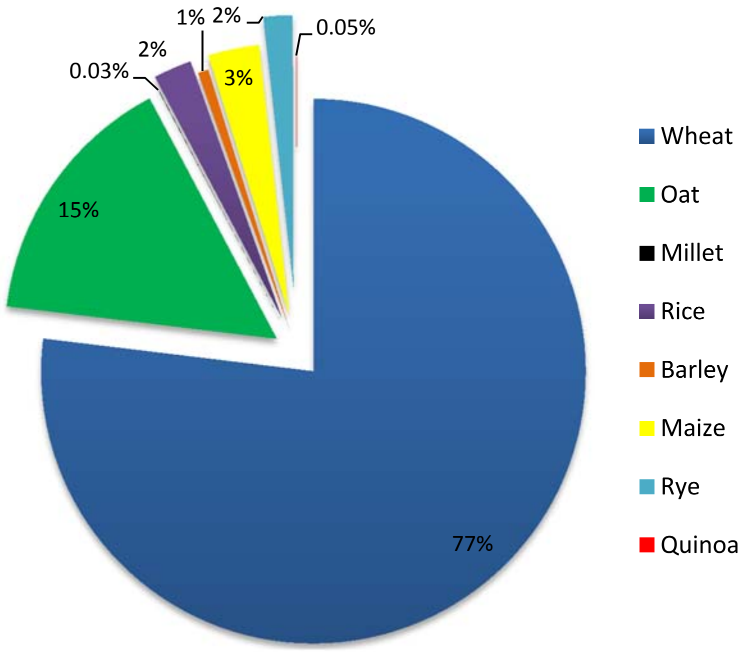


Figure 3.2 Main grain type of all whole grain foods consumed

3.5.7 Whole grain intake

Whole grain intake is presented as median (g/day) due to the skewed effect of the non-consumers in the population. Median daily intake described for age is reported in Table 3.7 and Figure 3.4, for consumers only reported in Table 3.8 and Figure 3.4, for sex reported in Figure 3.5, adjusting for energy intake in Table 3.9 and Figure 3.6, for social class reported in Table 3.10 and Figure 3.7 and for day of consumption in Table 3.11 and Figure 3.8.

Table 3.7 Whole grain intake from all foods described by age

Age (years)	N	Whole grain grams per day				
		Median	IQR	Min	Max	Weighted Median
1.5 up to 5	484	14.1	4.9, 26.5	0.0	89.7	14.3
5 to 12	577	14.9	5.2, 27.6	0.0	132.1	14.9
13 to 17	441	10.2	0.8, 24.2	0.0	138.7	10.2
18 to 24	194	12.1	0.0, 24.0	0.0	109.3	12.1
25 to 34	228	11.8	0.0, 33.6	0.0	285.6	12.2
35 to 44	311	19.9	6.7, 39.7	0.0	219.7	20.4
45 to 54	275	23.5	7.1, 44.0	0.0	180.8	23.4
55 to 64	258	23.4	8.4, 46.7	0.0	141.9	24.1
65+	305	23.5	8.82, 40.0	0.0	141.5	23.5
All	3073	16.7	4.8, 33.1	0.0	285.6	15.8

Median daily intake of whole grain ranged from 10 to 24g/d across age groups, with the lowest intake in those aged 13 to 17 years (Table 3.7). Median daily intake was 20 and 13g/d for adults (18+ years) and children/teenagers (1.5 to 17 years), respectively. Whole grain intake tended to increase with age (Figure 3.3) with the exception of teenagers (13-17 years) and younger adults up to age 34 years, whose intakes were lower than for all other age groups. In the oldest age grouping, 65years+, there was a small decline in weighted median daily intake compared with the previous age group.

Little or no differences in median daily whole grain intake were seen when considering only foods containing 10% or more whole grain compared with all whole grain foods (Figure 3.3). However, when considering only foods containing 51% or more whole grain, median daily intakes were much lower. When using this cut-off value, median intake ranged from 3 to 16 g/d, again with the lowest intake in those aged 13 to 17 years (Figure 3.3). Daily whole grain intake of foods with 51% or more whole grain content declined by age in children and teenagers up to age 17 years, remained low in young adults up to age 34 years and was similar across adults from ages 35 to 65+ years.

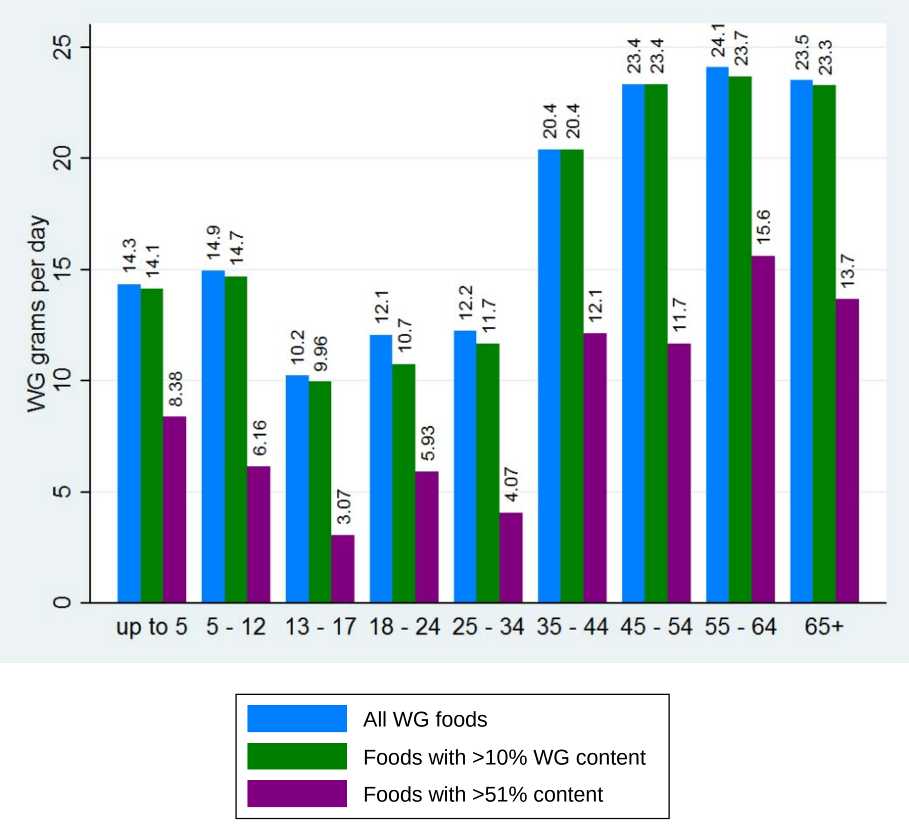


Figure 3.3 Median whole grain intake per day by age

3.5.7.1 Consumers only

Median whole grain intakes in adult consumers, consumers-10 and consumers-51 only were 26, 26 and 23g/d, respectively. Median whole grain intakes in child/teenage consumers, consumers-10 and consumers-51 only were 16, 17 and 15g/d, respectively. Median daily intake of whole grain ranged from 15 to 29g/d across age groups, with the lowest intake in those aged 13 to 17 years (Table 3.8). Whole grain intake tended to increase with age (Figure 3.4) with the exception of teenagers (13-17 years). In the oldest age grouping, 65years+, there was a small decline in median daily intake compared with the previous age group. Little differences in whole grain intake were seen by considering consumer only intakes from foods with 10% or more whole grain and there were small reductions in the numbers of consumers. There were 1% fewer adult and 2% fewer child/teenage consumers-10. When considering only foods containing 51% or more whole grain, median daily intakes were lower in older adults but were similar for children/teenagers and adults up to age 44 years. When using this cut-off value, median intake ranged from 14 to 26 g/d, again with the lowest intake in those aged 13 to 17 years (Figure 3.4). Daily whole grain intake of foods with 51% or more whole grain content declined by age in children and teenagers up to age 17 years, remained low in young adults up to age 24 years and was similar across adults from ages 25 to 65+ years. There were less consumers with 17% fewer adult and 25% fewer child/teenage consumers-51.

Table 3.8 Whole grain intake of all foods for consumers only

Age (years)	N	% of total pop	Whole grain grams per day				
			Median	IQR	Min	Max	Weighted Median
1.5 up to 5	426	88	16.7	8.1, 28.3	0.1	89.7	16.7
5 to 12	514	89	17.1	8.4, 30.4	0.5	132.1	16.8
13 to 17	335	76	16.0	7.6, 28.6	0.2	138.7	14.8
18 to 24	143	73	18.3	9.9, 28.5	0.9	109.3	18.6
25 to 34	167	73	25.5	8.8, 40.7	0.4	285.6	26.2
35 to 44	263	85	25.9	12.8, 42.2	0.7	217.7	26.0
45 to 54	233	84	29.0	12.2, 46.5	0.4	180.8	28.8
55 to 64	218	84	27.5	14.9, 50.9	0.9	141.9	28.9
65+	270	85	26.4	15.1, 43.3	0.3	141.5	26.4
All	2569	84	20.4	9.9, 36.4	0.1	285.6	20.1

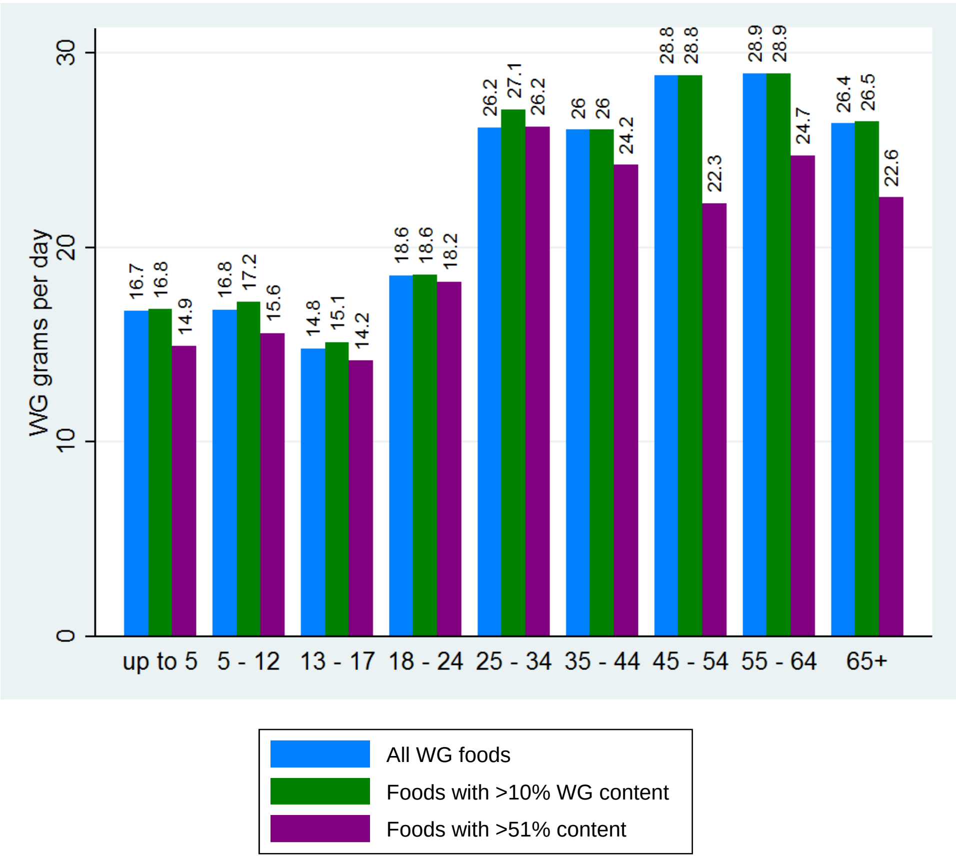


Figure 3.4 Median whole grain intake per day for consumers only by age

3.5.7.2 Sex and age

Median whole grain intakes, of all foods and foods with 10% or more whole grain content, for adult males and females were 20 and 19g/d respectively (Figure 3.5) which were not significantly different (p=0.455, Mann-Whitney). For children and teenage males and females, median intakes were significantly higher for males compared with females (p<0.001, Mann-Whitney) at 15 and 11g/d, respectively. Considering foods with 51% or more whole grain content, median daily whole grain intake of adults was reversed with females having a slightly higher intake than males (Figure 3.5), although this difference in intake was not significant (p=0.914, Mann-Whitney).

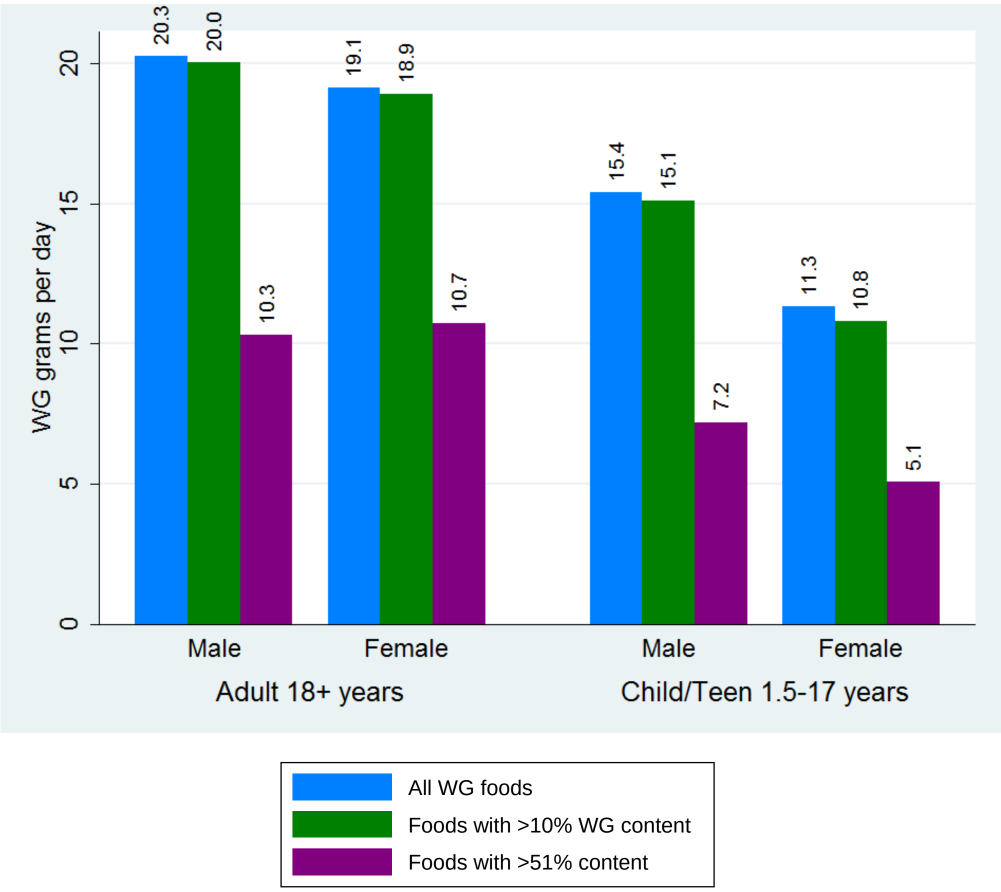


Figure 3.5 Median whole grain intake per day by sex

3.5.7.3 Energy-adjusted whole grain intake

Adjusting whole grain intake for total energy (MJ) consumed per day did not alter the pattern of intake across age, with the lowest consumption in teenagers (13-17 years) of 1.5g/MJ per day (Table 3.9, Figure 3.6).

Table 3.9 Median whole grain intake per day by age adjusted for total energy per day

Age (years)	N	Whole grain grams per MJ per day				
		Median	IQR	Min	Max	Weighted Median
1.5 up to 5	484	2.7	0.9, 5.0	0.0	15.6	2.7
5 to 12	577	2.2	0.8, 4.1	0.0	15.1	2.2
13 to 17	441	1.5	0.1, 3.2	0.0	14.3	1.5
18 to 24	194	1.5	0.0, 3.3	0.0	14.3	1.6
25 to 34	228	1.7	0.0, 4.4	0.0	23.8	1.7
35 to 44	311	2.9	0.8, 5.2	0.0	18.3	2.9
45 to 54	275	3.1	1.0, 5.9	0.0	12.7	3.1
55 to 64	258	3.4	1.2, 6.4	0.0	14.9	3.4
65+	305	3.4	1.3, 5.7	0.0	18.6	3.4
All	3073	2.3	0.7, 4.8	0.0	23.8	2.3

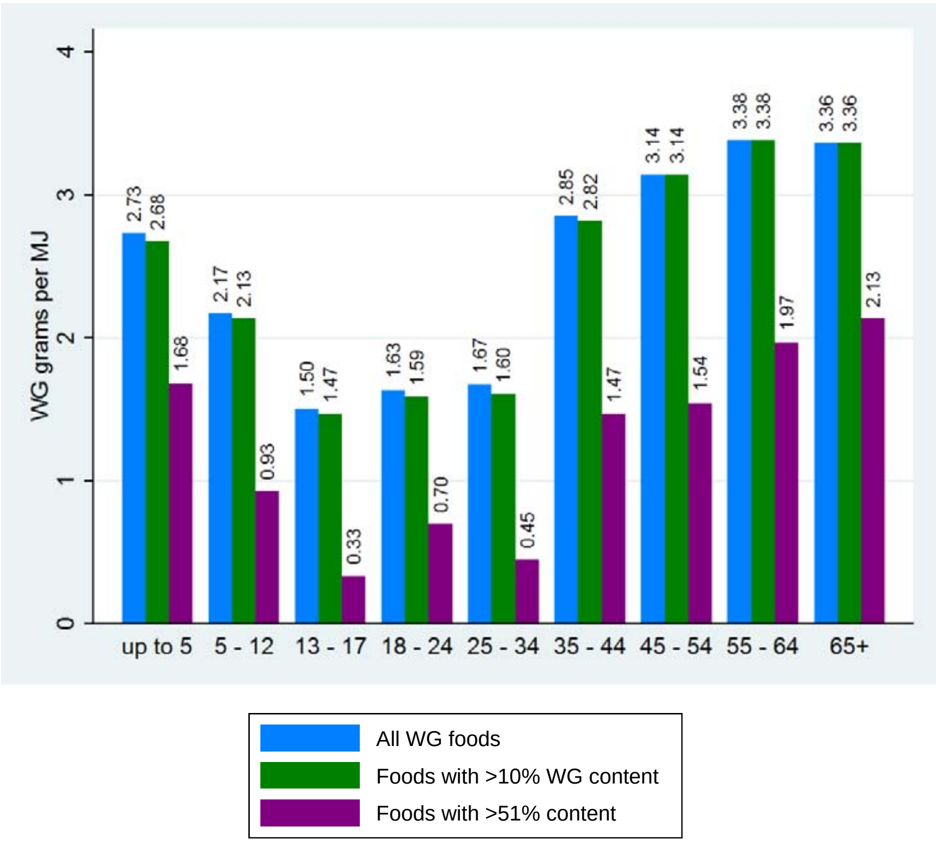


Figure 3.6 Median whole grain intake per day adjusted for total energy intake by age

Median energy-adjusted whole grain intake for adults was 2.5g/MJ per day and 3.1g/MJ per day for males and females, respectively. Median energy adjusted whole grain intake for children/teenagers was 2.2g/MJ per day and 1.9g/MJ per day for males and females, respectively.

No significant difference between unadjusted whole grain intake for adult males and females was observed, however, after adjustment for energy intake a significant difference ($p=0.002$, Mann-Whitney) was present with a higher intake seen in females. In children/teenagers a significant difference in unadjusted median whole grain intake for males and females was observed, however, after adjustment for energy intake the difference was no longer significant ($p=0.05$, Mann-Whitney). Considering foods with 10% and 51% or more whole grain content, the differences in whole grain intake by sex for both adults and children were also observed and were of a similar magnitude.

3.5.7.4 Social class

Details of social class were available for 3008 (98%) of the participants completing a diet diary. Median daily whole grain intake of all foods increased by social classification, with highest intakes in the most advantaged social class and smallest in the lower two classes 7 and 8 (Table 3.10, Figure 3.7). Each NS-SEC classification contained absolute non-consumers of whole grain with 9% absolute non-consumers in class 1 increasing up to 26% and 20% in classes 7 and 8, respectively. There was a significant difference in median whole grain intake per day ($p<0.001$, Kruskal Wallis) with social class measured by the NS-SEC.

Table 3.10 Median whole grain intake per day, all foods, by social class measured by the NS-SEC

Social class using NS-SEC (8)		N (%)	Whole grain grams per day				
			Median	IQR	Min	Max	Weighted Median
1	Higher managerial & professional occupations	446 (15%)	23.9	10.1, 38.9	0.0	219.7	23.8
2	Lower managerial & professional occupations	833 (28%)	18.0	6.7, 34.5	0.0	141.9	17.9
3	Intermediate occupations	256 (8%)	17.1	5.0, 31.3	0.0	157.7	17.0
4	Small employers & own account workers	330 (11%)	15.6	3.7, 31.5	0.0	157.0	14.8
5	Lower supervisory & technical occupations	327 (11%)	14.7	3.6, 34.4	0.0	156.4	14.8
6	Semi-routine occupations	404 (13%)	12.3	2.0, 28.8	0.0	180.9	13.5
7	Routine occupations	333 (11%)	8.1	0.0, 21.2	0.0	285.6	8.1
8	Never worked	79 (3%)	9.9	0.9, 24.2	0.0	98.9	8.1
	All	3008	16.2	4.4, 32.3	0.0	285.6	15.9

Little differences in median intakes across NS-SEC classes were seen when restricting to foods containing 10% or more whole grain (Figure 3.7). Considering foods with 51% or more whole grain content the trend across NS-SEC classifications was less varied between highest class and classification 6. At this cut-off, median whole grain intake was 0g/d for the lower two social classes and ranged between 5 and 14g/d across the remaining classes.

Figure 3.7 Median whole grain intake per day by social class

3.5.7.5 Day of consumption

It was assumed that there was equal representation of days across which the diet diaries were recorded due to the NDNS design (described in the methodology). However, during year three of the survey (2010-2011) flexibility of diary start day was given to participants and, therefore, there was a slightly higher proportion of weekend days on which diet diaries were recorded (Table 3.11). Median whole grain intake on weekdays ranged from 12.3g on Wednesdays to 15.8g on Mondays. Intake on both Saturdays and Sundays was below this at 9.7g and 7.7g, respectively. Averaged across weekdays, median intake was 16.3g/d and for the weekend 12.5g/d which was significantly different ($p<0.001$, Wilcoxon). There were only small differences in median intakes across the week considering only foods containing 10% or more whole grain. In contrast, restricting to only foods containing 51% or more whole grain, median intake was 0g on every day when including the weekend and 7.3g/d when averaged across weekdays only.

Table 3.11 Whole grain intake, all foods, by day of consumption

Day	N	Whole grain intake grams				
		Median	IQR	Min	Max	Weighted Median
Monday	1653	16.2	0.0, 37.4	0.0	285.6	15.8
Tuesday	1484	14.0	0.0, 36.0	0.0	285.6	13.7
Wednesday	1400	13.0	0.0, 36.0	0.0	285.6	12.3
Thursday	1701	13.6	0.0, 34.5	0.0	250.3	14.1
Friday	1965	14.3	0.0, 35.6	0.0	224.4	14.3
Saturday	2026	10.8	0.0, 32.9	0.0	241.7	9.7
Sunday	2010	8.2	0.0, 31.9	0.0	285.6	7.7
Weekdays	3073	16.4	1.8, 34.3	0.0	285.6	16.3
Weekends	2383	12.9	0.0, 30.1	0.0	285.6	12.5

In adults, median whole grain intake declined across the week starting with the highest intake on Mondays (Figure 3.8), was lower on Wednesdays followed by an increase on Thursdays before declining to the weekend days. In children/teenagers median whole grain intake was much lower on weekends than weekdays where intake was highest on Mondays and Fridays.

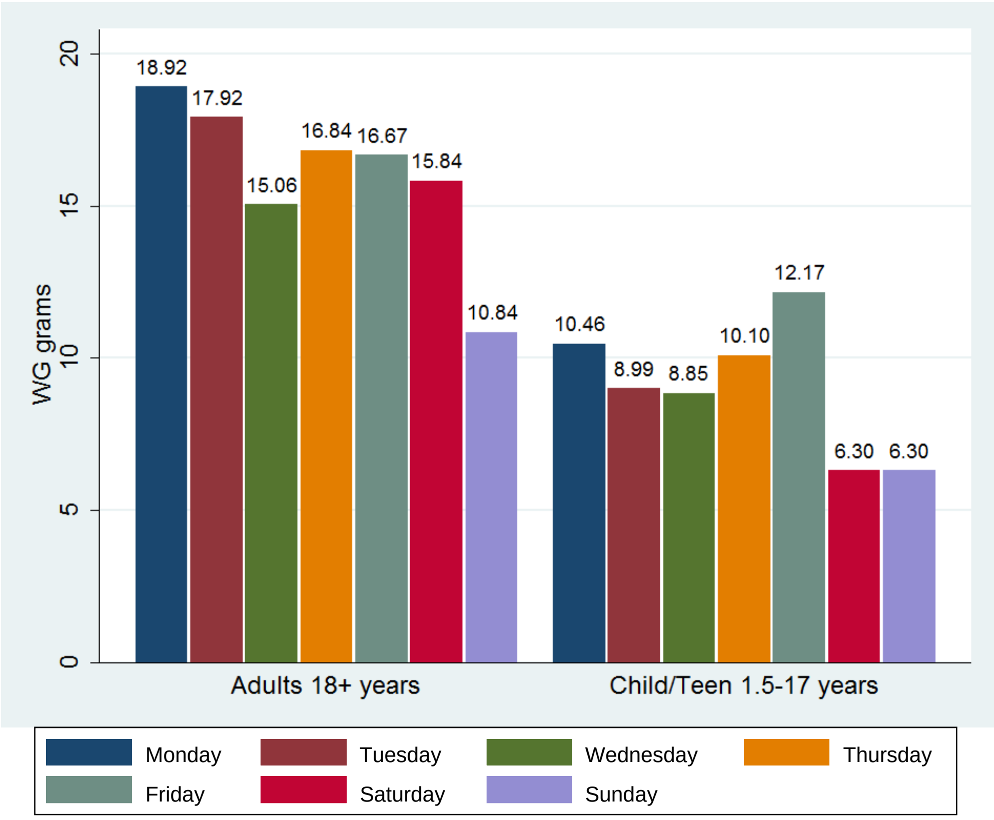


Figure 3.8 Median whole grain intake, all foods, by day for adults and children

3.5.8 Servings of whole grain intake

A suggested serving portion of whole grain is 16g (Oldways Whole Grains Council, 2003-2013a). As previously reported and shown in Figure 3.9, 18% of adults and 15% of children/teenagers did not consume any whole-grain foods during the food diary recording period. The current recommendation in the US is for adults to eat at least 3 (48g) to 5 (80g) servings of whole grain and children to eat 2 (32g) to 3 or more servings a day (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015-2020). In this population 83% of adults did not consume 3 servings of whole grain and 83% of children/teenagers did not consume 2 servings per day. As shown in Figure 3.9, 44% of adults and 57% of children/teenagers did not consume one serving of whole grain per day.

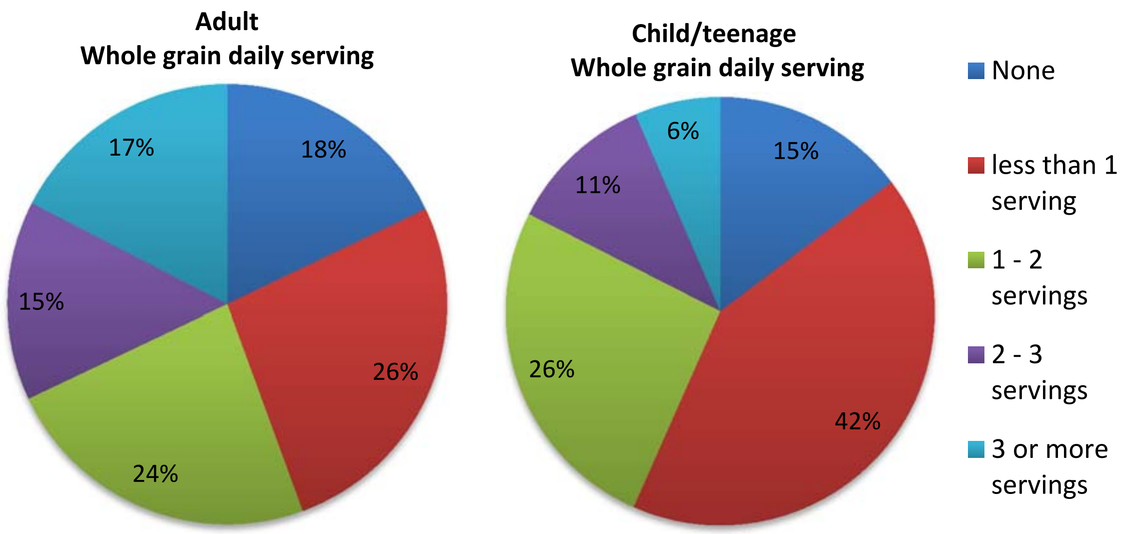


Figure 3.9 Proportion of consumers per whole grain serving

Considering foods containing 10% or more whole grain, 83% of adults did not consume 3 servings of whole grain and 84% of children/teenagers did not consume 2 servings per day. Considering foods containing 51% or more whole grain, 89% of adults did not consume 3 servings of whole grain and 90% of children/teenagers did not consume 2 servings per day.

3.5.9 Who whole-grain foods were consumed with

The four-day diet diaries included details of who meals were eaten with and information on 92% of the whole-grain foods consumed was available. Whilst 48% of adults ate whole-grain foods alone, averaged across the whole population most whole-grain foods were consumed in the company of family (48% including parents, partners, carers, children and siblings), smaller amounts were consumed with friends and 32% of whole-grain foods were eaten alone (Table 3.12).

Table 3.12 Who whole grain foods were eaten with

	Adult 19+		Children/Teenagers		Total	
	Eating occasions	**%**	**Eating occasions**	**%**	**Eating occasions**	**%**
Alone	3046	48.9	771	13.4	3817	31.9
Partner	1126	18.1	27	0.5	1153	9.6
Partner & Children	227	3.6	6	0.1	233	2.0
Child/Children	350	5.6	4	0.1	354	2.96
Family (incl. Relatives)	360	5.8	665	11.6	1,025	3.0
Friends	176	2.8	744	13.0	920	7.7
Family & Friends	25	0.4	70	1.2	95	0.8
Parent(s)/Carer	27	0.4	1421	24.7	1448	12.1
Siblings	7	0.1	544	9.5	551	4.6
Parent(s)/Carer & Siblings	7	0.1	939	16.4	946	7.9
Carer & Other Children	1	0.02	52	0.9	53	0.4
Work colleagues	310	5.0	10	0.2	320	2.7
Flatmate	16	0.3	4	0.1	20	0.2
Others General public	3	0.1	1	0.02	4	0.03
Others - Known to Respondent	31	0.5	18	0.3	49	0.4
Not specified	523	8.4	468	8.2	991	8.3
Total	**6235**	**100**	**5744**	**100**	**11979**	**100**

3.5.10 Location of whole grain food consumption

Eating location details for 99% of all whole-grain foods consumed were available. Specific eating locations with the frequency and percent of all whole-grain foods consumed are presented in Table 3.13. In summary, 83% of all whole-grain foods were eaten within the home environment, 6% eaten at the workplace, 6% at school, 1.4% “on the go”, 1% in a food establishment and less than 1% each during social entertainment, in a community group and in an outside place. For adults only, a slightly larger proportion (11%) of whole-grain food-eating occasions were at the work place whereas for children/teenagers only, a larger proportion of whole-grain food-eating occasions were at school.

Table 3.13 Location of whole-grain food consumption

Location		Adults		Children/Teenagers		Total	
		Eating occasions	%	Eating occasions	%	Eating occasions	%
Home	Carer's home	-	-	13	0.2	13	0.1
	Friend's or Relative's house	98	1.6	195	3.4	293	2.5
	Home - Bedroom	165	2.7	164	2.9	329	2.8
	Home - Dining Room	607	9.7	756	13.2	1363	11.4
	Home - Garden	63	1.0	45	0.8	108	0.9
	Home - Kitchen	1892	30.3	1569	27.3	3461	28.9
	Home - Living Room	2009	32.2	1606	28.0	3615	30.2
	Home - Other	303	4.9	248	4.3	551	4.6
	Home - Unspecified	103	1.7	100	1.7	203	1.7
	Holiday Accommodation	7	0.1	7	0.1	14	0.1
	Total	5247	84.2	4703	81.9	9950	83.1
Work	Work - Canteen - Bought food	20	0.3	5	0.1	25	0.2
	Work - Canteen - Food from home	113	1.8	9	0.2	122	1.0
	Work - Canteen - Other	22	0.4	-	-	22	0.2
	Work - Desk	311	5.0	6	0.1	317	2.7
	Work - Other	221	3.5	11	0.2	232	1.9
	Total	687	11.0	31	0.5	718	6.0
School	Nursery/Kindergarten	-	-	65	1.1	65	0.5
	School - Canteen - Bought food	-	-	65	1.1	65	0.5
	School - Canteen - Food from home	8	0.1	312	5.4	320	2.7
	School - Canteen - Other	2	0.03	2	0.03	4	0.03
	School - Classroom	4	0.1	46	0.8	46	0.4
	School - Other	-	-	146	2.5	150	1.3
	School - Playground	-	-	54	0.9	54	0.5
	Total	14	0.2	690	12.0	704	5.9
On the go	Street	6	0.1	25	0.4	31	0.3
	Bus, car, train	72	1.2	67	1.2	139	1.2
	Total	78	1.3	92	1.6	170	1.4
Food establishment	Coffee shop, cafe, deli, sandwich bar	37	0.6	27	0.5	64	0.5
	Fast food outlet	1	0.02	5	0.1	6	0.1
	Restaurant, pub, night club	34	0.6	11	0.2	45	0.4
	Total	72	1	43	0.8	115	1.0
Entertainment	Sports club, sports leisure venue	10	0.2	18	0.3	28	0.2
	Leisure Activities, shopping , cinema	20	0.3	40	0.7	60	0.5
	Total	30	0.5	58	1.0	88	0.7
Community	Place of Worship	6	0.1	7	0.1	13	0.1
	Community Centre, Day Centre	7	0.1	3	0.1	10	0.1
	Public Hall, Function Room	5	0.1	2	0.03	7	0.1
	Total	18	0.3	12	0.2	30	0.3
Other	Other place	7	0.1	7	0.1	14	0.1
	Outside - Other	35	0.6	55	1.0	90	0.8
	Unspecified	47	0.8	53	0.9	100	0.8
	Total	89	1.4	115	2.0	204	1.7

3.5.11 Dietary intakes of whole grain consumers vs. non-consumers

Mean nutrient values derived from the four-day diet diaries of whole grain consumers vs. non-consumers are presented in Table 3.14. Significant differences between adult whole grain consumers and non-consumers were seen for mean daily intake of energy from protein, energy from non-milk extrinsic (NME) sugar, fibre, iron, calcium, vitamin E, potassium, phosphorus, magnesium, thamin and riboflavin. All of these reported intakes were significantly higher in the whole grain consumers except for energy intake from NME sugars which were higher in non-consumers ($p<0.05$, Table 3.14). In children/teenagers, significant differences between whole grain consumers and non-consumers were seen with higher mean daily intake of energy from carbohydrates, energy from total sugars, fibre, iron, calcium, potassium, phosphorus, magnesium, thamin and riboflavin for whole grain consumers. Mean daily intakes of energy from alcohol and sodium were significantly higher in the non-whole grain consumers.

The correlations of daily whole grain intake with other nutrients consumed in the four-day diet diary are presented in Table 3.14. Moderate positive correlation of whole grain consumption was seen with consumption of iron, potassium, phosphorus and magnesium and strong positive correlation with fibre intake in adults. In children/teenagers, moderate positive correlation of whole grain consumption was seen with fibre, iron and magnesium daily intake.

Table 3.14 Dietary intakes of all whole grain consumers vs. non-consumers

Daily nutrient intake	Child/Teen 1.5 – 18 years						Adult 19+ years					
	Consumers n=1333		Non-consumers n=249		t-test	Correlation with daily WG intake	Consumers n=1236		Non-consumers n=255		t-test	Correlation with daily WG intake
	Mean	SD	Mean	SD	p-value		Mean	SD	Mean	SD	p-value	
Energy (kcal)	1608	443	1590	543	0.681	0.16†	1839	578	1851	702	0.843	0.20†
Energy (MJ)	6.8	1.9	6.7	2.3	0.668	0.16†	7.7	2.4	7.8	2.9	0.859	0.20†
% energy from protein	14.8	2.6	14.7	2.9	0.826	0.07†	16.7	4.0	16.0	4.4	0.045	0.11†
% energy from carbohydrate	51.2	5.4	50.0	5.3	0.006*	0.09†	45.5	7.4	44.7	8.1	0.170	0.10†
% energy from total sugar	22.9	6.1	21.9	6.0	0.015*	0.00	19.6	6.3	19.2	7.5	0.473	0.01
% energy from NME sugars	14.4	5.7	14.7	5.9	0.470	-0.08†	11.1	5.6	13.2	7.5	<0.001*	-0.15†
% energy from fat	33.7	4.8	34.3	4.9	0.126	-0.11†	33.2	6.5	34.0	6.7	0.106	-0.09†
% energy from saturated fat	13.2	2.9	12.7	3.0	0.053	-0.03	12.3	3.4	12.5	3.6	0.539	-0.08†
% energy from alcohol	0.3	2.2	0.9	3.8	0.046*	-0.07†	4.6	6.8	5.4	7.8	0.185	-0.08†
Fibre (g/10MJ)	17.0	4.5	14.7	4.5	<0.001*	0.41†	19.2	6.1	14.5	5.3	<0.001*	0.39†
Sodium (mg/10MJ)	2930.7	655.0	3056.8	783.0	0.028*	-0.03	2979.9	776.3	3087.3	807.4	0.065	-0.08†
Iron (mg/10MJ)	13.5	3.1	11.6	3.3	<0.001*	0.36†	14.6	3.5	12.4	5.6	<0.001*	0.22†
Calcium (mg/10MJ)	1218.4	377.3	1118.6	433.4	0.003*	0.09†	1104.6	308.5	996.8	389.4	0.001*	0.12†
Vitamin E (mg/10MJ)	10.6	2.9	11.1	3.7	0.070	0.04	11.7	3.8	11.0	4.4	0.027*	0.08†
Potassium (mg/10MJ)	3323.2	664.3	3208.2	685.8	0.037*	0.09†	3816.7	876.1	3331.5	837.1	<0.001*	0.18†
Phosphorus (mg/10MJ)	1580.0	274.5	1475.1	310.3	<0.001*	0.22†	1667.2	322.4	1516.7	414.2	<0.001*	0.27†
Magnesium (mg/10MJ)	298.7	53.8	265.2	47.8	<0.001*	0.43†	344.7	73.6	287.0	100.9	<0.001*	0.39†
Thamin (mg/10MJ)	2.0	0.5	1.8	0.5	<0.001*	0.18†	1.9	0.6	1.8	0.7	0.001*	0.13†
Riboflavin (mg/10MJ)	2.3	0.8	1.9	0.9	<0.001*	0.14†	2.2	0.8	1.9	0.9	<0.001*	0.14†
Niacin (mg/10MJ)	42.6	11.1	43.0	15.6	0.739	0.08†	48.3	14.3	47.3	15.3	0.367	0.10†
Vitamin B6 (mg/10MJ)	2.8	1.0	3.0	2.0	0.346	0.00	3.0	1.1	2.9	1.3	0.723	0.03
Vitamin B12 (µg/10MJ)	6.1	2.6	5.9	3.3	0.448	0.05	7.5	5.4	6.8	6.0	0.134	0.06†
Vitamin D (µg/10MJ)	3.0	1.9	3.2	3.3	0.548	0.03	3.9	2.7	3.8	3.2	0.775	0.06†

WG: Whole grain; *p-value<0.05; †correlation co-efficient p<0.05

3.5.12 Whole grain tertiles

Whole grain intakes were split into tertiles of intakes and compared to non-consumers. Adult whole grain intakes in tertile 1 (T1) ranged from 0.3 to 16g/d with a mean of 8g/d in tertile 2 (T2) ranged from 17 to 35g/d with a mean of 26g/d and in tertile 3 (T3) ranged from 36 to 286g/d with a mean of 61g/d. There were more adult females than males in T1 and T2 and more adult males in T3 and non-consumers (Table 3.15). Child/teenage whole grain intakes in T1 ranged from 0.1 to 10g/d with a mean of 5g/d in T2 ranged from 11 to 24g/d with a mean of 16g/d and in T3 ranged from 25 to 139g/d with a mean of 40g/d. There were more girls than boys in T1 and T2, more boys than girls in T3 and an equal split of boy and girl non-consumers (Table 3.15).

Table 3.15 Adult and child whole grain intake by tertile of intake

	Whole grain intake (g/d)				
	Non-consumers	Mean (SD)			Total population
		T1 (Lowest)	T2	T3 (Highest)	
Children/Teenagers (1.5-17 years)	0	5.4 (2.8)	16.5 (3.7)	40.1 (16.4)	17.8 (18.1)
Sex %male	50%	44%	49%	60%	51%
Age, years Mean (SD)	10.7 (5.2)	9.6 (4.9)	9.1 (4.7)	8.9 (4.7)	9.4 (4.9)
n (%) *unweighted*	227 (15)	415 (28)	418 (28)	442 (29)	1502 (100)
Adults (18+ years)	0	8.4 (4.6)	25.7 (5.5)	61.0 (26.8)	26.2 (27.8)
Sex %male	56%	44%	43%	55%	49%
Age, years Mean (SD)	40.6 (17.7)	44.1 (19.1)	49.6 (18.9)	49.4 (17.7)	46.4 (18.8)
n (%) *unweighted*	277 (18)	431 (27)	426 (27)	437 (28)	1571 (100)

T: Tertile; SD: Standard deviation

3.5.13 Whole grain tertile and nutrient intakes

Mean nutrient intakes of non-consumers and by tertile of consumption are presented in Table 3.16. Significant associations, adjusted for sex, for higher intakes of whole grain were seen with greater intake of total energy and energy from protein, carbohydrates and total sugar (in children/teenagers only). Higher intake of whole grain was also significantly associated with greater intake of fibre, iron, calcium, vitamin E (in adults only), potassium, phosphorus, magnesium, thamin, riboflavin, niacin (in children/teenagers only), vitamin B12 (in adults only) and vitamin D (in adults only). Higher intake of whole grain, adjusted for sex, was significantly associated with lower intake of energy from NME sugar, fat and alcohol (in adults only). Further adjustment for age did not attenuate most of the associations of nutrient intakes with whole grain intake groups. In adults, further adjustment for age, resulted in the difference in energy intake from fat between non-consumers and whole grain consumers in T3 becoming significant (p=0.026) as well as the difference in energy intake from saturated fat between non-consumers and whole grain consumers in T2 and T3 also becoming significant (p=0.015). Finally, mean intakes of vitamins B12 and D for whole grain consumers in T3 were no longer significantly different from mean intakes in non-consumers nor was there a significant increase in these nutrient intakes across tertiles, after adjustment for age (vit B12 p=0.511, vit D p=0.112, Table 3.16). In children/teenagers, further adjustment for age, resulted in significant differences in total energy intakes (kcal and MJ) between whole grain consumers in T2 and T3 compared with non-consumers, whereas these were previously not significantly different and the differences in calcium intakes between whole grain consumers in T2 and T3 compared with non-consumers were no longer significant.

Table 3.16 Dietary intakes of non-consumers and by tertile of whole grain consumption.

	Child/Teenage mean					**Adult mean**				
	Whole grain intake per day					**Whole grain intake per day**				
Nutrient	**0g/d**	**T1**	**T2**	**T3**	**p-value**	**0g/d**	**T1**	**T2**	**T3**	**p-value**
Energy (kcal)	1549	1528	1582	1683†	<0.001*	1862	1743	1784	1987†	<0.001*
Energy (MJ)	6.5	6.4	6.7	7.1†	<0.001*	7.8	7.3	7.5	8.4†	<0.001*
% energy from protein	14.8	14.6	14.5	15.1	0.025*	15.8	16.2	16.9†	16.7†	0.009
% energy from carbohydrate	50.3	50.7	51.5†	51.8†	0.001*	44.9	44.5	45.5	46.6†	<0.001*
% energy from total sugar	21.8	22.7	23.6†	23.0†	0.007*	19.5	19.1	19.8	19.9	0.282
% energy from NME sugars	14.3	14.6	14.8	13.8	0.021*	13.6	12.0†	11.2†	10.6†	<0.001*
% energy from fat	34.7	34.4	33.8†	33.0†	<0.001*	33.7	34.0	32.9	32.8	0.032*
% energy from saturated fat	13.0	13.4	13.3	13.1	0.371	12.4	12.7	12.2	12.2	0.200
% energy from alcohol	0.2	0.2	0.1	0.1	0.185	5.6	5.3	4.7	3.9†	0.030*
Fibre (g/10MJ)	14.8	15.1	16.8†	19.3†	<0.001*	14.4	16.2†	19.2†	21.6†	<0.001*
Sodium (mg/10MJ)	3051	2978	2885†	2910†	0.050	3090	3027	2989	2934†	0.115
Iron (mg/10MJ)	11.7	12.3†	13.3†	15.0†	<0.001*	12.3	13.6†	14.7†	15.2†	<0.001*
Calcium (mg/10MJ)	1147	1169	1234†‡	1276†‡	<0.001*	984	1044	1114†	1149†	<0.001*
Vitamin E (mg/10MJ)	11.1	10.5†	10.7	10.5	0.207	11.0	11.2	11.8	12.1†	<0.001*
Potassium (mg/10MJ)	3233	3255	3322	3422†	<0.001*	3303	3549†	3884†	3916†	<0.001*
Phosphorus (mg/10MJ)	1489	1520	1563†	1665†	<0.001*	1502	1556	1674†	1752†	<0.001*
Magnesium (mg/10MJ)	264.7	276.1†	294.3†	326.0†	<0.001*	286	306†	344†	376†	<0.001*
Thamin (mg/10MJ)	1.8	1.9†	2.0†	2.1†	<0.001*	1.8	1.8	2.0†	2.0†	<0.001*
Riboflavin (mg/10MJ)	2.0	2.1	2.3†	2.4†	<0.001*	1.8	2.0	2.2†	2.3†	<0.001*
Niacin (mg/10MJ)	41.7	41.7	41.4	44.2†	0.002*	47.9	46.7	48.5	49.1	0.130
Vitamin B6 (mg/10MJ)	2.8	2.8	2.8	2.9	0.474	3.1	2.9	3.0	3.0	0.581
Vitamin B12 (µg/10MJ)	6.0	5.8	6.1	6.4	0.050	6.7	6.9	7.6	7.7†‡	0.033*‡
Vitamin D (µg/10MJ)	3.3	2.9	3.1	3.1	0.268	3.7	3.5	4.0	4.1†‡	0.007*‡
n (*unweighted*)	*227*	*415*	*418*	*442*		*277*	*431*	*426*	*437*	

T: Tertile; NME: Non-milk extrinsic; *p<0.05; association across intakes of whole grain and nutrient intake (linear regression, adjusted for sex); † Significantly different from non-consumers (p<0.05 t-test, adjusted for sex). ‡p>0.05 after adjustment for sex and age

3.5.14 Association of whole grain intake with intake of other foods

Mean dietary intakes of other foods for non-consumers and by tertile of consumption are presented in Table 3.17. Higher intake of whole grain was significantly associated with greater intake of milk, cheese (in children/teenagers only), yoghurt, fats and spreads, fish (in adults only), fruit and vegetables, wholemeal bread, RTEBC, biscuits and cakes (in adults only) (Table 3.17). Higher intake of whole grain was also significantly associated with lower intake of white meat (in children/teenagers only), red meat (in adults only), white bread and savoury crisps and snacks (in adults only).

Table 3.17 Dietary intakes of other foods for non-consumers and by tertile of whole grain consumption

	Child/Teenage mean					**Adult mean**				
	Whole grain intake per day					**Whole grain intake per day**				
Food (g)	**0g/d**	**T1**	**T2**	**T3**	**p-value**	**0g/d**	**T1**	**T2**	**T3**	**p-value**
Milk	184.8	177.2	207.2	237.1†	0.003*	117.4	135.8†	170†	197.6†	<0.001*
Cheese	8.2	10.3	9.6	11.7†	0.039*	14	13.2	14.2	17.5	0.057
Yoghurt	18.1	25.6†	31.8†	41.1†	<0.001*	13.8	26.5†	27.4†	41†	<0.001*
Eggs and Egg dishes	12.9	9.0†	11.0	11.0	0.163	18.4	17.1	18.8	20.9	0.665
Fats and Spreads	8.6	7.9	7.7	9.5	0.029*	12.2	10.4	10.0†	13.4	0.001*
Meat	85.3	78.9	74.2†	75.8†	0.066	121.3	108.1	99.2†	98.9†	0.003*
White meat	32.6	28	25.6†	23.5†	0.002*	37.8	36.6	33.8	33.7	0.686
Red meat	52.7	51	48.6	52.2	0.623	83.5	71.6	65.4†	65.2†	0.001*
Fish and fish dishes	9.3	9.8	10.4	11.9	0.163	15.2	19.5†	27.5†	30.4†	<0.001*
Fruit and vegetables	154.6	173.5†	193.1†	220.2†	<0.001*	214.1	245†	302.3†	352.8†	<0.001*
Fruit	63.2	79.9†	92†	105.9†	<0.001*	60.3	83.7†	110.4†	142†	<0.001*
Vegetables	91.4	93.6	101.1	114.3†	<0.001*	153.9	161.3	191.9†	210.8†	<0.001*
Pasta, rice & cereals	87.5	76.8	76.8	79.1	0.713	74.1	72.9	69.4	81.7	0.520
Bread (all breads)	68.7	65.1	68.8	82.3†	<0.001*	89.1	73.6†	76.0†	99.6†	<0.001*
White	62.3	55.1	48.2†	34.2†	<0.001*	82.0	56.5†	42.2†	27.6†	<0.001*
Wholemeal	0.0	1.1†	5.1†	22†	<0.001*	0.0	2.9†	13.2†	48.7†	<0.001*
RTEBC	9.5	18.8†	26.5†	39.9†	<0.001*	5.32	16.7†	33.9†	46.3†	<0.001*
High fibre RTEBC	0.0	7.4†	17†	30.8†	<0.001*	0.19	9.2†	28.0†	40.7	<0.001*
Other RTEBC	9.5	11.4	9.5	9.1	0.069	5.1	7.5†	5.9	5.6	0.073
Biscuits	11.6	14.1	17.1†	17.1†	0.002*	8.0	11.6†	13.5†	17.1†	<0.001*
Buns, cakes, pastries	15.5	18.1	18.9	18.6	0.442	14.6	17.8	21.4†	23.3†	0.002*
Confectionary	15.3	19.5	17.3	17.8	0.351	10.8	10.2	8.9	9.5	0.708
Sugar	4.8	9.2†	7.7†	7.5†	0.018*	1.2	2.4	1.4	1.7	0.813
Chocolate	10.5	10.2	9.6	10.3	0.883	9.6	7.8	7.5	7.8	0.850
Savoury crisps & snacks	12.4	10.1	11.7	10.3	0.147	8.2	6.4	6.1†	5.3†	0.030*
n (unweighted)	*227*	*415*	*418*	*442*		*277*	*431*	*426*	*437*	

T: tertile; RTEBC: Ready to eat breakfast cereal; *P<0.05; **P<0.01; ***P<0.001; NS (P≥0.05) association across intakes of whole grain and other food intake (linear regression, adjusted for sex); †significantly different from non-consumers (t-test, adjusted for sex).

Mean intakes of milk, cheese (in children/teenagers only), yoghurt, fish (in adults only), fruit and vegetables, wholemeal bread, RTEBC, biscuits, cakes (in adults only) and sugar confectionary (in children/teenagers only) were significantly higher in consumers in T3 compared with non-consumers (Table 3.17). However, mean intakes of white meat (in children/teenagers only), red meat (in adults only), white bread and savoury crisps and snacks (in adults only) were significantly lower in consumers in T3 compared with non-consumers. Adjustment for age and sex did not attenuate any of the associations found with intakes of other foods.

The correlation between daily intakes of other foods and whole grain in adults was modestly positively correlated (rho range 0.1 - 0.3) with daily median milk, yoghurt, fruit and vegetable intake. Daily whole grain intake in adults was moderately negatively correlated (rho range 0.3 - 0.5) with daily intake of white bread and positively correlated with RTEBC intake. A strong positive correlation (rho range 0.5 - 0.8) of adult daily whole grain intake was seen with high fibre RTEBC and wholemeal bread intakes. Similar to adults, child and teenage daily whole grain intake was modestly negatively correlated with white bread intake, and positively correlated with fruit and vegetable intake, moderately positively correlated with RTEBC intake and strongly positively correlated with high fibre RTEBC and wholemeal bread intake.

3.5.15 Associations of whole grain intake with health outcomes

Sample sizes are reduced for blood analytes due to the exclusion of children under the age of 11 years and adults over the age of 64 years, reducing the statistical power of analyses. Mean health marker values for non-consumers and by tertile of whole grain consumption are presented in Table 3.18. Significant associations were seen from the lowest to highest levels of whole grain intake with a fall in systolic blood pressure (in children/teenagers only) and a fall in white blood cell count. After further adjustment for age, the association with systolic blood pressure in children/teenagers was no longer significant. After further adjustment for age and total energy intake, the fall in white blood cell count across non-consumers and tertiles of intakes remained significant (for both children/teenagers p=0.049 and adults p=0.009). In comparison with non-consumers of whole grain, adult consumers in T1 had significantly lower CRP concentrations (T1: 2.8 vs 3.8mg/L, p=0.045). However, the reductions in CRP concentrations of adult consumers in T2 and T3, although present, were not significantly different from non-consumers. No other significant associations or differences were seen between whole grain intake and the other health markers.

Table 3.18 Health marker outcomes for non-consumers and by tertile of whole grain consumption

	Children/Teenagers				
	Whole grain intake per day				p-value
Health marker	**0g/d**	**T1**	**T2**	**T3**	
	Mean (SD)				
Weight (kg)	60.1 (14.0)	57.8 (15.6)	56 (12.4)	57.4 (13.7)	0.208
BMI	22.0 (4.0)	21.9 (4.7)	21.3 (3.7)	21.1 (3.6)	0.379
n (unweighted)	*120*	*155*	*146*	*147*	
Waist to hip ratio	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)	0.782
n (unweighted)	*94*	*119*	*112*	*104*	
Systolic blood pressure (mmHg)	110.3 (9.6)	109.3 (10.4)	107.1 (9.9)† ‡	107.4 (9.5)† ‡	0.031*‡
Diastolic blood pressure (mmHg)	63.3 (8.3)	63.3 (7.8)	62.6 (7.8)	61.6 (8.0)	0.357
n (unweighted)	*111*	*192*	*193*	*186*	
Total cholesterol (mmol/L)	3.9 (0.5)	4.2 (0.5)	4.0 (0.5)	4.0 (0.6)	0.455
HDL (mmol/L)	1.4 (0.2)	1.4 (0.2)	1.4 (0.2)	1.4 (0.2)	0.798
LDL (mmol/L)	2.2 (0.4)	2.5 (0.5)	2.3 (0.4)	2.3 (0.5)	0.267
CRP (mg/L)	3.0 (5.7)	2.1 (1.9)	2.0 (2.1)	1.6 (0.7)	0.294
Triglycerides (mmol/L)	0.8 (0.3)	0.8 (0.2)	0.8 (0.3)	0.7 (0.2)	0.742
WBC (10^9/L)	7.3 (2.0)	5.9 (0.9)†	6.2 (1.1)	6.0 (1.3)	0.050*
Haemoglobin (g/dL)	14.1 (1.1)	13.6 (0.7)	13.5 (0.6)	13.8 (0.8)	0.223
Creatinine (µmol/L)	66.1 (11.1)	65.9 (10.8)	62.4 (9.8)	16.8 (13.4)	0.426
n (unweighted)	*42*	*51*	*54*	*53*	
	Adults				
Weight (kg)	78.1 (18.6)	76.8 (16.6)	76.8 (15.7)	77.9 (16.4)	0.910
BMI	27.2 (6.1)	27.3 (5.7)	27.3 (5.1)	27.1 (5.0)	0.940
n (unweighted)	*240*	*401*	*394*	*408*	
Waist to hip ratio	0.9 (0.1)	0.9 (0.1)	0.9 (0.1)	0.9 (0.1)	0.141
n (unweighted)	*199*	*316*	*329*	*312*	
Systolic blood pressure (mmHg)	125 (14.5)	126.4 (15.5)	127.3 (14.8)	127.7 (16.1)	0.582
Diastolic blood pressure (mmHg)	73.0 (9.9)	73.3 (9.0)	73.3 (9.8)	73.9 (10.4)	0.960
n (unweighted)	*138*	*256*	*272*	*254*	
Total cholesterol (mmol/L)	5.1 (0.7)	5.2 (0.7)	5.1 (0.7)	5.2 (0.7)	0.571
HDL (mmol/L)	1.4 (0.2)	1.5 (0.2)	1.5 (0.2)	1.5 (0.2)	0.448
LDL (mmol/L)	3.1 (0.5)	3.1 (0.6)	3.0 (0.6)	3.2 (0.6)	0.384
CRP (mg/L)	3.8 (2.5)	2.8 (1.5)†	2.9 (3.0)	3.0 (3.1)	0.238
Triglycerides (mmol/L)	1.5 (0.6)	1.4 (0.8)	1.3 (0.5)	1.3 (0.5)	0.358
WBC (10^9/L)	6.9 (1.2)	6.5 (1.0)	6.3 (1.0)†	5.9 (0.9)†	0.008*
Haemoglobin (g/dL)	14.3 (0.1)	14.0 (0.8)	14.1 (0.7)	14.2 (0.8)	0.592
Creatinine (µmol/L)	79.6 (0.8)	79.7 (10.0)	80.8 (8.9)	82.9 (9.3)	0.455
n (unweighted)	*87*	*160*	*163*	*170*	

T: tertile; SD: Standard deviation; BMI: Body mass index: HDL: High-density lipoprotein; LDL: Low-density lipoprotein; CRP: C-reactive protein; WBC: White blood cell count *P<0.05 association across intakes of whole grain and health marker (linear regression, adjusted for sex); †significantly different from non-consumers (t-test, adjusted for sex); ‡p>0.05 after adjustment for sex, age and total energy intake

3.6 Summary

Two hundred and twenty one whole-grain foods were identified in the UK NDNS 2008-2011 which were categorised into 33% RTEBC, 20% sweet snacks, 14% bread, 13% porridge, 6% savoury snacks, 5% other cereals, 5% bakes, 3% rice and 1% pasta. In this population, whole grain intakes were low with 18% of adults and 15% of children and teenagers not consuming any whole grains. Whole grain intake was greatest in adults, females and in those with more advantaged socioeconomic position whereas intake was lowest in teenagers and younger adults and those less socioeconomic advantaged. Restricting whole grain intake to that from foods that contained 10% or more whole grain did not attenuate results, however, restricting intake from foods that contained 51% or more whole grain resulted in lower and less varied intakes. The majority of whole-grain foods were eaten on weekdays, in the home and with either family members or alone. A significant decrease in white blood cell count was seen across intake tertiles, after adjustment for age and sex. In adults, CRP concentrations were significantly lower in low consumers compared with non-consumers. However, no other markers of health were significantly associated with whole grain intakes in either adults or children and teenagers. Dietary intake of many nutrients in whole grain consumers were closer to nutrient reference values and indicative of an overall better diet.

The results of this study and those in the next chapters will be discussed in the final section of this thesis.

Chapter 4 Whole grain intake in the Newcastle Thousand Families Study and its association with health markers

4.1 Introduction

This chapter will focus on the analysis of data from the NTFS, a birth cohort from Newcastle upon Tyne (Pearce *et al.*, 2009b; Pearce *et al.*, 2012). This cohort contains a wealth of diet, health and lifestyle information from across the lifecourse, in particular from age 50 years and onwards. The previous chapter, identified that whole grain intakes increased with increasing age, with the greatest intakes in those aged 45 and over. No significant association between whole grain intakes and anthropometric measures, blood pressure and the majority of blood lipid measures in the UK NDNS data were identified, which may have been due to low overall whole grain intakes. The NTFS data present an opportunity to investigate associations of whole grain intake with cardio-metabolic health markers, in a population with potentially higher whole grain intakes, since in the NDNS analyses whole grain intakes were highest in older adults.

At the last full-scale NTFS follow-up, in 2009 (age 62), a food frequency questionnaire was completed by the returning study members. However, this questionnaire did not include specific detail on whole-grain and non-whole-grain foods. In order to be able to estimate whole grain intake from this last and the previous 1997 NTFS follow-up (age 50), a new more detailed questionnaire focusing on cereal foods was required. This new questionnaire incorporated whole-grain food information identified in the NDNS dietary information detailed in the previous chapter. On completion of the new questionnaire, whole grain intake could be estimated from the NTFS follow-ups at age 50 and 62 as well as investigating potential links with the cardio-metabolic measures and diet taken at the same time points.

4.2 Aim

The aim of this work was, through development of a new questionnaire, to quantify whole grain intakes in the NTFS at each follow-up and to investigate potential associations between estimated whole grain intakes, intakes of other foods and nutrients and cardio-metabolic measures in this study cohort.

The following sections of this chapter describe the study cohort and available data (sections 4.3.1 and 4.3.2), the development of the new questionnaire and portion size estimation (sections 4.3.3 and 4.3.4), the methodology used to estimate whole grain intake (sections 4.3.5 and 4.3.6) and finally, the results of intake estimation and analysis in relation to cardio-metabolic measures (section 4.4).

4.3 Methodology

4.3.1 Background to the Newcastle Thousand Families Study

The NTFS is a prospective birth cohort. All families of babies born in May and June 1947, in the North East English city of Newcastle upon Tyne, were invited to be part of the study. The study was initially set up by Sir James Spence, a paediatrician, who planned to recruit 1000 families (approximately a 6th of annual births in the city) in order to observe and understand the illnesses of early childhood and infancy which were contributing to the high level of infant mortality at the time (Spence *et al.*, 1954; Pearce *et al.*, 2009b; Pearce *et al.*, 2012). All but four of the 1146 babies born in May and June 1947, were originally recruited. In order to keep track of study members, a red spot was placed on their health records so that general practitioners could notify the study team of any illnesses, thus the study members became known as the 'Red Spots'. To focus on other health outcomes, educational performance and family life, the study was continued throughout childhood up to the age of 15 years with visits from the study team to the participants' home or school (Spence *et al.*, 1954; Miller *et al.*, 1960; Miller *et al.*, 1974). A full scale follow-up of the cohort took place when the study members were aged around 50 years to consider the potential for early origins of adult disease. Between 1996 and 1998, 89% of the surviving cohort were retraced aged 49-51 years, of which 574 returned a health and lifestyle questionnaire and 412 attended for a clinical examination (Pearce *et al.*, 2009b; Pearce *et al.*, 2012). Data collected during 1996 to 1998 will be referred to as the 50-year follow-up from this point onwards. The cohort were again followed-up in 2009-2011 at the age of 62-64 years, with a focus on health and well-being. A similar health and lifestyle questionnaire was returned by 434 study member and 354 attended for a clinical exam. Data collected during 2009 to 2011 will be referred to as the 60-year follow-up from this point onwards.

4.3.2 Data collected during 50- and 60-year follow-ups

4.3.2.1 Health and lifestyle information

Questionnaires completed during the 50- and 60-year follow-ups contained a large range of questions on health and lifestyle. In particular, details of occupation and retirement, smoking, diet, general health and family health history were recorded.

To assess dietary intake, the European Prospective Investigation into Cancer and Nutrition (EPIC)-Norfolk food frequency questionnaire (FFQ) was included within the study health and lifestyle questionnaire. The EPIC-Norfolk questionnaire has been widely used and validated for estimating dietary intake (Bingham *et al.*, 1997; McKeown *et al.*, 2001). The EPIC-Norfolk FFQ is semi-quantitative and designed to measure usual food intake during the previous year. Responses can be converted into average daily nutrient intakes using the freely available FFQ EPIC Tool of Analysis (FETA) software which is based on the previous Compositional Analyses from Frequency Estimates (CAFÉ) programme for calculating nutrient intakes (Mulligan *et al.*, 2014). Responses to each food item question were; never or less than once a month, 1 to 3 times a month, once a week, 2 to 4 times a week, 5 to 6 times a week, every day, 2 to 3 times a day, 4 to 5 times a day, 6 or more times a day. These responses were coded with values 1 to 9 as defined by the FETA software guide (University of Cambridge, 2014). Responses to the FFQ questions on milk type and quantity, cereal type(s) and fat use were coded using food codes obtained from look up lists provided in the FETA software guide. Missing data were treated as missing at random and all missing responses relating to frequency of food intake were assumed to be non-consumption of the food. Participants with three or more missing responses in the Norfolk-EPIC FFQ were excluded from analysis because of invalid completion since these questionnaires instructed not to leave any 'lines' blank.

Spreadsheets of coded data were inputted to the software programme which calculated average daily nutrient intakes of: calcium, carotene (total), carbohydrate (total), cholesterol, copper, englyst fibre (non-starch polysaccharides), iron, folate (total), iodine, potassium, energy (kcal and kj), magnesium, manganese, sodium, niacin, phosphorus, protein, vitamin A (retinol), vitamin B2 (riboflavin), selenium, vitamin B1 (thiamin), nitrogen, total sugars, vitamin B12 (cobalamin), vitamin B6 (pyridoxine), vitamin C (ascorbic acid), vitamin D (ergocalciferol), vitamin E (alpha tocopherol equivalents), zinc, total fat, monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) and saturated fatty acids (SFA). Daily intakes of the following food groups were also calculated by the software: alcoholic beverages, cereals and cereal products, eggs and egg dishes, fats and oils, fish & fish products, fruit, meat and meat products, milk and milk products, non-alcoholic beverages, nuts and seeds, potatoes, soups & sauces, sugars; preserves and snacks and vegetables. The EPIC-Norfolk questionnaire was also used to estimate whole grain intake, full details are given in section 4.3.5.2.

Socio-economic status (SES) was derived from occupational details recorded in the 50-year questionnaire. Due to the high levels of retirement reported in the 60-year questionnaire, social classification based on occupation was coded from the 50-year questionnaire only.

Occupation of the main wage earner (either the study member or their partner) was coded according to the 1990 UK Registrar General's Standard Occupational Classification (SOC90) (Government Statistical Service, 1995). Social class derived from the SOC90 codes has 6 groups; I (professional, etc. occupations), II (managerial and technical occupations), IIIN (skilled occupations non-manual), IIIM (skilled occupations manual), IV (partly skilled occupations) and V (unskilled occupations) where I is assumed to be the most advantaged and V the least advantaged (Office for Population Censuses and Surveys, 1991). If the main wage earner was retired at/by age 50, previous occupational details from 1982 (age 35), which were retrospectively asked for as part of the 50-year questionnaire, were used if available.

Educational history and details of qualifications were recorded in the 50-year questionnaire. Five categories of the highest education level or equivalent qualifications achieved by the 50-year questionnaire were derived; None, O-level or equivalent (e.g. clerical/commercial or apprenticeship qualifications), A-level or equivalent (e.g. city and guilds, nursing or teaching qualifications), university degree and post graduate qualifications.

Smoking status was self-reported at the time of both the 50- and 60-year questionnaires and three categories of current smoking status were derived; Never smoked, ex-smoker and current smoker.

Medication use was self-reported in both the 50- and 60-year questionnaires. Study members were asked to record the full name, amount and reason for use, of any medications they were currently taking or receiving. The reasons given for taking each medication were crossed checked with the medication name and online patient information leaflets (www.patient.info). All medications were then coded according to the British National Formulary (BNF, a guide for prescribing, dispensing and administering medicines) and grouped on codes defining their medical use e.g. analgesic, anti-biotic, anti-coagulant, anti-depressant, anti-fungal, anti-histamine, anti-inflammatory, anti-spasmodic, anti-viral, corticosteroid, thyroid hormone etc. The total number of medications taken by each participant was summed. An indicator variable was created for study members taking any CVD or blood pressure lowering medication which included all BNF 2.1-2.11 codes e.g. anti-anginals, anti-coagulants, anti-platelets, angiotensin-converting-enzyme (ACE) inhibitors, angiotensin receptor blockers (ARBs), alpha-blockers, beta-blockers, calcium-channel blockers and thiazide diuretics. An indicator variable was created for study members taking lipid lowering medications which included all BNF 2.12 codes e.g. ezetimibe, fibrate and statin medications. Finally, an indicator variable was created for study members taking any diabetic medications to control blood glucose levels (BNF 6.1 codes).

4.3.2.2 Clinical, cardio-metabolic measures

During the 50- and 60-year follow-up periods study members were invited to attend a clinical assessment at the Royal Victoria Infirmary, Newcastle upon Tyne or, for a small number of participants, in regional centres where required. The measurement procedures followed the same protocols for both the 50-year and 60-year assessments, unless otherwise stated. Invited study members were asked to fast overnight before attending their assessment the following morning where fasted blood samples were taken. The following measures, described in detail below, are referred to as the cardio-metabolic measures available from the NTFS, consisting of anthropometric measures, blood pressures, blood lipids and results of oral glucose tolerance tests.

Height, weight and waist and hip circumferences were measured according to the World Health Organisation Monitoring Trends and Determinants in Cardiovascular Disease project (World Health Organization, 1998). Height was measured to the nearest 5 mm and weight to the nearest 100g with study members wearing light clothes. Waist circumference was measured around the unclothed waist and hip circumference measured over the top of underwear, both to the nearest centimetre. Body mass index (BMI) was calculated from weight (kg) divided by height (m) squared. Body fat percentage was estimated, in the 50-year clinic visits only, from impedance measured using a Holtain body composition analyser (Holtain Ltd, Crymych, Wales, UK).

Blood and pulse pressures were measured according to the British Hypertension Society guidelines (Petrie *et al.*, 1990) with a sphygmomanometer and a 35cm cuff. Two readings were taken after study members had been seated for 20 minutes after venepuncture. The mean of the two readings were used in analyses. Carotid intima-media thickness was measured, during the 50-year clinic visits only, bilaterally by B mode ultrasonography (7 MHz linear array, Acuson 128/XP-10) at three locations in the common and internal carotid arteries and averaged over the six sites (Howard *et al.*, 1993; Lamont *et al.*, 2000).

Following the overnight fast in the 50-year follow-up, study members without diabetes underwent an oral glucose tolerance test. A 75g oral glucose load was given and plasma glucose concentrations at 0, 30 and 120 minutes were measured on a Yellow Springs Analyser (YSI Stat Plus 2300; Yellow Springs Instruments, Farnborough, UK). Serum insulin at the same time-points was determined by enzyme-linked immunosorbent assay (ELISA) (Dako Ltd, Ely, UK) (interassay coefficients of variation 3.1 and 3.3%, respectively). Insulin resistance was calculated using the homeostasis model assessment of insulin resistance (HOMA-IR) (Matthews *et al.*, 1985). Insulin secretion was estimated as the ratio of the 30-min increment in insulin concentration to the 30-min increment in glucose concentration following oral glucose loading, relative to the baseline concentrations.

Following the overnight fast in the 60-year follow-up study members without diabetes underwent a World Health Organisation standard oral glucose tolerance test using 388ml of Lucozade. Plasma glucose concentrations taken at 0, 30 and 120 minutes were measured on a Yellow Springs Analyser. Serum insulin was not measured and therefore insulin resistance cannot be calculated at this age.

Blood lipid analyses in the 50-year follow-up were performed, shortly after sample collection, on a DAX analyser (Bayer, Basingstoke). Total cholesterol was measured using a cholesterol oxidase/peroxidise method with calibrants traceable to the Centres for Disease Control definitive method (as described by Pearce *et al.* (2009a)). Serum HDL cholesterol was measured using a cholesterol oxidase method after precipitation of apolipoprotein B (APO-B) containing lipoproteins with phosphotungstic acid and magnesium chloride (interassay coefficient of variation 2.2%). LDL cholesterol concentrations were derived by the Friedewald equation (Friedewald *et al.*, 1972). Triglyceride concentrations were estimated by a lipase-glycerol kinase method on a Cobas Bio centrifugal analyser (Roche Products Ltd, Welwyn, UK) using a commercial kit (Sigma Diagnostics, Poole, UK) (interassay coefficient of variation 1.3%). Plasma fibrinogen was derived from prothrombin time using an automatic coagulator. Blood samples also underwent a full blood count test where blood haemoglobin, haematocrit, white blood cell (leucocyte) counts and platelet (thrombocyte) concentrations were estimated.

During the year 60 follow-up blood samples were analysed for total cholesterol, HDL cholesterol, LDL cholesterol (derived by the Friedewald equation), triglyceride and non-high sensitivity CRP concentrations. LDL cholesterol values were not calculated for participants with a triglyceride value greater than 4.5mmol/L. Non-high sensitivity CRP concentrations were measured from values of 5mg/L and greater. For the purpose of analysis, all concentrations recorded as ‘less than 5‘ were coded as values of 4.9 mg/L. Fibrinogen was estimated using the Clauss method (derived from fibrin clot formation time) as well as, for a smaller number of samples, derived from prothrombin time using an automatic coagulator. A full blood count test estimated concentrations of blood haemoglobin, haematocrit, white blood cell (leucocyte) count and platelet (thrombocyte) concentration.

4.3.3 Development of a cereal foods questionnaire (CFQ)

In order to obtain a detailed account of whole grain intake in the NTFS participants, a new questionnaire was developed. Initially, an adapted version of the EPIC-Norfolk FFQ, which was first used in the GrainMark Study (a whole grain intervention study) (Haldar *et al.*, 2010) was used as a starting point and further developed. The EPIC-Norfolk and GrainMark FFQs consist of 5 sections covering consumption of grain foods - bread and savoury biscuits; potatoes, rice and pasta; cereals; sweets and snacks as well as a question on product information of the most frequently consumed breakfast cereals. The GrainMark FFQ expanded the type and number of cereal foods included in these questions in order to estimate whole grain intake. To clarify if certain homemade foods were whole grain or not, the sweets and snacks questions were further expanded. For example the line to report frequency of consumption of home-made cakes was expanded to two lines 1) made with white flour 2) made with wholemeal flour. Furthermore other, most frequently consumed, whole-grain foods that had been previously identified in NDNS diet diaries were added to the questionnaire. The alternative non-whole grain variety of these foods were also added in order to help participants recognise if they consumed the whole-grain or non-whole-grain food version. The additional foods were; half and half/50:50 white and wholemeal bread and rolls, wholemeal tortilla wraps, lasagne/cannelloni/moussaka made with wholemeal pasta, quinoa, flake and cluster cereals, crunchy cluster cereals, chocolate and plain hob nob biscuits, breakfast biscuits, soft cereal bars, crunchy cereal bars, whole-grain snacks, tortilla crisps and popcorn.

The CFQ was replicated as an online e-questionnaire by a Newcastle University computing officer (Mr Steven Hall). The e-questionnaire was accessible to NTFS members via a secure login page requiring a unique username and password. A copy of the CFQ is available in appendix C and screen shots of the online questionnaire are available in appendix D.

4.3.4 Estimation of average portion sizes

To calculate estimated whole grain intake from the CFQ, an average portion size had to be estimated to be multiplied by the reported frequency of consumption. In the EPIC-Norfolk FFQ participants are asked to report their consumption of foods with an indication of average portion size given. For example, intake of potatoes, rice and pasta is asked to be reported by medium serving and intake of sweet biscuits are asked to be reported as per one biscuit. These servings are not quantity specific portion sizes, therefore the NDNS rolling programme data (2008-2012) for adults 18+ years was used to estimate portion sizes (full details of this process are described below). Further information on portion sizes was also obtained from the Foods Standards Agency's Food Portion Sizes book (FSA-FPSB) (Mills and Patel, 1993; Food Standards Agency, 2002a) and, for branded foods, from manufacturer packaging.

All foods consumed in the NDNS diet diaries for adults were collated and sorted into groups, using NDNS food group codes, appropriate to the CFQ questions (Table 4.2, appendix E). For some of the CFQ questions there was more than one food product that could be reported and hence more than one NDNS food code assigned to that CFQ question. Any foods in NDNS diaries reported as raw weight were excluded since this did not reflect the actual portion size consumed. For the CFQ questions that had more than one food product/code assigned to it, the frequency of consumption for each food was accounted for. This resulted in weighting the portion size to account for foods more commonly consumed than others. To weight the portion size, the frequency of consumption was divided by the total frequency of consumption from all foods assigned to the CFQ question, this was denoted as the relative contribution. For each food assigned to a CFQ question, the average (mean and median) gram intake of that food was multiplied by its relative contribution. Finally, this was summed to obtain the weighted portion size (both mean and median) for all foods assigned that the CFQ question. The mean and median weighted portion sizes were used to inform an average portion size. Notes were taken on specific consumption habits found in the data, for example consuming two biscuits per portion. Portion sizes for specific foods were also obtained from the FSA-FPSB which were also noted and for branded specific products recommended portion size information was also obtained (Table 4.1, Table 4.2).

To explain in detail the portion size estimation, an example for brown rice is as follows. First all foods that fall into the brown rice category were identified using NDNS sub-food-group codes 1F:Rice (manufactured products and ready meals) and 1G:Rice (other, including homemade dishes). Following this, 4 food codes were identified in the NDNS food level dietary data as follows;

49: Rice, brown, boiled
10009: Brown basmati rice, cooked
10010: Brown easycook Italian/American rice, raw
10011: Brown easycook Italian/American rice, cooked

(NB there are more than 4 brown rice food codes in NDNS food databanks, but these were the 4 foods reported in food diaries from years 1-4 of the rolling programme).

Since the portion size of raw rice would be largely different to that of the cooked version, this food was excluded from portion size estimation. The frequency of consumption and the average (mean and median) gram intake of the remaining rice food codes was recorded (Table 4.1, column 4). The relative contribution of each food was calculated by dividing the frequency of consumption by the total frequency consumption of all brown rice, and was then multiplied by the average (mean and median) gram intakes to give the 'multiplier' (Table 4.1). Both mean and median values were used since portion sizes may have been skewed and both were taken into consideration of the final portion size decision. The weighted portion size (mean and median) was the sum of all 'multiplier' values. In the FSA-FPSB, a medium serve of brown rice is 180g and no brand specific detail was specified. A final portion size of 135g for a medium serve of brown rice was used.

Table 4.1 Portion size estimation for brown rice (extract from appendix E)

Question in cereal foods questionnaire	NDNS diet diary records 2008-2012			Relative contribution %	Portion size (g)				Comments	Weighted portion size (g)		Final decided potion size
	NDNS Food Code	Food Name	Frequency consumed		Mean	Multiplier (mean)	Median	Multiplier (median)		Mean	Median	
(b)Brown rice (½ plateful, or in a dish e.g. rice salad, risotto)	49	*RICE, BROWN, BOILED*	29	30.53	145.10	44.30	175.00	53.42	FPSB: medium serve 180g.	**134.5**	**126.3**	Average portion 135g
	10009	*BROWN BASMATI RICE, COOKED*	14	14.74	179.60	26.47	180.00	26.53				
	10011	*BROWN EASYCOOK RICE, COOKED*	48	50.53	126.22	63.78	91.65	46.31				
		Total (not including raw)	95									

Comments column contains information from the Foods Standards Agency's Food Portion Size Book (FPSB), detail on consumption habits (CH) from NDNS diet diaries and portion sizes from manufacturers for specific branded products (BP).

Full details of portion size estimation calculations can be found in appendix E, due to the large detail in the appendix a summary is given in Table 4.2.

Table 4.2 Summary of portion size estimation for CFQ

Cereal food questionnaire question	Number of food varieties	Frequency consumed	Weighted portion size (g) mean	Weighted portion size (g) median	Food Portion Size Book details, branded product details (*) & Consumer habits (CH)	Final portion size (g)	Whole grain % per serve
1. Bread and savoury biscuits							
(a) White bread & rolls, white pitta bread (one slice/roll) - Not whole grain						-	0
(b) Brown bread & rolls (one slice/roll)	12	545	59.65	57.82	Medium slice fresh 36g, toasted 31g CH: 2 slices per serve	36	0
(c) WM bread & rolls (one slice/roll)	9	2296	61.21	61.36		36	58
(d) Half and Half/50:50 white and WM bread & rolls (one slice/roll)	6	489	68.73	67.41	Medium slice 38g CH: 2 slices per serve	36	27
(e) WM pitta bread (each)	1	49	110.40	85.00	Small 75g, large 95g	85	65
(f) Granary bread & rolls (one slice/roll)	6	711	62.14	65.27	Similar to brown bread	36	51
(g) Rye bread & rolls (one slice/roll)	2	49	34.32	30.61	Average slice 25g CH: 2 slices per serve	33	57
(h) Oatmeal bread & rolls (one slice/roll)	2	94	73.15	78.22		36	12
(i) Naan bread, chapatti (each)	6	166	109.00	112.00	Naan filled 155g, plain 160g. Chapatti no fat 55g, with fat 60g	55	0
(j) Tortilla wraps (each) - Not whole grain						-	0
(k) WM tortilla wraps (each)	1	5	89.92	72.00		72	66
(m) Cream crackers, cheese biscuits (each) - Not whole grain						-	0
(n) WM crackers (per cracker)	1	54	19.97	17.60	Farmhouse cracker 8g CH: 2 or 3 per serve	8	21
(o) Crispbread, e.g. Ryvita (one)	8	244	18.34	21.07	WM crispbread 5g, Ryvita 10g, cracker bread 10g. CH: 2/3 per serve	10	83
(p) Oatcakes (per cake)	1	65	28.81	26.00	Round cake 13g, triangle 17g. CH: 2/3 per serve	15	78
2. Rice and pasta (medium serving)							
(a) White rice (½ plateful, or in a dish e.g. rice salad, risotto) - Not whole grain						-	0
(b) Brown rice (½ plateful, or in a dish e.g. rice salad, risotto)	3	95	134.50	126.30	Medium serve 180g	135	34
(c) White or green pasta e.g. spaghetti, macaroni, noodles, (½ plate)	27	1024	191.80	194.80	Macaroni boiled 230g, noodles 280g, spaghetti 220g, tortellini 320g	200	0
(d) WM pasta e.g. spaghetti, macaroni, noodles, (½ plate)	1	41	192.70	175.00	WM pasta boiled 220g	200	31
(e) Tinned pasta e.g. spaghetti, ravioli, macaroni, (½ standard tin)	7	55	217.70	224.60	Canned macaroni 210g, ravioli 220g, spaghetti 210g	200	0
(f) Tinned WM pasta e.g. spaghetti, ravioli, macaroni, (½ tin)	0	0	-	-	CH: None consumed	200	15
(g) Lasagne, cannelloni, moussaka made with white/green pasta (individual meal)	5	49	530.60	542.60	Lasagne 420g, cannelloni 340g CH: recorded as recipes	500	0
(h) Lasagne, cannelloni, moussaka made with WM pasta (individual meal)	0	0	-	-	CH: None consumed	500	28
(i) Pizza (10" = 1, 12" = 2, 12+"= 3 -4) - Not whole grain						-	0
(j) Quinoa (½plateful, or in a dish e.g. salad)	1	2	150.00	150.00		150	28

3. Cereals (One bowl)							
(a) Porridge, Readybrek, OatSo Simple	24	420	166.90	163.90	Small 110g, medium 160g, large 210g CH: Either small or medium	170	11
(b) Sugar coated cereals e.g. Sugar Puffs, Coca Pops, Frosties	17	387	37.50	34.00	Small 20g, medium 30g, Large 50g	40	0
(c) Non-sugar coated cereals e.g. Cornflakes, Rice Crispies	11	621	31.40	29.97	Small 20g, medium 30g, Large 50g	30	0
(d) Muesli	7	443	41.06	35.31	Crunchy small 40g, medium 60g, large 100g. Not crunchy small 30g, medium 50g, large 80g	40	57
(e) Bran containing cereals e.g. All Bran	4	96	26.78	23.36	All-bran type cereals small 30g, medium 40g, large 60g CH: Some have a tablespoon of bran	30	0
(f) Multigrain cereals e.g. Cheerios	6	117	32.63	31.80	1 tablespoon Cheerios 5g	30	54
(g) Bran Flakes	4	225	29.92	30.27	Corn flake type cereal small 20g, medium 30g, large 50g. 1 tablespoon bran flakes 8g. CH: Some have a tablespoon of bran	30	53
(h) Weetabix	4	547	41.00	40.00	Weetabix 20g *Weetabix 18.75g. CH: 2 biscuits per serve	40	80
(i) Shredded Wheat, Shreddies, Frosted/Raisin Wheats	11	335	43.51	43.33	Shredded wheat (2) 45g, mini small 35g, medium 45g, large 70g CH: 2 wheats per serve	45	80
(j) Special K	7	213	30.23	28.92	*Special K (all varieties) 30g	30	13
(k) Whole-grain cereals with fruit e.g. Sultana Bran, Fruit n Fibre, Optivia	10	244	38.15	36.05	*Sultana Bran, Fruit & Fibre, Just Right 40g, Grapenuts 45g	40	51
(l) Flake and cluster cereals e.g. Clusters, Oats and More	4	51	24.65	27.05	*Oats and more 40g	25	51
(m) Crunchy cluster cereal e.g. Crunchy Nut Clusters	6	115	38.56	32.17	Clusters 30g *Crunchy Nut Clusters 45g	40	51
4. Sweets and snacks							
a) Sweet biscuits, chocolate, e.g. Penguin, Kit-Kat (one) Excluding (1) and (2) below - Not whole grain						-	0
(1) chocolate digestive (one)	2	227	34.38	36.00	One biscuit 18g. CH: 2 per serve	18	8
(2) chocolate hob nob (one)	1	36	32.78	32.00	One biscuit 16g. CH: 2 per serve	16	38
(b) Sweet biscuits, plain, e.g. Nice, ginger, rich tea, crunch cream (one) Excluding (1) and (2) below - Not whole grain							0
(1) plain digestive (one)	2	378	30.80	30.00	One biscuit 15g. CH: 2 per serve	15	14
(2) plain hob nob (one)	2	67	30.24	28.45	One biscuit 14g. CH: 2 per serve	14	42
(c) Breakfast biscuits, e.g. Belvita (one)	1	23	39.13	50.00	*Belvita biscuits 12.5g each	12.5	29
(d) Soft cereal bars, e.g. NutriGrain (one)	3	24	37.00	37.00	*Nutrigrain bar 37g	37	12
(e) Crunchy cereal bars, e.g. Alpen, Special K (one)	23	325	32.96	30.18	*Branded bars range 20-40g	32	9
(f) Flapjacks (each)	5	50	45.40	36.04	Boots 70g, large 90g, coated 50g	45	35
(g) Crisps or other packet snacks, e.g. Walkers crisps, Wotsits (one packet) - Not whole grain						-	0
(h) Whole-grain snacks, e.g. Walkers Sunbites (one packet)	3	26	26.42	26.35	Twiglets 25/50/100g. *Sunbites 25g CH: 25g or 45g serves	25	64
(i) Tortilla crisps, e.g. Doritos, Nachos (one packet)	2	102	38.66	24.95	Tortilla Chips 50/100g *Doritos 30g	40	63
(j) Popcorn (one packet)	4	25	91.41	57.38	Popcorn 25/75g *Popcorn bags range 70-200g	90	55

4. Sweets and snacks continued							
(l) Homemade cakes, e.g. fruit sponge (medium slice)							
(1) made with white flour	44	194	53.04	49.17	Various cakes 35-120g CH: Includes fruit, sponge, carrot, cup, loaf and cheese cakes, gateau, swissroll	60	0
(2) made with WM flour	0	0	-	-	CH: None consumed		15
(m) Readymade cakes, e.g. fruit sponge (medium slice)							
(1) made with white flour	59	888	63.13	58.41	Various cakes 28-120g CH: Includes cake slices & bars. Fruit, sponge, carrot, cup, loaf and cheese cakes, gateau, swissroll (purchased)	60	0
(2) made with WM flour	2	5	53.00	53.00	Malt loaf 35g, Fruit cake 60g CH: WM fruit cake & Malt loaf		15
(n) Home baked buns / pastries, e.g. scones (each)							
(1) made with white flour	12	110	59.23	49.45	Various buns, pastries, scones 28-90g CH: Includes buns, pastries and scones	60	0
(2) made with WM flour	4	25	53.51	54.36	Buns 60g, scones 50g CH: WM buns & scones		40
(o) Readymade buns / pastries, e.g. croissants, doughnuts (each)							
(1) made with white flour	30	728	66.78	63.42	Various buns, pastries, scones, croissants, doughnuts, teacakes 45-180g. CH: Includes buns, pastries, scones, croissants, doughnuts and teacakes (purchased)	60	0
(2) made with WM flour	0	0	-	-	CH: None consumed		40
(p) Home baked fruit pies, tarts, crumbles (per individual pie/medium serving)							
(1) made with white flour	24	133	94.30	96.79	Various crumbles, pies and tarts 34-170g. CH: Includes crumbles, pies and tarts	80	0
(2) made with WM flour	1	1	68.00	68.00	CH: Jam treacle WM tart		25
(q) Readymade fruit pies, tarts, crumbles (per individual pie/medium serving)							
(1) made with white flour	16	271	85.34	76.26	CH: Includes crumbles, pies and tarts (purchased)	80	0
(2) made with WM flour	0	0	-	-	CH: None consumed		25
(r) Home baked sponge puddings (medium slice)							
(1) made with white flour	11	64	127.28	128.25	Various sponge puddings 95-190g CH: Includes all sponge puddings	120	0
(2) made with WM flour	0	0	-	-	CH: None consumed		17
(s) Readymade sponge puddings (medium slice)							
(1) made with white flour	6	36	114.54	115.83	Various sponge puddings 100-300g CH: Includes all sponge puddings (purchased)	120	0
(2) made with WM flour	0	0	-	-	CH: None consumed		17

WM: Wholemeal

4.3.5 Calculation of whole grain intake

4.3.5.1 Whole grain percentage of foods

The whole grain content of foods consumed was previously calculated for the work detailed in chapter three (whole grain intake in the NDNS, (Jones *et al.*, 2017)). The whole grain percentage for each question of the CFQ is presented in Table 4.2-above. For the CFQ questions that had more than one food variety, the whole grain percentage of the food was multiplied by the relative contribution and the total from all foods was summed.

4.3.5.2 Whole grain intake

In the 50- and 60-year FFQ whole grain intake was calculated based on the consumption of only six whole-grain foods (wholemeal bread and rolls, crispbread, porridge, cereals, brown rice and wholemeal pasta). In the CFQ whole grain intake was calculated based on the consumption of 42 whole-grain foods plus responses to other free text boxes of whole-grain foods. Responses to each whole-grain food in all the questionnaires (CFQ, 50- and 60-year FFQs) were given values depending on the frequency of consumption over a year; never or less than once a month (0), 1 to 3 times a month (24), once a week (52), 2 to 4 times a week (156), 5 to 6 times a week (286), every day (365), 2 to 3 times a day (913), 4 to 5 times a day (1643), 6 or more times a day (2190). This value was multiplied by the food specific portion size (grams) and the whole grain percentage to estimate the whole grain intake from each whole-grain food. Missing responses to one or two whole-grain food questions were treated as missing at random and non-consumption of that food was assumed. Participants with three or more missing responses were excluded as this indicated the questionnaires were not completed correctly (instructions were to *"complete every line – tick one box per line"* and if the CFQ was completed online it was not possible to give a missing answer).

The total of all responses in the questionnaire was summed to give whole grain intake in grams per year. These values were divided by 365 to give whole grain intake per day and average (mean and median) intakes were reported. Whole grain intake was also reported in tertiles (low, medium and high consumers) and by sex, SES and achieved education level.

4.3.6 Assumptions for whole grain intake calculated from 50- and 60-year questionnaires

The 50- and 60-year FFQs did not distinguish between whole grain and non-whole grain breakfast cereals. However, a later question in the same questionnaire on regular breakfast cereal consumption asked about the brand and type of the three most often consumed. These reported cereals were checked to see if they contained any whole grain. The number of reported whole-grain breakfast cereals was used to estimate the proportion of usual whole grain consumption with the whole grain content of these cereals used to estimate whole grain intake from breakfast cereals (see example below). The whole grain content of cereals was sourced from previously calculated for the work detailed in chapter three or from manufacturers' websites for any branded products not previously assessed. From portion size details included in section 4.3.4 (above) the estimated average cereal portion size was 40g.

For example, one participant reported consuming breakfast cereals every day in the FFQ. They also recorded the three most often consumed cereals as "Kellogg's Cornflakes", "Weetabix" and "Nestle Shredded Wheat". *Weetabix* and *Nestlé Shredded Wheat* are whole-grain cereals with a whole grain dry matter content of 80.8% and 86.0%, respectively (Appendix B). Since *Kellogg's Cornflakes* do not contain any whole grain it was assumed that this participant would usually consume whole grain cereals ⅔ of the time, with a whole grain dry matter content of 55.6% of all the breakfast cereals consumed. Therefore, it was estimated that the whole grain intake from breakfast cereals would be 365 (breakfast cereals eaten every day over the last year) x 0.556 (55.6% whole grain) x 40g (average portion size of breakfast cereal) = 8117.6g whole grain per year or 22.24g whole grain per day. For participants who reported 2 types of breakfast cereals, intakes were calculated as a proportion of the two and for participants who reported only one type of breakfast cereal this was used to calculate whole grain intake from breakfast cereals. If a participant recorded that they did usually eat breakfast cereals, but gave no details on the type of cereal(s) it was assumed to be non-whole-grain.

Similar to breakfast cereals, the 50- and 60-year FFQs also did not distinguish between whole grain and non-whole grain sweets and snacks. Since these details were not available, it was assumed that whole grain intake from these foods would be minimal and so were not included in the whole grain intake calculation.

4.3.7 Changes in diet

At the end of the 60-year EPIC-Norfolk FFQ, participants were asked how much they thought that their eating habits had changed since they were 50 years old. Responses were no, small or major changes have occurred. Those that reported either small or major changes were further asked to tick any of the following that may explain their change in eating habits; a) change in the food that you like or dislike, b) your enjoyment of food, c) concerns about safety/content of foods, d) the type and variety of foods available, e) price of foods, f) advertising of food products, g) desire to maintain health, f) your body weight, i) ill health or disability prevents you from cooking for yourself, j) special diet in self/ family member(s)/ friend(s), k) dental problems, l) religion, m) ethical/political concerns, n) the knowledge you have about food, o) cooking ability/skill, p) ease of shopping, q) kitchen equipment, r) other (please specify). The number and percentage of responses to this question are reported.

The same change in diet question was included in the CFQ to assess any changes since the 60-year assessment. Additionally, participants were asked if, since the last assessment, they had changed the amount of whole-grain foods they usually ate. If they responded yes, a free text box was included for explanation of the reasons for a change. The number and percentage of responses to this question are reported with free text grouped into common themes.

4.3.8 Ethical approval and distribution

Ethical approval for the NTFS was granted from the appropriate Local Research Ethics Committees for all measures including the 50-year follow-up and all participants gave their written consent. Ethical approval for the 60-year follow-up was obtained from Sunderland Local Research Ethics Committee and again all participants gave their written consent. Ethical approval for the CFQ was granted by Newcastle University Faculty of Medical Sciences Ethics Committee on 11th April 2014 (project number 00753/2014). Subsequently, the CFQ was posted and emailed to the NTFS members. All remaining members of the NTFS (those than had not deceased or requested not to be contacted), who had returned for the 60-year follow-up, were sent a participant information sheet, including unique login details for the online questionnaire, a paper CFQ and a pre-paid addressed return envelope. Furthermore, study members for whom email addresses were available, were emailed the participant information and unique login details for the online questionnaire with the option to return the paper questionnaire which was due to arrive in the post.

4.3.9 Statistical analyses

All data/variables were checked for the presence values outside of appropriate and normal ranges, where applicable, and all invalid/inappropriate values were cleaned (cross-checked with physical records where available) or removed. After checking, remaining plausible outlying or extreme values were retained since these were real data, unless any outlying values had high influence/leverage on regression models. All cases where outlying data have been removed have been described within the appropriate results section to follow.

Mean (SD) and median (IQR) whole grain intakes (g/d) calculated from CFQ, 50-year and 60-year FFQs were reported for the total population, separately for males and females and by SES, highest achieved education level and cigarette smoking status (for 50- and 60-year only). Whole grain intakes, from 50- and 60-year FFQ, were adjusted for total energy intake (MJ) at the same respective time point and reported as mean (SD) and median (IQR) in g/10MJ per day for the total population, separately for males and females and by SES, highest achieved education level and cigarette smoking status.

Nutrient intakes estimated from EPIC-Norfolk at both 50- and 60-year follow-ups were also adjusted for total energy intake per day by dividing each nutrient intake variable by total energy intake in kJ per day and multiplying by 1000 to give each nutrient intake per day per 10MJ of energy intake. To assess the correlation between whole grain intake and nutrient intakes, Spearman's correlation co-efficients were estimated. Mean (SD) intakes of energy, macro and micro nutrients per 10MJ per day were reported by tertile of whole grain intake. Linear regression models (as technically detailed in chapter 3 section 3.4.2) were used to investigate trends across tertiles of whole grain intake and energy, macro and micro nutrient intakes, using Wald tests adjusting for sex as a potential confounder. Differences in energy, macro and micro nutrient intakes between tertiles were tested using t-tests within the regression models, adjusting for sex as a potential confounder. The same analysis methods were used to investigate linear trends and differences in intakes of other foods and whole grain intakes.

Average whole grain intakes, anthropometric measures and cardio-metabolic markers were reported as mean (SD) and median (IQR) for the total population with available data and separately for males and females. Sex differences in these measures were tested using unpaired t-tests and Mann-Whitney U tests, depending on the distribution of the data. SES, achieved education level, cigarette smoking status and use of medications were treated as categorical and are reported as total n (%) and separately for males and females. Sex differences in these measures were tested for using Chi-squared tests.

Whole grain intake (g/d) was investigated for linear association with each cardio-metabolic and anthropometric measure in univariate regression models. Individual models were then adjusted for the potential confounders of sex and the use of medications (CVD medication including blood pressure medication, lipid lowering medications and where applicable diabetes medication) and dietary energy intake. If a significant association remained after these adjustments, further adjustment was made for potential confounding factors; smoking status, SES and achieved education level. All regression models were tested for whole grain intake and sex interactions, which were retained if found to be significant, before considering the confounding adjustments described above. Since the power of the regression analyses may not be adequate to detect a whole grain intake and sex interaction, the univariate and adjusted regression models were repeated separately for males and females.

$P<0.05$ was used to denote significance throughout all statistical analysis, although due to small sample sizes borderline significant associations are reported. All analyses were done in Stata version 13 (StataCorp, 2013) updated to version 14 in 2015 (StataCorp, 2015).

4.4 Results

4.4.1 Cohort characteristics

There were 574 NTFS members that returned a health and lifestyle questionnaire, during 50-year follow-up and 434 retuned a health and lifestyle questionnaire during the 60-year follow-up. During the 50-year follow-up, 25 participants completed a summary version of the health and lifestyle questionnaire which did not include a FFQ therefore, these participants were excluded from analysis. There were also seven participants with three or more missing responses to the 50-year FFQ and six participants with three or more missing responses to the 60-year FFQ, who were excluded from whole grain intake calculation. This resulted in a whole grain intake estimation for 542 participants from the 50-year follow-up, and 428 participants from the 60-year follow-up. In 2014, CFQs were sent to 424 remaining study members who returned during the 60-year follow-up. There were 356 study members who returned a CFQ, 85 (24%) online and 271 (76%) via post. There were 24 participants with three or more missing responses in their CFQ and were excluded from analyses. Therefore whole grain intake could be estimated for 332 NTFS who completed the CFQ. Demographic details of the NTFS members included in analyses are presented in Table 4.3. There were slightly more females than male participants at all time points (Table 4.3). The SES and achieved education levels of study members were similar at all time points with the majority coming from the more advantaged classifications (SES I and II classification) but having achieved no or O-level (or equivalent) qualifications. Finally, there were higher percentages of missing SES and education level data for the 60 and 67 year follow-ups since these included study members who returned for these follow-ups that had not previously taken part during the 50-year follow-up.

Table 4.3 Demographic summary of the NTFS members at each follow-up period

		50-year cohort with valid WG intake data		60-year cohort with valid WG intake data		67-year cohort with valid WG intake data	
		n		n		n	
Sex	Male	247	46%	195	46%	149	45%
	Female	295	54%	233	54%	183	55%
SES measured at 50-year follow-up	I	56	10%	46	11%	41	12%
	II	205	38%	147	34%	129	39%
	IIIN	58	11%	39	9%	22	7%
	IIIM	118	22%	76	18%	58	17%
	IV	56	10%	31	7%	24	7%
	V	23	4%	12	3%	9	3%
	Missing	26	5%	77	18%	49	15%
Achieved education level by 50-year follow-up	None	182	34%	114	27%	80	24%
	O-level or eq	167	31%	118	28%	92	28%
	A-level or eq	98	18%	67	16%	58	17%
	Degree	47	9%	34	8%	32	10%
	Postgrad	23	4%	17	4%	15	5%
	Missing	25	5%	78	18%	55	17%
Total	*n*	*542*		*428*		*332*	

WG: whole grain; SES: Socio-economic status; eq: equivalent

4.4.2 Dietary intake estimates

Nutrient and food group intakes were determined and analysed from 50- and 60-year FFQ which had not previously been done using the FETA software. Due to the focus on the whole grain intake and diet, individual nutrient and food group data are not presented here. However, summaries of male and female dietary intakes from 50- and 60-year follow-up are available in Appendix F.

4.4.3 Whole grain intake

4.4.3.1 Estimated from the Cereal Foods Questionnaire

Median whole grain intake was 33g/d (IQR 18 – 50) for the 332 study members who had valid intake data from the CFQ. Average intakes were not significantly different between males and females nor across SES measured at 50-year follow-up. Average whole grain intakes were higher for those who had completed a degree or postgraduate qualification in comparison to those with an O level, A level or no qualifications (Table 4.4). There was one male study member who recorded consuming no whole grain in the CFQ.

Table 4.4 Whole grain intake at age 67 measured by cereal food questionnaire

		n	Whole grain intake per day					p-value*
			Mean	SD	Median	IQR		
Total population		332	38.2	28.9	32.9	17.9	49.6	
Sex	Males	149	36.3	28.4	30.9	16.4	50.1	0.188[a]
	Females	183	39.7	29.3	33.7	19.6	49.1	
SES measured at age 50	I	41	36.4	30.7	29.6	17.8	48.1	0.217[b]
	II	129	41.6	28.7	35.9	20.5	54.9	
	3n	22	43.7	38.8	29.1	20.3	69.8	
	3m	58	37.9	26.1	34.8	21.0	51.3	
	IV	24	27.1	16.1	24.7	13.9	39.1	
	V	9	43.6	35.1	27.4	18.9	61.4	
	missing	49	32.3	29.1	26.7	11.5	45.4	
Achieved education level by 50-year follow-up	None	80	32.9	21.9	26.2	17.5	45.9	<0.001[b]
	O level or eq	92	40.7	29.7	36.6	18.4	57.4	
	A level or eq	58	31.8	23.1	28.6	16.7	40.4	
	Degree	32	55.6	39.7	43.6	35.6	73.9	
	Postgrad	15	55.3	33.7	45.7	31.0	60.0	
	missing	55	33.4	28.2	30.9	11.6	47.4	

SD: Standard deviation; IQR: Inter-quartile range; SES: Socio-economic status; eq: equivalent; *Tests for significant differences in intakes between groups excluding missing group; [a]Mann-Whitney U test; [b]Kruskal-Wallis test.

As recorded in the CFQ, the greatest contribution to whole grain intake came from whole-grain breads and breakfast cereals. Additionally 11% of whole grain intake came from porridge consumption, 10% from sweet and savoury whole-grain snacks, 6% from wholemeal pasta consumption, 4% from brown rice consumption with smaller amounts from cakes and other cereals (Figure 4.1).

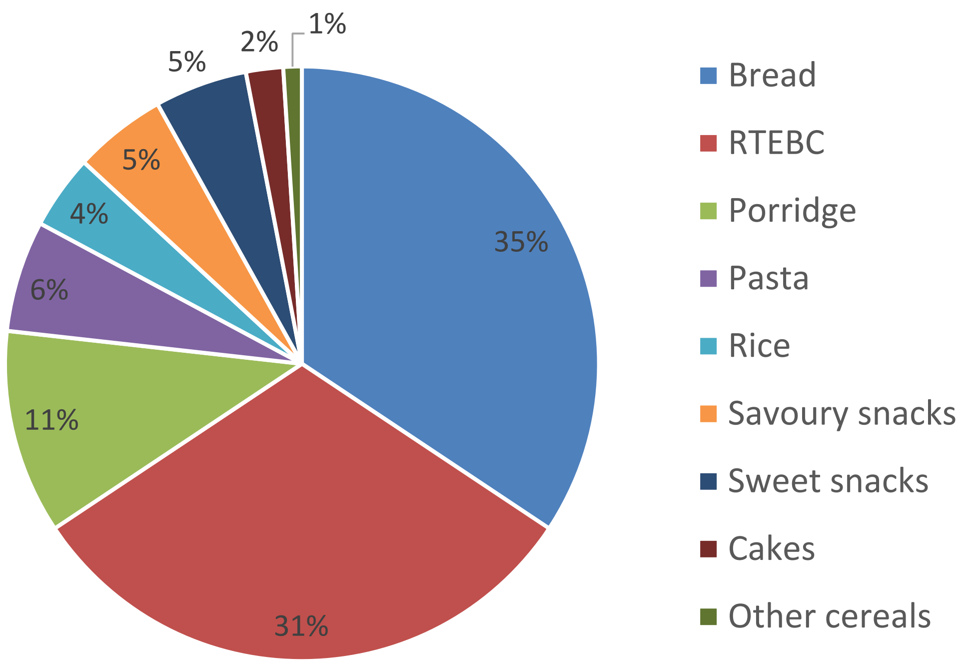


Figure 4.1 Contribution of foods to whole grain intake

Excluding whole grain intake from cakes and sweet biscuits, median whole grain intake was 26g/d (IQR 12 - 40g/d) for the 332 study members who had valid intake data from the CFQ. As seen previously (including cakes and sweet biscuits), average whole grain intakes were not significantly different between males and females nor across SES at age 50. Average whole grain intake was higher for those who had completed a degree or postgraduate qualification in comparison to those with an O level, A level or no qualifications. There were 8 study members who recorded consuming no whole grain in the CFQ, excluding cakes and sweet biscuits.

4.4.3.2 Estimated from the 50- and 60-year health and lifestyle questionnaires

Median whole grain intake was 19g/d (IQR 4 - 40g/d) during the 50-year follow-up and 21g/d (IQR 10 - 32g/d) during the 60-year follow-up (Table 4.5). Females had significantly higher intakes of whole grain than males at both time points. During the 50-year follow-up there were no significant differences in whole grain intake between SES, however at 60-year follow-up those in the more advantaged classifications had higher whole grain intakes compared with those in the least advantaged classifications. Whole grain intake measured at both the 50- and 60-year follow-up was significantly different across the highest level of education or qualification gained. Whole grain intake was higher in those that had achieved at least a degree or higher. Finally, those that were current smokers at either the 50- or 60-year follow-up had significantly lower whole grain intakes compared with ex-smokers or those that had never smoked. There were 66 and 28 study members who recorded consuming no whole grain in the 50- and 60-year questionnaire, respectively.

Table 4.5 Whole grain intake estimated from 50- and 60-year questionnaires using the EPIC-Norfolk FFQ

		Whole grain intake per day at 50-year follow-up								Whole grain intake per day at 60-year follow-up							
		n	%	Mean	SD	Median	IQR		p-value*	n	%	Mean	SD	Median	IQR		p-value*
Total population		542		28.3	29.7	19.4	4.2	40.8		428		24.2	18.6	20.9	9.9	32.4	
Males		247	46	22.8	26.2	16.1	1.4	33.2	<0.001[a]	195	46	22.7	20.8	19.4	6.6	32.3	0.007[a]
Females		295	54	32.9	31.5	25.0	8.9	52.6		233	54	25.5	16.6	23.3	15.2	32.4	
SES at age 50	**I**	56	10	31.6	31.4	25.3	9.0	42.9	0.160[b]	46	11	23.9	16.9	21.3	13.6	31.4	0.013[b]
	II	205	38	31.5	31.1	25.1	8.0	46.9		147	34	28.5	19.5	27.1	15.8	39.0	
	3N	58	11	27.3	31.8	16.3	3.0	41.2		39	9	22.7	19.9	17.9	5.6	36.3	
	3M	118	22	23.9	26.8	16.4	1.4	33.8		76	18	20.7	18.0	18.9	7.1	29.5	
	IV	56	10	25.7	25.9	18.4	2.2	50.2		31	7	21.0	16.9	18.9	8.9	29.7	
	V	23	4	26.8	29.6	18.9	3.0	33.5		12	3	18.2	12.9	15.8	10.7	24.2	
	Missing	26	5	25.1	29.0	12.0	1.4	49.9		77	18	22.6	18.2	20.9	9.4	30.9	
Achieved education level by 50-year follow-up	**None**	182	34	27.1	30.9	16.4	2.4	41.4	0.019[b]	114	27	19.4	16.4	16.6	7.5	26.7	<0.001[b]
	O level or eq	167	31	26.9	27.5	19.1	3.0	41.0		118	28	23.1	19.2	20.9	7.1	32.2	
	A level or eq	98	18	26.1	28.0	20.5	4.4	35.8		67	16	24.9	28.2	24.9	16.4	39.0	
	Degree	47	9	38.0	35.4	28.2	13.2	52.2		34	8	32.7	22.0	32.3	17.9	46.0	
	Postgrad	23	4	40.2	32.2	30.6	17.5	48.0		17	4	36.2	18.9	29.7	25.5	37.9	
	Missing	25	5	26.1	22.5	25.7	10.1	34.7		78	18	23.2	17.6	21.0	10.2	30.4	
Smoking status at follow-up	**Never smoked**	207	38	32.3	30.0	25.2	9.5	44.7	<0.001[b]	171	40	26.0	17.7	24.0	14.8	35.5	0.009[b]
	Ex-smoker	172	32	32.3	30.6	24.5	8.9	49.2		194	45	23.8	19.1	20.9	8.9	33.1	
	Current smoker	161	30	18.4	25.6	7.7	1.2	25.0		60	14	19.8	19.3	16.4	8.6	25.4	
	Missing	2	0	68.2	10.1	68.2	61.0	75.3		3	1	32.9	4.5	31.5	29.2	37.9	

SD: Standard deviation; IQR: Inter-quartile range; SES: Socio-economic status; eq: equivalent;
*Tests for significant differences in intakes between groups excluding missing group; [a]Mann-Whitney U test; [b]Kruskal-Wallis test

As recorded using the EPIC-Norfolk questionnaire, whole grain intake in the 50-year follow-up came from 51% wholemeal breads, 24% breakfast cereals, 7% porridge, 7% brown rice, 7% wholemeal pasta and 4% crispbread. Whole grain intake in the 60-year follow-up was from 42% wholemeal breads, 26% breakfast cereals, 17% porridge, 6% brown rice, 5% wholemeal pasta and 4% crispbread.

Whole grain intakes were split into tertiles of intake. At the 50-year follow-up, tertile 1 (T1) consisted of 183 study members with whole grain intakes ranging from 0 to 9g/d and median 1g/d. The middle tertile (T2) consisted of 179 study members with whole grain intakes ranging from 10 to 32g/d and median 20g/d. Finally the third tertile (T3) consisted of 180 study members with whole grain intakes ranging from 33 to 149g/d and median 57g/d. At the 60-year follow-up the T1 consisted of 143 study members with whole grain intakes ranging from 0 to 15g/d and median 5g/d. T2 consisted of 143 study members with whole grain intakes ranging from 16 to 29g/d and median 21g/d. Finally the T3 consisted of 142 study members with whole grain intakes ranging from 30 to 116g/d and median 40g/d.

4.4.4 Energy adjusted whole grain intake

Median whole grain intake, adjusted for total dietary energy intake, was 23g/d/10MJ (IQR 5 - 52g/d/10MJ) estimated from the 50-year follow-up. Energy adjusted whole grain intake was significantly higher at median 31g/d/10MJ (IQR 10 - 61g/d/10MJ) in females compared with males with a median 16g/d/10MJ (IQR 2 - 38g/d/10MJ). Similar to the patterns seen for unadjusted whole grain intake, there were no significant differences in energy adjusted whole grain intake across SES, and intake was significantly higher in those that had achieved at least a degree or higher.

Median whole grain intake, adjusted for total dietary energy intake, was 36g/d/10MJ (IQR 17 - 51g/d/10MJ) estimated from the 60-year follow-up. Energy adjusted whole grain intake was significantly higher at median 39g/d/10MJ (IQR 23 - 52g/d/10MJ) in females compared with males with a median 31g/d/10MJ (IQR 10 - 50g/d/10MJ). Similar to the patterns seen in unadjusted whole grain intake, those in the more advantaged SES classifications had higher energy adjusted whole grain intakes compared with those in the least advantaged classifications. Energy adjusted whole grain intake was also significantly higher in those that had achieved at least a degree or higher.

4.4.5 Cross-sectional investigations in 50- and 60 year follow-ups

4.4.6 Whole grain intake and diet

The EPIC-Norfolk FFQ responses from 574 NTFS participants at the 50-year follow-up and from 434 participants at the 60-year follow-up were collated, cleaned, coded and processed using the FETA software to obtain average daily nutrient intakes. As recommended by the FETA programme, participants with more than 10 missing FFQ items were excluded. In the 50-year follow-up there were 8 study members with more than 10 missing items and 25 study members completed a summary version of health and lifestyle questionnaire which did not include the EPIC-Norfolk FFQ. In the 60-year follow-up there were 8 study members with more than 10 missing items. There were additionally two study members from the 50-year follow-up and three study members from the 60-year follow-up for which whole grain intake could not be estimated. This left EPIC-Norfolk FFQ and whole grain intake data available for 539 participants at the 50-year follow-up and 423 participants at the 60-year follow-up (and 350 participants at both time points) to be processed for average nutrient intakes through the FETA programme.

4.4.6.1 Whole grain and nutrient intakes

Table 4.6 summarises the correlation between daily nutrient and whole grain intakes and summarises daily nutrient intakes per whole grain tertile in the year 50 follow-up. Whole grain intake was moderately, significantly positively correlated with total carbohydrate, fibre, folate, iron, magnesium, manganese, selenium and thamin (vitamin B1) intakes per 10MJ of energy intake and significantly moderately negatively correlated with total fat, saturated fat, MUFA and dietary cholesterol intakes per 10MJ of energy intake.

After adjustment for sex, there were significantly, increasing trends in daily intakes of energy (kcal and MJ), total carbohydrate, carotene, copper, fibre, folate, iron, magnesium, manganese, niacin, phosphorus, sodium, selenium, thiamin, riboflavin, vitamin B6, vitamin C and zinc with each increasing tertile of whole grain intake (Table 4.6). There were also significantly decreasing trends in daily intakes of total fat, saturated fat, MUFA and dietary cholesterol with increasing tertile of whole grain intake, adjusting for sex. Compared with those in T1 of whole grain intake, those in T2 and T3 had significantly higher intakes of total carbohydrate, carotene, fibre, folate, iron, magnesium, manganese, thiamin, vitamin B6 and vitamin C per 10MJ of energy intake, adjusted for sex. Compared with those in T1 of whole grain intake, only those in T3 had significantly higher energy intakes and intakes of copper, niacin, potassium, phosphorus, sodium, selenium, thaimin and zinc per 10MJ or energy, adjusted for sex (all $p<0.05$, Table 4.6). Those in T2 of whole grain intake had significantly higher total sugar intakes in comparison to those in T1, adjusted for sex, however this trend did not continue to those in T3 of whole grain intake. Compared with those in T1 of whole grain intake, those in the T2 and T3 had significantly lower intakes of total fat, saturated fat, MUFA and cholesterol per 10MJ of energy intake ($p<0.05$, Table 4.6). Compared with those in T1 of whole grain intake, only those in T3 had significantly lower intakes of alcohol per 10MJ or energy, adjusted for sex.

Table 4.6 Average daily nutrient intakes per tertile of whole grain intake estimated at 50-year follow-up (n=539)

Nutrient	Correlation with whole grain intake	Whole grain intake tertile (min-max intake) T1 (0 - 9g/d, n=182)		T2 (10 - 32g/d, n=178)		T3 (33 - 149g/d, n=179)		p-value*
		Mean	**(SD)**	**Mean**	**(SD)**	**Mean**	**(SD)**	
Energy (kcal)	0.13	1954.1	(671.7)	2066.7	(708.9)	2144.3 [a]	(1150.4)	0.037
Energy (MJ)	0.13	8.2	(2.8)	8.7	(3.0)	9.0 [a]	(4.8)	0.033
Protein (g/10MJ)	0.09	99.8	(18.9)	101.1	(17.6)	104.3	(19.0)	0.236
Total Fat (g/10MJ)	-0.32	95.7	(15.0)	89.8 [a]	(15.2)	82.7 [b]	(16.9)	<0.001
Saturated Fat (g/10MJ)	-0.36	37.4	(8.3)	33.7 [b]	(7.5)	30.3 [b]	(8.8)	<0.001
PUFA (g/10MJ)	0.06	16.7	(5.3)	16.9	(4.9)	17.0	(4.8)	0.970
MUFA g/10MJ)	-0.34	33.4	(6.3)	31.4 [a]	(6.5)	28.0 [b]	(7.3)	<0.001
Carbohydrate (g/10MJ)	0.39	265.2	(39.4)	284.8 [b]	(40.3)	302.1 [b]	(39.8)	<0.001
Total Sugars (g/10MJ)	0.13	130.1	(37.7)	140.6 [a]	(37.4)	139.9	(37.1)	0.041
Alcohol (g/10MJ)	-0.10	18.2	(22.4)	14.1	(19.1)	11.7 [a]	(15.7)	0.088
Calcium (mg/10MJ)	0.09	1124.5	(318.4)	1141.9	(309.5)	1200.9	(303.4)	0.165
Carotene-total (g/10MJ)	0.28	3373.5	(1765.9)	3820.5 [a]	(1910.6)	4473.5 [b]	(1792.5)	<0.001
Cholesterol (mg/10MJ)	-0.30	361.5	(92.4)	340.3 [a]	(88.0)	298.7 [b]	(89.5)	<0.001
Copper (mg/10MJ)	0.29	1.4	(0.4)	1.4	(0.3)	1.6 [b]	(0.5)	<0.001
Fibre (g/10MJ)	0.57	16.5	(4.6)	19.8 [b]	(5.9)	24.8 [b]	(6.4)	<0.001
Folate (mcg/10MJ)	0.30	341.5	(85.8)	363.9 [a]	(94.8)	408.3 [b]	(98.0)	<0.001
Iron (mg/10MJ)	0.49	12.5	(2.1)	14.0 [b]	(2.7)	15.9 [b]	(3.3)	<0.001
Iodine (mcg/10MJ)	0.08	166.6	(49.9)	177.7	(48.6)	180.9	(57.5)	0.120
Magnesium (mg/10MJ)	0.44	359.6	(73.1)	387.2 [a]	(77.8)	443.0 [b]	(81.9)	<0.001
Manganese (mg/10MJ)	0.57	3.5	(1.0)	3.9 [a]	(1.0)	5.4 [b]	(1.4)	<0.001
Niacin (mg/10MJ)	0.19	27.2	(7.3)	28.2	(7.0)	30.2 [b]	(6.8)	0.001
Nitrogen (g/10MJ)	0.10	16.0	(3.0)	16.2	(2.8)	16.8	(3.0)	0.145
Potassium (mg/10MJ)	0.11	4430.8	(908.9)	4582.9	(963.4)	4720.0 [a]	(989.0)	0.078
Phosphorus (mg/10MJ)	0.28	1659.7	(279.8)	1721.0	(278.0)	1863.9 [b]	(301.8)	<0.001
Sodium (mg/10MJ)	0.17	3252.5	(606.2)	3275.8	(570.4)	3502.1 [a]	(702.5)	0.001
Selenium (mcg/10MJ)	0.39	75.5	(18.3)	77.0	(17.9)	94.8 [b]	(23.4)	<0.001
Vitamin A (mcg/10MJ)	-0.16	853.1	(704.0)	752.1	(573.6)	713.5	(954.6)	0.280
Vitamin B1 (mg/10MJ)	0.44	1.7	(0.4)	1.9 [b]	(0.4)	2.1 [b]	(0.4)	<0.001
Vitamin B2 (mg/10MJ)	0.13	2.4	(0.6)	2.5	(0.6)	2.6 [a]	(0.7)	0.032
Vitamin B6 (mg/10MJ)	0.18	2.6	(0.6)	2.8 [a]	(0.6)	2.9 [a]	(0.6)	0.002
Vitamin B12 (mcg/10MJ)	-0.05	8.4	(3.4)	8.3	(3.2)	8.3	(4.4)	0.925
Vitamin C (mg/10MJ)	0.26	118.0	(61.2)	139.9 [a]	(70.5)	157.2 [b]	(72.9)	<0.001
Vitamin D (mcg/10MJ)	0.07	3.8	(1.7)	4.2	(1.8)	4.2	(2.2)	0.115
Vitamin E (mg/10MJ)	0.09	15.5	(5.6)	16.2	(5.0)	16.3	(5.0)	0.463
Zinc (mg/10MJ)	0.22	10.8	(2.3)	11.1	(2.1)	12.0 [b]	(2.1)	<0.001

SD: Standard deviation; *Tests for significant trend across increasing tertile, adjusted for sex
[a] Significantly different from low tertile at p<0.05, t-test adjusted for sex; [b] Significantly different from low tertile at p<0.001, t-test adjusted for sex.

Table 4.7 summarises the correlation between daily nutrient and whole grain intakes and summarises daily nutrient intakes per whole grain tertile in the 60-year follow-up. Whole grain intake was significantly moderately positively correlated with energy (kcal and MJ), copper, fibre, iron, magnesium and manganese intakes per 10MJ of energy intake, and significantly moderately negatively correlated with saturated fat intakes per 10MJ of energy intake.

After adjustment for sex, there were significantly increasing trends in daily intakes of energy (kcal and MJ), total carbohydrate, copper, fibre, folate, iron, magnesium, manganese, thiamin and vitamin E with increasing tertile of whole grain intake (Table 4.7). There were also significantly decreasing trends in daily intakes of total fat, saturated fat, MUFA and dietary cholesterol with increasing tertile of whole grain intake, adjusting for sex. Compared with those in T1 of whole grain intake, those in T2 and T3 had significantly higher intakes of total carbohydrate, copper, fibre, iron, magnesium, manganese and thiamin per 10MJ of energy intake, adjusted for sex. Compared with those in T1 of whole grain intake, only those in T3 had significantly higher energy intakes and intakes of PUFA, total sugars, folate, phosphorus and vitamin E per 10MJ or energy, adjusted for sex. Compared with those in T1 of whole grain intake, those in T2 and T3 had significantly lower intakes of total fat, saturated fat and cholesterol per 10MJ of energy intake. Compared with those in T1 of whole grain intake, only those in T3 had significantly lower intakes of MUFA per 10MJ or energy, adjusted for sex.

Table 4.7 Average daily nutrient intakes per tertile of whole grain intake estimated at 60-year follow-up (n=423)

Nutrient	Correlation with whole grain intake	**Whole grain intake tertile** (min-max intake) T1 (0 - 15g/d, n=142) Mean	(SD)	T2 (16 - 29 g/d, n=140) Mean	(SD)	T3 (30 - 116 g/d, n=141) Mean	(SD)	p-value*
Energy (kcal)	0.33	1412.3	(468.0)	1497.2	(416.3)	1741.2 [b]	(473.3)	<0.001
Energy (MJ)	0.33	5.9	(2.0)	6.3	(1.7)	7.3 [b]	(2.0)	<0.001
Protein (g/10MJ)	-0.01	117.4	(26.2)	117.2	(19.3)	114.9	(18.3)	0.330
Total Fat (g/10MJ)	-0.24	91.4	(17.1)	87.3 [a]	(13.7)	83.0 [b]	(13.7)	<0.001
Saturated Fat (g/10MJ)	-0.32	35.7	(9.1)	32.8 [a]	(7.8)	29.7 [b]	(6.7)	<0.001
PUFA (g/10MJ)	0.19	15.0	(4.4)	15.4	(3.6)	16.2 [a]	(5.0)	0.080
MUFA g/10MJ)	-0.19	32.6	(7.1)	31.3	(5.5)	29.7 [b]	(6.2)	0.002
Carbohydrate (g/10MJ)	0.27	263.7	(47.0)	278.8 [a]	(33.6)	289.9 [b]	(39.1)	<0.001
Total sugars (g/10MJ)	0.12	138.4	(42.5)	142.8	(34.1)	149.6 [a]	(38.8)	0.094
Alcohol (g/10MJ)	-0.04	14.2	(18.7)	11.2	(15.6)	12.0	(14.8)	0.615
Calcium (mg/10MJ)	0.01	1270.4	(448.0)	1283.0	(325.7)	1272.9	(344.3)	0.968
Carotene-total (g/10MJ)	0.14	4988.7	(3135.5)	5519.0	(2482.5)	5562.6	(2258.6)	0.367
Cholesterol (mg/10MJ)	-0.28	406.7	(119.9)	371.5 [a]	(110.7)	338.5 [b]	(96.3)	<0.001
Copper (mg/10MJ)	0.34	1.4	(0.4)	1.6 [a]	(0.5)	1.7 [b]	(0.6)	<0.001
Fibre (g/10MJ)	0.42	19.9	(7.7)	23.4 [b]	(6.3)	25.5 [b]	(5.1)	<0.001
Folate (mcg/10MJ)	0.22	314.9	(125.1)	336.9	(122.4)	374.3 [a]	(118.2)	0.002
Iron (mg/10MJ)	0.35	14.3	(3.7)	15.8 [a]	(3.0)	16.5 [b]	(2.9)	<0.001
Iodine (mcg/10MJ)	0.02	213.9	(74.1)	210.9	(63.2)	212.5	(62.5)	0.688
Magnesium (mg/10MJ)	0.32	403.7	(90.6)	434.8 [a]	(82.6)	462.2 [b]	(72.0)	<0.001
Manganese (mg/10MJ)	0.39	4.0	(1.3)	4.6 [a]	(1.4)	5.2 [b]	(1.3)	<0.001
Niacin (mg/10MJ)	0.07	31.5	(9.4)	32.0	(7.9)	32.3	(6.6)	0.844
Nitrogen (g/10MJ)	-0.02	18.8	(4.2)	18.8	(3.1)	18.5	(2.9)	0.481
Potassium (mg/10MJ)	0.05	5096.7	(1181.3)	5148.2	(963.3)	5158.5	(853.4)	0.988
Phosphorus (mg/10MJ)	0.14	1919.8	(370.6)	1977.2	(294.0)	2013.5 [a]	(284.1)	0.129
Sodium (mg/10MJ)	0.07	3482.1	(699.0)	3646.8	(699.1)	3639.2	(793.2)	0.134
Selenium (mcg/10MJ)	0.18	84.6	(27.8)	87.0	(21.3)	91.2	(22.3)	0.125
Vitamin A (mcg/10MJ)	-0.08	758.6	(701.5)	841.2	(925.0)	769.8	(1047.9)	0.702
Vitamin B1 (mg/10MJ)	0.23	2.0	(0.4)	2.1 [a]	(0.4)	2.2 [b]	(0.3)	<0.001
Vitamin B2 (mg/10MJ)	0.06	2.8	(0.8)	2.8	(0.6)	2.8	(0.7)	0.899
Vitamin B6 (mg/10MJ)	0.08	3.2	(0.7)	3.3	(0.6)	3.3	(0.5)	0.344
Vitamin B12 (mcg/10MJ)	-0.01	10.5	(4.9)	10.4	(4.2)	10.3	(4.4)	0.717
Vitamin C (mg/10MJ)	0.12	162.1	(99.2)	174.3	(75.2)	182.3	(66.2)	0.324
Vitamin D (mcg/10MJ)	0.03	4.7	(2.5)	4.6	(2.2)	4.7	(2.2)	0.569
Vitamin E (mg/10MJ)	0.14	13.9	(4.1)	14.9	(3.9)	15.6 [a]	(4.6)	0.006
Zinc (mg/10MJ)	0.10	12.9	(2.8)	13.3	(2.1)	13.4	(2.3)	0.463

SD: Standard deviation; *Tests for significant trend across increasing tertile, adjusted for sex
[a] significantly different from low tertile at p<0.05, t-test adjusted for sex; [b] significantly different from low tertile at p<0.001, t-test adjusted for sex.

4.4.6.2 Whole grain and intakes of foods

Whole grain intake estimated from the 50-year follow-up was significantly positively correlated with intakes of cereals and cereal products, milk and milk products, fish and fish products, fruit and vegetables (Table 4.8). Whole grain intake was also significantly negatively correlated with intakes of eggs and egg dishes, meat and meat products, sugars, preserves and snacks and alcoholic beverages. After adjustment for sex, mean intakes of cereals and cereal products, fish and fish products, fruits and vegetables were significantly higher for those in T2 and T3 of whole grain intake, compared with T1 (Table 4.8). Mean intake of meat and meat products was significantly lower for those in T3 only, compared to T1 after adjustment for sex.

Table 4.8 Daily intakes of food groups per tertile of whole grain intake estimated at 50-year follow-up

		Whole grain intake tertile (min-max intake)						
	Correlation with whole grain intake	**T1** (0 - 9g/d, n=182)		**T2** (10 - 32g/d, n=178)		**T3** (33 - 149g/d, n=179)		
Food group (g/d)		**Mean**	**(SD)**	**Mean**	**(SD)**	**Mean**	**(SD)**	**p-value***
Cereals and cereal products	0.49	176.8	(86.5)	237.3 [a]	(116.0)	313.4 [b]	(265.9)	<0.001
Milk and milk products	0.09	373.7	(200.0)	394.2	(215.8)	410.6	(191.0)	0.253
Eggs and egg dishes	-0.10	18.9	(14.9)	21.0	(17.0)	16.6	(14.4)	0.050
Fats and oils	-0.03	29.6	(18.8)	29.8	(24.8)	31.6	(45.7)	0.599
Meat and meat products	-0.16	127.2	(69.6)	121.0	(73.3)	105.3 [a]	(67.9)	0.036
Fish and fish products	0.17	34.4	(28.2)	44.2 [a]	(37.3)	45.8 [a]	(34.7)	0.002
Fruit	0.34	142.2	(124.3)	224.5 [a]	(208.0)	262.2 [b]	(192.2)	<0.001
Vegetables	0.25	218.2	(90.7)	249.6 [a]	(123.5)	297.5 [b]	(154.5)	<0.001
Potatoes	-0.08	103.9	(54.1)	106.0	(56.3)	101.3	(63.8)	0.796
Nuts and seeds	0.02	2.9	(9.3)	3.0	(5.3)	3.9	(15.0)	0.451
Soups and sauces	0.08	48.6	(43.1)	56.9	(44.2)	60.9	(87.5)	0.161
Sugars, preserves and snacks	-0.13	52.4	(44.4)	45.6	(39.6)	42.5 [a]	(43.6)	0.082
Alcoholic beverages	-0.09	309.4	(470.9)	192.9 [a]	(322.6)	156.7 [a]	(280.2)	0.011
Non-alcoholic beverages	0.02	1124.6	(430.4)	1095.7	(397.5)	1142.9	(407.8)	0.590

SD: Standard deviation; *Tests for significant trend across increasing tertile, adjusted for sex
[a] significantly different from low tertile at p<0.05, t-test adjusted for sex; [b] significantly different from low tertile at p<0.001, t-test adjusted for sex.

Whole grain intake estimated from the 60-year follow-up was significantly positively correlated with intakes of cereals and cereal products, milk and milk products, fats and oils, fish and fish products, fruits, vegetables, nuts and seeds and soups and sauces (Table 4.9). After adjustment for sex, mean intakes of cereals and cereal products and fruits were significantly higher for those in T2 and T3 of whole grain intake, compared with T1 (Table 4.9). Mean intakes of milk and milk products, vegetables, nuts, seeds soups and sauces were significantly higher for those in T3 only, compared with T1 after adjustment for sex.

Table 4.9 Daily intakes of food groups per tertile of whole grain intake estimated at 60-year follow-up

Food group (g/d)	Correlation with whole grain intake	**Whole grain intake tertile** (min-max intake) T1 (0 - 15g/d, n=142)		T2 (16 - 29 g/d, n=140)		T3 (30 - 116 g/d, n=141)		p-value*
		Mean	**(SD)**	**Mean**	**(SD)**	**Mean**	**(SD)**	
Cereals and cereal products	0.56	114.4	(62.7)	166.3 [b]	(70.9)	222.8 [b]	(92.2)	<0.001
Milk and milk products	0.18	321.4	(198.0)	340.0	(169.1)	393.1 [a]	(185.9)	0.005
Eggs and egg dishes	0.03	16.5	(13.3)	15.4	(12.5)	18.4	(17.0)	0.202
Fats and oils	0.13	17.0	(13.0)	18.2	(13.2)	19.1	(12.3)	0.362
Meat and meat products	0.01	111.2	(70.1)	103.7	(51.0)	108.9	(70.3)	0.707
Fish and fish products	0.14	36.8	(29.4)	39.0	(23.8)	42.6	(24.6)	0.203
Fruit	0.37	149.4	(130.2)	188.4 [a]	(132.4)	253.4 [b]	(135.9)	<0.001
Vegetables	0.30	221.9	(126.2)	251.7	(102.6)	300.3 [b]	(133.2)	<0.001
Potatoes	0.03	80.5	(61.9)	82.3	(41.6)	80.5	(39.7)	0.933
Nuts and seeds	0.17	3.3	(6.0)	4.0	(6.7)	7.2 [b]	(11.3)	<0.001
Soups and sauces	0.21	49.7	(47.5)	55.0	(45.9)	69.0 [a]	(53.8)	0.004
Sugars, preserves and snacks	0.01	32.3	(26.5)	28.7	(24.1)	31.8	(26.1)	0.544
Alcoholic beverages	0.01	145.5	(265.5)	107.4	(209.9)	141.6	(254.5)	0.528
Non-alcoholic beverages	0.02	855.1	(412.7)	842.5	(415.8)	875.2	(393.6)	0.780

SD: Standard deviation; *Tests for significant trend across increasing tertile, adjusted for sex
[a] significantly different from low tertile at p<0.05, t-test adjusted for sex; [b] significantly different from low tertile at p<0.001, t-test adjusted for sex.

4.4.7 Whole grain intake and cardio-metabolic markers

4.4.7.1 Examinations at the 50-year follow-up

At the 50-year follow-up there were a total of 404 study members (56% female) who attended for clinical examination and also completed the EPIC-Norfolk FFQ from which whole grain intake was estimated. Descriptive statistics of whole grain intake and cardio-metabolic measures for those with available data are shown in Table 4.10. There was a slightly smaller number of participants with cardio-metabolic measures than with body weight and blood pressure measures due to missing data. Median whole grain intake was 21g/d (IQR 4 – 44g/d) for the total population with cardio-metabolic measures and was significantly higher in females compared with males (25 vs 16g/d, $p<0.001$, Table 4.10). Average systolic blood pressures were higher than the normal range (90 - 120mmHg), but were not hypertensive (>140mmHg), and average diastolic blood pressures fell with the normal range (60 - 80mmHg) for both males and females. Average BMI values were slightly higher than 25kg/m^2 (the upper healthy status level) for both men and women. Average values of all other cardio-metabolic markers fell within reference ranges (Table 4.10) (McMorran *et al.*, 2016). There were significant sex differences in the majority of average (mean or median) cardio-metabolic measures (Table 4.10).

Of the 404 study participants, 47 (12%) reported taking a CVD medication and 3 (1%) reported taking a lipid lowering medication. One participant recorded taking medication for diabetes, however they have been excluded from analyses since no fasting blood sample was obtained from them. There were slightly smaller numbers of participants with blood lipid, oral glucose, carotid and body fat measures since some study members did not wish to take part in these tests. One female taking a lipid lowering medication who also had a very high body fat percentage was excluded from the analysis as an extreme outlier. One study member with a very low haemoglobin measure was also excluded from the analysis as an extreme outlier. Mean total dietary energy intakes for those with cardio-metabolic and whole grain intake data (n=404) were 9MJ per day for males and 8MJ per day for females. At the 50-year follow-up 34% of males and 47% of females had never smoked, 45% of males and 24% of females were ex-smokers and 26% of males and 29% of females were current smokers.

Table 4.10 Summary of whole grain intake and cardio-metabolic markers at 50-year follow-up

	Total population					Males					Females					
	n	Mean	SD	Median	IQR	n	Mean	SD	Median	IQR	n	Mean	SD	Median	IQR	p-value*
Whole grain intake (g/d)	404	29.4	30.4	21.4	4.4-43.5	178	24.3	28.3	16.0	1.9-34.7	226	33.5	31.4	25.4	8.9-52.6	<0.001
Systolic BP (mmHg)	404	125.7	16.9	122.5	115-134	178	128.4	17.6	126.0	117-136	226	123.6	16.1	121.0	112-131	0.001
Diastolic BP (mmHg)	404	78.5	10.1	78.5	70.5-84.5	178	81.7	10.1	81.0	75-87	226	76.0	9.4	76.0	69-82	<0.001
Pulse pressure (mmHg)	404	75.2	9.4	75.0	70-80	178	75.0	10.3	75.0	70-80	226	75.3	8.5	75.5	70-80	0.630
CIMT (mm)	350	0.8	0.2	0.8	0.7-0.8	158	0.8	0.2	0.8	0.7-0.9	192	0.7	0.1	0.7	0.6-0.9	0.001
Height (m)	401	1.7	0.09	1.7	1.6-1.7	177	1.7	0.06	1.7	1.7-1.8	224	1.6	0.06	1.6	1.6-17	<0.001
Weight (kg)	402	74.1	14.6	72.4	62.1-73.1	178	80.9	12.6	79.7	72.8-88.9	224	68.6	13.7	64.9	59.4-74.7	<0.001
BMI (kg/m^2)	401	26.6	4.6	26.0	23.2-29.3	177	26.9	3.6	26.8	24.3-29.4	224	26.4	5.2	25.1	22.5-29.2	0.008
Waist: Hip ratio	404	0.9	0.1	0.9	0.8-0.9	178	1.0	0.1	1.0	0.9-1.0	226	0.8	0.1	0.8	0.7-0.8	<0.001
Body fat (%)	399	39.2	8.7	39.2	33.9-44.9	177	36.3	7.0	36.6	32-41.3	222	41.5	9.1	42.2	35.4-48.0	<0.001
Cholesterol (mmol/L)	398	5.1	1.3	5.1	4.3-5.9	177	5.3	1.4	5.3	4.4-6.1	221	5.0	1.2	4.9	4.2-5.8	0.075
HDL (mmol/L)	398	1.1	0.4	1.1	0.8-1.3	177	1.0	0.3	1.0	0.8-1.2	221	1.2	0.4	1.2	0.9-1.4	<0.001
LDL (mmol/L)	398	3.8	1.3	3.7	2.9-4.6	177	4.0	1.3	3.9	3.2-3.9	221	3.7	1.2	3.5	2.9-4.4	0.011
Triglycerides (mmol/L)	398	1.3	0.9	1.0	0.7-1.6	177	1.5	1.2	1.3	0.8-1.9	221	1.1	0.6	0.9	0.6-1.4	<0.001
APO-A1 (g/L)	398	1.4	0.4	1.4	1.2-1.6	177	1.3	0.3	1.3	1.1-1.4	221	1.5	0.4	1.4	1.3-1.8	<0.001
APO-B (g/L)	398	0.6	0.2	0.6	0.5-0.8	177	0.7	0.2	0.7	0.6-0.8	221	0.6	0.2	0.6	0.5-0.7	<0.001
Haemoglobin (g/dL)	398	13.9	1.5	13.9	12.9-14.9	177	15.1	1.0	15.1	14.5-15.7	221	13.0	1.2	13.1	12.4-13.7	<0.001
Fibrinogen (g/L)	396	2.9	0.7	2.9	2.5-3.3	176	2.9	0.7	2.8	2.4-3.3	220	3.0	0.7	2.9	2.5-3.4	0.200
Haematocrit (%)	391	40.5	4.2	40.4	37.6-43.5	172	43.7	2.8	43.7	41.9-45.6	219	38.0	3.4	38.0	36.2-40.0	<0.001
WBC ($x10^9/L$)	393	6.8	5.0	6.1	5.1-7.6	174	7.1	7.1	6.1	5.2-7.4	219	6.6	2.1	6.1	5.0-7.7	0.326
PLT ($x10^9/L$)	393	248.0	56.4	247.0	209-284	174	239.1	49.9	237.5	206-271	219	255.1	60.2	255.0	214-291	0.005
Fasting glucose (mmol/L)	393	5.3	0.6	5.2	4.9-5.5	174	5.5	0.6	5.4	5.1-5.7	219	5.1	0.5	5.0	4.8-5.3	<0.001
2 hour glucose (mmol/L)	391	5.7	1.4	5.6	4.7-6.5	173	5.7	1.4	5.6	4.8-6.5	218	5.7	1.4	5.6	4.7-6.5	0.954
Fasting insulin (mU/L)	382	8.2	6.5	7.1	4.8-9.9	169	9.6	8.5	7.7	5.6-11.1	213	7.1	4.0	6.2	4.3-8.8	<0.001
2 hour insulin (mU/L)	384	41.7	37.7	31.6	17.4-54.0	170	45.3	42.6	33.2	16.2-62.9	214	38.8	33.1	29.3	18.8-47.8	0.320
HOMA-IR (mmol/L)	382	2.0	1.7	1.6	1.1-2.3	169	2.4	2.1	1.8	1.3-2.7	213	1.7	1.1	1.4	1.0-2.0	<0.001
HOMA-β (%)	382	95.6	71.1	81.7	60.0-112.8	169	101.5	94.0	80.4	59.8-118.1	213	90.9	45.1	82.5	60.8-108.9	0.887

BP: Blood pressure; BMI: Body mass index; CIMT: Carotid intima-media thickness; HDL: High density lipoprotein; LDL: Low density lipoprotein; APO: Apolipoprotein; PAI-1: Plasminogen activator inhibitor 1; WBC: White blood cell (leucocyte) count; PLT: Platelet (thrombocyte) concentration; HOMA-IR: Homeostasis model assessment of insulin resistance; HOMA- β: Homeostasis model assessment of beta cell function; * Mann-Whitney U test for sex difference

4.4.7.2 Regressions of cardio-metabolic measures and whole grain intake from 50-year follow-up

Linear regression analysis of the associations between whole grain intake and cardio-metabolic measures at 50-year follow-up, adjusted for sex, dietary energy intake, CVD and lipid medication use are shown in Table 4.11. There were borderline significant negative associations between whole grain intake and blood pressures (systolic p=0.055, diastolic p=0.057). These associations were attenuated (magnitude reduced) after further adjustment for smoking status, achieved education level and SES at 50-year follow-up and became non-significant (Table 4.12). Inclusion of these adjustment factors reduced the model sample size. However, sensitivity analyses of the association between whole grain intake and blood pressures, in the smaller sample sizes, showed similar regression co-efficients and confidence intervals (systolic blood pressure model: whole grain intake co-eff -0.04 95%CI -0.09, 0.02 p=0.166 n=375; diastolic blood pressure model: whole grain intake co-eff -0.03 95%CI -0.05, 0.01 p=0.146 n=375). There were no significant sex-whole grain intake interactions with blood pressures (systolic blood pressure p=0.504, diastolic blood pressure p=0.256) and in sex specific analyses there were no significant associations between whole grain intake and blood pressures in either males or females.

There were no significant associations between whole grain intake and height, weight, BMI or waist to hip ratio (p>0.05, Table 4.11). There was a significant linear association between body fat percentage (measured by impedance) and whole grain intake at 50-year follow-up. After adjustment for sex, CVD and lipid medication use and dietary energy intake, body fat was 0.03% lower (95%CI -0.06, -0.002, p=0.033) for each gram of whole grain consumed per day (Table 4.11). After further adjustment for smoking status, achieved education level and SES at 50-year follow-up, body fat was 0.05% lower (95%CI -0.07, -0.02, p=0.002) for each gram of whole grain consumed per day (Table 4.12).

Table 4.11 Associations between whole grain intake (independent) and cardio-metabolic measures (dependent) at 50-year follow-up, adjusted for sex, medication use and dietary energy intake.

Cardio-metabolic measure (dependant)	n	Whole grain intake (g/d) co-eff*	95%CI	p-value
Systolic BP (mmHg)	403	-0.053	(-0.106, 0.001)	0.055
Diastolic BP (mmHg)	403	-0.030	(-0.061, 0.001)	0.057
Pulse pressure (mmHg)	403	-0.014	(-0.045, 0.017)	0.367
CIMT (mm)	349	0.000	(-0.001, 0.000)	0.084
Height (m)	400	0.000	(0.000, 0.000)	0.944
Weight (kg)	401	-0.024	(-0.068, 0.019)	0.271
BMI (kg/m^2)	400	-0.009	(-0.024, 0.006)	0.216
Waist: Hip ratio	403	0.000	(0.000, 0.000)	0.533
Body fat (%)	398	-0.029	(-0.056, -0.002)	0.033 [a]
Cholesterol (mmol/L)	396	-0.006	(-0.010, -0.002)	0.003 [a]
HDL (mmol/L)	396	0.000	(-0.002, 0.001)	0.407
LDL (mmol/L)	396	-0.006	(-0.010, -0.002)	0.007 [a]
Triglycerides (mmol/L)	396	-0.001	(-0.004, 0.002)	0.665
APO-A1 (g/L)	396	-0.001	(-0.003, 0.000)	0.053
APO-B (g/L)	396	-0.001	(-0.001, 0.000)	0.090
Haemoglobin (g/dL)	395	-0.005	(-0.009, -0.002)	0.003 [a]
Fibrinogen (g/L)	394	-0.002	(-0.004, 0.000)	0.079
Haematocrit (%)	389	-0.017	(-0.027, -0.007)	0.001 [a]
WBC (x10^9/L)	391	-0.009	(-0.026, 0.007)	0.283
PLT (x10^9/L)	391	0.047	(-0.140, 0.235)	0.621
Fasting glucose (mmol/L)	392	-0.001	(-0.003, 0.000)	0.138
2 hour glucose (mmol/L)	390	-0.001	(-0.005, 0.004)	0.745
Fasting insulin (mU/L)	381	-0.003	(-0.024, 0.019)	0.791
2 hour insulin (mU/L)	383	-0.032	(-0.160, 0.096)	0.624
HOMA-IR (mmol/L)	381	-0.001	(-0.007, 0.004)	0.634
HOMA-β (%)	381	0.022	(-0.217, 0.262)	0.855

BP: Blood pressure; BMI: Body mass index; CIMT: Carotid intima-media thickness; HDL: High density lipoprotein; LDL: Low density lipoprotein; APO: Apolipoprotein; WBC: White blood cell (leucocyte) count; PLT: Platelet (thrombocyte) concentration; HOMA-IR: Homeostasis model assessment of insulin resistance; HOMA- β: Homeostasis model assessment of beta cell function; *The co-efficient represents the change in cardio-metabolic outcome per 1g/d increase in whole grain intake; [a]p-value <0.05; 95%CI: 95% confidence interval

In addition to whole grain intake, females (56% of the sample), those taking a CVD medication (12% of the sample) and those not currently smoking (never smoked or ex-smokers, 58% of the sample) had significantly higher body fat percentage in comparison to males, those not taking a CVD medication and smokers, respectively (Table 4.12).This finding was reflective of the cohort since current smokers had lower mean BMI and weight measures compared to never and ex-smokers. The three study members taking lipid lowering medication also had significantly lower body fat percentages in comparison to those not taking the medication.

Achieved level of education by 50-year follow-up and SES were not associated with body fat percentage (all p>0.05, Table 4.12) nor did these factors attenuate the inverse association between body fat percentage and whole grain intake. The fully adjusted linear regression model accounted for 18% of the variation in body fat percentage with satisfactory regression diagnostic plots (Appendix G). There was no significant sex-whole grain intake interaction with body fat measured by impedance (p=0.117) however, in sex specific analyses the association between whole grain intake and body fat percent was not significant in males, but remained in females only. After adjustment for medication use, total energy intake and cigarette smoking status, female body fat was 0.05% lower (95%CI -0.09, -0.01, p=0.008) per gram of whole grain consumed per day (Table 4.13). This association was not attenuated by further adjustment of achieved education level or SES at 50-year follow-up. The final linear regression model for females only, accounted for 7% of the variation in body fat percentage with satisfactory regression diagnostic plots (Appendix G).

Whole grain intake was also found to be significantly inversely associated with total and LDL cholesterol concentrations. After adjustment for sex, medication use and total energy intake, both total and LDL cholesterol were 0.01mmoll/L lower per each gram of whole grain consumed per day (Table 4.11). These associations were not attenuated and remained significant after adjustment for smoking status, achieved level of education and SES (Table 4.12). The fully adjusted linear regression models accounted for 5% of the variation in total cholesterol concentrations and 6% of the variation in LDL cholesterol concentrations. There were no significant sex-whole grain intake interactions with total cholesterol (p=0.874) or LDL cholesterol (p=0.971) however, in sex specific analyses the association between whole grain intake and total cholesterol was not significant in males, but remained in females only. After adjustment for medication use, total energy intake and cigarette smoking status, total and LDL cholesterol in females were 0.01mmol/L lower (total cholesterol 95%CI -0.011, -0.001, p=0.016; LDL cholesterol 95%CI -0.011, -0.0004, p=0.035) per each gram of whole grain consumed per day (Table 4.13). These association was not attenuated for further adjustment of achieved education level or SES at 50-year follow-up. The linear regression models for females accounted for only 5% and 6% of the variation in total cholesterol and LDL cholesterol concentrations respectively.

A significant linear association was seen between whole grain intake and haemoglobin (Table 4.11), but was attenuated and confounded by smoking status at 50-year follow-up. There was also a significant smoking status-sex interaction associated with haemoglobin concentrations. Female smokers had significantly higher haemoglobin concentrations in comparison to female never or ex-smokers. Similarly, a significant linear association seen between whole grain intake and haematocrit percentage volume was attenuated and confounded by smoking status at 50-year follow-up. There were no significant sex-whole grain interactions associated with either haemoglobin (p=0.161) or haematocrit percentage volume (p=0.166), and in sex specific analyses no significant associations were seen.

Finally, no significant linear associations were seen in any glucose or insulin measures, taken from the oral glucose tolerance test during the 50-year follow-up (Table 4.11).

Table 4.12 : Fully adjusted linear regression model of cardio-metabolic outcome and whole grain intake, adjusted for sex, medication use, dietary energy intake, smoking status, achieved educational level and SES at 50-year follow-up.

Outcome		Model of **systolic blood pressure** (n=375)				Model of **diastolic blood pressure** (n=375)				Model of **body fat percentage** (n=369)				Model of **total cholesterol** (n=368)				Model of **LDL-cholesterol** (n=368)			
		co-eff	**95%CI**		**p-value**	**co-eff**	**95%CI**		**p-value**	**co-eff**	**95%CI**		**p-value**	**co-eff**	**95%CI**		**p-value**	**co-eff**	**95%CI**		**p-value**
Whole grain intake (g/d)		-0.04	-0.10	0.01	0.144	-0.03	-0.06	0.00	0.086	-0.05	-0.07	-0.02	0.002	-0.01	-0.01	0.00	0.004	-0.01	-0.01	0.00	0.009
Sex	**Male**	Reference category				Reference category				Reference category				Reference category				Reference category			
	Female	-5.14	-8.72	-1.55	0.005	-5.42	-7.47	-3.37	<0.001	6.31	4.54	8.09	<0.001	-0.14	-0.41	0.14	0.328	-0.25	-0.53	0.02	0.070
CVD-med	**No**	Reference category				Reference category				Reference category				Reference category				Reference category			
	Yes	9.65	4.47	14.83	<0.001	6.00	3.03	8.97	<0.001	4.97	2.41	7.54	<0.001	0.04	-0.36	0.43	0.859	0.00	-0.40	0.39	0.981
Lipid-med	**No**	Reference category				Reference category				Reference category				Reference category				Reference category			
	Yes	-36.31	-55.34	-17.27	<0.001	-16.21	-27.12	-5.30	0.004	-2.89	-14.39	8.61	0.622	-1.12	-2.58	0.34	0.131	-0.78	-2.23	0.67	0.292
Dietary energy intake (MJ)		-0.03	-0.47	0.41	0.888	0.03	-0.23	0.28	0.846	0.09	-0.13	0.31	0.418	0.00	-0.03	0.03	0.987	0.00	-0.03	0.04	0.943
Smoking status at 50-year follow-up	**Never**	Reference category			0.217	Reference category			0.066	Reference category			0.005	Reference category			0.931	Reference category			1.000
	Ex	0.30	-3.73	4.34	*0.883*	1.57	-0.74	3.88	*0.182*	1.01	-0.98	3.00	*0.318*	0.05	-0.26	0.36	*0.749*	0.00	-0.31	0.31	*0.990*
	Current	-3.48	-7.90	0.95	*0.124*	-1.61	-4.14	0.93	*0.214*	-2.74	-4.94	-0.55	*0.014*	-0.01	-0.35	0.33	*0.953*	0.00	-0.34	0.34	*0.996*
Achieved education level up 50-year follow-up	**None**	Reference category			0.348	Reference category			0.675	Reference category			0.170	Reference category			0.835	Reference category			0.835
	O level	-3.19	-7.31	0.94	*0.133*	-0.93	-3.29	1.43	*0.441*	-1.95	-3.99	0.10	*0.062*	0.12	-0.20	0.44	*0.466*	0.09	-0.23	0.41	*0.589*
	A level	-0.54	-5.84	4.76	*0.841*	0.60	-2.44	3.64	*0.699*	0.21	-2.41	2.83	*0.874*	0.04	-0.37	0.45	*0.862*	0.01	-0.40	0.42	*0.970*
	Degree Postgrad	-3.60	-9.52	2.33	*0.234*	-0.90	-4.30	2.49	*0.601*	-0.20	-3.12	2.72	*0.893*	0.17	-0.29	0.63	*0.468*	0.18	-0.27	0.64	*0.434*
SES at 50-year follow-up	**I**	Reference category			0.689	Reference category			0.639	Reference category			0.759	Reference category			0.470	Reference category			0.391
	II	2.63	-3.23	8.49	*0.378*	1.76	-1.60	5.12	*0.303*	-0.03	-2.90	2.85	*0.984*	0.03	-0.42	0.49	*0.891*	0.02	-0.43	0.47	*0.936*
	3n	3.88	-3.25	11.01	*0.285*	2.98	-1.11	7.07	*0.153*	-0.55	-4.10	2.99	*0.759*	-0.18	-0.73	0.38	*0.535*	-0.21	-0.76	0.35	*0.466*
	3m	2.98	-3.62	9.58	*0.376*	1.79	-1.99	5.57	*0.353*	0.87	-2.37	4.12	*0.597*	0.18	-0.34	0.69	*0.499*	0.13	-0.38	0.64	*0.618*
	IV	4.86	-3.04	12.77	*0.227*	2.73	-1.76	7.23	*0.232*	-1.36	-5.21	2.49	*0.489*	-0.06	-0.67	0.56	*0.856*	-0.04	-0.65	0.57	*0.902*
	V	8.00	-1.90	17.89	*0.113*	4.49	-1.18	10.16	*0.120*	1.27	-3.69	6.22	*0.615*	-0.44	-1.22	0.34	*0.265*	-0.56	-1.34	0.21	*0.152*

LDL: low-density lipoprotein; med: medication use; p-values in *italics* represent the Wald test of difference from reference category; co-eff: regression co-efficient representing the change in cardio-metabolic outcome per 1g/d increase in whole grain intake; NB: results shown for sex, CVD-med, Lipid-med, dietary energy intake, smoking status, achieved education level and SES are for exploration of potential confounding.

Table 4.13 Associations between cardio-metabolic outcome and whole grain intake in females only, adjusted for medication use, dietary energy intake and smoking status at 50-year follow-up.

Outcome		Model of **body fat percentage** (n=221)				Model of **total cholesterol** (n=221)				Model of **LDL-cholesterol** (n=221)			
		co-eff	**95%CI**		**p-value**	**co-eff**	**95%CI**		**p-value**	**co-eff**	**95%CI**		**p-value**
Whole grain intake (g/d)		-0.05	-0.09	-0.01	0.008	-0.01	-0.01	0.00	0.016	-0.01	-0.01	0.00	0.035
CVD-med	**No**	Reference category				Reference category				Reference category			
	Yes	5.45	1.87	9.03	0.003	0.20	-0.27	0.68	0.396	0.11	-0.37	0.60	0.638
Lipid-med	**No**	Reference category				Reference category				Reference category			
	Yes	-	-	-	-	0.30	-1.99	2.60	0.795	0.72	-1.61	3.05	0.544
Dietary energy intake (MJ)		0.12	-0.15	0.39	0.383	0.02	-0.02	0.05	0.314	0.02	-0.01	0.06	0.237
Smoking status at 50-year	**Never**	Reference category			0.553	Reference category			0.443	Reference category			0.371
	Ex	1.17	-1.74	4.08	*0.429*	-0.16	-0.54	0.23	*0.427*	-0.19	-0.59	0.20	*0.328*
	Current	-0.60	-3.45	2.25	*0.677*	0.12	-0.25	0.50	*0.518*	0.12	-0.27	0.50	*0.552*

LDL: low-density lipoprotein; co-eff: regression co-efficient; med: medication use; p-values in italics represent the Wald test of difference from reference category; co-eff: co-efficient representing the change in cardio-metabolic outcome per 1g/d increase in whole grain intake; NB: results shown for sex, CVD-med, Lipid-med, dietary energy intake, smoking status, achieved education level and SES are for exploration of potential confounding.

4.4.7.3 Cardio-metabolic measures by whole grain intake tertile from 50-year follow-up

Mean and SD of all cardio-metabolic measures by tertile of whole grain intake are shown in Table 4.14. Across tertiles, blood pressures, weight, waist to hip ratio, CIMT, total cholesterol, LDL cholesterol, triglycerides, APO-A1, APO-B, haemoglobin fibrinogen, haematocrit and fasting glucose measures were greatest in T1 and lowest in T3 of whole grain intake. However, not all of these trends were significant after adjustment for sex, medication use and dietary energy intake (Table 4.14). Haemoglobin, haematocrit and fibrinogen concentrations were significantly lower in T3 compared with T1 of whole grain intake, after adjustment for sex, medication use and dietary energy intake. These significant differences were confounded by smoking status at 50-year follow-up. For those with haemoglobin measures in T1, 30% had never smoked, 24% were ex-smokers and 46% were current smokers whereas in T3 of whole grain intake 46% had never smoked, 38% were ex-smokers and 16% were current smokers. Significant differences in whole grain intake and smoking status in this cohort was reported in section 4.4.3.2 (Table 4.5). Interestingly, fasting insulin, 2-hour insulin and HOMA-β cell function levels were significantly higher in the T2 compared with T1 of whole grain intake, after adjustment for sex, medication use and dietary energy intake (Table 4.14). Fasting insulin concentrations in all tertiles were within normal reference ranges (<25mU/L) as well as the 2-hour insulin concentrations (16-166mU/L).

Table 4.14 Average cardio-metabolic measures by tertile of daily whole grain intake at 50-year follow-up.

Cardio-metabolic measure	Total n	**Whole grain intake tertile** (min-max intake) **T1** (0 - 9g/d) Mean	(SD)	**T2** (10 - 32g/d) Mean	(SD)	**T3** (33 - 149g/d) Mean	(SD)	p-value*
Systolic BP (mmHg)	404	128.06	(17.90)	126.02	(17.18)	123.25	(15.41)	0.236
Diastolic BP (mmHg)		79.91	(10.61)	78.94	(10.15)	76.78	(9.31)	0.247
Pulse pressure (mmHg)		75.47	(8.38)	75.89	(9.71)	74.29	(9.84)	0.395
n per tertile		*130*		*134*		*140*		
CIMT (mm)	350	0.78	(0.18)	0.76	(0.14)	0.75	(0.14)	0.557
n per tertile		*110*		*114*		*126*		
Height (m)	401	1.68	(0.08)	1.67	(0.09)	1.65	(0.08)	0.586
Weight (kg)		75.40	(13.98)	75.30	(14.65)	71.61	(14.98)	0.250
BMI (kg/m^2)		26.69	(4.37)	27.01	(4.83)	26.11	(4.53)	0.336
n per tertile		*128*		*134*		*139*		
Waist: Hip ratio	404	0.89	(0.09)	0.87	(0.09)	0.85	(0.10)	0.825
n per tertile		*130*		*134*		*140*		
Body fat (%)	399	39.00	(8.71)	40.15	(9.01)	38.50	(8.28)	0.091
n per tertile		*127*		*133*		*139*		
Cholesterol (mmol/L)	397	5.26	(1.36)	5.17	(1.19)	5.02	(1.25)	0.491
HDL (mmol/L)		1.09	(0.34)	1.11	(0.38)	1.11	(0.34)	0.867
LDL (mmol/L)		3.91	(1.31)	3.81	(1.20)	3.67	(1.24)	0.600
Triglycerides (mmol/L)		1.33	(0.87)	1.27	(1.03)	1.20	(0.87)	0.933
APO-A1 (g/L)		1.47	(0.40)	1.43	(0.40)	1.42	(0.39)	0.156
APO-B (g/L)		0.67	(0.16)	0.63	(0.18)	0.63	(0.19)	0.414
Haemoglobin (g/dL)		14.33	(1.41)	13.98	(1.43)	13.56[a]	(1.45)	0.045
n per tertile		*125*		*133*		*139*		
Fibrinogen (g/L)	395	3.05	(0.69)	2.92	(0.69)	2.87[a]	(0.66)	0.044
n per tertile		*125*		*132*		*138*		
Haematocrit (%)	390	41.64	(4.30)	40.56	(3.90)	39.36[a]	(4.23)	0.026
n per tertile		*123*		*131*		*136*		
WBC (x10^9/L)	392	7.40	(8.27)	6.49	(2.07)	6.53	(2.09)	0.331
PLT (x10^9/L)		250.48	(49.76)	240.23	(64.82)	253.48	(53.01)	0.120
n per tertile		*125*		*131*		*136*		
Fasting glucose (mmol/L)	393	5.37	(0.72)	5.23	(0.50)	5.21	(0.52)	0.413
n per tertile		*123*		*132*		*138*		
2 hour glucose (mmol/L)	391	5.50	(1.22)	5.85	(1.48)	5.74	(1.38)	0.132
n per tertile		*121*		*132*		*138*		
Fasting insulin (mU/L)	382	7.74	(4.54)	9.39[a]	(9.16)	7.61	(4.69)	0.038
n per tertile		*120*		*127*		*135*		
2 hour insulin (mU/L)	384	36.57	(32.57)	50.80[a]	(48.37)	37.41	(27.44)	0.003
n per tertile		*118*		*130*		*136*		
HOMA-IR (mmol/L)	382	1.91	(1.45)	2.22	(2.23)	1.81	(1.25)	0.113
HOMA-β (%)		85.39	(45.22)	110.96[a]	(102.00)	90.12	(49.37)	0.008
n per tertile		*120*		*127*		*135*		

BP: Blood pressure; BMI: Body mass index; CIMT: Carotid intima-media thickness; HDL: High density lipoprotein; LDL: Low density lipoprotein; APO: Apolipoprotein; WBC: White blood cell (leucocyte) count; PLT: Platelet (thrombocyte) concentration; HOMA-IR: Homeostasis model assessment of insulin resistance; HOMA- β: Homeostasis model assessment of beta cell function; *Tests for significant trend across increasing tertile, adjusted for sex, medication use and dietary energy intake. [a] Significantly different from low tertile at $p<0.05$, t-test adjusted for sex, medication use and dietary energy intake.

When mean and SD of all cardio-metabolic measures by tertile of whole grain intake were estimated separately for males and females, there were significant differences in fasting and

2-hour insulin concentrations in males only and body fat percentages in females only across whole grain intake tertiles. In males mean fasting and 2-hour insulin concentrations were higher in T2 compared with T1 but not with T3. After adjustment for medication use, dietary energy intake and smoking status, fasting insulin concentrations were on average 3.9mU/L (95%CI 0.6, 7.1) higher and 2-hour insulin concentrations were on average 20.3mU/L higher in T2 compared to T1. In females, mean body fat percentage was significantly lower in T3 compared with T1 and T2 of whole grain intake. After adjustment for medication use, dietary energy intake and smoking status, females in T3 had on average 3.6% (95% CI -6.7, -0.6, p=0.020) lower body fat than females in T1 and 3.5% (95% CI –6.2, -0.8, p=0.012) lower body fat than females in T2 . Further adjustment for achieved education level and SES did not attenuate these associations.

4.4.7.4 Examinations at the 60-year follow-up

At the 60-year follow-up there were a total of 345 study members (54% female) who attended for clinical examination and also completed the EPIC-Norfolk FFQ, from which whole grain intake was estimated. Descriptive statistics of whole grain intake and cardio-metabolic measures for those with available data are shown in Table 4.15. There was a slightly smaller number of participants with cardio-metabolic measures due to missing data, non-fasting or refusal to provide a blood sample and haemolysis of samples during lab analyses. Median whole grain intake was 21g/d (IQR 10 - 33) for the total population with cardio-metabolic measures and was borderline significantly different in males and females (Table 4.15). Median whole grain intake was 20g/d (IQR 8 - 33) for males and was 23g/d (IQR 15 - 33) for females. Average systolic blood pressures were higher than the normal range, but were not hypertensive, and average diastolic blood pressures fell with the normal range for both males and females. Average BMI values were higher than the healthy status level for both men and women and fell within the overweight range (25 – 29.9kg/m^2). Average cholesterol concentrations were slightly elevated in both males and females (>5mmol/L), as were LDL and HDL cholesterol concentrations in females only (HDL>1mmol/L, LDL>3mmol/L). The remaining cardio-metabolic measures fell within reference ranges and there were significant sex differences in the majority of average (mean or median) cardio-metabolic measures (Table 4.15).

Of the 345 study participants with whole grain intake and cardio-metabolic measures, 123 (36%) reported taking a CVD medication and 83 (24%) reported taking a lipid lowering medication. There were 14 (4%) participants who reported taking a medication for diabetes, however they have been excluded from analyses of blood measures since no fasting blood sample was obtained. Mean total dietary energy intakes for those with cardio-metabolic and whole grain intake data (n=345) were 7MJ per day for males and 6MJ per day for females. At the 60-year follow-up, 37% of males and 49% of females had never smoked, 51% of males and 43% of females were ex-smokers and 12% of males and 8% of females were current smokers.

Table 4.15 Summary of whole grain intake and cardio-metabolic markers at 60-year follow-up

	Total population					Males					Females					
	n	**Mean**	**SD**	**Median**	**IQR**	**n**	**Mean**	**SD**	**Median**	**IQR**	**n**	**Mean**	**SD**	**Median**	**IQR**	**p-value***
Whole grain intake (g/d)	345	24.5	18.2	21.2	10.2-32.9	157	23.4	20.3	20.1	8.0-32.9	188	25.4	16.3	23.4	15.4-33.0	0.059
Systolic BP (mmHg)	343	133.4	16.6	132.3	121.7-142.3	156	134.4	16.2	134.2	123-144	187	132.6	17.0	131.0	120.7-141.3	0.199
Diastolic BP (mmHg)	343	78.8	7.9	79.0	73.3-83.7	156	80.1	7.8	80.0	75.3-84.0	187	77.7	7.9	77.3	72.0-83.3	0.008
Pulse pressure (mmHg)	343	54.6	12.5	52.7	45.0-61.3	156	54.3	11.6	53.0	45.8-60.3	187	54.9	13.2	51.7	44.7-62.3	0.838
Height (m)	345	1.7	0.1	1.7	1.6-1.7	157	1.7	0.1	1.7	1.7-1.8	188	1.6	0.1	1.6	1.5-1.6	<0.001
Weight (kg)	345	78.3	16.0	76.5	67.3-88.6	157	85.8	14.7	83.0	76.2-93.4	188	72.0	14.3	69.6	61.9-80.5	<0.001
BMI (kg/m^2)	345	28.0	5.1	27.3	24.5-30.9	157	28.2	4.5	27.4	25.0-30.9	188	27.8	5.5	26.8	23.8-31.1	0.222
Waist: hip ratio	336	0.9	0.1	0.9	0.9-1.0	152	1.0	0.1	1.0	0.9-1.0	184	0.9	0.1	0.9	0.8-0.9	<0.001
Whole grain intake (g/d)†	331	24.3	18.2	21.0	10.1-32.9	150	22.9	20.0	19.3	8.0-32.9	181	25.4	16.5	23.6	15.4-32.3	0.045
Cholesterol (mmol/L)	310	5.5	1.1	5.5	4.8-6.3	140	5.2	1.0	5.2	4.5-5.8	170	5.8	1.1	5.8	5.0-6.5	<0.001
HDL (mmol/L)	310	1.6	0.4	1.6	1.3-1.8	140	1.4	0.4	1.4	1.1-1.6	170	1.7	0.4	1.7	1.4-2.0	<0.001
LDL (mmol/L)	307	3.3	1.0	3.2	2.6-3.9	137	3.1	0.9	3.0	2.4-3.7	170	3.5	1.1	3.3	2.8-4.1	0.002
Triglycerides (mmol/l)	310	1.5	0.8	1.3	0.9-1.8	140	1.6	1.0	1.3	1.0-2.0	170	1.4	0.6	1.2	0.9-1.7	0.251
CRP‡ (mmol/L)	279	5.8	2.6	4.9	4.9-4.9	128	6.0	3.2	4.9	4.9-4.9	151	5.6	2.1	4.9	4.9-4.9	0.666
Fibrinogen (g/L)	169	4.0	0.8	4.0	3.4-4.4	83	3.9	0.8	3.9	3.3-4.1	86	4.1	0.7	4.1	3.6-4.6	0.026
Clauss fibrinogen (g/L)	280	3.1	0.5	3.1	2.7-3.4	127	3.0	0.5	3.0	2.6-3.3	153	3.2	0.5	3.2	2.8-3.5	0.013
Haemoglobin (g/dL)	297	14.0	1.1	13.9	13.2-14.7	135	14.7	1.0	14.7	14.0-15.4	162	13.3	0.8	13.4	12.8-13.8	<0.001
Haematocrit (%)	297	41.1	3.1	41.1	39.0-43.2	135	42.9	2.6	42.9	41.2-44.5	162	39.9	4.9	39.5	38.2-41.4	<0.001
RBC ($x10^{12}/L$)	297	4.6	0.4	4.6	4.3-4.9	135	4.8	0.3	4.9	4.6-5.1	162	4.4	0.3	4.4	4.2-4.6	<0.001
WBC ($x10^9/L$)	297	5.8	1.6	5.4	4.6-6.6	135	6.0	1.7	5.8	4.8-6.9	162	5.5	1.5	5.2	4.4-6.4	0.003
PLT ($x10^9/L$)	296	239.1	48.5	236.0	207-268	135	226.8	46.8	224.0	194-255	161	249.4	47.6	249.0	217-276	<0.001
Fasting glucose (mmol/L)	318	5.5	1.0	5.4	5.1-5.9	142	5.6	0.6	5.6	5.2-6.0	176	5.5	1.3	5.3	5.0-5.7	<0.001
2 hour glucose (mmol/L)	313	6.5	2.2	6.2	5.3-7.4	140	6.4	1.8	6.2	5.3-7.3	173	6.5	2.5	6.3	5.2-7.4	0.951

SD: Standard deviation; IQR: Inter-quartile range; BP: Blood pressure; BMI: Body mass index; HDL: High density lipoprotein; LDL: Low density lipoprotein; CRP: C-reactive protein; RBC: Red blood cell count; WBC: White blood cell (leucocyte) count; PLT: Platelet (thrombocyte) concentration; *Mann-Whitney U test for sex differences. †excluding study members taking diabetes medication (n=14). ‡Non-high sensitivity

4.4.7.5 Regressions of cardio-metabolic measures and whole grain intake from the 60-year follow-up

Linear regression analysis of the associations between whole grain intake and cardio-metabolic measures at the 60-year follow-up, adjusted for sex, dietary energy intake, CVD and lipid medication use are shown in Table 4.16. There were significant negative associations between whole grain intake and diastolic blood pressure, height, BMI, WBC, fasting glucose and 2 hour glucose concentrations. The significant association with height was reversely confounded by sex. After adjustment for sex, medication use and dietary energy intake, diastolic blood pressures were 0.07 mmHg lower, BMIs were 0.04kg/m^2 lower, WBC were 0.02x10^9/L lower, fasting glucose concentrations were 0.01mmol/L and 2-hour glucose concentrations were 0.02mmol/L lower per gram of whole grain consumed per day (Table 4.16). None of these associations were attenuated by further adjustment for achieved education level or SES measured at 50-year follow-up (Table 4.17). In addition to whole grain intake, smoking status at 60-year follow-up was also associated with white blood cell counts, fasting glucose concentrations and 2-hour glucose concentrations. In comparison to those that had never smoked, current smokers had significantly lower white blood cell counts, fasting glucose concentrations and 2-hour glucose concentrations (Table 4.17).

Whole grain intakes were also found significantly negatively associated with non-high sensitivity CRP concentrations (Table 4.16). However, on further exploration of this regression, the model residuals were not appropriately distributed. Within the cohort at the 60-year follow-up, 83% had CRP protein concentrations lower than 5mmol/L, therefore coding of these to 4.9 gave a large skew to the data distribution. There were significant differences in whole grain intakes between those with CRP concentrations lower than or equal to 5mmol/L and those with concentrations greater than 5mmol/L. Whole grain intakes were significantly higher at median 23g/d (IQR 10 – 36g/d) in those with CRP concentrations lower than or equal to 5mmol/L compared with median intakes of 17g/d (IQR 9 – 27 g/d) in those with concentrations greater than 5mmol/L (Mann-Whitney p=0.0293).

Table 4.16 Associations between whole grain intake (independent) and cardio-metabolic measures (dependent) at 60-year follow-up, adjusted for sex, medication use and dietary energy intake.

Cardio-metabolic measure (dependant)		**Whole grain intake** (g/d)		
	n	**co-eff***	**95%CI**	**p-value**
Systolic BP (mmHg)	340	-0.926	(-0.197, 0.011)	0.081
Diastolic BP (mmHg)	340	-0.069	(-0.118, -0.020)	0.006 [a]
Pulse pressure (mmHg)	340	-0.023	(-0.102, 0.055)	0.563
Height (m)	341	0.001	(0.000, 0.001)	0.004 [a]
Weight (kg)	341	-0.057	(-0.145, 0.030)	0.197
BMI (kg/m^2)	341	-0.039	(-0.068, -0.009)	0.010 [a]
Waist: hip ratio	334	0.000	(-0.001, 0.000)	0.079
Cholesterol (mmol/L)	306	0.001	(-0.005, 0.007)	0.802
HDL (mmol/L)	306	0.001	(-0.002, 0.004)	0.449
LDL (mmol/L)	303	0.000	(-0.005, 0.006)	0.899
Triglycerides (mmol/l)	306	-0.002	(-0.007, 0.003)	0.431
CRP† (mmol/L)	275	-0.017	(-0.035, -0.001)	0.048 [a]
Fibrinogen (g/L)	167	-0.002	(-0.008, 0.005)	0.603
Clauss fibrinogen (g/L)	277	-0.003	(-0.007, 0.001)	0.092
Haemoglobin (g/dL)	293	-0.004	(-0.010, 0.002)	0.220
Haematocrit (%)	293	-0.012	(-0.029, 0.005)	0.159
RBC ($x10^{12}/L$)	293	-0.002	(-0.004, 0.001)	0.175
WBC ($x10^9/L$)	293	-0.015	(-0.025, -0.004)	0.006 [a]
PLT ($x10^9/L$)	292	-0.253	(-0.569, 0.063)	0.117
Fasting glucose (mmol/L)	314	-0.007	(-0.014, 0.000)	0.036 [a]
2 hour glucose (mmol/L)	309	-0.016	(-0.030, -0.002)	0.027 [a]

95%CI: 95% confidence interval; BP: Blood pressure; BMI: Body mass index; HDL: High density lipoprotein; LDL: Low density lipoprotein; CRP: C-reactive protein; RBC: Red blood cell count; WBC: White blood cell (leucocyte) count; PLT: Platelet (thrombocyte) concentration.*The co-efficient represents the change in cardio-metabolic outcome per 1g/d increase in whole grain intake; †Non-high sensitivity; [a] p-value <0.05

Table 4.17 Fully adjusted linear regression model of cardio-metabolic outcome and whole grain intake, adjusted for sex, medication use, dietary energy intake, smoking status, achieved educational level and SES at 60-year follow-up.

Outcome		Model of **diastolic blood pressure** (n=277)				Model of **Body mass index** (n=278)				Model of **white blood cell count** (n=240)				Model of **fasting glucose** (n=253)				Model of **2-hour glucose** (n=252)			
		co-eff	95%CI		p-value	co-eff	95%CI		p-value	co-eff	95%CI		p-value	co-eff	95%CI		p-value	co-eff	95%CI		p-value
Whole grain intake (g/d)		-0.07	-0.12	-0.01	0.019	-0.04	-0.07	-0.01	0.020	-0.02	-0.03	0.00	0.008	-0.01	-0.01	0.00	0.001	-0.02	-0.03	-0.01	0.005
Sex	**Male**	Reference category				Reference category				Reference category				Reference category				Reference category			
	Female	-1.52	-3.53	0.49	0.137	0.13	-1.11	1.37	0.840	-0.25	-0.67	0.17	0.235	-0.16	-0.32	0.00	0.053	0.08	-0.37	0.53	0.726
CVD-med	**No**	Reference category				Reference category				Reference category				Reference category				Reference category			
	Yes	0.32	-1.93	2.58	0.778	2.98	1.58	4.37	0.000	0.54	0.08	1.01	0.022	0.14	-0.04	0.33	0.127	0.59	0.08	1.10	0.023
Lipid-med	**No**	Reference category				Reference category				Reference category				Reference category				Reference category			
	Yes	-1.11	-3.72	1.51	0.405	0.61	-1.01	2.22	0.460	0.33	-0.21	0.87	0.225	0.17	-0.05	0.38	0.126	-0.12	-0.71	0.47	0.682
Diabetes-med	**No**	Reference category				Reference category				-	-	-	-	-	-	-	-	-	-	-	-
	Yes	0.61	-4.23	5.46	0.804	2.78	-0.22	5.77	0.069												
Dietary energy intake (MJ)		0.15	-0.37	0.68	0.565	0.15	-0.17	0.48	0.352	0.09	-0.02	0.20	0.111	0.03	-0.02	0.07	0.231	0.02	-0.10	0.14	0.797
Smoking status at 60-year follow-up	**Never**	Reference category			0.673	Reference category			0.006	Reference category			<0.001	Reference category			0.148	Reference category			0.022
	Ex	-0.15	-2.15	1.86	*0.886*	-0.21	-1.45	1.03	*0.740*	-0.10	-0.52	0.31	*0.623*	-0.07	-0.23	0.09	*0.392*	-0.59	-1.03	-0.15	*0.010*
	Current	-1.53	-4.97	1.90	*0.380*	-3.42	-5.54	-1.29	*0.002*	1.77	1.02	2.53	*<0.001*	-0.28	-0.57	0.00	*0.054*	-0.69	-1.48	0.11	*0.090*
Achieved education level up to 50-year follow-up	**None**	Reference category			0.086	Reference category			0.176	Reference category			0.294	Reference category			0.636	Reference category			0.567
	O level	-0.37	-2.79	2.06	*0.767*	-1.49	-2.99	0.00	*0.051*	-0.31	-0.81	0.19	*0.221*	-0.03	-0.22	0.16	*0.755*	-0.25	-0.78	0.29	*0.363*
	A level	-0.14	-3.10	2.82	*0.925*	-0.08	-1.91	1.74	*0.928*	-0.22	-0.83	0.39	*0.476*	0.09	-0.15	0.32	*0.469*	0.16	-0.49	0.81	*0.627*
	Degree Postgrad	3.45	0.05	6.85	*0.047*	-0.79	-2.90	1.32	*0.461*	0.23	-0.48	0.94	*0.516*	0.11	-0.17	0.39	*0.432*	-0.08	-0.85	0.70	*0.842*
SES at 50-year follow-up	**I**	Reference category			0.485	Reference category			0.210	Reference category			0.265	Reference category			0.527	Reference category			0.052
	II	0.78	-2.13	3.70	*0.598*	1.59	-0.21	3.40	*0.083*	0.58	-0.02	1.18	*0.059*	0.22	-0.02	0.45	*0.068*	0.24	-0.41	0.89	*0.468*
	3n	0.55	-3.21	4.31	*0.774*	0.91	-1.41	3.24	*0.441*	0.19	-0.58	0.97	*0.626*	0.13	-0.17	0.43	*0.391*	-0.30	-1.12	0.53	*0.477*
	3m	2.44	-1.04	5.92	*0.169*	2.15	0.00	4.31	*0.050*	0.78	0.06	1.50	*0.035*	0.19	-0.09	0.47	*0.177*	0.79	0.02	1.56	*0.044*
	IV	1.67	-2.60	5.94	*0.442*	-0.24	-2.89	2.40	*0.856*	0.33	-0.56	1.22	*0.468*	0.22	-0.12	0.57	*0.207*	-0.27	-1.24	0.69	*0.576*
	V	4.93	-0.58	10.44	*0.079*	1.71	-1.70	5.12	*0.324*	0.39	-0.83	1.61	*0.528*	0.04	-0.42	0.50	*0.873*	-0.10	-1.37	1.17	*0.875*

med: medication use; p-values in italics represent the Wald test of difference from reference category; co-eff: regression co-efficient representing the change in cardio-metabolic outcome per 1g/d increase in whole grain intake; NB: results shown for sex, CVD-med, Lipid-med, dietary energy intake, smoking status, achieved education level and SES are for exploration of potential confounding.

Table 4.18 Associations between cardio-metabolic outcome and whole grain intake in males only, adjusted for medication use, dietary energy intake and smoking status at 60-year follow-up.

Outcome		Model of **Body mass index** (n=154)				Model of **HDL-cholesterol** (n=137)				Model of **white blood cell count** (n=132)				Model of **fasting glucose** (n=139)				Model of **2-hour glucose** (n=138)			
		co-eff	95%CI		p-value	co-eff	95%CI		p-value	co-eff	95%CI		p-value	co-eff	95%CI		p-value	co-eff	95%CI		p-value
Whole grain intake (g/d)		-0.034	-0.067	-0.001	0.043	0.004	0.001	0.007	0.015	-0.019	-0.033	-0.005	0.010	-0.006	-0.011	-0.001	0.031	-0.022	-0.036	-0.008	0.003
CVD-med	**No**	Reference category				Reference category				Reference category				Reference category				Reference category			
	Yes	2.168	0.581	3.756	0.008	-0.116	-0.270	0.037	0.136	0.912	0.214	1.610	0.011	0.123	-0.136	0.381	0.351	0.880	0.164	1.595	0.016
Lipid-med	**No**	Reference category				Reference category				Reference category				Reference category				Reference category			
	Yes	1.064	-0.643	2.771	0.220	-0.067	-0.234	0.099	0.425	0.143	-0.611	0.897	0.708	0.115	-0.164	0.394	0.416	-0.200	-0.969	0.568	0.607
Diabetes-med	**No**	Reference category				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Yes	4.297	1.112	7.482	0.009																
Dietary energy intake (MJ)		0.171	-0.133	0.476	0.267	-0.011	-0.040	0.019	0.480	0.115	-0.014	0.243	0.079	-0.002	-0.050	0.046	0.929	-0.029	-0.168	0.111	0.685
Smoking status at 60-year follow-up	**Never**	Reference category			0.001	Reference category			0.292	Reference category			0.127	Reference category			0.1649	Reference category			0.101
	Ex	0.261	-1.137	1.660	*0.712*	0.060	-0.072	0.192	*0.371*	-0.003	-0.587	0.582	*0.993*	0.029	-0.190	0.248	*0.795*	-0.220	-0.825	0.385	*0.473*
	Current	-3.974	-6.208	-1.740	*0.001*	0.180	-0.055	0.415	*0.133*	0.933	-0.024	1.890	*0.056*	-0.301	-0.656	0.053	*0.095*	-1.065	-2.039	-0.091	*0.032*

HDL: High density lipoprotein; med: medication use; p-values in italics represent the Wald test of difference from reference category; co-eff: regression co-efficient representing the change in cardio-metabolic outcome per 1g/d increase in whole grain intake; NB: results shown for sex, CVD-med, Lipid-med, dietary energy intake, smoking status, achieved education level and SES are for exploration of potential confounding.

There was a significant sex-whole grain intake interaction with HDL cholesterol concentrations. In sex-specific analyses there was a significant association between whole grain intake and HDL cholesterol concentrations in men only. After adjustment for medication use, dietary energy intake and smoking status at the 60-year follow-up, male HDL cholesterol concentrations were 0.004mmol/L higher per whole grain gram consumed per day (Table 4.18). There were no other significant sex-whole grain intake interaction with cardio-metabolic measures, however in sex-specific analysis there were significant associations between whole grain intake and white blood cell counts, fasting glucose and 2-hour glucose concentrations in males but not females. There were also significant associations between whole grain intake and diastolic blood pressures concentrations in females but not males. Finally, there were significant associations between whole grain intake and BMI in both males and females. After adjustment for medication use, dietary energy intake and smoking status at 60-year follow-up, male BMIs were 0.03kg/m^2 lower, HDL cholesterol concentrations were 0.004mmol/L higher, WBC were 0.02x10^9/L lower, fasting glucose concentrations were 0.01mmol/L and 2-hour glucose concentrations were 0.02mmol/L lower per gram of whole grain consumed per day (Table 4.18). After adjustment for medication use, dietary energy intake and smoking status at 60-year follow-up, female diastolic blood pressures were 0.12 mmHg lower and BMIs were 0.05kg/m^2 lower for each gram of whole grain consumed per day (Table 4.19). Further adjustment for SES and achieved education level up to 50-year follow-up did not attenuate these associations and regression diagnostic plots were satisfactory (Appendix G).

Table 4.19 Associations between cardio-metabolic outcome and whole grain intake in females only, adjusted for medication use, dietary energy intake and smoking status at 60-year follow-up.

		Model of **diastolic blood pressure** (n=185)				Model of **Body mass index** (n=186)			
		co-eff	95%CI		p-value	co-eff	95%CI		p-value
Whole grain intake (g/d)		-0.123	-0.202	-0.043	0.003	-0.055	-0.108	-0.001	0.046
CVD-med	**No**	Reference category				Reference category			
	Yes	0.216	-2.431	2.862	0.872	2.457	0.633	4.282	0.009
Lipid-med	**No**	Reference category				Reference category			
	Yes	0.583	-2.493	3.659	0.709	-0.071	-2.192	2.049	0.947
Diabetes-med	**No**	Reference category				Reference category			
	Yes	-0.200	-6.445	6.044	0.950	2.402	-1.903	6.706	0.272
Dietary energy intake (MJ)		0.902	0.179	1.625	0.015	0.116	-0.381	0.612	0.647
Smoking status at 60-year follow-up	**Never**	Reference category			0.622	Reference category			0.555
	Ex	-0.576	-2.964	1.812	*0.635*	-0.788	-2.424	0.848	*0.343*
	Current	1.522	-2.778	5.822	*0.486*	-1.137	-4.101	1.827	*0.450*

med: medication use; p-values in italics represent the Wald test of difference from reference category. co-eff: co-efficient representing the change in cardio-metabolic outcome per 1g/d increase in whole grain intake; NB: results shown for sex, CVD-med, Lipid-med, dietary energy intake, smoking status, achieved education level and SES are for exploration of potential confounding.

4.4.7.6 Cardio-metabolic measures by whole grain intake tertile from 60-year follow-up

Mean and SD of all cardio-metabolic measures by tertile of whole grain intake at the 60-year follow-up are shown in (Table 4.20). Across tertiles diastolic blood pressures, weights, BMIs, waist-hip ratios, white blood cell and platelet counts were greatest in T1 of whole grain intake and lowest in T3 of whole grain intake. However, not all of these trends were significant after adjustment for sex, medication use and dietary energy intake (Table 4.20). Diastolic blood pressures, BMIs, Clauss fibrinogen concentrations, haematocrit concentrations and white blood cell counts were significantly lower in T3 compared with T1 of whole grain intake, after adjustment for sex, medication use and dietary energy intake (Table 4.20). The differences between T1 and T3 Clauss fibrinogen concentrations were attenuated by smoking status at the 60-year follow-up. Further adjustment for SES and achieved education level up to the 50-year follow-up did not attenuate the differences between T1 and T3 diastolic blood pressures, haematocrit concentrations or white blood cell counts.

When mean and SD of all cardio-metabolic measures by tertile of whole grain intake were estimated separately for males and females, significant trends across intake tertiles were found for white blood cell counts and 2-hour glucose concentrations in males, and diastolic blood pressure, BMI and haematocrit percent for females. After adjustment for medication use, dietary energy intake and smoking status, males in T3 had on average white blood cell counts 0.7×10^9/L lower (95%CI -1.4, -0.1, p=0.028) and 2-hour glucose concentrations 0.8mmol/L lower (95%CI -1.5, -0.1, p=0.022) than those in T1 of whole grain intake. After adjustment for medication use, dietary energy intake and smoking status, females in T3 had on average blood pressure 5.2mmHg (95% CI -8.3, -2.1, p=0.001) lower than females in T1. Average female BMI in T3 was 2.9 kg/m^2 (95% CI –5.0, -0.7, p=0.009) lower and in T2 was 2.1kg/m^2 (95% CI –4.1, -0.1, p=0.044) lower than females in T1. Average female haematocrit content in T3 was 1.6% (95% CI –2.7, -0.5, p=0.005) lower and in T2 was 1.5% (95% CI –2.5, -0.4, p=0.006) lower than females in T1. Further adjustment for achieved education level and SES dis not attenuate these associations.

There was a significant whole grain intake tertile-sex interaction for HDL-cholesterol concentrations. In sex-specific analyses HDL cholesterol concentrations were significantly higher in T3 compared with T1 for males only. After adjustment for medication use, dietary energy intake and cigarette smoking status at 60-year follow-up, male HDL cholesterol concentrations were on average 0.23mmol/L higher in T3 compared to T1 (95%CI 0.08, 0.37, p=0.002). No significant differences were observed in females.

Table 4.20 Average cardio-metabolic measures by tertile of daily whole grain intake at 60-year follow-up, adjusted for sex, medication use and dietary energy intake.

Cardio-metabolic measure	Total n	**Whole grain intake tertile** (min-max intake) **T1** (0 - 15g/d)		**T2** (16 - 29g/d)		**T3** (30 - 116g/d)		
		Mean	**(SD)**	**Mean**	**(SD)**	**Mean**	**(SD)**	**p-value***
Systolic BP (mmHg)	343	134.24	(14.41)	135.35	(18.46)	130.81	(16.60)	0.107
Diastolic BP (mmHg)		80.33	(7.49)	79.09	(7.92)	77.12 [a]	(8.14)	0.013
Pulse pressure (mmHg)		53.91	(10.58)	56.26	(13.99)	53.69	(12.64)	0.339
n per tertile		*111*		*112*		*120*		
Height (m)	345	1.68	(0.09)	1.66	(0.09)	1.68	(0.08)	0.073
Weight (kg)		81.35	(14.64)	77.53	(17.22)	76.22	(15.75)	0.162
BMI (kg/m^2)		28.83	(5.07)	28.16	(4.99)	26.99 [a]	(4.97)	0.019
n per tertile		*111*		*113*		*121*		
Waist: hip ratio	336	0.94	(0.09)	0.93	(0.10)	0.91	(0.09)	0.100
n per tertile		*109*		*109*		*118*		
Cholesterol (mmol/L)	310	5.50	(1.17)	5.45	(1.12)	5.62	(1.04)	0.370
HDL (mmol/L)		1.54	(0.47)	1.60	(0.47)	1.63	(0.41)	0.682
LDL (mmol/L)		3.28	(1.03)	3.20	(1.02)	3.37	(0.97)	0.290
Triglycerides (mmol/l)		1.51	(0.65)	1.54	(1.00)	1.35	(0.74)	0.329
n per tertile		*101*		*99*		*110*		
CRP† (mmol/L)	279	5.98	(3.34)	6.03	(2.47)	5.35	(1.90)	0.142
n per tertile		*94*		*87*		*98*		
Fibrinogen (g/L)	169	3.85	(0.71)	4.20	(0.83)	3.93	(0.69)	0.055
n per tertile		*52*		*56*		*61*		
Clauss fibrinogen (g/L)	280	3.11	(0.56)	3.21	(0.53)	2.99 [a]	(0.48)	0.011
n per tertile		*92*		*88*		*100*		
Haemoglobin (g/dL)	297	14.29	(1.12)	13.78	(1.09)	13.82	(1.09)	0.101
Haematocrit (%)		42.05	(2.89)	40.58 [a]	(3.27)	40.71 [a]	(2.91)	0.026
RBC ($x10^{12}/L$)		4.72	(0.39)	4.56	(0.38)	4.58	(0.40)	0.086
WBC ($x10^9/L$)		6.02	(1.71)	5.87	(1.72)	5.46 [a]	(1.40)	0.044
PLT ($x10^9/L$)		242.45	(49.08)	241.96	(51.24)	233.44	(45.20)	0.188
n per tertile		*94*		*97*		*106*		
Fasting glucose (mmol/L)	318	5.62	(0.69)	5.67	(1.58)	5.37	(0.54)	0.082
n per tertile		*106*		*99*		*113*		
2 hour glucose (mmol/L)	313	(6.65)	1.78	6.68	(2.88)	6.13	(1.73)	0.124
n per tertile		*105*		*98*		*110*		

SD: Standard deviation; BP: Blood pressure; BMI: Body mass index; HDL: High density lipoprotein; LDL: Low density lipoprotein; CRP: C-reactive protein; RBC: Red blood cell count; WBC: White blood cell (leucocyte) count; PLT: Platelet (thrombocyte) concentration.*Tests for significant trend across increasing tertile, adjusted for sex, medication use and dietary energy intake. [a] Significantly different from low tertile at $p<0.05$, t-test adjusted for sex, medication use and dietary energy intake; †Non-high sensitivity

4.4.8 Changes in diet

4.4.8.1 Diet changes from 50- to 60-year follow-up

Of the study members who returned the 60-year follow-up questionnaire, 104 (24%) reported that there had been no change in their eating habits since age 50 years, 233 (54%) reported that there had been small changes in their eating habits, 81 (19%) reported that there had been major changes in their eating habits and 10 (2%) did not provide a response. Of the study members who reported small changes, the majority indicated the changes were explained by their desire to maintain health and their body weight (Table 4.21). Between 25-45% of study members with small diet changes also indicated the changes were explained by changes in their enjoyment of foods, the type and variety of foods available, concerns about food safety, knowledge of food, foods they liked or disliked, price of foods, ease of shopping and cooking ability or skill. Of the study members who reported major eating habit changes, the majority indicated the changes were explained by their desire to maintain health, their body weight, their enjoyment of foods and concerns about food safety (Table 4.21). Study members with major changes also indicated the changes were explained by changes in their knowledge of food, the type and variety of foods available, the foods they liked or disliked, from a special diet for themselves or a family member, ease of shopping, their cooking ability or skill, and the price of foods.

Table 4.21 Reasons for eating habit changes from 50- to 60-year follow-up

Reasons for diet change	**Small (n=233)**		**Major (n=81)**	
Change in the food you like or dislike	81	35%	35	43%
Your enjoyment of food	102	44%	47	58%
Concerns about safety/content of foods e.g. food scares/organic foods	93	40%	41	51%
The type and variety of foods available	99	42%	36	44%
Price of foods	77	33%	21	26%
Advertising of food products	23	10%	4	5%
Desire to maintain health	170	73%	65	80%
Your body weight	151	65%	54	67%
Ill health or disability prevents you from cooking for yourself	14	6%	7	9%
Special diet in self/family member/friend(s)	36	15%	27	33%
Dental problems	24	10%	4	5%
Religion	4	2%	1	1%
Ethical/political concerns	17	7%	6	7%
The knowledge you have about food	89	38%	38	47%
Cooking ability/skill	59	25%	22	27%
Ease of shopping	61	26%	23	28%
Kitchen equipment	28	12%	13	16%
Others				
Health issues - *general, blood pressure, cholesterol, cancer, coeliac, diabetes, digestion problems, medication change*	8	3%	11	14%
Lifestyle change - *Moved to another country, drink less alcohol, got a new job*	1	0%	4	5%
Retired-*more time to plan and cook food, different daily routine, more home cooking*	7	3%	1	1%
Reduced appetite - *eat less as get older, smaller portion sizes, prefer lighter meals, loss of partner, divorced, less interest in cooking*	7	3%	3	4%
Stopped smoking	2	1%	0	0%
Partner/family diet - *partner cooks, live with family, partner's intolerances*	4	2%	0	0%
Environmental issues - *sustainability (organic products), buy locally grown foods, less meat*	2	1%	0	0%

4.4.8.2 Diet changes from 60-to 67-year questionnaire

Of the study members who returned the CFQ, 99 (30%) reported that there had been no change in their eating habits since completing the 60-year questionnaire, 190 (57%) reported that there had been small changes, 32 (10%) reported that there had be major changes in their eating habits and 11 (3%) did not provide a response. Of the study members who reported small changes, the majority indicated the changes were explained by their desire to maintain health and their body weight (Table 4.22). Between 20-30% of study members with small diet changes also indicated the changes were explained by changes in the foods they liked or disliked, concerns about food safety, knowledge of food, enjoyment of food, type and variety of foods available and for a specific health problem. Of the study members who reported major eating habit changes, the majority indicated the changes were explained by their desire to maintain health, for a specific health problem and their body weight (Table 4.22). Study members with major changes also indicated the changes were explained by changes in the foods they liked or disliked, enjoyment of food, knowledge of food and for a special diet e.g. vegetarian, low fat, gluten free diets.

Of the 332 study members who completed the CFQ, 264 (80%) reported that they had not changed the amount of whole-grain foods usually eaten since completing the 60-year follow-up and the remaining 20% (66) said they had changed. From free text responses the majority of study members who had increased the amount of whole-grain foods they usually eat was because of increased knowledge about the health benefits of whole-grain foods, choosing to eat more whole-grain foods and preference for the taste of whole-grain foods (Table 4.23). Other reasons for an increase in whole-grain foods usually eaten were social influences, satiety and special diets for health issues of weight loss. Digestive issues were mentioned as reasons for both an increase and a decrease in whole-grain foods usually eaten.

Table 4.22 Reasons for eating habit changes from 60- to 67-year follow-up

Reasons for dietary change	Small (n=190)		Major (n=32)	
Change in the food you like or dislike	55	29%	7	22%
Your enjoyment of food	47	25%	12	38%
Concerns about safety/content of foods e.g. food scares/organic foods	50	26%	5	16%
The type and variety of foods available	47	25%	4	13%
Price of foods	37	19%	4	13%
Advertising of food products	5	3%	1	3%
Desire to maintain health	133	70%	24	75%
Your body weight	115	61%	17	53%
Ill health or disability prevents you from cooking for yourself	6	3%	2	6%
Dental problems	4	2%	2	6%
Religion	0	0%	0	0%
Ethical/political concerns	3	2%	1	3%
The knowledge you have about food	49	26%	10	31%
Cooking ability/skill	20	11%	4	13%
Ease of shopping	22	12%	1	3%
Kitchen equipment	3	2%	1	3%
Others				
Specific health problem: *Cardiovascular related, Type 2 diabetes, Cancers, Depression, Arthritis, Alzheimer's, Digestive issues and other specific conditions*	39	21%	20	63%
Special diet: *Vegetarian, Gluten free, Low fat, salt, sugar, fibre, starch, diary, Weight loss diet, Alkaline diet, Fasting diet*	14	7%	7	22%
Other: *Retirement, Loss of partner, Family influence, Being cared for, Stopped smoking, New partner*	9	5%	5	16%

Table 4.23 Reasons for change in usual whole-grain food consumption from 60- to 67-year follow-up

Reason for change	Increase WG intake	Frequency		Decrease WG intake	Frequency	
Digestive problems	*Improve digestion, reduce constipation, better for bowel, IBS control*	6	9%	*Certain WG food intolerance, bowel issues, constipation or diarrhoea*	4	6%
Choose more/less whole grain	*Eat more WG bread, muesli, rice, pasta, porridge*	9	14%	*Eat more fruit, less bread, help meet 5-a-day target*	2	3%
Satiety	*Is more filling, keeps you fuller for longer*	2	3%			
Social influence	*Partner loves healthy food, eat what family eats, family eats more WG, loss of a partner*	4	6%			
Special diet for health issue	*Wheat allergy eat rye instead, diabetes, recovering from cancer treatment*	4	6%	*Very low calorie diet for diabetes*	1	2%
Special diet weight loss	*Slimming world diet, cut refined grains for whole grains to reduce weight, for weight loss, weight control*	5	8%			
Taste preference	*Taste has changed now prefer WG, prefer WG to white bread, prefer wholemeal, prefer 50/50, taste good, taste better*	9	14%	*Prefer chick pea pancakes to wholemeal bread*	1	2%
WG health knowledge	*WG are better for you, generally more healthy, improve health, maintain health, believe WG is healthier*	24	36%	*Not convinced by evidence*	1	2%

WG: Whole grain

4.5 Summary

Whole grain intake in the NTFS, estimated from a newly developed questionnaire, was median 33g/d at age 67 years. There were no significant differences between males and females nor by SES at age 50 years. Higher intakes were seen for those who had achieved a degree or higher qualification by age 50 years. Whole grain intake was mainly from whole-grain breads and breakfast cereals with smaller contributions from porridge. Whole grain intake in this population was median 21g/d at 60-year follow-up and 19g/d at 50-year follow-up. There were differences in intakes between male and females in the 50- and 60-year follow-up with females consuming higher amounts of whole grain, this was also reflected in energy adjusted whole grain intake. There were also higher whole grain intakes in this population for those who had achieved a degree or higher qualification by 50-year follow-up and for those who were ex-smokers or had never smoked. In the 50- and 60-year follow-up better overall dietary nutrient profiles were seen for the highest whole grain consumers compared with the lowest, with the exception for total sugars and sodium intakes.

After adjustments for potential confounding factors (sex, dietary energy intake, medication use, smoking status, SES, highest achieved qualification), whole grain intakes were inversely associated with body fat percentage, total and LDL cholesterol concentrations at 50-year follow-up and diastolic blood pressure, BMI, WBC, fasting glucose and 2-hour glucose concentrations at 60-year follow-up. There was also a positive association between whole grain intake and HDL cholesterol concentrations at 60-year follow-up, after adjustment. The associations found differed by sex, were small in magnitude (but significant) and the majority were mirrored by differences between the highest and lowest tertiles of whole grain consumption.

Chapter 5 Discussion

This final chapter discusses the results of the analyses in Chapters three and four, making comparison with published literature, noting strengths, weaknesses and limitations of the work, giving thoughts to the public health implications of the findings and finally some suggestions for further research.

5.1 Summary of the main findings

Whole grain intake estimated in two UK cohorts, the NDNS and the NTFS, was low. Through assessment of 4 day food diet diaries from the NDNS 2008-2011 and estimating the whole grain content of 221 foods, median whole grain intake was found to be 20g/d in adults (19+ years) and 13g/d in children/teenagers (1.5-18 years) with 18% of adults and 15% of children and teenagers not consuming any whole grains. Whole grain intake estimated from FFQs in the NTFS was also low at 19g/d at 50-year follow-up, 21g/d at 60-year follow-up and 32g/d 67-year follow-up with 12%, 7% and 0.3% non-consumption at the respective follow-ups. Across both populations whole grain intakes were highest in adults, females, those with more advantaged socioeconomic position (in the NDNS only) and those who had achieved a degree or higher qualification by age 50 years (in the NTFS only). Whole grain intake came mainly from whole-grain breads and RTEBC in both populations with smaller amounts from sweet snacks in children and porridge in adults. Consumers with the highest whole grain intakes had better quality dietary nutrient profiles such as higher intakes of fibre, iron and magnesium and lower intake of fats. The highest whole grain consumers also had higher intakes of fruits and vegetables and lower intakes of meat products. Higher whole grain intakes were associated with some but not all cardio-metabolic markers in both cohorts. A significant decrease in NDNS adult and child white blood cell counts was seen across increasing whole grain intake tertiles, after adjustment for age and sex. In NDNS adults only, CRP concentrations were significantly lower in low whole grain consumers compared with non-consumers. After adjustments for potential confounding factors (sex, dietary energy intake, medication use, smoking status, SES, highest achieved qualification) in the NTFS cohort, whole grain intakes were inversely associated with body fat percentage, total and LDL cholesterol concentrations at 50-year follow-up and diastolic blood pressure, BMI, WBC, fasting glucose and 2-hour glucose concentrations at 60-year follow-up.

5.2 Whole grain intake

Whole grain intake estimated in both these UK cohorts was low. Previous analyses of whole grain intake in the NDNS considered only foods containing ≥10% whole grain. In these analyses of adults in 1986-7 and 2000-1 and of young people (4-18 years) in 1997, median whole grain intakes were 16, 14 and 7g/d, respectively (Thane *et al.*, 2005; Thane *et al.*, 2007). A comparison of median intakes by age is shown in Figure 5.1 which includes the current analysis. Compared with the 2000-1 data, the 2008-11 data showed a modest increase in whole grain intake across all age groups. The earlier analyses only included whole-grain foods with >10% whole grain. However, the higher intake reported for the latest analysis does not appear to be attributable to the extra foods with <10% whole grain included since the average intakes of adults and children/teenagers from all whole-grain food sources did not differ from the average whole grain intake from foods containing ≥10% whole grain (Section 3.12).

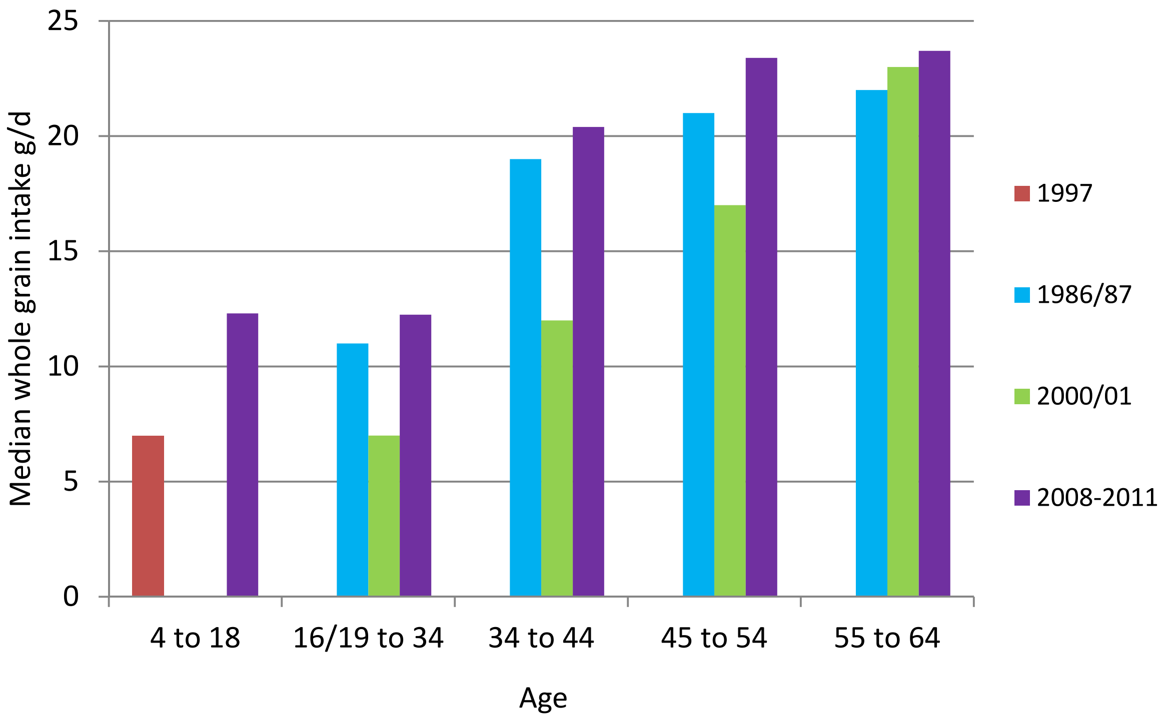


Figure 5.1 Median whole grain intakes from the UK National Diet and Nutrition Surveys by age

In the current NDNS analysis 221 foods were identified as containing any whole grain ingredient and were coded separately in the original NDNS analysis. In 1986/7 and 2000/1, 196 and 153 whole grain foods were identified containing at least 10% whole grain (Thane *et al.*, 2007). This difference may in part contribute to the small increase in whole grain intake seen in this population. However, in all three analyses similar foods are coded as unique items so the variety/range of foods may not differ greatly. For example, branded RTEBCs are coded separately to supermarket own brand RTEBCs, so the apparent increase in the number of whole-grain foods may be misleading.

It is important to note here some methodological differences between the results reported in the current analysis (of the NDNS 2008-11 rolling programme) and the previous analysis of the NDNS that may also account for the apparent increase in whole grain intake. Firstly, since 2008 the NDNS has been conducted as an annual rolling programme recruiting approximately 1000 participants per year, whereas previous NDNS studies were run as a series of cross-sectional studies. In the cross-sectional NDNS studies, diet dairies were recorded over seven days whereas in the rolling programme diaries are recorded over only four days. Differences in number of recording days have been shown to have little effect on comparisons of average consumption of food groups or mean nutrient intakes, however caution should be taken when comparing percentages of food group consumption and meeting dietary recommendation between this analysis and that of the previous cross-sectional NDNS studies (Bates *et al.*, 2012a). Finally, the diet diaries in previous NDNS studies were weighed food intake diaries whereas in the rolling programme estimated weights and quantities were used to quantify food intake. This helped to reduce participant burden in the rolling programme, however it may result in inaccuracies in the reported portion size of foods actually consumed and recorded in diet diaries.

There was also a difference in diet assessment between the NDNS and the NTFS studies, with the latter using a FFQ based on the EPIC FFQ at 50- and 60-year follow-up (Mulligan *et al.*, 2015) and a specially designed FFQ at 67-year follow up. FFQ are considered advantageous in studies investigating dietary intake because they impose less subject burden, but they are considered less precise than diet diaries (Rollo *et al.*, 2016). At 50- and 60-year follow-up the FFQ may have underestimated whole grain intake due to the smaller number of whole-grain foods in the FFQ, although the values are very similar to those from the NDNS. In contrast, the slightly higher intake seen at 67-year follow-up is probably expected since this specially-designed FFQ contained many more whole-grain foods and this may have introduced a bias to the diet recording.

5.2.1 Comparisons with other populations

While there has been a small increase in whole grain intake between the previous NDNS surveys and this analysis from the rolling programme, and small increases in whole grain intake in the NTFS between follow-ups, average intakes remain low with no age group consuming more than one serving per day (16-32g). The maximum median whole grain intake was 24g/d in NDNS adults and 32g/d in NTFS participants at age 67-years, both falling significantly below the 3 servings (equivalent to 48g/d) shown to be associated with CVD and T2D risk reductions (Ye *et al.*, 2012) and the current US dietary recommendation (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015-2020). Comparison of whole grain intake between these UK studies and other countries should be interpreted with caution, since survey methods and sampling, dietary assessment, whole grain and whole-grain food definitions differ. Nevertheless, comparable nationally representative populations (summarised in Table 1.1) including the US and Australia, also report that average whole grain intakes are low and do not meet notional targets, with the most recent data reporting that 92% of US adults and 55% of Australian adults do not meet the recommended 3 whole grain servings per day (Cleveland *et al.*, 2000; O'Neil *et al.*, 2010a; O'Neil *et al.*, 2010b; Zanovec *et al.*, 2010; Grain & Legumes Nutrition Council (GLNC), 2014a; Grain & Legumes Nutrition Council (GLNC), 2014b; Reicks *et al.*, 2014; Albertson *et al.*, 2016; Grain & Legumes Nutrition Council (GLNC), 2016). This may indicate that the recommended target intakes in the US may be too high for the UK general population to achieve, although targets need to reflect an intake that provides a meaningful nutritional or health effect as well as consideration of what is feasible. Current US intakes are equivalent to about one ounce-equivalent per day which if approximated to 16g/d, was achieved by 55% of adults in the NDNS. This suggests that, despite having no tangible whole grain recommendations in the UK, adults and children in this population may be faring better than the US population. However, it is possible that apparent differences in intake are reflective of the definition of whole grain intake in the US in terms of 'ounce equivalents per day' and the approximation to 16g/d. In the USDA food patterns equivalent database, used to calculated grain intakes in the US national surveys, one ounce equivalent of grains can be either 16g or 28.35g of grain depending on the food source which makes interpretation by researchers and comparison with other reports difficult (Albertson *et al.*, 2016). Therefore, direct comparison of ounce equivalent to gram intakes may not be meaningful. It would be helpful, for comparative purposes and researchers, for all national surveys to use a consistent reporting method such as reporting whole grain intake in grams per day rather than ounce-equivalents or servings, and reporting absolute whole grain intake rather than whole-grain food intake, since the whole grain content of whole-grain foods differ (Ross *et al.*, 2015).

Whole grain intakes for children/teenagers in the NDNS analysis were lower than those reported for Irish children and teenagers (Devlin *et al.*, 2013) where median whole grain intakes, on a wet weight basis, were 12.7g/d for children and 13.4g/d for teenagers, approximately 2.5g and 1.2g higher, than the corresponding values seen for the NDNS population. This was similar for adults, although the difference was greater, where in the UK NDNS whole grain intakes of adults were on average 9g/d lower than Irish adults and 4% less UK adults met a minimum of 48g/d (Burns *et al.*, 2013). One explanation for this difference may be that whole grain intakes in the NDNS analysis were estimated on a dry weight basis whereas in the Irish analysis intakes were estimated on a wet weight basis. This can produce quite large differences in intake estimates, particularly for foods such as rice and pasta which are more commonly prepared by boiling in water, hence a much lower whole grain content is consumed in comparison to the dry weight food. For example, the whole grain content of wholemeal pasta has been calculated at 91% thus if 100g of boiled wholemeal pasta is consumed then the wet weight whole grain intake would be 91g. However, boiled wholemeal pasta contains approximately 69% water (including 14% water content from wholemeal flour) (Food Standards Agency, 2002b; Jones *et al.*, 2017). Therefore, whole grain intake from boiled wholemeal pasta on a dry weight as consumed basis would be 31g per 100g consumed. Such inconsistences in the reporting of whole grain intake from all observational and intervention studies have been noted and recommendations given, such as *"quantify the amount of whole grain in the food or product in grams on a dry-weight basis"*, that will enable easier comparison between studies (Ross *et al.*, 2015). Another possible explanation for the higher reported whole grain intakes in Irish children and teenagers may be from higher consumption of certain whole-grain foods, such as soda bread, in Ireland compared with the UK. However, since the NDNS of the UK covers Northern Ireland, which shares a cultural and historical food consumption environment with the Republic of Ireland and whole-grain soda breads were identified in NDNS diaries, this is less likely to be the case.

Similar to the UK, whole grain intakes in other nationally representative surveys of adults, children and adolescents are low, with median whole grain intakes of 0g/d reported in French, Italian, Malaysian and Singaporean (children only) populations (Bellisle *et al.*, 2014; Ak *et al.*, 2015; Sette *et al.*, 2015; Neo *et al.*, 2016). Additionally, low whole grain intakes were also reported in a German longitudinal cohort study with whole grain intakes of males and females of 18 and 15g/d in children and 19 and 16g/d in adolescents (Alexy *et al.*, 2010). Results in the Dutch national dietary survey report, which considered ‘unrefined grain’ foods (*ongeraffineerde granen*), are difficult to compare to the UK and other countries since the ‘unrefined grain’ foods included foods that do not meet the whole grain definition. Nevertheless, median ‘unrefined grain’ food intakes of 113 and 87g/d in adult men and women, and 85 and 70g/d in boys and girls, indicate that whole grain intakes are also low in the Netherlands (Rijksinstituut voor Volksgezondheid en Milieu (RIVM), 2015) and below the three whole-grain product servings (90g/d) seen to be associated with reduced disease risk (Aune *et al.*, 2016).

In contrast to the low whole grain intakes in the UK, whole grain intake in Scandinavian countries (Particularly Denmark, Sweden and Norway where data are available) are much higher, with national adult averages reported to be 37g/d in Sweden and 58g/d in Denmark (Amcoff *et al.*, 2012; Mejborn *et al.*, 2014). This has also been shown in the HELGA cohort (the HELGA is a research project on Nordic health and whole-grain foods) with median adult whole grain intakes from 31 to 49g/d in Danish and Swedish men and women, and Norwegian women (Kyrø *et al.*, 2012). The higher whole grain intakes in these Scandinavian populations may be due to the cultural food environment in Scandinavian countries and a strong tradition of consuming whole-grain foods, such as rye bread, that are more commonly consumed in Nordic diets. More recently, Danish whole grain intakes have also increased markedly by 72% from a total population (adults and children) average of 32 g/day in 2000-2004 to 55g/day in 2011-2012 following the Danish national campaign to promote whole grain intake (Mejborn *et al.*, 2013). The proportion of Danes meeting the Danish target of 75 g/10MJ rose from 5 to 27% of the population (Danish Whole Grain Partnership, 2014) over this time period.

Whole grain intakes in the NDNS and NTFS are lower than the reported average global consumption which was estimated at 38.4g/d in 2010 across 187 countries (Micha *et al.*, 2015). However, this study estimated a whole grain intake for the UK of 72.5g/d, much higher than any UK study has reported and the results of the current work. Whole grain intake estimates in the Micha *et al.* (2015) study for other countries and regions such as Africa, Asia and the US, were also considerably different from national publications (to my knowledge there are no whole grain intake reports, to date, from Africa). Further examination of this publication highlighted that available data on whole grain intake was limited, with empirical data sourced for 35 countries of the 187. Additionally Micha *et al.* (2015) acknowledged that the statistical method used, a hierarchical Bayesian model, which estimated or imputed data can often over-estimate individual based-dietary intakes. In addition, no detail was given on the definition of whole grain or whole-grain foods included and as such it is unclear as to whether the estimates reported are for absolute whole grain intake or whole-grain product intake. Therefore, the whole grain intake estimates from this publication should be interpreted with great caution.

5.2.2 Demographics (age, sex and SES)

Whole grain intakes were shown to increase with age with the highest intakes seen for adults aged 55-64 years in the NDNS. This was also mirrored in the NTFS analysis where average intakes increased across the three follow-up periods. Whole grain intakes reported in other studies in different countries have also been shown to increase with age and be higher in adults compared with children (Bellisle *et al.*, 2014; McGill *et al.*, 2015; Sette *et al.*, 2015; Albertson *et al.*, 2016; de la Fuente-Arrillaga *et al.*, 2016). Since food and energy intakes are required to be higher in adults compared with children/teenagers it makes sense that whole grain intake would also be higher. However, in the analysis from the NDNS, energy adjusted intakes were also higher in adults compared with children/teenagers (2.5 vs 2.2g/d/MJ in males, 3.1 vs 1.9g/d/MJ in females). This suggests that children/teenagers are less likely to be choosing whole-grain foods in comparison with adults or perhaps whole-grain foods are less accessible to children/teenagers. Indeed a UK-based focus group study of adolescents aged 11-16 years identified that, although the participants had tried whole-grain foods before, taste, visual appeal and poor availability outside of the home remained barriers to eating whole grains for this age-group (Kamar *et al.*, 2016). This has also been highlighted by researchers in the US who have developed school-based programmes aimed to help children choose whole grains, increase whole-grain food consumption in the school environment (Burgess-Champoux *et al.*, 2008; Roth-Yousey *et al.*, 2009; Chu *et al.*, 2011; Schroeder *et al.*, 2016) and ultimately, in addition increase whole grain intake in the home environment in order to achieve national intake recommendations (Radford *et al.*, 2014). Differences in intakes between adults and children, raises an important consideration for any whole grain public health recommendation to be age specific, as are most current dietary reference values and the US food based guidelines (Department of Health, 1991; U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015-2020)

No significant difference in median whole grain intakes for adult males and females was observed in the NDNS when data were unadjusted for energy intake. However, when adjusting for energy intake, a significant difference was present with a higher intake reported in females. This was also mirrored in the NTFS at 50- and 60-year follow-up with females having higher median whole grain intakes than males, with or without energy adjustment. This suggests a greater importance for whole-grain foods in the diets of women once the expected higher total energy/food consumption in males is accounted for. In children/teenagers the reverse was seen with significantly higher whole-grain food consumption in younger males than younger females. Once adjusted for energy intake the apparent difference was removed. These data confirm the higher total food consumption in boys compared with girls but suggests that the overall pattern of whole grain food intake is the same for both genders. These observations emphasise the importance of energy adjustment in describing whole grain intake between sexes but also imply a change in eating habits with age where, as females age they increase their consumption of whole-grain foods. This may reflect a more health-conscious selection of foods in women compared with men, which could be an area for further investigation.

Whole grain intake significantly increased with higher SES in the NDNS and NTFS at 60-year follow-up. SES measured by the NS-SEC is based on occupation and therefore the increase in whole grain intake may be explained by income and possibly education. Indeed, significantly higher whole grain intakes were seen for those with the higher levels of achieved education by age 50 in the NTFS. Those in a more advantaged socio-economic position may have a higher education and knowledge about whole-grain foods and health as well as the financial ability to purchase such foods, since whole-grain foods are sometimes more expensive than their refined grain counterparts on offer (Kantor *et al.*, 2001; Seal and Jones, 2007). Qualitative studies also highlight income and food cost as a barriers of whole grain intake as well as a barrier to adherence of dietary guidelines (Kuznesof *et al.*, 2012; Nicklas *et al.*, 2013). In contrast, there were no significant differences in NTFS whole grain intakes across SES at 50- and 67-year follow-up, although there was an increasing trend with higher whole grain intake in the most advantaged classifications. This may be due to the age of the cohort with many study members having taken retirement and subsequently their SES classification was based on prior occupation.

5.2.3 Whole-grain foods

In the current NDNS analysis, 221 whole-grain foods were identified and consumed over the diet diary assessment days. Despite the recording of diet diaries spanning a three year period this number of whole-grain foods is low. However, in the previous analysis of the NDNS in 1986/7 and 2000/1, 196 and 153 whole-grain foods were identified, respectively (Thane *et al.*, 2005; Thane *et al.*, 2007) so the latest analysis represents an increase of 45% in the number of whole-grain foods since 2001 and likely reflects the increasing availability and production of whole-grain foods. The Mintel new products database estimates that almost 20 times as many new whole-grain products were introduced globally in 2010 than in 2000 (Oldways Whole Grains Council, 2003-2013b; Mintel, 2010) and specifically in the UK ready-to-heat whole-grain rice has recently seen rapid sales growth (Mintel, 2016). The new whole-grain product increase can be seen in the UK-based NDNS, since 35% of products identified were new products, although some may be new variations of old products.

The majority of the 221 foods identified in the NDNS data set were RTEBC, sweet snacks, breads and porridge. Breads, RTEBC and porridge were also the main foods contributing to whole grain intake in the NTFS, although the range of whole-grain foods identified may be somewhat limited in this analysis due to the design of the FFQ used to estimate whole grain intake in that study as mentioned previously. Nonetheless, breads and RTEBC are part of a traditional UK diet. Breads have been a staple food for generations, although 2015 UK household shopping and eating habits data indicate a long term downward trend with 12 and 17% reduction in white and wholemeal bread purchases, respectively, since 2012 (DEFRA, 2017). RTEBC are a convenient breakfast meal particularly in children and targeted advertisement of RTEBC towards younger children may account for their high consumption. Porridge is becoming a more popular breakfast meal particularly in the convenience and ‘food to go’ market (Mintel, 2013b) and is readily available in an appropriate form for the very young. The sweet snacks food group includes cereal bars which have had increasing product introduction (Mintel, 2013a), although their whole grain content is typically low. The popularity of RTEBC and breads in the UK are similar to other populations such as Irish children and teenagers where 44-59% and 14-27% of foods consumed were RTEBC and breads, respectively (Devlin *et al.*, 2013). Adult food consumption habits in this UK population are also similar to those seen in the US where 32% and 30% of whole-grain foods contributing to whole grain intake were breads and RTEBC (Cleveland *et al.*, 2000).

Interestingly in the current analyses, smaller amounts of whole grain intake came from the consumption of brown rice and whole-grain pasta. Although wholemeal bread has a higher whole grain content than brown rice and wholemeal pasta (55% vs 34% or 31%), rice and pasta are typically consumed in larger portion sizes, for example a slice of bread is ~36g delivering ~20g of whole grain whereas an average serving of rice is ~135g and pasta is ~200g, delivering ~46g and ~62g of whole grain, respectively (Appendix E). It was shown that the UK population the two most commonly consumed cereals and cereal products were 'white bread' 'pasta, rice, pizza and other miscellaneous cereals', eaten by more than 70% of the total population (Bates *et al.*, 2014). Since the current analysis shows that many of the UK population already choose whole-grain breads there perhaps lies a greater potential for substitution of refined grain rice and pasta for whole-grain versions to aid increases in whole grain intakes. This may also be an area for development from food manufacturers with opportunity to provide a wider variety of whole-grain pasta and rice dishes. The recent introductions of ready-to-heat whole-grain rice packets is one example and development of fresh whole-grain pasta products could be a next step.

5.2.4 Whole grain content of whole-grain foods

Of the whole-grain foods identified 44% contained less than 51% whole grain and 5% contained less than 10% whole grain. Standard definitions on the amount of whole grain which should be included in a product for it to be classified as a 'whole-grain food' do not exist. In 1999, the US FDA defined "*a whole-grain food as one that contains ≥51% wholegrain ingredient by weight per reference amount customarily consumed"* in order to establish a whole-grain health claim (U.S. Food and Drug Administration, 1999), and any food carrying the health claim must comply with this content level. As a consequence many whole grain studies use this definition for whole-grain foods in their analysis (Cho *et al.*, 2013). Ferruzzi *et al*. (2014) have recently proposed that whole-grain foods should provide 8g of whole grain/30g serving (27/100g) without also including a fibre requirement for the food. However, it is possible to consume substantial amounts of foods containing a smaller percentage of whole-grain ingredients which will significantly contribute to total whole grain intake. The consequences of using different cut-off points for inclusion of whole-grain foods are highlighted in this and previous NDNS analyses where restricting to foods containing less than 51% whole grain would largely underestimate intakes (Thane *et al.*, 2005; Thane *et al.*, 2007). It is also important to consider whether lower whole grain content may indicate higher contents of fat, sugar and salt which should be kept to a minimum for foods to have a healthy balance. The Healthgrain forum have recently proposed that a whole-grain food should contain at least 30% whole grain content on a dry matter basis with more whole-grain ingredients than refined grain ingredients in the final product. This is in addition to compliance with country-specific fat, salt and sugar limitations (Ross *et al.,* 2017). The various whole-grain food definitions proposed raises issues in developing public health strategies for promoting whole grain intake where confusion may arise in consumers' understanding the difference between 'whole grain intake' and 'whole-grain food intake'. A scientific consensus and subsequent studies using one definition of a whole-grain food would add to the evidence concerning health benefits of whole grains and aid public bodies in recommending food-based whole grain guidance.

5.2.5 Consumption day, location and with whom

In the NDNS population more whole-grain foods were consumed on weekdays than at weekends. This may reflect a difference in meal selection of take away and restaurant meals at weekends which typically do not include whole-grain ingredients. There may also be the tendency to eat more healthy meals during the week and have a break from this diet at weekends. In addition, respondents may be more likely to consume RTEBC during weekdays since these may be easier/quicker to prepare on working or school days. However, this may not apply to all where weekends may give consumers time to home cook meals and consider food selection more carefully. It is also important to note that the assumption of equal representation of days during which the diet diaries were recorded may not be fully valid due to year three of the survey (2010-2011), where flexibility of the diary start day was given to participants and therefore participants may have opted to record their diet on days when not eating away from the home. The current analysis also showed that 83% of whole grains were consumed within the home environment and with family members (for children). For adults, they were more likely to consume whole-grains alone. This highlights school and work environments as possible places in which to advocate increased availability of whole grains. As previously mentioned, in the US school programmes are being developed to increase whole grain intake and awareness in children. Developing similar strategies for work public place canteens may help adults in a similar way and was shown to be effective in the recent public-private campaign to increase whole grain intake in Denmark (Danish Whole Grain Partnership, 2014).

5.3 Whole grain intake and diet quality

Dietary intake analysis in both NDNS and NTFS populations showed that the diets of high whole grain consumers were more nutrient dense than those of non- or low-consumers. Intakes of a number of vitamins and minerals, for example vitamin E, iron, copper, magnesium and several B vitamins, were significantly increased in those consuming the highest amount of whole grain in all analyses. This is reflective of the naturally higher content of these nutrients in whole-grain foods which are lost in the manufacture of refined flours unless replaced by fortification. It is difficult to rule out confounding of overall healthy diet and lifestyle which comes hand in hand with whole grain consumption, so it is not entirely clear whether these differences in nutrient intake are solely due to the intake of whole grain or the combined effect of consuming a healthier diet overall. However, this pattern of improved nutrient profile has also been shown in similar population studies investigating the difference between whole grain consumers and non-consumers in North America and Europe (O'Neil *et al.*, 2010a; O'Neil *et al.*, 2010b; Kyrø *et al.*, 2011; Devlin *et al.*, 2013; Bellisle *et al.*, 2014; Sette *et al.*, 2015).

For many populations, including the US, whole-grain foods make a substantial contribution to total dietary fibre intake (Reicks *et al.*, 2014). Findings, for the cross-section of the NDNS and NTFS populations, confirm this observation, with nutritionally significant higher fibre intakes in those that consumed even a small amount of whole grain (on average in the NDNS 5g/10MJ/d more in children/teenagers and 7g/10MJ/d more in adults and in the NTFS 8g/10MJ/d at 50-year follow-up and 6g/10MJ/d at 60-year follow-up, Tables 3.16, 4.6 and 4.7). Once again, it is important to note that the higher dietary fibre intake reported here may not exclusively come from whole-grain foods, but may also come from other sources such as fruit and vegetable intakes which were also significantly higher in both NDNS and NTFS whole grain consumers compared with non- or low- consumers (Tables 3.17, 4.8 and 4.9). A recent publication concluded that whole-grain foods only contribute small amounts of dietary fibre to the US diet, although this analysis may be limited due to the short two day dietary recording periods of the US national data considered (Kranz *et al.*, 2017). There remains good reason to believe that higher dietary fibre intake could be a result of increased whole grain intake since the recommended intake of 5 portions of fruit and vegetables per day in the UK was achieved by only 25% of the NDNS population presently studied (Bates *et al.*, 2012a). In addition, most whole-grain cereals are a rich source of fibre; for example, whole-grain wheat contains between 9 and 17g of fibre per 100g, more than most vegetables (generally <6g per 100g) (Fardet, 2010).

This suggests that the majority of the increase in fibre intake may be attributed to the increase in whole grain intake. On the basis of the epidemiological evidence of the benefits of increased whole grain and fibre intakes, the recently revised Nordic nutrition recommendations (Nordic Co-operation, 2012) state that fibre intake should come from "*foods naturally rich in dietary fibre such as whole grain…*" whereas whole grains had not been mentioned before. A greater emphasis on a recommendation to increase whole grain intake in the UK would potentially contribute to increasing fibre intakes in this population, as seen in a 4-month whole-grain food intervention study where a marked increase in dietary fibre intake was achieved compared with baseline (Brownlee *et al.*, 2010).
The current UK advice from the Eatwell Guide, includes images of whole-grain foods and the emphasis on choosing '*wholegrain and higher fibre versions with small amounts of salt fat and sugar*' (Public Health England, 2016). The inclusion of whole-grain food images within the 'carbohydrates' section of the plate is a step in the right direction. However, putting greater emphasis on increasing whole grain consumption will be essential if the recent recommendation by the UK SACN to increase the dietary reference value for dietary fibre to 30g/d for adults and 15-25g/d for children, with no more than 5% of dietary energy coming from free sugars, is to be achieved (Scientific Advisory Committee on Nutrition, 2015). A quantity-specific recommendation for whole grain intake would be more helpful to the general public than the general statement in the Eatwell Guide since 30g/d fibre will be impossible to achieve without the inclusion of whole grains. For example, the British Nutrition Foundation have developed a 7-day meal plan which is designed to indicate the amount of different foods needed to achieve the fibre and free sugars targets (British Nutrition Foundation, 2015). Within this meal plan more than half of the carbohydrate-rich foods are whole-grain foods. In order to achieve 30g/d of dietary fibre an adult would need to consume almost 6 servings a day of whole grain, in addition to over 8 portions of fruit and vegetables a day (Table 5.1). This gives a very clear indication of the need to consume substantial quantities of whole grain, in addition to fruit, vegetables together with high-fibre beans and pulses which are also included in the meal plan.

Table 5.1 Estimated whole grain servings based on a sample meal plan to achieve the new fibre and free sugars recommendations

Meal plan day	Whole-grain food (portion*)	Estimated whole grain servings†	Fruit and vegetable portions‡
Monday	Muesli (50g) 2 Oatcakes (26g) Brown rice (180g) Wholemeal pitta (47.5g)	9.1	9.9
Tuesday	Wholewheat pasta (230g) 2 Chocolate digestive biscuits (36g)	7.5	7.8
Wednesday	2 fortified wheat biscuits (40g) Brown rice (180g)	5.8	9.5
Thursday	Wholegrain toast (31g) 2 slices wholewheat bread (72g)	3.7	7.1
Friday	2 fortified wheat biscuits (40g) Wholemeal wrap (70g)	4.9	6.2
Saturday	2 slices wholemeal toast (62g) Wholewheat spaghetti (220g) Flapjack slice (70g)	9.4	10.4
Sunday	Porridge (160g)	1.1	7.8
Total *per week*		41.6	58.6
per day		5.9	8.4

*portion sizes from Food Standards Agency (2002a); †16g whole grain per serve; ‡from (British Nutrition Foundation, 2015)

5.4 Whole grain intakes & cardio-metabolic measures

5.4.1 Anthropometric measures

In the NDNS no associations or trends were seen across non-consumers and by tertile of whole grain intake for adult and child/teenage weight, BMI or waist to hip ratio. Indeed, the differences between non-consumers and tertiles of whole grain intake were small or non-existent, for example mean child NDNS BMIs were 21 or 22 and mean waist to hip ratios were 0.8 for non-consumers and in each tertile of whole grain consumers. Similarly, no significant associations between increasing whole grain intake and BMI, waist circumference and other body weight measures were reported in the US national survey of adolescents, after adjustment for food group intake as well as other lifestyle factors such as physical activity level (Hur and Reicks, 2012). In this study, and the present survey, whole grain intakes were low (fewer than one third of the adolescents consumed >0.5 ounce-equivalents per day) and thus the level of whole grain intake in children/teenagers may be too small to show an effect on body weight. Another reason why whole grain intake was not associated with body mass in the present analysis may be because the majority of children/teenagers had body weight within healthy ranges (Bates *et al.*, 2012a). In adolescents from the Avon Longitudinal Study of Parents and Children (ALSPAC), UK, 3-year excess weight gain was inversely associated with whole grain and high-fibre RTEBC intake, after adjustment for physical activity and pubertal status, despite similar whole grain intakes to those of the NDNS children/teenagers reported in the present analysis (Dong *et al.*, 2015). In contrast the Dortmund Nutritional and Anthropometric Longitudinally Designed (DONALD) study of adolescents in Germany showed no changes in percentage body fat with changes in whole grain intake over four years of follow-up, suggesting that whole grain intake may not be relevant in the development of body fatness or BMI during puberty (Cheng *et al.*, 2009). However, reported whole grain intake in the adolescents was relatively low (mean 34g/d/1000kcal including some foods that are not whole grain according to the accepted definition) and did not change between baseline and follow-up.

In contrast, adults with higher whole grain intake in the NTFS showed significant decreasing trends of mean BMI by increasing tertile of whole grain intake at 60-year follow-up and non-significant decreasing trends at 50-year follow-up. The non-significant trend at 50-year follow-up may be because whole grain intakes overall at 50-year follow-up were lower than at 60-year follow-up. Nevertheless, decreasing trends in BMI were seen and have also been shown in other cross-sectional adult studies (Good *et al.*, 2008; Harland and Garton, 2008;

O'Neil *et al.*, 2010c; Giacco *et al.*, 2011). Whilst there was no direct measurement of whole grain, a systematic review of dietary intakes and long-term weight change in adults provides suggestive evidence for a protective role for whole grains as part of a prudent dietary pattern against increasing weight (Fogelholm *et al.*, 2012). In addition, some studies that have also reported non-significantly lower BMI values, have instead seen significantly lower waist to hip ratios and body fat percentages, suggesting that higher whole grain consumers had less central adiposity rather than lower overall body mass (Steffen *et al.*, 2003; McKeown *et al.*, 2009). Interestingly, this was also the case for the NTFS at 50-year follow-up where higher whole grain consumers had significantly lower body fat percentage but not BMI values. Unfortunately, body fat mass was not measured in the 60-year follow-up but reductions in BMI were seen (Tables 4.11 and 4.15). Intervention studies have also suggested that any effect of whole grains on weight status is through changes in body fat around the abdominal area (Katcher *et al.*, 2008; Kristensen *et al.*, 2012). However, not many intervention studies corroborate this suggestion possibly due to different intervention methodologies (Kris-Etherton and Harris, 2013), methods for measuring body fat distribution and compliance to the whole grain intervention (Kristensen *et al.*, 2017).

One important point to reiterate here for the suggested evidence of association between whole grain intake and body fat is the cross-sectional nature in the current analyses and potential for confounding. Since body mass measures were taken at the same cross-section in time it is difficult to disentangle the direction of association, although in the NTFS the recording of diet aimed to assess habitual diet in the previous year, this was not the case in the NDNS where non-significant results were found. Additionally, the models for the association between body fat percentage or BMI and whole grain intake in the NTFS included adjustment for smoking status, medication use, SES and achieved education level, which helps to rule out potential confounding from such factors. Other factors, such as physical activity that were not accurately assessed in this cohort, remain to be considered. As previously discussed, high whole grain consumers are more likely to be more physically active, have a heathier diet and lifestyle and as such are more likely to have healthier body composition.

5.4.2 Blood pressure

Bloods pressure measurements were not significantly different between non-consumers and across tertiles of whole grain intake in both adults and children/teenagers in the NDNS. After confounder adjustments, blood pressure measurements were also not significantly associated with whole grain intake nor different across whole grain intake tertiles in the NTFS members in the 50-year follow-up. Likewise, in the study members at the 60-year follow-up for systolic and pulse pressures. However, small improvements in diastolic blood pressures were seen with increased whole grain intake in the NTFS at 60-year follow-up. For each gram increase in whole grain intake per day, diastolic blood pressure were 0.07mmHg lower.

Interestingly in sex-specific analyses, the improvement in diastolic blood pressures were seen for females only with 0.12mmHg lower diastolic blood pressures per gram increase in whole grain intake per day and 5.2mmHg lower diastolic blood pressures for females with the highest whole grain intakes compared with the lowest. Since there were no significant differences in diastolic blood pressures between males and females in the regression model at 60-year follow-up (Table 4.17), no significant sex-whole grain intake interaction seen and a negative non-significant regression coefficient in the male only model, the reduction in sample size, subsequent reduction of statistical power and small effect size, may explain why whole grain intake was not significantly associated with diastolic blood pressures specifically in males.

Mirroring the reduction in diastolic blood pressures with higher whole grain intake in the NTFS at 60-year follow-up, one intervention study, comparing a whole grain diet with a macronutrient matched refined grain diet, has also reported significant reductions in blood pressure in overweight or obese adults greater than 50 years old (Kirwan *et al.*, 2016). Another intervention study reported lower diastolic blood pressures in mildly hypercholesterolemic adults following a whole grain intervention of 20% of energy from whole wheat/brown rice, barley or a half and half mix of wheat/rice and barley in comparison with a unrefined grain control diet (Behall *et al.*, 2006). Of the intervention studies on healthy middle-aged individuals, to my knowledge, only one has reported reductions in systolic blood and pulse pressures (but not diastolic blood pressure) following a 12 week whole wheat and oat dietary intervention compared with individuals in the refined grain control group (Tighe *et al.*, 2010). In the remaining intervention studies blood pressures have been largely unaffected in healthy or overweight but otherwise healthy participants (Seal and Brownlee, 2010; Ye *et al.*, 2012; Seal and Brownlee, 2015) (Table 2.3). For healthy people a reduction in blood pressure from increased whole grain intake is not necessarily desirable and is not the outcome of focus in such populations. In addition, average blood pressures, which were elevated but not hypertensive, in the NTFS at 60-year follow-up were higher than at 50-year follow-up and higher than the NDNS adults. This highlights the effect of aging on blood pressure and raises the question as to whether no changes in blood pressure across time should be studied as a beneficial effect of whole grain intake as populations age, rather than reductions in blood pressures in acute intervention studies.

5.4.3 Blood lipids

Total and LDL cholesterol concentrations were significantly inversely associated with whole grain intake in the NTFS members at 50-year follow-up. In addition, HDL cholesterol concentrations were significantly positively associated with whole grain intake in male study members at 60-year follow-up. In contrast, no association between whole grain intake and blood lipid measures were found in the NDNS participants. This may be because of the low whole grain intakes levels within this population and the potentially higher reported whole grain consumption from oat-based foods, namely porridge, in the older NTFS cohort. Other studies have shown improvements in blood lipid concentrations in those with higher whole grain intakes (Jensen *et al.*, 2006; Ye *et al.*, 2012), however, results of whole grain interventions studies have not been consistent. A meta-analysis estimated only small, 0.09 and 0.12 mmol/L, lower mean total and LDL cholesterol concentrations from whole grain intakes compared with the control across 24 randomised controlled studies (Hollaender *et al.*, 2015).When separating studies by the type of whole grain intervention (mixed, wheat, oat, rye, barley and rice), whole-grain oats appeared to exhibit the greatest hypocholesterolaemia effect. This may be due to beta-glucans found mainly in oats and barley, which have consistent blood cholesterol lowering properties in randomised controlled trials (Ho *et al.*, 2016). This raises the issue that whole grains are a mixed entity of differing grain types, that although being a similar in composition, they are not identical. In particular they have varying amounts of soluble/insoluble fibres and as such may elicit differing physiological responses in the human body.

5.4.4 Inflammatory and other blood measures

Across tertiles of whole grain intake in the NDNS participants there was a significant reduction in white blood cell count and significantly lower CRP concentrations in adults between non- and low-whole grain consumers. There was also a small inverse association between whole grain intake and white blood cell count in the NTFS at 60-year follow up and significantly lower white blood cell counts for those in the highest compared with the lowest tertile of whole-grain intakes. Generally, higher white blood cell counts are associated with higher levels of infection which would be associated with markers of inflammatory status such as circulating CRP concentrations. Although CRP measurements taken in the NTFS participants at 60-year follow-up were not ‘high sensitivity-CRP’ and are therefore not strictly comparable to the NDNS data, those with lower CRP concentrations also had significantly higher whole grain intake compared with those with CRP <0.05mmol/L, the level of detection for the assay. In adults from the NDNS, significantly lower CRP concentrations were seen in whole grain consumers in T1 compared with non-consumers (T1: 2.8 vs 3.8mg/L, Table 3.17). However, the reductions in CRP concentrations of adult consumers in tertiles two and three, although present, were not significantly different from non-consumers. It has been suggested that the anti-inflammatory and immune stimulating properties of whole grains may be due to the presence of fatty acids, oligosaccharides and antioxidants (Fardet, 2010) but the exact mechanism is unclear and requires further investigation.

White blood cell counts and CRP concentrations are markers of immune response and inflammation within the body and are linked to the pathogenesis of CVD and T2D (Donath (Masters *et al.*, 2010; Donath and Shoelson, 2011). It is interesting that even at the reported low level of whole grain intake in NDNS and NTFS such associations were observed. Similar changes in CRP were seen in three cross-sectional studies where CRP concentrations were lower in whole-grain bread consumers and across whole grain intake categories (Montonen (Lutsey *et al.*, 2007; Masters *et al.*, 2010; Montonen *et al.*, 2013). In contrast to the observational results reported here, the associations of whole grain intake with inflammatory markers are not consistently supported by intervention studies (Buyken *et al.*, 2014). Many of these studies report no change in inflammatory markers, notably CRP and IL-6 over 4 month, 12 week and 6 week intervention periods (Andersson, 2007; Brownlee *et al.*, 2010; Tighe *et al.*, 2010; Ampatzoglou *et al.*, 2015b). Changes in white blood cell counts were also not significantly different in healthy adults following a 6 week whole grain diet, compared with the refined grain diet group (Vanegas *et al.*, 2017). The difference observed between the results of intervention studies and those derived from observational studies may be due in particular to short-term dietary intervention periods, but may also be affected by seasonality, small numbers of participants in the intervention groups and lack of direct anti-inflammatory effect. Whilst the observational associations are suggestive of better inflammatory and immune responses with increased whole grain consumption, it is also possible that the results reflect potential confounding from healthy lifestyle behaviours and diets of high whole grain consumers.

5.4.5 Glucose and insulin responses

Glucose and insulin responses to an oral glucose tolerance test were only available for the NTFS members at 50- and 60-year (glucose only) follow-up. The results for glucose and insulin responses are interesting, and difficult to interpret; significantly higher fasting and 2-hour insulin concentrations were seen in the mid-tertile whole grain consumers compared with the lowest tertile at 50-year follow-up, but this response was seen in the highest tertile where responses were similar to the lowest tertile. In the 60-year follow-up fasting and 2-hour glucose concentrations were inversely associated with whole grain intake, but no significant differences were seen between tertiles of whole grain intake. It is not clear whether these small, but significant differences have a biological significance, or are a 'chance' statistical finding (type 1 error). In other studies fasting glucose and insulin concentrations have been shown to be associated with greater whole-grain food intake. For example, pooled analysis from a meta-analysis of 14 cohort studies indicated 0.009mmol/l and 0.011pmol/l reductions in fasting glucose and insulin concentrations per 1-greater serving of whole grain intake, respectively (Nettleton *et al.*, 2010). In several studies where positive effects of consuming whole grain have been observed subjects in the intervention study population had impaired glucose metabolism and therefore there was greater potential for improvement (Pereira *et al.*, 2002; Lankinen *et al.*, 2011; MacKay *et al.*, 2012). In contrast, the NTFS population at both 50- and 60-year follow-up had fasting and 2-hour glucose measures which were within healthy ranges (indeed those with diabetes did not partake in the oral glucose test) and thus improvement may not necessarily be expected.

5.4.6 Mechanisms

The associations between whole grain intake and cardio-metabolic outcomes discussed so far cannot be implicated as causal effects since the analyses of the current work are observational and intervention studies investigating such associations do not consistently confirm cause and effect. However, there are mechanisms hypothesised as to how whole grains may exert physiological changes in consumers (Slavin *et al.*, 1997; Slavin, 2003; Seal, 2006; Fardet, 2010; Giacco *et al.*, 2011; Borneo and Leon, 2012; Karl and Saltzman, 2012). For example the higher fibre content of whole grains (both soluble and insoluble) may confer a range of effects such as altered intestinal transit time, and changes to the gut microbiome resulting in better overall gut health and increased satiety. Other proposed mechanisms include slowing digestion time (which impacts on glucose and insulin metabolism), anti-oxidant, anti-inflammatory theories, increased gut microbial diversity and effects on fermentation and short chain fatty acid production and bile acid metabolism. These suggest mechanisms are not fully understood and it is likely that for whole grains a combination of factors are involved. Additionally, since whole grains are not consumed alone, they are instead part of a diet made up from many other foods and as such identifying specific mechanisms within the human body may be impossible. The lack of mechanistic evidence to support such hypotheses and the inconsistent results of intervention studies compared with the evidence from observational studies should not undermine recommendations to increase whole grain intakes.

5.5 Strengths, weaknesses and limitations

5.5.1 The data

The analyses and results reported in this thesis come from two rich data sources, the NDNS and the NTFS. The NDNS is a representative UK survey and contains detailed dietary information that has allowed for the most up to date and accurate assessment of whole grain intake in the UK. The NTFS contains a broad range of longitudinal prospectively measured health and lifestyle measures from a socio-economically representative birth cohort from Newcastle upon Tyne. The estimation of whole grain intake, adhering to the Healthgrain whole grain definition (van der Kamp *et al.*, 2014), in these two populations are the first within the UK to also investigate potential associations with other dietary intakes and markers of cardio-metabolic health and provide an important insight as to how the UK population compares with other countries.

5.5.2 Representativeness and weighting

The NDNS was designed to be representative of the UK population and therefore contains a spectrum of participants from a representative range of socio-economic backgrounds. Furthermore weighting of the data, as detailed in section 3.6, maintains this representation during data analysis. From the offset, the NTFS recruited all babies born in May and June in 1947 and therefore contains study members born from the complete range of socioeconomic backgrounds in the Newcastle upon Tyne region at that time. However, over time some NTFS study members changed their socioeconomic position in society and some of the subjects moved away from the Newcastle area (Tiffin *et al.*, 2005). Therefore the study at 50-, 60- and 67-year follow-up, although containing subjects with a wide range of SES, and with many participants remaining in the Newcastle area, may not be representative of the UK population and not directly comparable to the NDNS adult population. This may explain why SES differences in whole grain intakes were seen in the NDNS analysis whereas at 50-year follow-up in the NTFS there was none.

The analysis and results presented in chapter three (NDNS) were weighted using variables provided by the NDNS team. Weighting the data should remove bias occurring due to differences in the probability of households and individuals who were randomly sampled to take part in the survey as well as to remove any bias from those who were selected to take part but did not respond or refused. Further weighting of anthropometric and blood measures in principle removes any potential bias from those who opted out of participating in these assessments.

Whilst the data in the analysis of the NTFS were not weighted, the population demographics were not different between 50-, 60- and 67-year follow-up (Table 4.3). At 50-year follow-up 89% of the original surviving NTFS cohort were retraced and 574 returned a health and lifestyle questionnaire. These study members were more likely to be female and from more advantaged socioeconomic backgrounds a demographic which is commonly seen in most research studies exploring nutrition and health effects.

5.5.3 Dietary assessment methods and self-reporting

Comparison of whole grain intakes from the NDNS and NTFS should carefully consider that differences in nutrient and food intakes may be attributed to the different dietary assessment methods used. In the NDNS whole grain intakes were calculated from four-day estimated weight diet diaries and whilst these provide a detailed account of dietary intakes over the four days they are one snap-shot in time. In contrast, whole grain intakes in the NTFS were calculated from FFQ, which were designed to assess habitual diet during the previous year before questionnaire completion. There is no ‘gold standard’ for measuring dietary intakes since there are both positives and negatives associated with all intake assessment methods.

As with any diet assessment misreporting of food consumption is a cause for concern as it is possible to both under and over report diet. In the NDNS rolling programme a short four-day recording period and follow-up visits made to the survey participants by trained interviewers helped to minimise misreporting. A double labelled water assessment of energy intake and expenditure in sub-samples of NDNS participants, who took part in years one and three, has shown that participants aged 16 and over on average underreport dietary energy intake by

32% in comparison with energy expenditure (Lennox *et al.*, 2014) suggesting overall evidence of underreporting energy intake in the NDNS, and hence overall food intake. One potential reason why energy intakes may be underreported could be due to recording estimated portion sizes rather than weighed food intake as done in NDNS studies prior to the rolling programme. However, portion size atlases were given to all adult participants in the NDNS rolling programme and were trialled in young persons in the second quarter of the third year (2011) survey. Food photograph atlases have been shown to improve the accuracy of self-reported food intakes with good agreement between estimated intakes using photographs and weighed diaries (Foster *et al.*, 2017). Nevertheless, underreporting of diet in the NDNS must be considered when interpreting findings. Similarly there is potential for underreporting within FFQs (the method used to assess habitual diet in the NTFS). However, average energy intakes calculated from the FFQ at 50-year follow-up were in line with those expected for men and women (10MJ/d in men and 9MJ/d in women). On the other hand energy intakes calculated from the FFQ at 60-year follow-up were lower than expected (7MJ in men and 6MJ/d in women) and are a potential underestimate of habitual dietary intake. Again, the issue of misreporting should be considered when interpreting findings.

As technology develops there gives the potential to more accurately and reliably measure dietary intakes that potentially reduces participant burden as well as data collection resources. For example, 24 hour recall dietary assessment can now be recorded online or via a mobile phone app, with nutrient and food intake data made instantly available through the use of sophisticated databases (Cade, 2016; Rollo *et al.*, 2016). Additionally, biomarkers may help to reduce recall bias but may increase participant burden through having to give blood or urine samples. Alkylresorcinols have been used as a biomarker of whole grain, since they are contained within the bran fractions of wheat, rye and barley grains. Alkylresorcinols are absorbed by humans, are measurable in blood and remain stable in blood stored, Thus alkylresorcinols are useful to assess compliance in whole grain intervention studies (McKeown *et al.*, 2015) and along with dietary records can be used to distinguish between low and high whole grain consumers (Ross, 2012; Ross *et al.*, 2012). Unfortunately, this biomarker is only specific to wheat, rye and barley and therefore does not measure all whole grain intake particularly from oats which were a contributor to whole grain intake in the present UK analyses. Biological samples from the NTFS are available for alkylresorcinol analysis but unfortunately these analyses could not be completed within the timeframe of this study. Further analysis should include these data when they become available.

5.5.4 Non-consumers

Whole grain intakes in the NDNS were estimated from 4-day food diaries. Whilst this dietary assessment method provides great detail of foods consumed, it is important to remember that four days of recording is a small snap-shot in time and may not represent an overall dietary pattern. In particular, careful consideration must be made when referring to non-consumers of whole grain since it may be the case that the 'non-consumer' only did not consume a whole-grain food during the four days of dietary recording, and that they may have consumed whole grain on one or more of the other days in the week. However, it is a reasonable assumption that those with the highest whole grain intake over the four dietary recording days would habitually consume high amounts of whole grain. In contrast, whole grain intake estimated from FFQs in the NTFS analyses may give a better representation of non-consumers since the FFQ used was designed to assess habitual intake over the previous year. As such the level of non-consumption of whole grains was much lower with 12%, 7% and 0.3% non-consumption at the 50-, 60- and 67-year follow-up respectively. Since there were relatively few non-consumers in the study population they were not separated in the analysis as a separate group, rather they were included within the low intake tertile.

5.5.5 Calculation of whole grain content

In order to estimate whole grain intake, the whole grain content of all foods consumed in the NDNS and in the NFTS was calculated (Appendix A). These calculations included the whole-grain foods consumed in the NDNS 1986-87, 2000-01, a UK consumer food intake study and new calculations of whole-grain foods from the 2008-2011 NDNS rolling programme. Whilst making every effort to accurately source and calculate whole grain content of foods consumed, some assumptions made during calculation may lead to both small under- and over-estimations of whole grain intake. Matching foods to similar products and vague or no detail on product packaging may also result in under- and over-estimation. However, with a strict inclusion and exclusion criteria for whole grain ingredients and rigorous calculation the best possible estimate of whole grain intake has been calculated.

The whole grain intake estimates reported focus on dry matter whole-grain percentage to give the most accurate estimate of whole grain intake for comparison with published data which are generally reported on a dry matter basis. Different whole grains have different amounts of water content, for example wholemeal wheat is estimated to contain 14% water and whole oats 8.9% water (Food Standards Agency, 2002b). Previous studies on whole grain intake have used both dry (Thane *et al.*, 2005; Thane *et al.*, 2007) and wet matter (Cleveland *et al.*, 2000; Zanovec *et al.*, 2009) to calculate intake and in some cases (particularly for earlier studies) no information is provided. Therefore there is no standard practice as to whether dry or wet matter percentage is used, although a recent publication has emphasised the reporting of whole grain intake on a dry matter as consumed basis (Ross *et al.*, 2015). Accounting for water content will give a better estimate of whole grain intake regardless of which whole grain has been consumed and thus more accurate results are produced.

The NDNS data used in this thesis spanned a three year period during which food products may have changed or been re-formulated. For example, many RTEBC have reduced salt content, affecting the percentage of other ingredients and potentially affecting apparent nutrient intake. Additionally, granary breads were included in the estimation of whole grain intake in the NDNS population since it was thought that these breads were made with some wholemeal flour ingredients. Since this analysis, however, granary flours used in more modern recipes have been found to contain granary malted wheat flakes and wheat bran (Hovis Bakery, 2016) which are not defined as whole grain ingredients. Thus future analyses should not consider granary breads as whole grain nor include them in whole grain intake calculations. Granary breads were not included in the whole grain intake estimation for the NTFS at each follow-up and average whole grain intakes were marginally higher than that of the NDNS. This suggests that the contribution of granary breads to overall whole grain intake may be small although further investigation is needed to confirm this within the NDNS population.

In the NTFS estimation, and other cohort studies using FFQ, the type of whole-grain foods consumed is somewhat dictated by the food questions in the FFQ used. However, the CFQ that was developed to assess whole grain intakes in the NTFS at age 67 years, included the most commonly consumed whole-grain foods reported in the NDNS 2008-2011. In addition, extra questions were added to clarify if cakes and biscuits had been made with wholemeal or refined flours. Very small amounts (7 %) of cakes and biscuits were reported at 67-years, suggesting that potential intakes from these foods would not add greatly to overall whole grain intakes. In addition, free text boxes were made available in the CFQ for any foods not listed in the questionnaire. The foods reported in the free text were varieties of breads (bagels, ciabatta, garlic bread, spelt bread), branded RTEBC, cereal bars and single grains (cous cous), many of which were not actually whole-grain foods. This raises further issues about consumer understanding of the term ‘whole grain’ and the ability of consumers to identify whole grains, even if they profess to know what they are. This is a very much under-researched area and requires urgent action if whole grains are promoted further in public health initiatives.

In order to estimate whole grain intake from RTEBC in the NTFS at 50- and 60-year follow-up, assumptions were made on the frequency and whole grain content of RTEBC consumption. The assumptions were based on a secondary question, from the same questionnaire, that asked participants to state up to three types (name and brand) of their most frequently consumed RTEBC during the previous year. This assumption may not be completely realistic of the RTEBC actually consumed over the year but it was considered to be the best and most robust estimation method available for use at these time-points.

5.5.6 Development of the cereal food questionnaire and portion size estimations

The development of the CFQ required the estimation of food portion sizes to estimate whole grain intake. Food portion sizes were estimated from the adult NDNS reported gram intakes and were weighted to account for the differing consumption of foods within a food question. For example, the question on wholemeal bread and rolls asked for frequency per slice or per roll. An average slice of bread is ~36g whereas an average roll is ~48g and potentially one person would consume more slices of bread than rolls. By weighting portion sizes this gathers an average of portion size from breads and rolls with greater emphasis given to the most frequently consumed portion size. Since portion sizes can vary greatly, using the NDNS adult data gives a good representation of consumption since the NDNS adults were given a food photograph atlas to aid their dietary diary recording as well as being able to report specific quantities used, for example a teaspoon of sugar. In addition, portion size information was sourced from the Food Standards Agency, food portion size book and brand product packaging. These portion size details were accumulated in order to get the most likely portion size of each food consumed. Weighting portion sizes this way is appropriate for foods which are most similar in whole grain content (e.g. wholemeal bread and wholemeal rolls have the same whole grain content) and it is important when developing an FFQ not to include too diverse a group of foods within a single question in the FFQ. This methodology is by no means perfect but although it is possible that in addition there is variation in actual portion sizes consumed between participants, across the whole study group this will average out and give a fair reflection of whole grain intake for this study population.

5.5.7 Cross-sectional analyses

One important consideration of the results presented in this thesis is that the analyses are cross-sectional. Direct comparisons between dietary consumption and blood analytes in the NDNS analysis should be treated with caution due to the time which elapsed between the dietary recording period and blood sampling (a gap of at least 8 weeks). However the blood results should reflect the participants' habitual diet which should be represented in their diet diary. Similarly blood samples taken from the NTFS were arranged during the same period when the questionnaire was returned. However, the FFQ asked study members to record their usual food intakes during the previous year and fasting blood samples were taken at a single time point so should reflect the study member's usual health status.

5.5.8 Statistical analyses

With all statistical analysis there remains the chance for error. Multiple hypothesis testing can cause problems in some studies by leading to false significant findings (i.e type 1 error, where findings appear statistically significant, but that are not really). In this regard, all significant findings have been discussed in relation to an appropriate biological association, as well as, in relation to previous research findings. There is also the potential for type 2 error (i.e where a significant result is expected, but none is observed in the analysis) particularly if there is low power. The large sample size of the NDNS study helps to reduce the chance of error and the results found are not unexplainable or inconsistent with other published studies. In addition, a post hoc power calculation indicated that with the available sample sizes in the NDNS data (total n=1571 with dietary data, n=1443 with anthropometric data and n=580 with blood marker data) and using calculated standard deviations (of the analysis), a detectable difference of at least 1.1g/10MJ/d in fibre intake, 1.4kg/m^2 in BMI and 0.3mmol/L between adult whole grain consumers and non-consumers would be achieved with 80% power, at the alpha 0.05 level. These differences were also detectable with 80% power in the available data in children. These calculations indicated that analyses of the NDNS data had adequate power to detect relatively small changes in the cardio-metabolic measures. Where differences were not found, for example in average BMIs between whole grain intake tertiles, the non-significant p-values are genuine results rather than type 2 errors.

The NTFS cohort at 50-, 60- and 67-year follow-up had a smaller number participants, hence statistical power in analysis was likely reduced. However, significant associations were seen within the NTFS regression analyses, many of which are not dissimilar to other published findings. Post hoc power calculations indicated that with the available sample sizes in the

NTFS data (total n=542 with dietary data, n=402 with anthropometric data and n=398 with blood marker data) and using calculated standard deviations (of the analysis), a detectable difference of at least 1.8g/10MJ/d in fibre intake, 1.6kg/m^2 in BMI and 0.5mmol/L between whole grain consumers and non-consumers, in the 50-year follow-up, would be achieved with 80% power, at the alpha 0.05 level. At the 60-year follow-up, a detectable difference of at least 2.4g/10MJ/d in fibre intake, 1.9kg/m^2 in BMI and 0.5mmol/L between whole grain consumers and non-consumers, would be achieved with 80% power. These calculations indicated that the analyses had adequate power to detect appropriate differences in the cardio-metabolic measures between whole grain consumers and non-consumers in the NTFS. Furthermore, in the NTFS analyses few significant whole grain intake-sex interactions were found, however sex-specific analyses were also run, since there may not have been enough power in these models to detect significant interactions. Statistical power was also an issue in sex-specific models since these models contained even smaller sample sizes. It is therefore difficult to conclusively say whether the associations found in the NTFS were specific to either males or females, with the exception for the models where significant interactions were detected, and sex -specific models showed opposing effect sizes (this was only the case for HDL cholesterol in males, section 4.4.7.5). As such, the prior discussion of the associations between whole grain intake and cardio-metabolic measures has considered both males and females within adult populations with sex specific findings discussed where appropriate where the differences were large enough to be biologically relevant.

As mentioned throughout the discussion confounding is an issue in observational studies. The analyses within the NTFS included adjustment for the potential confounding of sex (since there were differences in male and female whole grain intakes and cardio-metabolic measures), energy intake (since those that consume higher amounts of whole grain may be eating more foods overall), medication use (since this would have a direction impact on cardio-metabolic measures and could serve as a marker of overall health status) and smoking (since whole grain consumers are less likely to smoke and smoking is associated with cardio-metabolic health measures. Additionally, further adjustments in regression modelling were made for SES and achieved education level since these factors may have also confounded any significant associations seen.

5.6 Public Health Implications

Whole grain intake in the UK was been shown to be low and in order to increase whole grain intake at a population level a quantity-specific whole grain recommendation should be developed. However, increasing whole grain intakes may be difficult. Studies in the US, have shown that despite having a quantity-specific recommendation of 3oz-equaivalents (approximately 48g) per day, this target has not been achieved. Assessing trends across 12 years of the NHANES showed that, although recommended intakes of total grains are being met, only small increases in whole grain intake were observed and less than 10% of Americans currently meet the recommendation for whole grain intakes. This suggests that despite the increasing consumer interest and availability of whole-grain foods, little progress in replacing intake of refined grains with whole grains has occurred in the past 12 years (Albertson *et al.*, 2016). In contrast, as previously mentioned, the Danish population has shown considerable success in improving whole grain intakes, demonstrating that with public and private partnership campaigns population dietary habits can change. Although the new Eatwell Guide and advice from Public Health England has raised the profile of whole-grain foods (Public Health England, 2016), a more explicit recommendation is justified. It is important that any new dietary recommendations focus on replacement of refined grain foods with whole-grain foods so that overall energy intake does not increase. There may be potential for co-ordinating a whole grain recommendation with the current UK fruit and vegetable guidance. For example, the current '5-a-day' campaign for portions of fruit and vegetables could be mirrored by a '3-a-day' campaign for whole grains. This would require further clarity in definitions of whole grain, whole-grain foods and mechanisms to enable consumers to identify portions of whole-grain foods. A scientific consensus and subsequent studies using one definition of a whole-grain food would add to the evidence concerning health benefits of whole grains and aid public bodies in recommending such food-based whole grain guidance. These in turn may aid the approval of whole grain health claims across Europe and allow manufacturers to label their foods effectively and in a way which is regulated for the consumer. A UK whole grain intake recommendation may also drive food manufacturers to develop new whole-grain foods which are appealing and affordable for the consumer, which in turn would help to increase whole grain consumption in the UK.

There are few adverse effects of public health recommendations advocating and promoting whole grain intake. To the best of my knowledge, no intervention study to date has reported any adverse effect of whole grain intake on diet and health markers, although some have reported less desirable gut symptoms such as bloating and flatulence. Of course it is important to note that for a small proportion of the population with a gluten intolerance, caution must be made when consuming whole grains containing gluten. However, gluten free whole grain alternatives such as amaranth, brown rice, buckwheat and quinoa are available and their consumption by those with gluten intolerance can be encouraged. Whole grain oats do not contain gluten but are sometimes cross-contaminated with wheat during harvesting or factory processing. Thus consumers should always check product labels for gluten-free oat ingredients for clarification. Additionally, there is no evidence that gluten free diets are of benefit in healthy populations. On the contrary, it has recently be shown in the US Nurses Heath Study of 199,794 women with over 30-years follow-up that those who reported consuming the least amount of gluten had an increased risk of developing T2D (American Heart Association, 2017). Although these findings do not implicate causality it has been shown that the majority of gluten free foods are nutritionally inferior and more costly (Wu *et al.*, 2015a), therefore for healthy populations it is not necessary to promote gluten and grain avoidance (Shewry and Hey, 2016).

5.7 Concluding remarks and suggestions for further research

Whole grain intake has been identified as generally low in this research of UK populations. An increase in whole grain consumption may help individuals to enhance nutrient intakes and better meet dietary nutrient reference values, since it was found that the diets of whole grain consumers were more nutrient dense that of non- or low-consumers. At a minimum increasing whole grain intake would aid individuals in meeting dietary fibre intake recommendations, but would also provide other important vitamins and minerals, such as vitamin E, iron, copper and magnesium, to their diets. Future studies investigating the impact on vitamin and mineral intake, in addition to those showing clear increases in cereal-fibre intake, could be useful particularly where refined grains are replaced with whole grain equivalents or whole grain intakes are substantially increased at the expense of other carbohydrate-rich foods.

Whole grain intake was estimated using data from two UK cohorts and this is one of a few studies assessing whole grain intake in the UK population. As a consequence a database of the whole grain contents of foods consumed in the UK has been collated and is now publically available (Jones *et al.*, 2017). This database could be incorporated into a range of dietary intake assessment tools and compositional databases including the NDNS databank so that whole grain intake in the UK can be more routinely measured and reported.

Despite low overall whole grain consumption in the UK population some associations were seen between higher whole grain intake and cardio-metabolic measures. Associations were small, but significant, suggesting that whole grains may have an important role in disease prevention, particularly for CVD and T2D. There are many possible mechanisms of action that have been proposed in relation to the high fibre and bioactive compound contents of whole grains. However, the exact pathways in which whole grains elicit physiological effects on humans remain unclear and no one single mechanism or component is likely to be responsible for the cardio-metabolic health benefits of whole grain consumption. The evidence for disease and mortality risk reduction from observational studies is strong and consistent and provides support for the promotion of whole grain intake. In contrast, interventional evidences is not consistent which may be a result of differing study methodologies, dietary interventions and the health status of the participants involved. Furthermore, it is known that as we age our health and health markers in general decline. We should re-consider the pharmacological paradigm which suggests that short-term dietary intervention with whole grains should improve or reduce disease risk in favour of a longer-term model which suggests that increased whole grain intake in the longer-term reduces age-related declines in health.

References

Ak, N., Koo, H.C., Jm, H.J., Mt, M.N., Tan, S.Y., Appukutty, M., Ar, N., Thielecke, F., Hopkins, S., Ong, M.K., Ning, C. and Tee, E.S. (2015) 'Whole Grain Intakes in the Diets Of Malaysian Children and Adolescents – Findings from the MyBreakfast Study', *PLoS ONE*, 10(10), p. e0138247.

Albertson, A.M., Reicks, M., Joshi, N. and Gugger, C.K. (2016) 'Whole grain consumption trends and associations with body weight measures in the United States: results from the cross sectional National Health and Nutrition Examination Survey 2001–2012', *Nutrition Journal*, 15(1), pp. 1-14.

Alexy, U., Zorn, C. and Kersting, M. (2010) 'Whole grain in children's diet: Intake, food sources and trends', *European Journal of Clinical Nutrition*, 64(7), pp. 745-751.

Amcoff, E., Edberg, A., Barbeieri, H.E., Lindroos, A.K., Nalsen, C., Pearson, M. and Lemming, E.W. (2012) *Riksmaten – vuxna 2010–11. Livsmedels- och näringsintag bland vuxna i Sverige*. Livsmedelsverket: Livsmedelsverket Byrå 4, U. [Online]. Available at: https://www.livsmedelsverket.se/matvanor-halsa--miljo/kostrad-och-matvanor/matvanor---undersokningar/riksmaten-2010-11---vuxna (Accessed: 16 November 2015).

American Association of Cereal Chemists (1999) 'Whole grain definition', *Cereal Foods World*, 45.

American Association of Cereal Chemists International (2013) *AACCI's Whole Grains Working Group Unveils New Whole Grain Products Characterization*. Available at: http://www.aaccnet.org/about/newsreleases/Pages/WholeGrainProductCharacterization.aspx (Accessed: 12 May 2016).

American Heart Association (2017) 'Low gluten diets may be associated with higher risk of type 2 diabetes'. AHA/ASA Newsroom. Available at: http://newsroom.heart.org/news/low-gluten-diets-may-be-associated-with-higher-risk-of-type-2-diabetes (Accessed: 20 March 2017).

Ampatzoglou, A., Atwal, K.K., Maidens, C.M., Williams, C.L., Ross, A.B., Thielecke, F., Jonnalagadda, S.S., Kennedy, O.B. and Yaqoob, P. (2015a) 'Increased whole grain consumption does not affect blood biochemistry, body composition, or gut microbiology in healthy, low-habitual whole grain consumers', *The Journal of Nutrition*, 145(2), pp. 215-21.

Ampatzoglou, A., Williams, C.L., Atwal, K.K., Maidens, C.M., Ross, A.B., Thielecke, F., Jonnalagadda, S.S., Kennedy, O.B. and Yaqoob, P. (2015b) 'Effects of increased wholegrain consumption on immune and inflammatory markers in healthy low habitual wholegrain consumers', *The European Journal of Nutrition*.

Anderson, J.W. (2003) 'Whole grains protect against atherosclerotic cardiovascular disease', *Proceedings of the Nutrition Society*, 62(1), pp. 135-42.

Anderson, J.W., Hanna, T.J., Peng, X. and Kryscio, R.J. (2000) 'Whole Grain Foods and Heart Disease Risk', *Journal of the American College of Nutrition*, 19(sup3), pp. 291S-299S.

Andersson, A.A.M., Dimberg, L., Åman, P. and Landberg, R. (2014) 'Recent findings on certain bioactive components in whole grain wheat and rye', *Journal of Cereal Science*, 59(3), pp. 294-311.

Andersson, A.T., S. Karlstrom, B. Kamal-Edin A, Landberg, R. Basu, S. Aman, P. Vessby, B. (2007) 'Whole-grain foods do not affect insulin sensitivity or markers of lipid perxidation and inflammation in healthy, moderately overweight subjects', *The Journal of Nutrition*, 137, pp. 1404-7.

Aune, D., Chan, D.S., Lau, R., Vieira, R., Greenwood, D.C., Kampman, E. and Norat, T. (2011) 'Dietary fibre, whole grains, and risk of colorectal cancer: systematic review and dose-response meta-analysis of prospective studies', *The BMJ*, 343, p. d6617.

Aune, D., Keum, N., Giovannucci, E., Fadnes, L.T., Boffetta, P., Greenwood, D.C., Tonstad, S., Vatten, L.J., Riboli, E. and Norat, T. (2016) 'Whole grain consumption and risk of cardiovascular disease, cancer, and all cause and cause specific mortality: systematic review and dose-response meta-analysis of prospective studies', *The BMJ*, 353, p. i2716.

Aune, D., Norat, T., Romundstad, P. and Vatten, L.J. (2013) 'Whole grain and refined grain consumption and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis of cohort studies', *European Journal of Epidemiology*.

Azadbakht, L., Mirmiran, P., Esmaillzadeh, A., Azizi, T. and Azizi, F. (2005) 'Beneficial Effects of a Dietary Approaches to Stop Hypertension Eating Plan on Features of the Metabolic Syndrome', *Diabetes Care*, 28(12), pp. 2823-2831.

Bates, B., Lennox, A., Prentice, A., Bates, C., Page, P., Nicholson, S. and Swan, G. (2014) *National Diet and Nutrition Survey Results from Years 1, 2, 3 and 4 (combined) of the Rolling Programme (2008/9 - 2011/12)*. Public Health England publications: 2014051. [Online]. Available at: https://www.gov.uk/government/statistics/national-diet-and-nutrition-survey-results-from-years-1-to-4-combined-of-the-rolling-programme-for-2008-and-2009-to-2011-and-2012 (Accessed: 23 May 2014).

Bates, B., Lennox, A., Prentice, A., Bates, C. and Swan, G. (2012a) *National Diet and Nutrition Survey. Headline results from Years 1,2 and 3 (combined) of the Rolling Programme (2008/9-2010/11)*. Department of Health. [Online]. Available at: https://www.gov.uk/government/publications/national-diet-and-nutrition-survey-headline-results-from-years-1-2-and-3-combined-of-the-rolling-programme-200809-201011 (Accessed: 01 Feb 2013).

Bates, B., Lennox, A., Prentice, A., Bates, C. and Swan, G. (2012b) *National Diet and Nutrition Survey. Headline results from years 1, 2 and 3 combined - Appendix E. Diary documents*. [Online]. Available at: https://www.gov.uk/government/statistics/national-diet-and-nutrition-survey-headline-results-from-years-1-2-and-3-combined-of-the-rolling-programme-200809-201011 (Accessed: 05 March 2013).

Behall, K.M., Scholfield, D.J. and Hallfrisch, J. (2006) 'Whole-Grain Diets Reduce Blood Pressure in Mildly Hypercholesterolemic Men and Women', *Journal of the American Dietetic Association*, 106(9), pp. 1445-1449.

Bellisle, F., Hebel, P., Colin, J., Reye, B. and Hopkins, S. (2014) 'Consumption of whole grains in French children, adolescents and adults', *British Journal of Nutrition*, 112(10), pp. 1674-84.

Biesinger, S., Michaels, H.A., Quadros, A.S., Qian, Y., Rabovsky, A.B., Badger, R.S. and Jalili, T. (2016) 'A combination of isolated phytochemicals and botanical extracts lowers diastolic blood pressure in a randomized controlled trial of hypertensive subjects', *Eur J Clin Nutr*, 70(1), pp. 10-16.

Bingham, S.A., Gill, C., Welch, A., Cassidy, A., Runswick, S.A., Oakes, S., Lubin, R., Thurnham, D.I., Key, T.J., Roe, L., Khaw, K.T. and Day, N.E. (1997) 'Validation of dietary assessment methods in the UK arm of EPIC using weighed records, and 24-hour urinary nitrogen and potassium and serum vitamin C and carotenoids as biomarkers', *International Journal of Epidemiology*, 26(suppl 1), p. S137.

Bodinham, C.L., Hitchen, K.L., Youngman, P.J., Frost, G.S. and Robertson, M.D. (2011) 'Short-term effects of whole-grain wheat on appetite and food intake in healthy adults: a pilot study', *British Journal of Nutrition*, 106(3), pp. 327-330.

Borneo, R. and Leon, A.E. (2012) 'Whole grain cereals: functional components and health benefits', *Food & Function*, 3(2), pp. 110-9.

Great Britain. The Bread and Flour Regulations 1998, No. 141: Elizabeth II. 141. (1998) London: The Stationery Office.

British Heart Foundation (2016) *CVD Statistics – BHF UK Factsheet*. Available at: https://www.bhf.org.uk/research/heart-statistics (Accessed: 10 Septemeber 2016).

British Nutrition Foundation (2015) *Adult weekly meal plan: what does 5% free sugars and 30g fibre look like?* Available at: https://www.nutrition.org.uk/attachments/article/872/FINALCOPY%20free%20sugars%20meal%20planner_updated%20December%202015.pdf (Accessed: 16 June 2016).

Brownlee, I.A., Moore, C., Chatfield, M., Richardson, D.P., Ashby, P., Kuznesof, S.A., Jebb, S.A. and Seal, C.J. (2010) 'Markers of cardiovascular risk are not changed by increased whole-grain intake: the WHOLEheart study, a randomised, controlled dietary intervention', *British Journal of Nutrition*, 104(1), pp. 125-34.

Buil-Cosiales, P., Toledo, E., Salas-Salvadó, J., Zazpe, I., Farràs, M., Basterra-Gortari, F.J., Diez-Espino, J., Estruch, R., Corella, D., Ros, E., Marti, A., Gómez-Gracia, E., Ortega-Calvo, M., Arós, F., Moñino, M., Serra-Majem, L., Pintó, X., Lamuela-Raventós, R.M., Babio, N., Gonzalez, J.I., Fitó, M. and Martínez-González, M.A. (2016) 'Association between dietary fibre intake and fruit, vegetable or whole-grain consumption and the risk of CVD: results from the PREvención con DIeta MEDiterránea (PREDIMED) trial', *British Journal of Nutrition*, 116(03), pp. 534-546.

Burgess-Champoux, T.L., Chan, H.W., Rosen, R., Marquart, L. and Reicks, M. (2008) 'Healthy whole-grain choices for children and parents: a multi-component school-based pilot intervention', *Public Health Nutrition*, 11(8), pp. 849-59.

Burns, A.M., Devlin, N.F.C., McNulty, B.A., Gibney, M.J. and Nugent, A.P. (2013) 'Dietary intake of whole grain in Irish adults', *Proceedings of the Nutrition Society*, 72, p. E135.

Buttriss, J.L. (2015) 'Fibre – Need to increase intake according to new recommendations', *Nutrition Bulletin*, 40(4), pp. 291-295.

Buyken, A.E., Goletzke, J., Joslowski, G., Felbick, A., Cheng, G., Herder, C. and Brand-Miller, J.C. (2014) 'Association between carbohydrate quality and inflammatory markers: Systematic review of observational and interventional studies', *The American Journal of Clinical Nutrition*, 99(4), pp. 813-833.

Cade, J.E. (2016) 'Measuring diet in the 21st century: use of new technologies', *Proceedings of the Nutrition Society*, pp. 1-7.

Cereal Partners Worldwide-Nestlé and General Mills (2013) *Oats and More*. Available at: https://www.cerealsuccess.co.uk/food-service/our-brands/oats-more/ (Accessed: 15 May 2013).

Chang, H.-C., Huang, C.-N., Yeh, D.-M., Wang, S.-J., Peng, C.-H. and Wang, C.-J. (2013) 'Oat Prevents Obesity and Abdominal Fat Distribution, and Improves Liver Function in Humans', *Plant Foods for Human Nutrition*, 68(1), pp. 18-23.

Chanson-Rolle, A., Meynier, A., Aubin, F., Lappi, J., Poutanen, K., Vinoy, S. and Braesco, V. (2015) 'Systematic Review and Meta-Analysis of Human Studies to Support a Quantitative Recommendation for Whole Grain Intake in Relation to Type 2 Diabetes', *PLoS ONE*, 10(6), p. e0131377.

Chen, G.-C., Tong, X., Xu, J.-Y., Han, S.-F., Wan, Z.-X., Qin, J.-B. and Qin, L.-Q. (2016a) 'Whole-grain intake and total, cardiovascular, and cancer mortality: a systematic review and meta-analysis of prospective studies', *The American Journal of Clinical Nutrition*, 104(1), pp. 164-172.

Chen, J., Huang, Q., Wei, S., Liu, Y., Chen, J. and Qing, L. (2016b) 'Meta-Analysis of the Association Between Whole and Refined Grain Consumption and Stroke Risk Based on Prospective Cohort Studies', *Asia Pacific Journal of Public Health*, 28(7), pp. 563-575.

Cheng, G., Karaolis-Danckert, N., Libuda, L., Bolzenius, K., Remer, T. and Buyken, A.E. (2009) 'Relation of Dietary Glycemic Index, Glycemic Load, and Fiber and Whole-Grain Intakes During Puberty to the Concurrent Development of Percent Body Fat and Body Mass Index', *American Journal of Epidemiology*, 169(6), pp. 667-677.

Cho, S.S., Qi, L., Fahey, G.C., Jr. and Klurfeld, D.M. (2013) 'Consumption of cereal fiber, mixtures of whole grains and bran, and whole grains and risk reduction in type 2 diabetes, obesity, and cardiovascular disease', *The American Journal of Clinical Nutrition*, 98(2), pp. 594-619.

Chu, Y.L., Warren, C.A., Sceets, C.E., Murano, P., Marquart, L. and Reicks, M. (2011) 'Acceptance of two US Department of Agriculture commodity whole-grain products: a school-based study in Texas and Minnesota', *Journal of the American Dietetic Association*, 111(9), pp. 1380-4.

Cleveland, L.E., Moshfegh, A.J., Albertson, A.M. and Goldman, J.D. (2000) 'Dietary intake of whole grains', *Journal of the American College of Nutrition*, 19(3 SUPPL.), pp. 331S-338S.

Cooper, D., Kable, M., Marco, M., De Leon, A., Rust, B., Baker, J., Horn, W., Burnett, D. and Keim, N. (2017) 'The Effects of Moderate Whole Grain Consumption on Fasting Glucose and Lipids, Gastrointestinal Symptoms, and Microbiota', *Nutrients*, 9(2), p. 173.

Costabile, A., Klinder, A., Fava, F., Napolitano, A., Fogliano, V., Leonard, C., Gibson, G.R. and Tuohy, K.M. (2008) 'Whole-grain wheat breakfast cereal has a prebiotic effect on the human gut microbiota: A double-blind, placebo-controlled, crossover study', *British Journal of Nutrition*, 99(1), pp. 110-120.

Craig, R., Fuller, E. and Mindell, J. (2015) *Health Survey for England 2014*. The Health and Social Care Information Centre. Available at: www.hscic.gov.uk/pubs/hse2014.

Danish Whole Grain Partnership (2014) *Press Release: Whole grain intake sets new record*. Available at: http://www.fuldkorn.dk/english (Accessed: 24 November 2015).

Davy, B.M., Davy, K.P., Ho, R.C., Beske, S.D., Davrath, L.R. and Melby, C.L. (2002) 'High-fiber oat cereal compared with wheat cereal consumption favorably alters LDL-cholesterol subclass and particle numbers in middle-aged and older men', *The American Journal of Clinical Nutrition*, 76(2), pp. 351-358.

de la Fuente-Arrillaga, C., Zazpe, I., Santiago, S., Bes-Rastrollo, M., Ruiz-Canela, M., Gea, A. and Martinez-Gonzalez, M.A. (2016) 'Beneficial changes in food consumption and nutrient intake after 10 years of follow-up in a Mediterranean cohort: the SUN project', *BMC Public Health*, 16(1), p. 203.

de Mello, V.D.F., Schwab, U., Kolehmainen, M., Koenig, W., Siloaho, M., Poutanen, K., Mykkänen, H. and Uusitupa, M. (2011) 'A diet high in fatty fish, bilberries and wholegrain products improves markers of endothelial function and inflammation in individuals with impaired glucose metabolism in a randomised controlled trial: The Sysdimet study', *Diabetologia*, 54(11), pp. 2755-2767.

de Munter, J.S.L., Hu, F.B., Spiegelman, D., Franz, M. and Van Dam, R.M. (2007) 'Whole grain, bran, and germ intake and risk of type 2 diabetes: A prospective cohort study and systematic review', *PLoS Medicine*, 4(8), pp. 1385-1395.

DEFRA (2017) *Family Food Survey 2015*. London: Department for Environment, Food and Rural Affairs (DEFRA). [Online]. Available at: https://www.gov.uk/government/collections/family-food-statistics (Accessed: 21 March 2017).

Department of Health (1991) Dietary Reference Values for Food Energy and Nutrients for the United Kingdom (41). London: HMSO.

Devlin, N.F., McNulty, B.A., Gibney, M.J., Thielecke, F., Smith, H. and Nugent, A.P. (2013) 'Whole grain intakes in the diets of Irish children and teenagers', *British Journal of Nutrition*, 110(2), pp. 354-62.

Donath, M.Y. and Shoelson, S.E. (2011) 'Type 2 diabetes as an inflammatory disease', *Nat Rev Immunol*, 11(2), pp. 98-107.

Dong, D., Bilger, M., van Dam, R.M. and Finkelstein, E.A. (2015) 'Consumption Of Specific Foods And Beverages And Excess Weight Gain Among Children And Adolescents', *Health Affairs*, 34(11), pp. 1940-1948.

Dong, J.-Y., Xun, P., He, K. and Qin, L.-Q. (2011) 'Magnesium Intake and Risk of Type 2 Diabetes: Meta-analysis of prospective cohort studies', *Diabetes Care*, 34(9), pp. 2116-2122.

EFSA Panel on Dietetic Products and Nutrition Allergies (2010) 'Scientific Opinion on the substantiation of health claims related to whole grain (ID 831, 832, 833, 1126, 1268, 1269, 1270, 1271, 1431) pursuant to Article 13(1) of Regulation (EC) No 1924/2006', *EFSA Journal*, 8(10), p. 1766.

Fang, L., Li, W., Zhang, W., Wang, Y. and Fu, S. (2015) 'Association between whole grain intake and stroke risk: Evidence from a meta-analysis', *International Journal of Clinical and Experimental Medicine*, 8(9), pp. 16978-16983.

Fardet, A. (2010) 'New hypotheses for the health-protective mechanisms of whole-grain cereals: what is beyond fibre?', *Nutrition Research Reviews*, 23(1), pp. 65-134.

Ferruzzi, M.G., Jonnalagadda, S.S., Liu, S., Marquart, L., McKeown, N., Reicks, M., Riccardi, G., Seal, C., Slavin, J., Thielecke, F., van der Kamp, J.W. and Webb, D. (2014) 'Developing a standard definition of whole-grain foods for dietary recommendations: summary report of a multidisciplinary expert roundtable discussion', *Advances in Nutrition*, 5(2), pp. 164-76.

Fitt, E., Cole, D., Ziauddeen, N., Pell, D., Stickley, E., Harvey, A. and Stephen, A.M. (2015) 'DINO (Diet In Nutrients Out) – an integrated dietary assessment system', *Public Health Nutrition*, 18(2), pp. 234-241.

Flight, I. and Clifton, P. (2006) 'Cereal grains and legumes in the prevention of coronary heart disease and stroke: a review of the literature', *European Journal of Clinical Nutrition*, 60(10), pp. 1145-59.

Flint, A.J., Hu, F.B., Glynn, R.J., Jensen, M.K., Franz, M., Sampson, L. and Rimm, E.B. (2009) 'Whole grains and incident hypertension in men', *The American Journal of Clinical Nutrition*, 90(3), pp. 493-8.

Foerster, J., Maskarinec, G., Reichardt, N., Tett, A., Narbad, A., Blaut, M. and Boeing, H. (2014) 'The Influence of Whole Grain Products and Red Meat on Intestinal Microbiota Composition in Normal Weight Adults: A Randomized Crossover Intervention Trial', *PLoS ONE*, 9(10), p. e109606.

Fogelholm, M., Anderssen, S., Gunnarsdottir, I. and Lahti-Koski, M. (2012) 'Dietary macronutrients and food consumption as determinants of long-term weight change in adult populations: a systematic literature review', *Food & Nutrition Research*, 56.

Food Standards Agency (2002a) *Food Portion Sizes* London: Stationary Office

Food Standards Agency (2002b) *McCance and Widdowson's The Composition of foods, Sixth summary edition*. Sixth summary edn. Cambridge: Royal Society of Chemistry.

Food Standards Australia New Zealand (2015) *Australia New Zealand Food Standards Code - Standard 2.1.1-Cereal and cereal products*. Commonwealth of Australia Gazette No. FSC 96 https://www.legislation.gov.au/Details/F2015L00420 (Accessed: 2016).

Foster, E., Hawkins, A., Barton, K.L., Stamp, E., Matthews, J.N.S. and Adamson, A.J. (2017) 'Development of food photographs for use with children aged 18 months to 16 years: Comparison against weighed food diaries – The Young Person's Food Atlas (UK)', *PLOS ONE*, 12(2), p. e0169084.

Fraser, G.E. (1999) 'Associations between diet and cancer, ischemic heart disease, and all-cause mortality in non-Hispanic white California Seventh-day Adventists', *The American Journal of Clinical Nutrition*, 70(3), pp. 532s-538s.

Friedewald, W.T., Levy, R.I. and Fredrickson, D.S. (1972) 'Estimation of the Concentration of Low-Density Lipoprotein Cholesterol in Plasma, Without Use of the Preparative Ultracentrifuge', *Clinical Chemistry*, 18(6), pp. 499-502.

Gaesser, G.A. (2007) 'Carbohydrate Quantity and Quality in Relation to Body Mass Index', *Journal of the American Dietetic Association*, 107(10), pp. 1768-1780.

Galea, L.M., Dalton, S.M.C., Beck, E.J., Cashman, C.J. and Probst, Y.C. (2016) 'Update of a database for estimation of whole grain content of foods in Australia', *Journal of Food Composition and Analysis*, 50, pp. 23-29.

Giacco, R., Clemente, G., Cipriano, D., Luongo, D., Viscovo, D., Patti, L., Di Marino, L., Giacco, A., Naviglio, D., Bianchi, M.A., Ciati, R., Brighenti, F., Rivellese, A.A. and Riccardi, G. (2010) 'Effects of the regular consumption of wholemeal wheat foods on cardiovascular risk factors in healthy people', *Nutrition, Metabolism and Cardiovascular Diseases*, 20(3), pp. 186-194.

Giacco, R., Costabile, G., Della Pepa, G., Anniballi, G., Griffo, E., Mangione, A., Cipriano, P., Viscovo, D., Clemente, G., Landberg, R., Pacini, G., Rivellese, A.A. and Riccardi, G. (2014) 'A whole-grain cereal-based diet lowers postprandial plasma insulin and triglyceride levels in individuals with metabolic syndrome', *Nutrition, Metabolism & Cardiovascular Diseases*, 24(8), pp. 837-844.

Giacco, R., Della Pepa, G., Luongo, D. and Riccardi, G. (2011) 'Whole grain intake in relation to body weight: from epidemiological evidence to clinical trials', *Nutrition Metabolism & Cardiovascular diseaes*, 21(12), pp. 901-8.

Giacco, R., Lappi, J., Costabile, G., Kolehmainen, M., Schwab, U., Landberg, R., Uusitupa, M., Poutanen, K., Pacini, G., Rivellese, A.A., Riccardi, G. and Mykkanen, H. (2013) 'Effects of rye and whole wheat versus refined cereal foods on metabolic risk factors: a randomised controlled two-centre intervention study', *Clinical Nutrition*, 32(6), pp. 941-9.

Good, C.K., Holschuh, N., Albertson, A.M. and Eldridge, A.L. (2008) 'Whole grain consumption and body mass index in adult women: an analysis of NHANES 1999-2000 and the USDA pyramid servings database', *Journal of the American College of Nutrition*, 27(1), pp. 80-7.

Government Statistical Service (1995) 'Standard Occupational Classification 1990 volume 2 - index', [Online]. Available at:

http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/guide-method/classifications/archived-standard-classifications/soc-and-sec-archive/index.html (Accessed: 05 May 2016).

Grain & Legumes Nutrition Council (GLNC) (2014a) Australian Grain and Legumes Consumption and Attitudinal Study Report.

Grain & Legumes Nutrition Council (GLNC) (2014b) 'Australians at Risk'. Available at: http://www.glnc.org.au/wp-content/uploads/2015/04/Australians-at-Risk-2014-Grains-Legumes-Consumption-Attitudinal-Study.pdf (Accessed: 15 January 2015).

Grain & Legumes Nutrition Council (GLNC) (2016) 'Only 30% of Australians are meeting whole grain recommendations for good health'. Available at: http://www.glnc.org.au/wp-content/uploads/2011/10/GLNC-Media-Release_WGBD_2016-12-05_CONSUMER.pdf (Accessed: 16 January 2017).

Hajihashemi, P., Azadbakht, L., Hashemipor, M., Kelishadi, R. and Esmaillzadeh, A. (2014) 'Whole-grain intake favorably affects markers of systemic inflammation in obese children: A randomized controlled crossover clinical trial', *Molecular Nutrition & Food Research*, 58(6), pp. 1301-1308.

Haldar, S., Beckmann, M., Bal, W., Fawcett, L., Ross, A.B., Brandt, K., Draper, J. and Seal, C.J. (2010) 'Comparing alkylresorcinols and mammalian lignans as biomarkers of wholegrain wheat or wholegrain rye intake in a dose-response intervention trial: the Grain Mark Study', *Proceedings of the Nutrition Society*, 69(OCE6).

Harland, J.I. and Garton, L.E. (2008) 'Whole-grain intake as a marker of healthy body weight and adiposity', *Public Health Nutrition*, 11(6), pp. 554-63.

Harris Jackson, K., West, S.G., Vanden Heuvel, J.P., Jonnalagadda, S.S., Ross, A.B., Hill, A.M., Grieger, J.A., Lemieux, S.K. and Kris-Etherton, P.M. (2014) 'Effects of whole and refined grains in a weight-loss diet on markers of metabolic syndrome in individuals with increased waist circumference: A randomized controlled-feeding trial', *The American Journal of Clinical Nutrition*, 100(2), pp. 577-586.

Harris, K.A. and Kris-Etherton, P.M. (2010) 'Effects of whole grains on coronary heart disease risk', *Current Atherosclerosis Reports*, 12(6), pp. 368-76.

He, M., van Dam, R.M., Rimm, E., Hu, F.B. and Qi, L. (2010) 'Whole-grain, cereal fiber, bran, and germ intake and the risks of all-cause and cardiovascular disease-specific mortality among women with type 2 diabetes mellitus', *Circulation*, 121(20), pp. 2162-8.

Health Promotion Board Singapore (2010) *Report of the National Nutritional Survey 2010*. Research and Strategic Planning Division. [Online]. Available at: http://www.hpb.gov.sg/HOPPortal/content/conn/HOPUCM/path/Contribution%20Folders/uploadedFiles/HPB_Online/Publications/NNS-2010.pdf. (Accessed: 23 Feb 2016).

Health Promotion Board Singapore (2012) *Food-based Dietary Guidelines for Adults*. Available at: http://www.hpb.gov.sg/HOPPortal/health-article/2758 (Accessed: 19 March 2016).

Helnæs, A., Kyrø, C., Andersen, I., Lacoppidan, S., Overvad, K., Christensen, J., Tjønneland, A. and Olsen, A. (2016) 'Intake of whole grains is associated with lower risk of myocardial infarction: the Danish Diet, Cancer and Health Cohort', *The American Journal of Clinical Nutrition*, 103(4), pp. 999-1007.

Hemery, Y., Rouau, X., Lullien-Pellerin, V., Barron, C. and Abecassis, J. (2007) 'Dry processes to develop wheat fractions and products with enhanced nutritional quality', *Journal of Cereal Science*, 46(3), pp. 327-347.

Ho, H.V.T., Sievenpiper, J.L., Zurbau, A., Blanco Mejia, S., Jovanovski, E., Au-Yeung, F., Jenkins, A.L. and Vuksan, V. (2016) 'The effect of oat β-glucan on LDL-cholesterol, non-HDL-cholesterol and apoB for CVD risk reduction: a systematic review and meta-analysis of randomised-controlled trials', *British Journal of Nutrition*, 116(8), pp. 1369-1382.

Hollaender, P.L., Ross, A.B. and Kristensen, M. (2015) 'Whole-grain and blood lipid changes in apparently healthy adults: a systematic review and meta-analysis of randomized controlled studies', *The American Journal of Clinical Nutrition*, 102(3), pp. 556-72.

Holland, B., Unwin, I.D. and Buss, D.H. (1988) *Cereal and cereal products: The third supplement to McCance & Widdowson's the composition of foods*. 5th edn. Cambridge: The Royal Society of Chemistry & Ministry of Agriculture, Fisheries and Food.

Hooper, B., Spiro, A. and Stanner, S. (2015) '30 g of fibre a day: An achievable recommendation?', *Nutrition Bulletin*, 40(2), pp. 118-129.

Hovis Bakery (2016) *Granary Original*. Available at: http://www.hovis.co.uk/our-range/granary#granary-original (Accessed: 09 Decemebr 2016).

Howard, G., Sharrett, A.R., Heiss, G., Evans, G.W., Chambless, L.E., Riley, W.A. and Burke, G.L. (1993) 'Carotid artery intimal-medial thickness distribution in general populations as evaluated by B-mode ultrasound. ARIC Investigators', *Stroke*, 24(9), pp. 1297-1304.

Hu, F.B. (2003) 'Plant-based foods and prevention of cardiovascular disease: an overview', *The American Journal of Clinical Nutrition*, 78(3), pp. 544S-551S.

Huang, T., Xu, M., Lee, A., Cho, S. and Qi, L. (2015) 'Consumption of whole grains and cereal fiber and total and cause-specific mortality: prospective analysis of 367,442 individuals', *BMC Medicine*, 13, p. 59.

Hur, I.Y. and Reicks, M. (2012) 'Relationship between whole-grain intake, chronic disease risk indicators, and weight status among adolescents in the National Health and Nutrition Examination Survey, 1999-2004', *Journal of the Academy of Nutrition & Dietetics*, 112(1), pp. 46-55.

Institute of Grocery Distribution (2007) 'UK Whole Grain Guidance Note', [Online]. Available at: http://www.igd.com/Research/Nutrition-food-and-farming/UK-Whole-Grain-Guidance/ (Accessed: 13 February 2014).

Jacobs, D.R., Jr. (2015) 'Nutrition: The whole cereal grain is more informative than cereal fibre', *Nature Reviews Endocrinology*, 11(7), pp. 389-390.

Jacobs, D.R., Jr. and Gallaher, D.D. (2004) 'Whole grain intake and cardiovascular disease: a review', *Current Atherosclerosis Reports*, 6(6), pp. 415-23.

Jacobs, D.R., Jr., Meyer, H. and Solvoll, K. (2001) 'Reduced mortality among whole grain bread eaters in men and women in the Norwegian County Study', *European Journal of Clinical Nutrition*, 55, pp. 337-343.

Jacobs, D.R., Jr., Meyer, K.A., Kushi, L.H. and Folsom, A.R. (1998) 'Whole-grain intake may reduce the risk of ischemic heart disease death in postmenopausal women: the Iowa Women's Health Study', *The American Journal of Clinical Nutrition*, 68(2), pp. 248-57.

Jacobs, D.R., Jr., Meyer, K.A., Kushi, L.H. and Folsom, A.R. (1999) 'Is whole grain intake associated with reduced total and cause-specific death rates in older women? The Iowa Women's Health Study', *American Journal of Public Health*, 89(3), pp. 322-9.

Jang, Y., Lee, J.H., Kim, O.Y., Park, H.Y. and Lee, S.Y. (2001) 'Consumption of Whole Grain and Legume Powder Reduces Insulin Demand, Lipid Peroxidation, and Plasma Homocysteine Concentrations in Patients With Coronary Artery Disease', *Arteriosclerosis, Thrombosis, and Vascular Biology*, 21(12), pp. 2065-2071.

Jensen, M.K., Koh-Banerjee, P., Franz, M., Sampson, L., Gronbaek, M. and Rimm, E.B. (2006) 'Whole grains, bran, and germ in relation to homocysteine and markers of glycemic control, lipids, and inflammation', *The American Journal of Clinical Nutrition*, 83(2), pp. 275-83.

Jensen, M.K., Koh-Banerjee, P., Hu, F.B., Franz, M., Sampson, L., Gronbaek, M. and Rimm, E.B. (2004) 'Intakes of whole grains, bran, and germ and the risk of coronary heart disease in men', *The American Journal of Clinical Nutrition*, 80(6), pp. 1492-9.

Joint Health Claims Initiative (2002) *Generic Health Claim for Wholegrain Foods and Heart Health*. Available at: http://webarchive.nationalarchives.gov.uk/nobanner/20130404135254/http://www.jhci.org.uk/approv/wgrainh.htm (Accessed: 15 October 2013).

Jones, A.R. (2007) Attitudinal and physiological responses to the consumption of wholegrain foods. PhD thesis. University of Newcastle upon Tyne.

Jones, A.R., Mann, K.D., Kuznesof, S.A., Richardson, D.P. and Seal, C.J. (2017) 'The whole grain content of foods consumed in the UK', *Food Chemistry*, 214, pp. 453-459.

Jonnalagadda, S.S., Harnack, L., Liu, R.H., McKeown, N., Seal, C., Liu, S. and Fahey, G.C. (2011) 'Putting the whole grain puzzle together: health benefits associated with whole grains--summary of American Society for Nutrition 2010 Satellite Symposium', *The Journal of Nutrition*, 141(5), pp. 1011S-22S.

Joshi, Y.B. and Praticò, D. (2012) 'Vitamin E in aging, dementia, and Alzheimer's disease', *BioFactors*, 38(2), pp. 90-97.

Juntunen, K.S., Laaksonen, D.E., Poutanen, K.S., Niskanen, L.K. and Mykkänen, H.M. (2003) 'High-fiber rye bread and insulin secretion and sensitivity in healthy postmenopausal women', *The American Journal of Clinical Nutrition*, 77(2), pp. 385-391.

Kaline, K., Bornstein, S.R., Bergmann, A., Hauner, H. and Schwarz, P.E. (2007) 'The importance and effect of dietary fiber in diabetes prevention with particular consideration of whole grain products', *Hormone & Metabolic Research*, 39(9), pp. 687-93.

Kamar, M., Evans, C. and Hugh-Jones, S. (2016) 'Factors influencing adolescent whole grain intake: A theory-based qualitative study', *Appetite*, 101, pp. 125-133.

Kantor, L.S., Variyam, J.N., Allshouse, J.E., Putnam, J.J. and Lin, B.H. (2001) 'Choose a variety of grains daily, especially whole grains: a challenge for consumers', *The Journal of Nutrition*, 131(2S-1), pp. 473S-86S.

Karl, J.P., Meydani, M., Barnett, J.B., Vanegas, S.M., Goldin, B., Kane, A., Rasmussen, H., Saltzman, E., Vangay, P., Knights, D., Chen, C.Y.O., Das, S.K., Jonnalagadda, S.S., Meydani, S.N. and Roberts, S.B. (2017) 'Substituting whole grains for refined grains in a 6-wk randomized trial favorably affects energy-balance metrics in healthy men and postmenopausal women', *The American Journal of Clinical Nutrition*.

Karl, J.P. and Saltzman, E. (2012) 'The Role of Whole Grains in Body Weight Regulation', *Advances in Nutrition: An International Review Journal*, 3(5), pp. 697-707.

Karmally, W., Montez, M.G., Palmas, W., Martinez, W., Branstetter, A., Ramakrishnan, R., Holleran, S.F., Haffner, S.M. and Ginsberg, H.N. (2005) 'Cholesterol-Lowering Benefits of Oat-Containing Cereal in Hispanic Americans', *Journal of the American Dietetic Association*, 105(6), pp. 967-970.

Katcher, H., Legro, R., Kunselman, A., Gillies, P., Demers, L., Bagshaw, D. and Kris-Etherton, P. (2008) 'The effects of a whole grain–enriched hypocaloric diet on cardiovascular disease risk factors in men and women with metabolic syndrome', *The American Journal of Clinical Nutrition*, 87, pp. 79-90.

Keenan, J.M., Goulson, M., Shamliyan, T., Knutson, N., Kolberg, L. and Curry, L. (2007) 'The effects of concentrated barley β-glucan on blood lipids in a population of hypercholesterolaemic men and women', *British Journal of Nutrition*, 97(6), pp. 1162-1168.

Key, T.J.A., Thorogood, M., Appleby, P.N. and Burr, M.L. (1996) 'Dietary habits and mortality in 11 000 vegetarians and health conscious people: results of a 17 year follow up', *British Medical Journal*, 313(7060), pp. 775-779.

Kirwan, J.P., Malin, S.K., Scelsi, A.R., Kullman, E.L., Navaneethan, S.D., Pagadala, M.R., Haus, J.M., Filion, J., Godin, J.-P., Kochhar, S. and Ross, A.B. (2016) 'A Whole-Grain Diet Reduces Cardiovascular Risk Factors in Overweight and Obese Adults: A Randomized Controlled Trial', *The Journal of Nutrition*.

Koloverou, E., Panagiotakos, D.B., Pitsavos, C., Chrysohoou, C., Georgousopoulou, E.N., Grekas, A., Christou, A., Chatzigeorgiou, M., Skoumas, I., Tousoulis, D., Stefanadis, C. and The, A.S.G. (2016) 'Adherence to Mediterranean diet and 10-year incidence (2002–

2012) of diabetes: correlations with inflammatory and oxidative stress biomarkers in the ATTICA cohort study', *Diabetes/Metabolism Research and Reviews*, 32(1), pp. 73-81.

Kranz, S., Dodd, K., Juan, W., Johnson, L. and Jahns, L. (2017) 'Whole Grains Contribute Only a Small Proportion of Dietary Fiber to the U.S. Diet', *Nutrients*, 9(2), p. 153.

Kris-Etherton, P. and Harris, K. (2013) 'Whole grain wheat intake-impact on weight loss, body composition and cardiometabolic factors-results from intervention studies', *Annals of Nutrition and Metabolism*, 63, p. 105.

Kris-Etherton, P.M., Hecker, K.D., Bonanome, A., Coval, S.M., Binkoski, A.E., Hilpert, K.F., Griel, A.E. and Etherton, T.D. (2002) 'Bioactive compounds in foods: their role in the prevention of cardiovascular disease and cancer', *The American Journal of Medicine*, 113(9, Supplement 2), pp. 71-88.

Kristensen, M. and Bugel, S. (2011) 'A diet rich in oat bran improves blood lipids and hemostatic factors, and reduces apparent energy digestibility in young healthy volunteers', *European Journal of Clinical Nutrition*, 65(9), pp. 1053-1058.

Kristensen, M., Pelletier, X., Ross, A. and Thielecke, F. (2017) 'A High Rate of Non-Compliance Confounds the Study of Whole Grains and Weight Maintenance in a Randomised Intervention Trial—The Case for Greater Use of Dietary Biomarkers in Nutrition Intervention Studies', *Nutrients*, 9(1), p. 55.

Kristensen, M., Toubro, S., Jensen, M.G., Ross, A.B., Riboldi, G., Petronio, M., Bugel, S., Tetens, I. and Astrup, A. (2012) 'Whole grain compared with refined wheat decreases the percentage of body fat following a 12-week, energy-restricted dietary intervention in postmenopausal women', *The Journal of Nutrition*, 142(4), pp. 710-6.

Kuznesof, S., Brownlee, I.A., Moore, C., Richardson, D.P., Jebb, S.A. and Seal, C.J. (2012) 'WHOLEheart study participant acceptance of wholegrain foods', *Appetite*, 59(1), pp. 187-93.

Kyrø, C., Skeie, G., Dragsted, L.O., Christensen, J., Overvad, K., Hallmans, G., Johansson, I., Lund, E., Slimani, N., Johnsen, N.F., Halkjaer, J., Tjonneland, A. and Olsen, A. (2011) 'Intake of whole grains in Scandinavia is associated with healthy lifestyle, socio-economic and dietary factors', *Public Health Nutrition*, 14(10), pp. 1787-95.

Kyrø, C., Skeie, G., Dragsted, L.O., Christensen, J., Overvad, K., Hallmans, G., Johansson, I., Lund, E., Slimani, N., Johnsen, N.F., Halkjaer, J., Tjonneland, A. and Olsen, A. (2012)

'Intake of whole grain in Scandinavia: intake, sources and compliance with new national recommendations', *Scandinavian Journal of Public Health*, 40(1), pp. 76-84.

Kyrø, C., Skeie, G., Loft, S., Landberg, R., Christensen, J., Lund, E., Nilsson, L.M., Palmqvist, R., Tjonneland, A. and Olsen, A. (2013) 'Intake of whole grains from different cereal and food sources and incidence of colorectal cancer in the Scandinavian HELGA cohort', *Cancer Causes & Control*, 24(7), pp. 1363-74.

Kyrø, C. and Tjønneland, A. (2016) 'Whole grains and public health', *BMJ*, 353.

Lamont, D., Parker, L., White, M., Unwin, N., Bennett, S.M.A., Cohen, M., Richardson, D., Dickinson, H.O., Adamson, A., Alberti, K.G.M. and Craft, A.W. (2000) 'Risk of cardiovascular disease measured by carotid intima-media thickness at age 49-51: lifecourse study', *BMJ*, 320(7230), pp. 273-278.

Landberg, R., Andersson, S.O., Zhang, J.X., Johansson, J.E., Stenman, U.H., Adlercreutz, H., Kamal-Eldin, A., Aman, P. and Hallmans, G. (2010) 'Rye whole grain and bran intake compared with refined wheat decreases urinary C-peptide, plasma insulin, and prostate specific antigen in men with prostate cancer', *The Journal of Nutrition*, 140(12), pp. 2180-6.

Lang, R. and Jebb, S.A. (2003) 'Who consumes whole grains, and how much?', *Proceedings of the Nutrition Society*, 62(1), pp. 123-7.

Lang, R., Thane, C.W., Bolton-Smith, C. and Jebb, S.A. (2003) 'Consumption of whole-grain foods by British adults: Findings from further analysis of two national dietary surveys', *Public Health Nutrition*, 6(5), pp. 479-484.

Lankinen, M., Schwab, U., Kolehmainen, M., Paananen, J., Poutanen, K., Mykkänen, H., Seppänen-Laakso, T., Gylling, H., Uusitupa, M. and Orešič, M. (2011) 'Whole Grain Products, Fish and Bilberries Alter Glucose and Lipid Metabolism in a Randomized, Controlled Trial: The Sysdimet Study', *PLoS ONE*, 6(8), p. e22646.

Lattimer, J.M. and Haub, M.D. (2010) 'Effects of Dietary Fiber and Its Components on Metabolic Health', *Nutrients*, 2(12), pp. 1266-1289.

Leinonen, K.S., Poutanen, K.S. and Mykkänen, H.M. (2000) 'Rye Bread Decreases Serum Total and LDL Cholesterol in Men with Moderately Elevated Serum Cholesterol', *The Journal of Nutrition*, 130(2), pp. 164-170.

Lennox, A., Bluck, L., Page, P., Pell, D., Cole, D., Ziauddeen, N., Steer, T., Nicholson, S., Goldberg, G. and Prentice, A. (2014) *National Diet and Nutrition Survey Results from*

Years 1, 2, 3 and 4 (combined) of the Rolling Programme (2008/9 - 2011/12)- Appendix X- Misreporting in the NDNS RP: summary results and thier interpretation. [Online]. Available at: https://www.gov.uk/government/statistics/national-diet-and-nutrition-survey-results-from-years-1-to-4-combined-of-the-rolling-programme-for-2008-and-2009-to-2011-and-2012 (Accessed: 23 May 2014).

Lennox, A., Fitt, E., Whitton, C., Roberts, C. and Prynne, C.J. (2012) National Diet and Nutrition Survey. Headline results from years 1, 2 and 3 combined - Appendix A. Dietary data collection and editing Department of Health. [Online]. Available at: https://www.gov.uk/government/statistics/national-diet-and-nutrition-survey-headline-results-from-years-1-2-and-3-combined-of-the-rolling-programme-200809-201011 (Accessed: 05 March 2013).

Li, B., Zhang, G., Tan, M., Zhao, L., Jin, L., Tang, X., Jiang, G. and Zhong, K. (2016a) 'Consumption of whole grains in relation to mortality from all causes, cardiovascular disease, and diabetes: Dose–response meta-analysis of prospective cohort studies', *Medicine*, 95(33), p. e4229.

Li, X., Cai, X., Ma, X., Jing, L., Gu, J., Bao, L., Li, J., Xu, M., Zhang, Z. and Li, Y. (2016b) 'Short- and Long-Term Effects of Wholegrain Oat Intake on Weight Management and Glucolipid Metabolism in Overweight Type-2 Diabetics: A Randomized Control Trial', *Nutrients*, 8(9), p. 549.

Lillioja, S., Neal, A.L., Tapsell, L. and Jacobs, D.R., Jr. (2013) 'Whole grains, type 2 diabetes, coronary heart disease, and hypertension: Links to the aleurone preferred over indigestible fiber', *BioFactors*, 39(3), pp. 242-258.

Liu, S. (2003) 'Whole-grain foods, dietary fiber, and type 2 diabetes: searching for a kernel of truth', *The American Journal of Clinical Nutrition*, 77(3), pp. 527-9.

Liu, S., Manson, J.E., Stampfer, M.J., Rexrode, K.M., Hu, F.B., Rimm, E.B. and Willett, W.C. (2000a) 'Whole grain consumption and risk of ischemic stroke in women: A prospective study', *The Journal of the American Medical Association*, 284(12), pp. 1534-40.

Liu, S., Mason, J.E., Stampfer, M.J., Hu, F.B., Giovannucci, E., Colditz, G.A., Hennekens, C.H. and Willet, W.C. (2000b) 'A Prospective Study of Whole-Grain Intake and Risk of Type 2 Diabetes Mellitus in US Women', *American Journal of Public Health*, 90(9), pp. 1409-1415.

Liu, S., Stampfer, M.J., Hu, F.B., Giovannucci, E., Rimm, E., Manson, J.E., Hennekens, C.H. and Willett, W.C. (1999) 'Whole-grain consumption and risk of coronary heart disease: results from the Nurses' Health Study', *The American Journal of Clinical Nutrition*, 70(3), pp. 412-9.

Lutsey, P.L., Jacobs, D.R., Jr., Kori, S., Mayer-Davis, E., Shea, S., Steffen, L.M., Szklo, M. and Tracy, R. (2007) 'Whole grain intake and its cross-sectional association with obesity, insulin resistance, inflammation, diabetes and subclinical CVD: The MESA Study', *British Journal of Nutrition*, 98(2), pp. 397-405.

MacKay, K.A., Tucker, A.J., Duncan, A.M., Graham, T.E. and Robinson, L.E. (2012) 'Whole grain wheat sourdough bread does not affect plasminogen activator inhibitor-1 in adults with normal or impaired carbohydrate metabolism', *Nutrition, Metabolism and Cardiovascular Diseases*, 22(9), pp. 704-711.

Maki, K.C., Beiseigel, J.M., Jonnalagadda, S.S., Gugger, C.K., Reeves, M.S., Farmer, M.V., Kaden, V.N. and Rains, T.M. (2010) 'Whole-Grain Ready-to-Eat Oat Cereal, as Part of a Dietary Program for Weight Loss, Reduces Low-Density Lipoprotein Cholesterol in Adults with Overweight and Obesity More than a Dietary Program Including Low-Fiber Control Foods', *Journal of the American Dietetic Association*, 110(2), pp. 205-214.

Martínez-González, M.Á., Corella, D., Salas-Salvadó, J., Ros, E., Covas, M.I., Fiol, M., Wärnberg, J., Arós, F., Ruíz-Gutiérrez, V., Lamuela-Raventós, R.M., Lapetra, J., Muñoz, M.Á., Martínez, J.A., Sáez, G., Serra-Majem, L., Pintó, X., Mitjavila, M.T., Tur, J.A., Portillo, M.d.P. and Estruch, R. (2012) 'Cohort Profile: Design and methods of the PREDIMED study', *International Journal of Epidemiology*, 41(2), pp. 377-385.

Masters, R.C., Liese, A.D., Haffner, S.M., Wagenknecht, L.E. and Hanley, A.J. (2010) 'Whole and refined grain intakes are related to inflammatory protein concentrations in human plasma', *The Journal of Nutrition*, 140(3), pp. 587-94.

Matthews, D.R., Hosker, J.P., Rudenski, A.S., Naylor, B.A., Treacher, D.F. and Turner, R.C. (1985) 'Homeostasis model assessment: insulin resistance and β-cell function from fasting plasma glucose and insulin concentrations in man', *Diabetologia*, 28(7), pp. 412-419.

McGill, C.R., Fulgoni, V.L., 3rd and Devareddy, L. (2015) 'Ten-year trends in fiber and whole grain intakes and food sources for the United States population: National Health and Nutrition Examination Survey 2001-2010', *Nutrients*, 7(2), pp. 1119-30.

McIntosh, G.H., Noakes, M., Royle, P.J. and Foster, P.R. (2003) 'Whole-grain rye and wheat foods and markers of bowel health in overweight middle-aged men', *The American Journal of Clinical Nutrition*, 77(4), pp. 967-74.

McKeown, N., Marklund, M., Ma, J., Ross, A., Lichtenstein, A., Livingston, K., Jacques, P., Rasmussen, H., Blumberg, J. and Chen, C.Y.O. (2015) 'Comparison of plasma alkylresorcinols (AR) and urinary AR metabolites as biomarkers of compliance in a short-term, whole-grain intervention study', *European Journal of Nutrition*, pp. 1-10.

McKeown, N.M., Day, N.E., Welch, A.A., Runswick, S.A., Luben, R.N., Mulligan, A.A., McTaggart, A. and Bingham, S.A. (2001) 'Use of biological markers to validate self-reported dietary intake in a random sample of the European Prospective Investigation into Cancer United Kingdom Norfolk cohort', *The American Journal of Clinical Nutrition*, 74(2), pp. 188-196.

McKeown, N.M., Yoshida, M., Shea, M.K., Jacques, P.F., Lichtenstein, A.H., Rogers, G., Booth, S.L. and Saltzman, E. (2009) 'Whole-Grain Intake and Cereal Fiber Are Associated with Lower Abdominal Adiposity in Older Adults', *The Journal of Nutrition*, 139(10), pp. 1950-1955.

McMackin, E., Dean, M., Woodside, J.V. and McKinley, M.C. (2013) 'Whole grains and health: attitudes to whole grains against a prevailing background of increased marketing and promotion', *Public health nutrition*, 16(4), pp. 743-751.

McMorran, J., Crowther, D.C., McMorran, S., Prince, C., YoungMin, S., Pleat, J. and Wacogne, I. (2016) 'General Practice Notebook - a UK medical refernce on the web'. Oxbridge Solutions Ltd. Available at: http://www.gpnotebook.co.uk/homepage.cfm (Accessed: 15 March 2016).

McNaughton, S.A., Mishra, G.D. and Brunner, E.J. (2008) 'Dietary Patterns, Insulin Resistance, and Incidence of Type 2 Diabetes in the Whitehall II Study', *Diabetes Care*, 31(7), pp. 1343-1348.

McRae, M.P. (2017) 'Health Benefits of Dietary Whole Grains: An Umbrella Review of Meta-analyses', *Journal of Chiropractic Medicine*, 16(1), pp. 10-18.

Mejborn, H., Biltoft-Jensen, A., Trolle, E. and Tetens, I. (2008) *Wholegrain: Definition and scientific background for recommendations of wholegrain intake in Denmark*. DTU Fødevareinstituttet. [Online]. Available at: http://www.food.dtu.dk//-/media/Institutter/Foedevareinstituttet/Publikationer/Pub-2008/Fuldkorn%20-

%20Definition%20og%20vidensgrundlag%20for%20anbefaling%20af%20fuldkornsindtag%20i%20Danmark.ashx (Accessed: 18 March 2016).

Mejborn, H., Ygil, K.H., Fagt, S., Trolle, E., Kørup, K. and Christensen, T. (2014) 'Danskernes fuldkornsindtag 2011-2013', *E-artikel fra DTU Fødevareinstitutet*, 2014(4), pp. 1-7.

Mejborn, H., Ygll, K.H., Fagt, S., Trolle, E. and Christensen, T. (2013) *Whole grain intake of Danes 2011-12*. DTU Fødevareinstituttet. [Online]. Available at: http://www.food.dtu.dk/english/-/media/Institutter/Foedevareinstituttet/Publikationer/Pub-2013/Rapport_Fuldkornsindtag_11-12_UK.ashx?la=da (Accessed: 18 March 2016).

Mellen, P.B., Walsh, T.F. and Herrington, D.M. (2008) 'Whole grain intake and cardiovascular disease: a meta-analysis', *Nutrition Metabolism & Cardiovascular diseaes*, 18(4), pp. 283-90.

Mertens, E., Markey, O., Geleijnse, J., Givens, D. and Lovegrove, J. (2017) 'Dietary Patterns in Relation to Cardiovascular Disease Incidence and Risk Markers in a Middle-Aged British Male Population: Data from the Caerphilly Prospective Study', *Nutrients*, 9(1), p. 75.

Meyer, K.A., Kushi, L.H., Jacobs, D.R., Jr., Slavin, J., Sellers, T.A. and Folsom, A.R. (2000) 'Carbohydrates, dietary fiber, and incident type 2 diabetes in older women', *The American Journal of Clinical Nutrition*, 71(4), pp. 921-30.

Micha, R., Khatibzadeh, S., Shi, P., Andrews, K.G., Engell, R.E. and Mozaffarian, D. (2015) 'Global, regional and national consumption of major food groups in 1990 and 2010: a systematic analysis including 266 country-specific nutrition surveys worldwide', *BMJ Open*, 5(9).

Miller, F.J.W., Court, S.D.M., Knox, E.G. and Brandon, S. (1974) *The School Years in Newcastle upon Tyne* London: Oxford University Press.

Miller, F.J.W., Court, S.D.M., Walton, W.S. and Knox, E.G. (1960) *Growing up in Newcastle upon Tyne*. London: Oxford University Press.

Mills, A. and Patel, S. (1993) *Food portion sizes*. 2nd edn. London: HMSO.

Mintel (2010) *Global New Products Database*. Available at: http://www.mintel.com/global-new-products-database.

Mintel (2013a) *Breakfast Cereals - UK - August 2013 Exceutive Summary*. [Online]. Available at: http://academic.mintel.com (Accessed: 15 May 2014).

Mintel (2013b) *Cereal, Energy and Snack Bars - UK - March 2013 Executive Summary*. [Online]. Available at: http://academic.mintel.com (Accessed: 15 May 2014).

Mintel (2016) *Pasta, Rice and Noodles-UK-February 2016 excecutive summary*. [Online]. Available at: http://academic.mintel.com (Accessed: 15 Feb 2017).

Montonen, J., Boeing, H., Fritsche, A., Schleicher, E., Joost, H.G., Schulze, M.B., Steffen, A. and Pischon, T. (2013) 'Consumption of red meat and whole-grain bread in relation to biomarkers of obesity, inflammation, glucose metabolism and oxidative stress', *European Journal of Nutrition*, 52(1), pp. 337-45.

Morris, J.N., Marr, J.W. and Clayton, D.G. (1977) 'Diet And Heart: A Postscript', *British Medical Journal*, 2(6098), pp. 1307-1314.

Mulligan, A.A., Lentjes, M.A.H., Bhaniani, A., Luben, R.N. and Khaw, K.T. (2015) 'Determinants of change in consumption of wholegrain foods in EPIC-Norfolk', *Proceedings of the Nutrition Society*, 74(OCE1).

Mulligan, A.A., Luben, R.N., Bhaniani, A., Parry-Smith, D.J., O'Connor, L., Khawaja, A.P., Forouhi, N.G. and Khaw, K.-T. (2014) 'A new tool for converting food frequency questionnaire data into nutrient and food group values: FETA research methods and availability', *British Medical Journal Open*, 4(3).

Murtaugh, M.A., Jacobs, D.R., Jr., Jacob, B., Steffen, L.M. and Marquart, L. (2003) 'Epidemiological support for the protection of whole grains against diabetes', *Proceedings of the Nutrition Society*, 62(1), pp. 143-9.

National Centre for Social Research, Medical Research Council, Resource Centre for Human Nutrition Research and University College London Medical School 5th Edition (2013) 'National Diet and Nutrition Survey, 2008-2011' *SN: 6533* [Computer file]. March 2013. Cholchester: UK Data Service. Available at: http://dx.doi.org/10.5255/UKDA-SN-6533-4.

Neo, J.E., Binte Mohamed Salleh, S., Toh, Y.X., How, K.Y.L., Tee, M., Mann, K., Hopkins, S., Thielecke, F., Seal, C.J. and Brownlee, I.A. (2016) 'Whole-grain food consumption in Singaporean children aged 6–12 years', *Journal of Nutritional Science*, 5.

Nettleton, J.A., McKeown, N.M., Kanoni, S., Lemaitre, R.N., Hivert, M.F., Ngwa, J., van Rooij, F.J., Sonestedt, E., Wojczynski, M.K., Ye, Z., Tanaka, T. and Garcia, M. (2010)

'Interactions of dietary whole-grain intake with fasting glucose- and insulin-related genetic loci in individuals of European descent: a meta-analysis of 14 cohort studies.', *Diabetes Care*, 33(12), pp. 2684-91.

Nicholson, S., Dearnley, K., Teucher, B. and Lennox, A. (2012) National Diet and Nutrition Survey. Headline results from years 1, 2 and 3 combined - Appendix L. Priority order of blood analytes. Department of Health. [Online]. Available at: https://www.gov.uk/government/statistics/national-diet-and-nutrition-survey-headline-results-from-years-1-2-and-3-combined-of-the-rolling-programme-200809-201011 (Accessed: 05 March 2013).

Nicklas, T.A., Jahns, L., Bogle, M.L., Chester, D.N., Giovanni, M., Klurfeld, D.M., Laugero, K., Liu, Y., Lopez, S. and Tucker, K.L. (2013) 'Barriers and Facilitators for Consumer Adherence to the Dietary Guidelines for Americans: The HEALTH Study', *Journal of the Academy of Nutrition and Dietetics*, 113(10), pp. 1317-1331.

Nilsson, A.C., Johansson-Boll, E.V. and Björck, I.M.E. (2015) 'Increased gut hormones and insulin sensitivity index following a 3-d intervention with a barley kernel-based product: a randomised cross-over study in healthy middle-aged subjects', *British Journal of Nutrition*, 114(06), pp. 899-907.

Nordic Co-operation (2012) *Nordic Nutrition Recommendations 2012*. Available at: http://www.norden.org/en/news-and-events/news/new-nordic-nutrition-recommendations-e-book-e-chapters-now-online (Accessed: 12 August 2014).

O'Neil, C.E., Nicklas, T.A., Zanovec, M. and Cho, S. (2010a) 'Whole-grain consumption is associated with diet quality and nutrient intake in adults: the National Health and Nutrition Examination Survey, 1999-2004', *Journal of the American Dietetic Association*, 110(10), pp. 1461-8.

O'Neil, C.E., Nicklas, T.A., Zanovec, M., Cho, S.S. and Kleinman, R. (2010b) 'Consumption of whole grains is associated with improved diet quality and nutrient intake in children and adolescents: the National Health and Nutrition Examination Survey 1999-2004', *Public Health Nutrition*, 14(2), pp. 347-55.

O'Neil, C.E., Zanovec, M., Cho, S.S. and Nicklas, T.A. (2010c) 'Whole grain and fiber consumption are associated with lower body weight measures in US adults: National Health and Nutrition Examination Survey 1999-2004', *Nutrition Research*, 30(12), pp. 815-22.

Office for National Statistics (2000) *Standard Occupational Classification 2000*. Available at: http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/guide-method/classifications/archived-standard-classifications/standard-occupational-classification-2000/index.html (Accessed: 3 March 2016).

Office for Population Censuses and Surveys (1991) 'Standard Occupational Classification 1990 volume 3 - social classifications and coding methodology', [Online]. Available at: http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/guide-method/classifications/archived-standard-classifications/soc-and-sec-archive/index.html (Accessed: 05 May 2016).

Oldways Whole Grains Council (2003-2013a) *What Counts as a Serving?* Available at: http://wholegrainscouncil.org/whole-grains-101/how-much-enough/what-counts-serving (Accessed: 6 March 2013).

Oldways Whole Grains Council (2003-2013b) *Whole Grain Statistics-Whole Grain Growth Worldwide 2000-2011*. Available at: http://wholegrainscouncil.org/newsroom/whole-grain-statistics (Accessed: 12 May 2016).

Oldways Whole Grains Council (2004) *Definition of whole grains*. Available at: http://wholegrainscouncil.org/definition-whole-grain (Accessed: 11 May 2016).

Ozawa, M., Shipley, M., Kivimaki, M., Singh-Manoux, A. and Brunner, E.J. (2016) 'Dietary pattern, inflammation and cognitive decline: The Whitehall II prospective cohort study', *Clinical Nutrition*, in press, pp. 1-7.

Pastorino, S., Richards, M., Pierce, M. and Ambrosini, G.L. (2016) 'A high-fat, high-glycaemic index, low-fibre dietary pattern is prospectively associated with type 2 diabetes in a British birth cohort', *The British journal of nutrition*, 115(9), pp. 1632-1642.

Pearce, M.S., Mann, K.D., Relton, C.L., Francis, R.M., Steele, J.G., Craft, A.W. and Parker, L. (2012) 'How the Newcastle Thousand Families birth cohort study has contributed to the understanding of the impact of birth weight and early life socioeconomic position on disease in later life', *Maturitas*, 72(1), pp. 23-8.

Pearce, M.S., Relton, C.L., Parker, L. and Unwin, N.C. (2009a) 'Sex differences in the association between infant feeding and blood cholesterol in later life: the Newcastle thousand families cohort study at age 49–51 years', *European Journal of Epidemiology*, 24(7), pp. 375-380.

Pearce, M.S., Unwin, N.C., Parker, L. and Craft, A.W. (2009b) 'Cohort profile: the Newcastle Thousand Families 1947 birth cohort', *Int J Epidemiol*, 38(4), pp. 932-7.

Pereira, M.A., Jacobs, D.R., Jr., Pins, J.J., Raatz, S.K., Gross, M.D., Slavin, J.L. and Seaquist, E.R. (2002) 'Effect of whole grains on insulin sensitivity in overweight hyperinsulinemic adults', *The American Journal of Clinical Nutrition*, 75(5), pp. 848-855.

Petrie, J.C., O'Brien, E.T., Littler, W.A. and de Swiet, M. (1990) *Recommendations on blood pressure measurement*. London: BMJ Publishing.

Pol, K., Christensen, R., Bartels, E.M., Raben, A., Tetens, I. and Kristensen, M. (2013) 'Whole grain and body weight changes in apparently healthy adults: a systematic review and meta-analysis of randomized controlled studies', *The American Journal of Clinical Nutrition*, 98(4), pp. 872-84.

Priebe, M., van Binsbergen, J., de Vos, R. and Vonk, R.J. (2008) 'Whole grain foods for the prevention of type 2 diabetes mellitus', *Cochrane Database of Systematic Reviews*, (1).

Public Health England (2015) *McCance and Widdowson's composition of foods integrated dataset*. Available at: https://www.gov.uk/government/publications/composition-of-foods-integrated-dataset-cofid (Accessed: 20 July 2016).

Public Health England (2016) *The Eatwell Guide*. Available at: http://www.nhs.uk/Livewell/goodfood/Pages/the-eatwell-guide.aspx (Accessed: 17 Feb 2016).

Radford, A., Langkamp-Henken, B., Hughes, C., Christman, M.C., Jonnalagadda, S., Boileau, T.W., Thielecke, F. and Dahl, W.J. (2014) 'Whole-Grain Intake in Middle School Students Achieves Dietary Guidelines for Americans and MyPlate Recommendations when Provided as Commercially Available Foods: A Randomized Trial', *Journal of the Academy of Nutrition and Dietetics*, 114(9), pp. 1417-1423.

Rave, K., Roggen, K., Dellweg, S., Heise, T. and tom Dieck, H. (2007) 'Improvement of insulin resistance after diet with a whole-grain based dietary product: results of a randomized, controlled cross-over study in obese subjects with elevated fasting blood glucose', *British Journal of Nutrition*, 98(5), pp. 929-936.

Reicks, M., Jonnalagadda, S., Albertson, A.M. and Joshi, N. (2014) 'Total dietary fiber intakes in the US population are related to whole grain consumption: Results from the

National Health and Nutrition Examination Survey 2009 to 2010', *Nutrition Research*, 34(3), pp. 226-234.

Richardson, D.P. (2000) 'The grain, the wholegrain and nothing but the grain: the science behind wholegrain and the reduced risk of heart disease and cancer', *Nutrition Bulletin*, 25(4), pp. 353-360.

Rijksinstituut voor Volksgezondheid en Milieu (RIVM) (2015) Memo: Consumptie van een aantal voedingsmiddelengroepen en nutriënten door de Nederlandse bevolking. Resultaten van VCP 2007-2010. RIVM. [Online]. Available at: http://www.rivm.nl/en/Topics/D/Dutch_National_Food_Consumption_Survey/Publications (Accessed: 08 December 2016).

Rollo, M.E., Williams, R.L., Burrows, T., Kirkpatrick, S.I., Bucher, T. and Collins, C.E. (2016) 'What Are They Really Eating? A Review on New Approaches to Dietary Intake Assessment and Validation', *Current Nutrition Reports*, 5(4), pp. 307-314.

Rose, D., Pevalin, D.J. and O'Reilly, K. (2005) The National Statistics Socio-economic Classification: Origins, Development and Use. Basingstoke: Palgrave Macmillan

Rose, D.J. (2014) 'Impact of whole grains on the gut microbiota: the next frontier for oats?', *British Journal of Nutrition*, 112(SupplementS2), pp. S44-S49.

Ross, A., van der Kamp, J.W., King, R., Le, K.-A., Mejborn, H., Seal, C. and Thielecke, F. (2017) 'A definition for whole-grain products - recommendations from the Healthgrain Forum', *Advances in Nutrition*, in press.

Ross, A.B. (2012) 'Present status and perspectives on the use of alkylresorcinols as biomarkers of wholegrain wheat and rye intake', *Journal of Nutrition and Metabolism* 2012, p. 462967.

Ross, A.B., Bourgeois, A., Macharia, H.N., Kochhar, S., Jebb, S.A., Brownlee, I.A. and Seal, C.J. (2012) 'Plasma alkylresorcinols as a biomarker of whole-grain food consumption in a large population: results from the WHOLEheart Intervention Study', *The American Journal of Clinical Nutrition*, 95(1), pp. 204-11.

Ross, A.B., Bruce, S.J., Blondel-Lubrano, A., Oguey-Araymon, S., Beaumont, M., Bourgeois, A., Nielsen-Moennoz, C., Vigo, M., Fay, L.B., Kochhar, S., Bibiloni, R., Pittet, A.C., Emady-Azar, S., Grathwohl, D. and Rezzi, S. (2011) 'A whole-grain cereal-rich diet increases plasma betaine, and tends to decrease total and LDL-cholesterol compared with a refined-grain diet in healthy subjects', *British Journal of Nutrition*, 105(10), pp. 1492-502.

Ross, A.B., Kristensen, M., Seal, C.J., Jacques, P. and McKeown, N.M. (2015) 'Recommendations for reporting whole-grain intake in observational and intervention studies', *The American Journal of Clinical Nutrition*, 101(5), pp. 903-907.

Roth-Yousey, L., Barno, T., Caskey, M., Asche, K. and Reicks, M. (2009) 'Whole-grain continuing education for school foodservice personnel: keeping kids from falling short', *Journal of Nutrition Education & Behavior*, 41(6), pp. 429-35.

Salmerón, J., Ascherio, A., Rimm, E.B., Colditz, G.A., Spiegelman, D., Jenkins, D.J., Stampfer, M.J., Wing, A.L. and Willett, W.C. (1997a) 'Dietary fiber, glycemic load, and risk of NIDDM in men', *Diabetes Care*, 20(4), pp. 545-50.

Salmerón, J., Manson, J.E., Stampfer, M.J., Colditz, G.A., Wing, A.L. and Willett, W.C. (1997b) 'Dietary fiber, glycemic load, and risk of non—insulin-dependent diabetes mellitus in women', *JAMA*, 277(6), pp. 472-477.

Schroeder, M., Dybsetter, A., Perdue, L., Kim, H., Blue, M. and Hurtado, G.A. (2016) 'Cooking With Whole Grains: A Skills-Based Training for Child Care Providers', *Journal of Nutrition Education and Behavior*, 48(3), pp. 229-230.e1.

Scientific Advisory Committee on Nutrition (2015) *Carbohydrates and Health*. London: TSO: The Stationary Office. [Online]. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/445503/SACN_Carbohydrates_and_Health.pdf (Accessed: 17 July 2015).

Seal, C. and Jones, A.R. (2007) 'Barriers to the Consumption of Whole Grain Foods', in Marquart, L., Jacobs Jr, D.R., McIntosh, G.H., Poutanen, K. and Reicks, M. (eds.) *Whole Grains and Health*. Blackwell Publishing, pp. 243-245.

Seal, C.J. (2006) 'Whole grains and CVD risk', *Proceedings of the Nutrition Society*, 65(1), pp. 24-34.

Seal, C.J. and Brownlee, I.A. (2010) 'Whole Grains and Health, Evidence from Observational and Intervention Studies', *Cereal Chemistry*, 87(2), pp. 167-174.

Seal, C.J. and Brownlee, I.A. (2015) 'Whole-grain foods and chronic disease: evidence from epidemiological and intervention studies', *Proceedings of the Nutrition Society*, FirstView, pp. 1-7.

Seal, C.J., Jones, A.R. and Whitney, A.D. (2006) 'Whole grains uncovered', *Nutrition Bulletin*, 31(2), pp. 129-137.

Seal, C.J., Nugent, A.P., Tee, E.S. and Thielecke, F. (2016) 'Whole-grain dietary recommendations: the need for a unified global approach', *British Journal of Nutrition*, 115(11), pp. 2031-2038.

Sette, S., D'Addezio, L., Piccinelli, R., Hopkins, S., Le Donne, C., Ferrari, M., Mistura, L. and Turrini, A. (2015) 'Intakes of whole grain in an Italian sample of children, adolescents and adults', *European Journal of Nutrition*, pp. 1-13.

Shewry, P.R. and Hey, S.J. (2016) 'Do we need to worry about eating wheat?', *Nutrition Bulletin*, 41(1), pp. 6-13.

Simmons, R.K., Harding, A.H., Wareham, N.J., Griffin, S.J. and on behalf of the, E.-N.p.t. (2007) 'Do simple questions about diet and physical activity help to identify those at risk of Type 2 diabetes?', *Diabetic Medicine*, 24(8), pp. 830-835.

Slavin, J. (2003) 'Why whole grains are protective: biological mechanisms', *Proceedings of the Nutrition Society*, 62(1), pp. 129-34.

Slavin, J. (2010) 'Whole Grains and Digestive Health', *Cereal Chemistry*, 87(4), pp. 292-296.

Slavin, J., Jacobs, D. and Marquart, L. (1997) 'Whole-grain consumption and chronic disease: protective mechanisms', *Nutrition and Cancer*, 27(1), pp. 14-21.

Smith, A.T., Kuznesof, S., Richardson, D.P. and Seal, C.J. (2003) 'Behavioural, attitudinal and dietary responses to the consumption of wholegrain foods', *Proceedings of the Nutrition Society*, 62(02), pp. 455-467.

Spence, J., Walton, W.S., Miller, F.J.W. and Court, S.D.M. (1954) *A Thousand Families in Newcastle upon Tyne*. London: Oxford University Press.

StataCorp (2013) *Stata Statistical Software* (Version 13) [Computer program]. College Station, TX: StataCorp LP.

StataCorp (2015) *Stata Statistical Software* (Version 14) [Computer program]. College Station, TX: StataCorp LP.

Staudacher, H.M. and Gibson, P.R. (2015) 'How healthy is a gluten-free diet?', *British Journal of Nutrition*, 114(10), pp. 1539-1541.

Steffen, L.M., Jacobs, D.R., Jr., Stevens, J., Shahar, E., Carithers, T. and Folsom, A.R. (2003) 'Associations of whole-grain, refined-grain, and fruit and vegetable consumption with risks of all-cause mortality and incident coronary artery disease and ischemic stroke: the Atherosclerosis Risk in Communities (ARIC) Study', *The American Journal of Clinical Nutrition*, 78(3), pp. 383-390.

Suhr, J., Vuholm, S., Iversen, K.N., Landberg, R. and Kristensen, M. (2017) 'Wholegrain rye, but not wholegrain wheat, lowers body weight and fat mass compared with refined wheat: a 6-week randomized study', *European Journal of Clinical Nutrition*.

Surget, A. and Barron, C. (2005) 'Histologie du grain de blé (Histology of wheat grain)', *Industrie des Céréales*, 145, pp. 3-7.

Tang, G., Wang, D., Long, J., Yang, F. and Si, L. (2015) 'Meta-analysis of the association between whole grain intake and coronary heart disease risk', *American Journal of Cardiology*, 115(5), pp. 625-629.

Thane, C.W., Jones, A.R., Stephen, A.M., Seal, C.J. and Jebb, S.A. (2005) 'Whole-grain intake of British young people aged 4-18 years', *British Journal of Nutrition*, 94(5), pp. 825-31.

Thane, C.W., Jones, A.R., Stephen, A.M., Seal, C.J. and Jebb, S.A. (2007) 'Comparative whole-grain intake of British adults in 1986-7 and 2000-1', *British Journal of Nutrition*, 97(5), pp. 987-992.

Thane, C.W., Stephen, A.M. and Jebb, S.A. (2009) 'Whole grains and adiposity: little association among British adults', *European Journal of Clinical Nutrition*, 63(2), pp. 229-37.

Thielecke, F. and Jonnalagadda, S.S. (2014) 'Can Whole Grain Help in Weight Management?', *Journal of Clinical Gastroenterology*, 48, pp. S70-S77.

Threapleton, D.E., Burley, V.J., Greenwood, D.C. and Cade, J.E. (2015) 'Dietary fibre intake and risk of ischaemic and haemorrhagic stroke in the UK Women/'s Cohort Study', *European Journal of Clinical Nutrition*, 69(4), pp. 467-474.

Threapleton, D.E., Greenwood, D.C., Burley, V.J., Aldwairji, M. and Cade, J.E. (2013) 'Dietary fibre and cardiovascular disease mortality in the UK Women's Cohort Study', *European Journal of Epidemiology*, 28(4), pp. 335-346.

Tiffin, P.A., Pearce, M.S. and Parker, L. (2005) 'Social mobility over the lifecourse and self reported mental health at age 50: prospective cohort study', *Journal of Epidemiology and Community Health*, 59(10), pp. 870-872.

Tighe, P., Duthie, G., Brittenden, J., Vaughan, N., Mutch, W., Simpson, W.G., Duthie, S., Horgan, G.W. and Thies, F. (2013) 'Effects of Wheat and Oat-Based Whole Grain Foods on Serum Lipoprotein Size and Distribution in Overweight Middle Aged People: A Randomised Controlled Trial', *PLOS ONE*, 8(8), p. e70436.

Tighe, P., Duthie, G., Vaughan, N., Brittenden, J., Simpson, W.G., Duthie, S., Mutch, W., Wahle, K., Horgan, G. and Thies, F. (2010) 'Effect of increased consumption of whole-grain foods on blood pressure and other cardiovascular risk markers in healthy middle-aged persons: a randomized controlled trial', *The American Journal of Clinical Nutrition*, 92(4), pp. 733-40.

Tipping, S. (2012) National Diet and Nutrition Survey. Headline results from years 1, 2 and 3 combined - Appendix B. Weighting the NDNS core sample. Department of Health. [Online]. Available at: https://www.gov.uk/government/publications/national-diet-and-nutrition-survey-headline-results-from-years-1-2-and-3-combined-of-the-rolling-programme-200809-201011 (Accessed: 05 March 2013).

Tiwari, U. and Cummins, E. (2011) 'Meta-analysis of the effect of β-glucan intake on blood cholesterol and glucose levels', *Nutrition*, 27(10), pp. 1008-1016.

Townsend, N., Bhatnagar, P., Wilkins, E., Wickramasinghe, K. and Rayner, M. (2015) *Cardiovascular disease statistics, 2015*. British Heart Foundation: London.

Truswell, A.S. (2002) 'Cereal grains and coronary heart disease', *European Journal of Clinical Nutrition*, 56(1), pp. 1-14.

U.S. Department of Agriculture - Agricultural Research Service (2012) *USDA National Nutrient Database for Standard Reference* (Release 25). Available at: https://ndb.nal.usda.gov/ndb/ (Accessed: 30 May 2013).

U.S. Department of Agriculture - Agricultural Research Service (2014) *Food Patterns Equivalents Database*. Available at: http://www.ars.usda.gov/Services/docs.htm?docid=23871 (Accessed: 9 July 2016).

U.S. Department of Health and Human Services and U.S. Department of Agriculture (2015-2020) *Dietary Guidelines for Americans* (8th edition). Available at: https://health.gov/dietaryguidelines/2015/guidelines/ (Accessed: 15 January 2016).

U.S. Food and Drug Administration (1999) *Health Claim Notification for Whole Grain Foods*. Available at:

http://www.fda.gov/Food/IngredientsPackagingLabeling/LabelingNutrition/ucm073639.htm (Accessed: 29 April 2016).

U.S. Food and Drug Administration (2003) *Health Claim Notification for Whole Grain Foods with Moderate Fat Content*. Available at: http://www.fda.gov/Food/IngredientsPackagingLabeling/LabelingNutrition/ucm073634.htm (Accessed: 29 April 2016).

U.S. Food and Drug Administration (2006) 'Draft guidance for Industry and FDA staff: Whole grain label statements', [Online]. Available at: http://www.fda.gov/food/guidanceregulation/guidancedocumentsregulatoryinformation/ucm059088.htm#ftn1 (Accessed: 11 April 2016).

University of Cambridge (2014) *The EPIC-Norfolk Food Frequency Questionnaire and FETA Software*. Available at: http://www.srl.cam.ac.uk/epic/epicffq/ (Accessed: 24 Novemeber 2015).

van der Kamp, J.W., Poutanen, K., Seal, C.J. and Richardson, D.P. (2014) 'The HEALTHGRAIN definition of 'whole grain'', *Food and Nutrition Research*, 58(22100).

Vanegas, S.M., Meydani, M., Barnett, J.B., Goldin, B., Kane, A., Rasmussen, H., Brown, C., Vangay, P., Knights, D., Jonnalagadda, S., Koecher, K., Karl, J.P., Thomas, M., Dolnikowski, G., Li, L., Saltzman, E., Wu, D. and Meydani, S.N. (2017) 'Substituting whole grains for refined grains in a 6-wk randomized trial has a modest effect on gut microbiota and immune and inflammatory markers of healthy adults', *The American Journal of Clinical Nutrition*.

Vitaglione, P., Mennella, I., Ferracane, R., Rivellese, A.A., Giacco, R., Ercolini, D., Gibbons, S.M., La Storia, A., Gilbert, J.A., Jonnalagadda, S., Thielecke, F., Gallo, M.A., Scalfi, L. and Fogliano, V. (2015) 'Whole-grain wheat consumption reduces inflammation in a randomized controlled trial on overweight and obese subjects with unhealthy dietary and lifestyle behaviors: role of polyphenols bound to cereal dietary fiber', *The American Journal of Clinical Nutrition*, 101(2), pp. 251-261.

Walter, J., Martínez, I. and Rose, D.J. (2013) 'Holobiont nutrition: Considering the role of the gastrointestinal microbiota in the health benefits of whole grains', *Gut Microbes*, 4(4), pp. 340-346.

Wang, J.-B., Fan, J.-H., Dawsey, S.M., Sinha, R., Freedman, N.D., Taylor, P.R., Qiao, Y.-L. and Abnet, C.C. (2016) 'Dietary components and risk of total, cancer and cardiovascular disease mortality in the Linxian Nutrition Intervention Trials cohort in China', *Scientific Reports*, 6, p. 22619.

Wei, H., Gao, Z., Liang, R., Li, Z., Hao, H. and Liu, X. (2016) 'Whole-grain consumption and the risk of all-cause, CVD and cancer mortality: a meta-analysis of prospective cohort studies', *British Journal of Nutrition*, 116(03), pp. 514-525.

Whincup, P. and Donin, A. (2015) 'Cereal fibre and type 2 diabetes: time now for randomised controlled trials?', *Diabetologia*, 58(7), pp. 1383-1385.

Williams, P.G., Grafenauer, S.J. and O'Shea, J.E. (2008) 'Cereal grains, legumes, and weight management: a comprehensive review of the scientific evidence', *Nutrition Reviews*, 66(4), pp. 171-182.

World Health Organization (1998) 'MONICA Manual, Part III: Population Survey', in *Monitoring Trends and Determinants in Cardiovascular Disease Project (MONICA) Manual*. Available at: http://www.thl.fi/publications/monica/manual/part3/iii-1.htm.

World Health Organization (2014) *Global status report on noncommunicable diseases 2014*. WHO Library Cataloguing-in-Publication Data. [Online]. Available at: http://www.who.int/nmh/publications/ncd-status-report-2014/en/ (Accessed: 20 July 2016).

World Health Organization (2016) *Obesity and overweight - Fact sheet*. Available at: http://www.who.int/mediacentre/factsheets/fs311/en/ (Accessed: 4 April 2016).

Wu, J.H.Y., Neal, B., Trevena, H., Crino, M., Stuart-Smith, W., Faulkner-Hogg, K., Yu Louie, J.C. and Dunford, E. (2015a) 'Are gluten-free foods healthier than non-gluten-free foods? An evaluation of supermarket products in Australia', *British Journal of Nutrition*, FirstView, pp. 1-7.

Wu, Y., Qian, Y., Pan, Y., Li, P., Yang, J., Ye, X. and Xu, G. (2015b) 'Association between dietary fiber intake and risk of coronary heart disease: A meta-analysis', *Clinical Nutrition*, 34(4), pp. 603-611.

Yamini, S. and Trumbo, P.R. (2016) 'Qualified health claim for whole-grain intake and risk of type 2 diabetes: an evidence-based review by the US Food and Drug Administration', *Nutrition Reviews*, 74(10), pp. 601-611.

Ye, E.Q., Chacko, S.A., Chou, E.L., Kugizaki, M. and Liu, S. (2012) 'Greater whole-grain intake is associated with lower risk of type 2 diabetes, cardiovascular disease, and weight gain', *The Journal of Nutrition*, 142(7), pp. 1304-13.

Zanovec, M., O'Neil, C.E., Cho, S.S., Kleinman, R.E. and Nicklas, T.A. (2010) 'Relationship between whole grain and fiber consumption and body weight measures among 6- to 18-year-olds', *The Journal of Pediatrics*, 157(4), pp. 578-83.

Zanovec, M., O'Neil, C.E., Cho, S.S. and Nicklas, T.A. (2009) 'Whole grain consumption and body weight measures in children and adolescents: Results from NHANES 1999-2004', *The FASEB Journal*, 23 (S1).

Zhang, G., Pan, A., Zong, G., Yu, Z., Wu, H., Chen, X., Tang, L., Feng, Y., Zhou, H., Chen, X., Li, H., Hong, B., Malik, V.S., Willett, W.C., Spiegelman, D., Hu, F.B. and Lin, X. (2011) 'Substituting White Rice with Brown Rice for 16 Weeks Does Not Substantially Affect Metabolic Risk Factors in Middle-Aged Chinese Men and Women with Diabetes or a High Risk for Diabetes', *The Journal of Nutrition*, 141(9), pp. 1685-1690.

Zhang, J., Li, L., Song, P., Wang, C., Man, Q., Meng, L., Cai, J. and Kurilich, A. (2012) 'Randomized controlled trial of oatmeal consumption versus noodle consumption on blood lipids of urban Chinese adults with hypercholesterolemia', *Nutrition Journal*, 11(1), p. 54.

Zhong, Y., Nyman, M. and Fåk, F. (2015) 'Modulation of gut microbiota in rats fed high-fat diets by processing whole-grain barley to barley malt', *Molecular Nutrition & Food Research*, 59(10), pp. 2066-2076.

Zhou, A.L., Hergert, N., Rompato, G. and Lefevre, M. (2015) 'Whole grain oats improve insulin sensitivity and plasma cholesterol profile and modify gut microbiota composition in C57BL/6J mice', *The Journal of Nutrition*, 145(2), pp. 222-30.

Zong, G., Gao, A., Hu, F.B. and Sun, Q. (2016) 'Whole Grain Intake and Mortality From All Causes, Cardiovascular Disease, and Cancer: A Meta-Analysis of Prospective Cohort Studies', *Circulation*, 133(24), pp. 2370-2380.

Appendices

Appendix A Calculation of the whole grain content of foods consumed in the NDNS 2008-2011

Table A.1 Whole grain dry matter content calculation of pasta, rice and other miscellaneous cereals

	NDNS Food Number	Food Name	Calculation source	Ingredients	Weight (g)	Calculation, including removal of water content of the whole grain	While grain dry matter per 100g	Main grain type
Pasta								
1	35	Pasta, spaghetti, Wholemeal, dried	M-Jones et al, M&W	spaghetti, Wholemeal raw per 100g	89.5			wheat
				water content per 100g	10.5	N/A	**89.5**	
2	36	Pasta spaghetti, Wholemeal boiled	M-Jones et al, M&W	spaghetti, Wholemeal boiled per 100g	30.9			wheat
				water content per 100g	69.1	N/A	**30.9**	
3	9208	Wholewheat Spaghetti canned in tomato sauce	M-Jones et al	Average cooked spaghetti content in a can- 48.33%, 30.9% dry matter	48.33			wheat
			M&W CoF, fried noodles	Other ingredients	51.67			
				Assume 2% weight loss in cooking				
				Total cooked weight	98	=((48.33*0.309)/98)*100	**15.2**	
Rice								
1	49	Rice, brown, boiled	M-Jones et al, M&W	Brown rice, boiled per 100g	34			rice
				water content per 100g	66	N/A	**34.0**	
2	10008	Brown Basmati Rice, raw	NC: M&W	Brown Rice (raw) per 100g	86.1			rice
				water content per 100g	13.9		**86.1**	
3	10009	Brown Basmati Rice, cooked	S-Jones et al	As for #49 Rice, brown, boiled			**34.0**	rice
4	10010	Brown easycook Italian/American rice, raw	NC: M&W	Same as for # 10008 Brown basmati rice, raw			**86.1**	rice
5	10011	Brown easycook Italian/American rice, cooked	S-Jones et al	As for #49 Rice, brown, boiled			**34**	rice
6	10013	Wild rice, cooked	NC: USDA Nutrient database	Wild rice dry per 100g	26.07			rice
				water content per 100g	73.93	N/A	**26.1**	
7	10017	Red rice, cooked	M-Jones et al, M&W	Red rice dry per 100g	21.2			rice
				water content per 100g	78.8	N/A	**21.2**	
Other Cereals								
1	4	Barley, Whole Grain, dried	M-Jones et al, M&W	Barley, dry per 100g	88.3			barley
				water content per 100g	11.7	N/A	**88.3**	
2	5	Barley, Whole Grain, boiled in water	M-Jones et al, M&W CoF	Barley, Pearl, boiled per 100g	30.4			barley
				water content per 100g	69.6	N/A	**30.4**	
3	18	Rye flour (100%)	M-Jones et al, M&W	Rye Flour, Whole per 100g	85			rye
				water content per 100g	15	N/A	**85.0**	
4	23	Oatmeal, raw	M-Jones et al, M&W CoF	Oatmeal, raw per 100g	91.1			oat
				water content per 100g	8.9	N/A	**91.1**	
5	24	Oats, rolled, quick cook	M-Jones et al, M&W	Oatmeal, quick cook raw per 100g	91.8			oat
				water content per 100g	8.2	N/A	**91.8**	

6	2643	Wholemeal flour with losses	M-Jones et al	As for #10021 Wholemeal flour, losses unknown			**86.0**	wheat
7	2687	Oats with losses on boiling		As for #23 Oatmeal raw, losses unknown			**91.1**	oat
8	3259	Millet, boiled	M-Jones et al, M&W CoF	Millet, dry per 100g	30.4			millet
				water content per 100g	69.6	N/A	**30.4**	
9	10021	Wholemeal flour, bread making	M-Jones et al, M&W	Wholemeal flour dry per 100g	86			wheat
				water content per 100g	14	N/A	**86.0**	
10	10022	Self raising Wholemeal flour	S-Jones et al	As for #10021 Wholemeal flour			**86.0**	wheat
11	10424	Quinoa, cooked	NC: NDNS Nutrient data bank	Quinoa dry per 100g	28.4			quinoa
				water content per 100g	71.6		**28.4**	

M-Jones et al: Matched to Jones et al (2007); S: Similar to Jones et al (2007); NC: New calculation:source; M&W: McCance & Widdowson's Composition of Foods, 6th Edition; M&W CoF: McCance & Widdowson's Composition of Foods, Cereal and Cereal products 3rd supplement: CPUK: Cereal Partners UK.

Table A.2 Whole grain dry matter content calculation of breads

	NDNS Food Number	Food Name	Calculation source	Ingredients	Weight (g)	Calculation, including removal of water content of the whole grain	While grain dry matter per 100g	Main grain type
Bread								
1	112	Bread, granary	M-Jones et al	Wholemeal flour (assume 51% per 100g)	51			wheat
				Other ingredients	43			
			M&W CoF, Milk bread	*Assume 10.5% weight loss in cooking*				
				Total cooked weight	89.5	=((51*0.86)/89.5)*100	**49**	
2	113	Bread, granary, toasted	M-Jones et al	As for #112 Bread, granary				wheat
			M&W, Wholemeal bread toasted	Assume a further 14.6% weight loss for toasting				
				Final toasted weight	76.43	=((51*0.86)/76.43)*100	57.4	
3	114	Bread, rye	M-Jones et al	Rye flour (assume 57% per 100g)	57			rye
				Other ingredients	43			
			M&W CoF, Milk bread	*Assume 10.5% weight loss in cooking*				
				Total cooked weight	89.5	=((57*0.85)/89.5)*100	**54.1**	
4	115	Bread, rye, toasted	M-Jones et al	As for 114 Bread, rye				rye
			M&W, Wholemeal bread toasted	*Assume a further 14.6% weight loss for toasting*				
				Final toasted weight	76.43	=((57*0.85)/76.43)*100	**63.4**	
5	117	Bread, pitta, Wholemeal	M-Jones et al	Wholemeal flour (68% per 100g)	68			wheat
				Other ingredients	32			
			M&W CoF, Milk bread	*Assume 10.5% weight loss in cooking*				
				Total cooked weight	89.5	=((68*0.86)/89.5)*100	**65.3**	
6	133	Bread, Wholemeal	M-Jones et al	Wholemeal flour (57% warburtons)	57			wheat
				Other ingredients	43			
			M&W CoF, Milk bread	*Assume 10.5% weight loss in cooking*				
				Total cooked weight	89.5	=((57*0.86)/89.5)*100	**54.8**	
7	138	Bread, Wholemeal, toasted	M-Jones et al	As for 133 Bread, Wholemeal				wheat
			M&W, Wholemeal bread toasted	*14.6% weight loss for toasting*				
				Final toasted weight	76.43	=((57*0.86)/76.43)*100	**64.1**	
8	161	Rolls, Wholemeal	M-Jones et al	As for #133 Bread, Wholemeal			**54.8**	wheat
9	169	Roll, granary/brown/ wheatgerm, toasted	M-Jones et al	As for #113 Bread, granary, toasted			**57.4**	wheat
10	172	Rolls, Wholemeal, toasted	M-Jones et al	As for #138 Bread, Wholemeal, toasted			**64.1**	wheat
11	173	Muffins, English, Wholemeal or bran	M-Jones et al	Wholemeal flour (60% per 100g)	60			wheat
				Other ingredients	40			
			M&W CoF, Bran Muffins	*Assume 16% weight loss in cooking*				
				Final cooked weight	84	=((60*0.86)/84)*100	**61.4**	
12	3172	Bread, Wholemeal, slimmers', toasted	M-Jones et al	As for #133 Bread, Wholemeal			**64.1**	wheat

13	3431	Soda bread, Wholemeal, toasted	M-Jones et al, M&W CoF	As for #3603 Soda bread, Wholemeal				wheat
			M&W, Wholemeal bread toasted	*Assume a further 14.6% weight loss for toasting*				
				Final toasted weight	627.38	=((500*0.86)/627.37)*100	**68.5**	
14	3457	Chapati, Wholemeal with olive oil	M-Jones et al	Wholemeal flour	340			wheat
				Oil	11			
				Other ingredients	250			
			M&W, tortillas	*Assume 17.3% weight loss in cooking*				
				Total cooked weight	497.03	=((340*0.86)/497.027)*100	**58.8**	
15	3603	Soda bread, Wholemeal	M-Jones et al, M&W CoF	Wholemeal flour	500			wheat
				Other ingredients	302			
			M&W CoF recipe	*8.4% weight loss in cooking*				
				Total cooked weight	734.63	=((500*0.86)/734.63)*100	**58.5**	
16	3904	Bread, white and Wholemeal with added wheatgerm	NC: Hovis website, accessed May 2013	As for #4168 Bread, white and Wholemeal best of both			**24.9**	wheat
17	3937	Chapati, Wholemeal, made with blended vegetable oil	S-Jones et al	As for #3457 Chapati, Wholemeal with olive oil			**58.8**	wheat
18	4168	Bread, white and Wholemeal best of both, e.g. Hovis	NC: Hovis website, accessed May 2013	Wholemeal flour - 29%	29			wheat
				Other ingredients	71	=29*0.86	**24.9**	
19	7614	Bread, Wholemeal, slimmers only, e.g. Nimble	M-Jones et al	As for #133 Bread, Wholemeal			**54.8**	wheat
20	7616	French stick, granary	M-Jones et al	As for #112 Bread, granary			**49**	wheat
21	7617	Bread, Oatmeal	M-Jones et al	Medium Oatmeal	100			oat
				Other ingredients	760			
			M&W CoF, Milk bread	*Assume 10.5% weight loss in cooking*				
				Total cooked weight	769.7	=((100*0.911)/769.7)*100	**11.8**	
22	7618	Bread, Oatmeal, toasted	NC: Adapted from Jones et al	As for 7617 Bread, oatmeal				oat
			M&W, Wholemeal bread toasted	*Assume 14.6% weight loss in toasting*				
				Final toasted weight	657.32	=((100*0.911)/657.32)*100	**13.9**	
23	7620	Rolls, brown/granary/ wheatgerm, crusty	M-Jones et al	As for #112 Bread, granary			**49**	wheat
24	7621	Rolls, brown/granary/ wheatgerm, soft	M-Jones et al	As for #112 Bread, granary			**49**	wheat
25	7769	Eggy bread, Wholemeal, milk, blended oil	M-Jones et al	Taken from Thane et al 2007			**10**	wheat
26	8019	Multiseed Bread, Wholemeal	S-Jones et al	As for #112 Bread, granary			**49**	wheat

27	8142	Rolls, white and Wholemeal blend	NC: Hovis website, accessed May 2013	As for #4168 Bread, white and wholemeal best of both			**24.9**	wheat
28	8595	Paratha, Wholemeal	NC: M&W CoF recipe	Brown flour- assume 50/50 White/Wholemeal	363			wheat
				Water	245			
				Butter	92			
				17.9% weight loss in cooking				
				Total cooked weight	574.7	=((181.5*0.86)/574.7)*100	**27.2**	
29	8603	Chapati, Wholemeal, made with sunflower oil	M-Jones et al	As for #3457 Chapati, Wholemeal with olive oil			**58.8**	wheat
30	10204	Multiseed Bread, Wholemeal, toasted	S-Jones et al	As for #113 Bread, granary, toasted			**57.4**	wheat
31	10754	Tortilla wrap, Wholemeal	NC: M&W CoF recipe	WG Flour	266			wheat
				Water	150			
				Salt	2.5			
			M&W recipe, Tortilla	*17.3% weight loss in cooking*				
				Total cooked weight	346.1	=((266*0.86)/346.09)*100	**66.1**	

M-Jones et al: Matched to Jones et al (2007); S: Similar to Jones et al (2007); NC: New calculation:source; M&W: McCance & Widdowson's Composition of Foods, 6th Edition; M&W CoF: McCance & Widdowson's Composition of Foods, Cereal and Cereal products 3rd supplement: CPUK: Cereal Partners UK.

Table A.3 Whole grain dry matter content calculation of ready-to-eat breakfast cereals (RTEBC)

	NDNS Food Number	Food Name	Calculation source	Ingredients	Weight (g)	Calculation, including removal of water content of the whole grain	While grain dry matter per 100g	Main grain type
RTEBC *Kellogg's*								
1	202	Kellogg's Bran flakes	M-Jones et al	Bran Flakes 63% Whole Wheat per 100g	63			
				Other ingredients	37	=(63*0.86)	**54.2**	wheat
2	203	Sultana Bran, bran flakes with sultanas	M-Jones et al	Sultana Bran 47% Whole Wheat	47			
				Other ingredients	53	=47*0.86	**40.4**	wheat
3	223	Kellogg's Special K	M-Jones et al	Special K 14% Whole Wheat	14			wheat
				Other ingredients	86	=14*0.86	**12.0**	
4	228	Kellogg's MultiGrain Start	M-Jones et al	Start (not available) use similar cereal				wheat/oat
				As for #6822 Kellogg's Just Right	26		**28.7**	80/20
5	229	Kellogg's Fruit 'n' Fibre	M-Jones et al	Fruit 'n' Fibre 69% Whole Wheat	69			wheat
				Other ingredients	31	=69*0.86	**59.3**	
6	2970	Kellogg's Special K with red berries	M-Jones et al	Special K red berries 12% Whole Wheat	12			wheat
				Other ingredients	88	=12*0.86	**10.3**	
7	5204	Kellogg's Frosted Wheats	M-Jones et al	Kellogg's frosted Wheats 83% Whole Wheat	83			wheat
				Other ingredients	17	=83*0.86	**71.4**	
8	6822	Kellogg's Just Right, ½-fat muesli	M-Jones et al	Kellogg's Just Right 26% Whole Wheat	26			wheat
				7% Whole Oats	7			
				Other ingredients	67	=(26*0.86)+(7*0.911)	**28.7**	
9	7051	Kellogg's Raisin Wheats	M-Jones et al	Raisin Wheats- 73% Whole Wheat	73			wheat
				Other ingredients	23	=73*0.86	**62.8**	
10	8013	Kellogg's Special K berries any fruit addition not choc or yogurt	S-Jones et al	As for #2970 Kellogg's Special K with red berries			**10.3**	wheat
11	8014	Kellogg's Special K bliss with choc or yogurt pieces	S-Jones et al	As for #223 Kellogg's Special K			**12.0**	wheat
12	8086	Kellogg's Crunchy nut clusters	NC: Kellogg's website, accessed May 2013	No information so use Kellogg's Crunchy Nut granola				oat
				Crunchy Nut granola - 44% Rolled Oats	44			
				Other ingredients	56	=(44*0.911)	**40.1**	
13	8140	Kellogg's Special K medley cereal	NC: Special K website, accessed May 2013	Special K Fruit and Nut Medley- 49% (rice,oat,wheat)				oat
				Rice - Not WG	16.33			
				Oats	16.33			
				Wheat - Not WG	16.33			
				Other ingredients	51		**14.9**	
						=16.33*0.911		

14	8486	Kellogg's Honey Nut Loops	M-Jones et al	Whole Oats Whole Wheat Whole Barley Whole Rye Other ingredients	31 26 2.5 2.5 38	=(31*0.911)+(26*0.86)+(2.5*0.883)+(2.5*0.85)	**54.9**	wheat/oat/ barley/rye 40/40/1/1
15	10125	Kellogg's Rice Krispies multiGrain breakfast cereal	NC: Kellogg's website, accessed May 2013	WG Oat flour-26% Other ingredients	26 74	=26*0.911	**23.7**	oat
16	10132	Kellogg's Optivia berry breakfast cereal	NC: Kellogg's website, accessed May 2013	Optivia berry- 65% WG cereal, assume equal proportions WG Oat flour Brown Rice Whole Wheat Other ingredients	 21 21 21 79	=(21*0.911)+(21*0.861)+ (21*0.86)	**55.3**	wheat/oat/ric e 33/33/33
17	10330	Kellogg's Special K Oats and honey	NC: Kellogg's website, accessed May 2013	Special K Oats and Honey Rice-Not WG Wholewheat Oats Barley Honey coated Oats Puffed Brown Rice Other ingredients	 28 26 13 5 5 1.5 21.5	=(26*0.86)+(13*0.911)+ (5*0.911)+(1.5*0.861)	**40.0**	wheat/oat/ barley/rice 50/40/9/1
18	10355	Kellogg's Special K Sustain cereal	NC: My supermarket website, accessed May 2013	Brown Rice- 34% Whole Wheat- 30% Other ingredients	34 30 36	=(34*0.861)+(30*0.86)	**55.1**	wheat/rice 50/50
19	10596	Kellogg's Special K fruit and nut clusters	NC: Special K website, accessed May 2013	As for # 8140 Kellogg's Special K medley cereal			**14.9**	
20	10762	Kellogg's Choc 'n' Roll breakfast cereal	NC: Kellogg's website, accessed May 2013	Wholewheat flour-40% Whole oat flour-5% Others	40 5 55	=(40*0.86)+(5*0.911)	**39.0**	wheat/oat 90/10
Nestle								
21	221	Nestlé Shredded Wheat	M-Jones et al	Shredded Wheat 100% Whole Wheat	100	=100*0.86	**86.0**	wheat
22	222	Shreddies, any brand, not frosted	M-Jones et al	Shreddies 93% Whole Wheat Other ingredients	93 7	=93*0.86	**80.0**	wheat
23	5199	Nestlé Nesquik chocolate cereal	NC: CPW website, accessed May 2013	Whole grain Wheat flour- 44.7% Other ingredients	44.7 55.3	=44.7*0.86	**38.4**	wheat
24	6824	Nestlé Honey Nut Shredded Wheat	M-Jones et al, CPUK	Honey Nut Shredded Wheat- 78% WG Wheat Other ingredients	78 22	=78*0.86	**67.1**	wheat

25	7637	Nestlé Multi Cheerios	M-Jones et al	Cheerios 12% Whole Wheat 22% Maize 16% Barley 19% Oats 3.8% Rice Other ingredients	12 22 16 19 3.8 27.2	=(12*0.86)+(22*0.878)+ (16*0.883)+(19*0.911)+ (3.8*0.861)	**64.3**	wheat/oat/ barley/maize/ rice 15/25/25/ 30/5
26	8163	Nestlé Honey Oats and More	NC: CPW website, accessed May 2013	WG Oats- 62% WG Wheat-6.8% Rice Flour-0.4% Not WG Other ingredients	62 6.8 0.4 30.8	=(62*0.911)+(6.8*0.86)	**62.3**	oat/wheat 90/10
27	8169	Nestlé Golden Nuggets	NC: CPW website, accessed May 2013	WG Wheat- 20.5% Wheat Flour-31.3% Not WG WG Maize- 11.3% Other ingredients	20.5 31.3 11.3 36.9	=(20.5*0.86)+(11.3*0.878)	**27.6**	wheat
28	8182	Nestlé Frosted Shreddies	M-Jones et al, CPUK	Whole Wheat-56% Other ingredients	56 44	=56*0.86	**48.4**	wheat
29	8190	Nestlé Shredded Wheat Fruitful, mini fruit	M-Jones et al, CPUK	Whole Wheat -67% Other ingredients	67 33	=67*0.86	**57.6**	wheat
30	8383	Nestlé Coco Shreddies	M-Jones et al, CPUK	Whole Wheat-56% Other ingredients	56 44	=56*0.86	**48.2**	wheat
31	8409	Nestlé Cookie Crisp cereal	NC: CPW website, accessed May 2013	WG Wheat- 34.6% Other ingredients	34.6 65.4	=34.6*0.86	**29.8**	wheat
32	8441	Nestlé Almond Oats and More	NC: CPW website, accessed May 2013	WG Oats-59.2% WG Wheat-5.5% Other ingredients	59.2 5.5 35.3	=(59.2*0.911)+(5.5*0.86)	**58.7**	oat/wheat 90/10
33	8712	Nestlé Clusters	NC: CPW website, accessed May 2013	Clusters are 75% WG Wheat flakes & 25% clusters WG Wheat flakes-65.2% WG Wheat Other ingredients Clusters-3% WG Wheat Clusters-1.5% Rolled Oats Other ingredients	 65.2 34.8 3 1.5 95.5	=0.75*(65.2*0.86)+ 0.25*((3*0.86)+(1.5*0.911))	**43.0**	wheat/oat 60/30
34	9032	Nestlé Curiously Cinnamon, formerly Cinnamon Grahams	NC: CPW website, accessed May 2013	Whole Grain Wheat flour-32.4% Other ingredients	32.4 67.6	=32.4*0.86	**27.9**	wheat
35	9275	Nestlé Honey Nut Cheerios	M-Jones et al, CPUK	Whole Wheat Maize Barley Oat Rice Other ingredients	15 7 13 15 10 40	=(15*0.86)+(7*0.878)+ (13*0.883)+(15*0.911)+ (10*0.861)	**52.8**	wheat/oat/ barley/maize/ rice 25/25/25/ 12.5/12.5
36	10254	Nestlé Raisin Oats and More	NC: CPW website, accessed May 2013	WG Oats-53.7% WG Wheat-6% Other ingredients	53.7 6 40.3	=(53.7*0.911)+(6*0.86)	**54.1**	oat/wheat 90/10

37	10511	Nestlé Shreddies, not frosted not coco	S-Jones et al	As for #222 Shreddies, any brand, not frosted			**80.0**	wheat
Weetabix								
38	212	Weetabix Ltd., Alpen muesli with added sugar	M-Jones et al	Alpen, 34% Whole Wheat	34			wheat/oat 50/50
				Alpen, 33% Whole Oats	33			
				Other ingredients	33	=(34*0.86)+(33*0.911)	**59.3**	
39	225	Weetabix Ltd., Weetabix	M-Jones et al	Weetabix 94% Whole Wheat	94			wheat
				Other ingredients	6	=94*0.86	**80.8**	
40	3875	Weetabix Ltd., Weetabix Mini's chocolate crisp, Previously known as Chocolate Weetabix Mini Crunch	S-Jones et al	As for 6132 Weetabix fruitibix			**66.7**	wheat
41	6132	Weetabix Ltd., Weetabix Fruitibix	M-Jones et al	Fruitibix Mini Crunch Banana-73% Whole Wheat				wheat
				Fruitibix Mini Crunch Fruit & Nut-82% Whole Wheat				
				Average of the two 77.5% Whole Wheat	77.5			
				Other ingredients	22.5	=77.5*0.86	**66.7**	
42	7629	Weetabix Ltd., Alpen Tropical Fruit, Muesli with extra fruit	M-Jones et al	Kellogg's Premium Fruit Muesli 38% Whole Oats	38			wheat/oat 25/75
				Whole Wheat- 14%	14			
				Other ingredients	48	=(38*0.911)+(14*0.86)	**46.7**	
43	7632	Weetabix Ltd., Weetos	M-Jones et al	Weetos 27% Whole Wheat	27			wheat
				Other ingredients	73	=27*0.86	**23.2**	
44	8103	Weetabix Ltd., Oatabix	NC: Weetabix website, accessed May 2013	Wholegrain Oats - 97%	97			oat
				Other ingredients	3	=97*0.911	**88.4**	
45	8183	Weetabix Ltd., Crunchy Bran	NC: Weetabix website, accessed June 2013	Wheat Bran-51% Not WG	51			
				WG Wheat- 32%	32			
				Oat Bran- 11% Not WG	11			
				Other ingredients	6	=(32*0.86)	**27.5**	
46	9207/ 10457	Weetabix Ltd., Disney breakfast cereals	NC: My supermarket website, accessed May 2013	Average of three in the Weetabix 'disney' range				rice/oat 50/50
				Disney Power Rangers Star Force				
				Whole Grain Rice flour-31%	31			
				Whole Grain Oats-27%	27			
				Other ingredients	42	=(31*0.861)+(27*0.911)	51.3	
			NC: www.ciao.co.uk, accessed May 2013	Disney Princess Stars				
				Whole Grain Rice flour-31%	31			
				Whole Grain Oats-27%	27			
				Other ingredients	42	=(31*0.861)+(27*0.911)	51.3	
			NC: My supermarket website, accessed May 2013	Disney Pirates Cereal				
				Whole Grain Rice flour-37%	37			
				Whole Grain Oats-37%	37			
				Other ingredients	26	=(37*0.861)+(37*0.911)	65.6	
				Average of the three		=(51.3+51.3+65.6)/3	**56.0**	

Other Brands								
47	210	Post Grapenuts	M-Jones et al	Grapenuts 51% Wholemeal flour	51			wheat
				Other ingredients	49	=51*0.86	**43.9**	
48	3415	Dorset cereal with fruit & nuts	M-Jones et al	As for #6836 Muesli with extra fruit			**46.7**	wheat/oat 25/75
49	10234	Whole Earth perfect balance cereal	NC: My supermarket website, accessed May 2013	Whole Wheat-51%	51			oat/wheat 90/10
				Rice Organically grown-28%	28			
				Other ingredients	21	=51*0.86	**43.9**	
50	10258	Hipp-a-bisc Toddler cereal	S-Jones et al	As for #225 Weetabix			**80.8**	wheat
51	10280	Cow and Gate Sun, Moon and Stars cereal 1 Year+	NC: Similar product to 9207	As for #9207 Weetabix Ltd., Disney breakfast cereals			**56.0**	wheat
52	10302	Dorset cereal with fruit	S-Jones et al	As for #3415 Dorset cereal with fruit and nuts			**46.7**	wheat/oat 25/75
53	10468	Honey Monster Honey Waffle breakfast cereal	NC: Honey Monster website, accessed May 2013	WG Wheat-20%	20			wheat/oat 80/20
				WG Oats-4.5%	4.5			
				Other ingredients	75.5	=(20*0.86)+(4.5*0.911)	**21.3**	
54	10660	Heinz Stage 3/4 breakfast cereal for babies	NC: Organix website, accessed May 2013	No detailed product information but similar ingredients to Organix Goodies Number Jumble cereal				wheat/oat/rice 50/30/20
				WG Rice flour	48			
				WG Wheat flour	24			
				WG Oat flour	12	=(48*0.861)+(24*0.86)+		
				Other ingredients	16	(12*0.911)	**72.9**	
Own brands/ No brand detail								
55	213	Crunchy Clusters-type cereal without nuts	M-Jones et al, CPUK	Using Nestle Clusters 65% Whole grain Wheat	65			wheat
				Other ingredients	35	=(65*0.86)	**55.9**	
56	214	Muesli without sugar	M-Jones et al	Alpen muesli no added sugar			**65.4**	wheat/oat 50/50
57	3008	Honey & nut bran flakes, spmkt own brand (Safeway)	M-Jones et al	Honey & Nut branflakes-56% Whole Wheat	57			wheat
				Other ingredients	43	=57*0.86	**49.0**	
58	4084	Oat & bran flakes, no additions, spmkt own brand	M-Jones et al	As for #202 Kellogg's Bran flakes			**54.2**	wheat
59	5202	Crunchy/Mixed cereal with choc and/or toffee, spmkt own brand (Sainsbury's)	S-Jones et al	As for #213 Crunchy Clusters-type cereal without nuts			**55.9**	wheat
60	5327	Fruit 'n' fibre, own brand	M-Jones et al	As for #229 Kellogg's fruit 'n' fibre			**59.3**	wheat
61	5328	Crunchy/crispy muesli-type cereal	M-Jones et al	As for #213 Crunchy Clusters-type cereal no nut			**55.9**	wheat
62	6823	Wholewheat Flakes, no sultanas	S-Jones et al	As for #202 Kellogg's Bran Flakes			**54.2**	wheat
63	6836	Muesli, no added sugar with extra fruit and nuts	S-Jones et al	As for #7629 Alpen Tropical Fruit			**46.7**	wheat/oat 25/75
64	7623	Bran flakes, no sultanas, spmkt own brand	M-Jones et al	As for #202 Kellogg's Bran flakes			**54.2**	wheat

65	7624	Bran flakes, with sultanas, spmkt own brand	M-Jones et al	As for #203 Sultana Bran			**40.4**	wheat
66	8118	Muesli, 55% fruit, spmkt own brand	M-Jones et al	As for #7629 Alpen Tropical Fruit			**46.7**	wheat/oat 25/75
67	8156	Oat Granola	NC: Quaker website, accessed May 2013	Quaker Oat granola- 55% rolled Oats	55			oat
				Other ingredients	45	=55*0.911	50.1	
			NC: Jordan’s website, accessed May 2013	Jordan’s Oat granola, R& Almond-65% Oat flakes	65			
				Other ingredients	35	=65*0.911	59.2	
			NC: Jordan’s website, accessed May 2013	Jordan’s Oat granola, F&N-58% Oat flakes	58			
				Other ingredients	42	=58*0.911	52.8	
			NC: Tesco online store, accessed May 2013	Kellogg's Crunchy Nut Oat granola- 44% Oats	44			
				Other ingredients	56	=44*0.911	40.1	
			NC: Sainsbury's online store, accessed May 2013	Fuel Nut loaded granola- 48% Oat flakes	48			
				Other ingredients	52	=48*0.911	43.7	
			NC: Sainsbury's online store, accessed May 2013	Sainsbury's Raisin Nut & Honey granola- 60% Oat	60			
				Other ingredients	40	=60*0.911	54.7	
			NC: Tesco online store, accessed May 2013	Tesco Finest Nut granola - 45% Oat flakes	45			
				Other ingredients	55	=45*0.911	41.0	
				Average of all Oat granolas		=(50.1+59.2+52.8+40.1+43.7 +54.7+41)/7	**48.8**	
68	8315	Harvest Morn raisin bran cereal (spmkt own brand, Aldi)	S-Jones et al	As for #7624 Bran flakes, with sultanas, spmkt own brand			**40.4**	wheat
69	8910	Boulders breakfast cereal, spmkt own brand (Tesco)	NC: Tesco online store, accessed May 2013	Multigrain boulders-22% Whole Wheat flour	22			wheat
				Maize flour- 18% Not WG	18			
				Oat flour-4% Not WG	4			
				Other ingredients	56	=22*0.86	**18.9**	
70	10123	Multi Grain Hoops breakfast cereal, spmkt own brand	NC: Sainsbury's online store, accessed May 2013	Cereal flours 75%, Other Ingredients 25%				wheat/oat 20/80
				WG Oat flour-58%	43.5			
				Barley flour-18% Not WG	13.5			
				WG wheat flour-12%	9			
				Maize flour-6% Not WG	4.5			
				Rice flour-6% Not WG	4.5			
				Other ingredients	25	=(43.5*0.911)+(9*0.86)	**47.4**	
71	10305	Malt Wheat cereal, Shreddies Type, spmkt own brand	S-Jones et al	As for #222 Shreddies, any brand, not frosted			**80.0**	wheat
72	10374	Special Flakes breakfast cereal, spmkt own brand (Tesco)	NC: Tesco online store, accessed May 2013	Tesco special flakes cereal				wheat
				Rice-68% Not WG	68			
				WG Wheat flakes-22%	22			
				Other ingredients	10	=22*0.86	**18.9**	
73	10510	Shreddies spmkt own brand, not frosted/coco, not Nestlé	S-Jones et al	As for #222 Shreddies, any brand, not frosted			**80.0**	wheat

M-Jones et al: Matched to Jones et al (2007); S: Similar to Jones et al (2007); NC: New calculation:source; M&W: McCance & Widdowson's Composition of Foods, 6th Edition; M&W CoF: McCance & Widdowson's Composition of Foods, Cereal and Cereal products 3rd supplement: CPUK: Cereal Partners UK, spmkt: Supermarket

Table A.4 Whole grain dry matter content calculation of porridge

	NDNS Food Number	Food Name	Calculation source	Ingredients	Weight (g)	Calculation, including removal of water content of the whole grain	While grain dry matter per 100g	Main grain type
Porridge								
1	215	Porridge, made up with water (with salt)	M-Jones et al, M&W CoF	Oatmeal	60			oat
				Salt	7			
				Water	500			
			M&W CoF recipe	14% weight loss in cooking				
				Total cooked weight	487.62	=((60*0.911)/487.62)*100	**11.2**	
2	216	Porridge, made up with Whole milk (with salt)	M-Jones et al, M&W CoF	As for #215 Porridge, but with milk instead of water			**11.2**	oat
3	217	Porridge, made up with Whole milk & water (with salt)	M-Jones et al, M&W CoF	As for #215 Porridge, but with 250g milk and 250g water			**11.2**	oat
4	219	Ready Brek, as served	M-Jones et al	Ready break 58% Whole Oats, 40g per serving therefore 23.2g Whole Oat per serving	40			oat
				Milk	200			
			M&W CoF, porridge	Assume 14% weight loss in cooking				
				Total cooked weight	206.4	=((23.2*0.911)/206.4)*100	**10.2**	
5	2675	Ready Brek, dry weight	M-Jones et al	Ready break 58% Whole Oats	58			oat
				Other ingredients	42	=58*0.911	**52.8**	
6	3210	Porridge with soya milk, sweetened	M-Jones et al	As for #215 Porridge made with water			**11.2**	oat
7	3211	Porridge with soya milk, unsweetened	M-Jones et al	As for #215 Porridge made with water			**11.2**	oat
8	3421	Ready Brek, made up with skimmed milk	M-Jones et al	As for #219 Ready Brek, as served			**10.2**	oat
9	3797	Porridge, made up with semi-skimmed milk	M-Jones et al	As for #215 Porridge, but with semi-skimmed milk instead of water			**11.2**	oat
10	3925	Porridge, made with skimmed milk, no sugar	M-Jones et al	As for #215 Porridge, but with skimmed milk instead of water			**11.2**	oat
11	5329	Instant Oat cereal with fruit and/or nuts, dry weight, e.g. Oat So Simple	NC: Oat So Simple baked apple taken from Jones et al	Oat So Simple Baked Apple- 71% rolled Oats	71			oat
				Other ingredients	29	=71*0.911	**64.7**	
12	7640	Ready Brek, plain, made with skimmed milk	M-Jones et al	As for #219 Ready Brek, as served			**10.2**	oat
13	7641	Ready Brek, flavoured, with Whole milk	M-Jones et al	Dry Ready Brek 41% Whole Oats, flavoured sachet 40g				oat
				Flavoured Ready Brek Whole Oats	=40*0.41			
				Milk	150			
				Other ingredients	23.6			
			M&W CoF, porridge	Assume 14% weight loss in cooking				
				Total cooked weight	163.4	=((16.4*0.911)/163.4)*100	**9.1**	

14	7642	Ready Brek, flavoured with semi-skimmed milk	M-Jones et al	As for #7641 Ready Break, flavoured but with semi-skimmed milk			**9.1**	oat
15	7646	Porridge made with bran and skimmed milk, added salt	M-Jones et al	As for #219 Ready Brek, as served			**10.2**	oat
16	8005	Ready Brek, flavoured, dry weight	M-Jones et al	Ready Brek flavoured dry- 41% Whole Oats Other ingredients	41 59	=41*0.911	**37.4**	oat
17	8756	Porridge made with 1/2 semi-skimmed milk 1/2 water, no added salt	NC: Adapted from Jones et al	As for #215 Porridge made with water, without salt Oatmeal Water 14% weight loss in cooking Total cooked weight	 60 500 481.6	=((60*0.911)/481.6)*100	**11.3**	oat
18	9348	Instant Oat cereal, made up with water	S-Jones et al	As for #215 Porridge made with water			**11.2**	oat
19	9549	Porridge made with 1/2 skimmed milk 1/2 water	M-Jones et al	As for #215 Porridge, but with 250g skimmed milk and 250g water			**11.2**	oat
20	9555	Porridge made with bran and semi-skimmed milk	M-Jones et al	As for #219 Ready Brek, as served			**10.2**	oat
21	10160	Hipp Organic creamed porridge, dry weight	NC: Ocado website, accessed May 2013	Hipp Organic creamy porridge- WG Oat flakes 28% Other ingredients	28 72	=28*0.911	**25.5**	oat
22	10284	Porridge, made up with water, no added salt	S-Jones et al	As for #215 Porridge			**11.2**	oat
23	10338	Porridge, made up with Whole milk, no added salt	S-Jones et al	As for #215 porridge			**11.2**	oat
24	10358	Plum Baby Four Grain porridge with plum and banana	NC: Amazon website, accessed June 2013	WG Spelt WG Oats Quinoa WG Millet Other ingredients	8 25 4 2 67	=(8*0.8898)+(25*0.911)+(4*0.8672)+(2*0.9133)	**35.2**	wheat/oat/quinoa/millet 20/65/10/5
25	10440	Instant hot Oat cereal, honey flavoured, dry weight e.g.: Ready Brek	S-Jones et al	As for #8005 Ready Brek flavoured, dry weight			**37.4**	oat
26	10473	Porridge made with 1% milk	S-Jones et al	As for #215 Porridge, but with 1% milk instead of water			**11.2**	oat
27	10514	Instant hot Oat cereal, not flavoured, dry weight e.g.: Ready Brek	S-Jones et al	As for #2675 Ready Brek, dry weight			**52.8**	oat
28	10515	Instant hot Oat cereal, not flavoured, dry weight e.g.: Oatsosimple	NC: Quaker website, accessed May 2013	Oat So Simple Original 100% Whole Oats plus Lecithin Assume 99% Whole Oats 1% Lecithin (soya)	 99 1	=(99*0.911)	**90.1**	oat

M-Jones et al: Matched to Jones et al (2007); S: Similar to Jones et al (2007); NC: New calculation:source; M&W: McCance & Widdowson's Composition of Foods, 6th Edition; M&W CoF: McCance & Widdowson's Composition of Foods, Cereal and Cereal products 3rd supplement: CPUK: Cereal Partners UK.

Table A.5 Whole grain dry matter content calculation of savoury snacks, sweet snacks, cakes, deserts and pastries

	NDNS Food Number	Food Name	Calculation source	Ingredients	Weight (g)	Calculation, including removal of water content of the whole grain	While grain dry matter per 100g	Main grain type
Savoury snacks (crispbreads, crackers, crisp-like snacks)								
1	256	Crispbread, rye	M-Jones et al	Ryvita original- Wholemeal rye	99			rye
				Salt	1	=99*0.85	**84.2**	
2	258	Crispbread extra light	S-Jones et al	As for #258 Crispbread, rye			**84.2**	rye
3	275	Twiglets	NC: My supermarket website, accessed May 2013	Jacobs Twiglets 77% Whole Wheat meal	77			wheat
				Other ingredients	23	=77*0.86	**66.2**	
4	4068	Crackerbread, Wholemeal, Ryvita	NC: Ryvita website, accessed May 2013	WG Wheat flour-97%	97			wheat
				Other ingredients	3	=97*0.86	**83.4**	
5	7325	High-fibre Ryvita	M-Jones et al	As for #256 Crispbread, Rye			**84.2**	rye
6	7652	Wholemeal or farmhouse crackers	M-Jones et al, M&W	Wholemeal flour	210			wheat
				Other ingredients	764.4			
			M&W recipe	11% weight loss in cooking				
				Total cooked weight	867.21	=((210*0.86)/867.216)*100	**20.8**	
7	7653	Crispbread, rye, with sesame seeds	NC: Ryvita website, accessed May 2013	Ryvita with sesame seeds -96% WholeGrain Rye	96			rye
				Other ingredients	4	=(96*0.85)	**81.6**	
8	7876	Tortilla Chips	NC: Doritos website, accessed May 2013	Sunflour oil -27%	27			maize
				Salt-0.74g per 100g	0.74			
				Whole Maize kernels	72.26	=72.26*0.878	**63.4**	
9	8117	MultiGrain Crispbread	NC: Ryvita website, accessed May 2013	WG rye flour- 87g per 100g	87			rye
				Other ingredients	13	=87*0.85	**74**	
10	8120	Crispbread, Whole Grain and seeded	NC: Ryvita website, accessed May 2013	As for 7653 Crispbread, rye with sesame seeds			**81.6**	rye
11	8155	Mini Crispbread snacks flavoured, Ryvita Minis	NC: Ryvita website, accessed May 2013	Ryvita Minis, Sweet Chilli-86% WG rye flour	86			rye
				Other ingredients	14	=86*0.85	73.1	
			NC: Ryvita website, accessed May 2013	Ryvita Minis, Salt & Vinegar-85% WG rye flour	85			
				Other ingredients	15	=85*0.85	72.3	
			NC: Ryvita website, accessed May 2013	Ryvita Minis, Cheese and Chive-87% WG rye flour	87			
				Other ingredients	13	=87*0.85	74	
				Average of the flavours		=(73.1+72.3+74)/3	**73.1**	

12	10070	Tortilla Chips in sunseed/high oleic sunflower oil, Doritos	NC: Doritos website, accessed May 2013	As for #7876 Tortilla Chips			**63.4**	maize
13	10182	Walkers Sunbites	NC: Walkers Sunbite website, accessed May 2013	All flavours contain 67% WG cereals, assume equal proportions				wheat/oat/ maize 33/33/33
				Whole Corn	22.33			
				Whole Wheat	22.33			
				Whole Oat flour	22.33			
				Other ingredients	33	=(22.33*0.878)+(22.33*0.86) +(22.33*0.911)	**59.2**	
Sweet snacks (biscuits, RTEBC bars, flapjack, popcorn, yogurts)								
1	259	Digestives, plain	NC: Tesco online store, accessed May 2013	McVities Digestives- 16% Wholemeal Wheat flour	16			wheat
				Other ingredients	84	=16*0.86	**13.8**	
2	260	Digestives, half coated in chocolate	NC: Sainsbury's online store, accessed May 2013	McVities milk chocolate/plain digestives 9% Wholemeal Wheat flour	9			wheat
				Other ingredients	91	=9*0.86	**7.7**	
3	261	Flapjacks, purchased	M-Jones et al, M&W	Rolled Oats	120			oat
				Other ingredients	212			
			M&W recipe	5% weight loss in cooking				
				Total cooked weight	315.4	=((120*0.911)/315.4)*100	**34.7**	
4	267	Oatcakes	M-Jones et al, M&W CoF	Oatmeal	224			oat
				Other ingredients	131.37			
			M&W CoF recipe	26.8% weight loss in cooking				
				Total cooked weight	260.13	=((224*0.911)/260.1345)*100	**78.4**	
5	276	Wholemeal biscuit, plain or flavoured	M-Jones et al, M&W CoF	Wholemeal flour	224			wheat
				Other ingredients	166.5			
			M&W CoF recipe	36.7% weight loss in cooking				
				Total cooked weight	247.18	=((224*0.86)/247.1865)*100	**77.9**	
6	357	Flapjacks, homemade	M-Jones et al, M&W	As for #261 Flapjacks, purchased			**34.7**	oat
7	706	Yogurt, Low fat with muesli/nuts	NC: Sainsbury's online store, accessed May 2013	Danone activia Honey breakfast pot				wheat/oat
				Low fat yogurt -89.4%	89.4			50/50
				Cereal clusters-10.6%	10.6			
				Assume cereal clusters are muesli type, 34% Whole Wheat, 33% Whole Oats		=((10.6*0.34)*0.86)+((10.6*0.33)*0.911)	**6.3**	

8	2268	Popcorn, plain or salted (made with oil/fat)	M-Jones et al, M&W CoF	Oil	45			maize
				Popping corn	75			
				Total cooked weight	120	=((75*0.878)/120)*100	**54.9**	
9	2269	Popcorn, sweet	M-Jones et al, M&W CoF	Oil	45			maize
				Popping corn	75			
				Sugar	200			
				Other ingredients	70			
				Total cooked weight	390	=((75*0.878)/390)*100	**16.9**	
10	4408	Popcorn salted, Microwave or purchased	S-Jones et al	As for #2268 Popcorn, plain or salted			**54.9**	maize
11	5752	Flapjack, with Oats & flour, dipped in chocolate	M-Jones et al, M&W	As for #261 Flapjacks, purchased			**34.7**	oat
12	5770	Cereal bar, fruit-filled e.g. Kellogg's NutriGrain	M-Jones et al, Thane et al	Whole Oats approx. 14%	14			oat
				Other ingredients	86	=14*0.911	**12.8**	
13	7656	Chewy cereal snack bar	M-Jones et al	Quaker Feaster Cranberry and Almond 29% Rolled Oats	23			oat
				Quaker Feaster Choc and Raisin 27% Rolled Oats				
				Tracker Roasted Nut 13% Oat flakes				
				Average of the bars, Oat ingredient	23			
				Other ingredients	77	=23*0.911	**21**	
14	7657	Digestives, with oats, plain, e.g. Hob Nobs	M-Jones et al	McVities HobNobs				wheat/oat 40/60
				Rolled Oats-36.35%	36.35			
				Wholemeal flour - 20.94%	20.94			
				Other ingredients	42.71	=(36.35*0.911)+(20.94*0.86)	**51.1**	
15	7658	Digestives, with oats & chocolate, ½ coated	M-Jones et al	Hob Nob, 19g with 25% chocolate				wheat/oat 40/60
				Rolled Oats	5.18			
				Wholemeal flour	2.98			
				Chocolate	4.75			
				Other ingredients	6.09			
				Total cooked weight	19	=(((5.18*0.911)+(2.98*0.86))/19)*100	**38.3**	
16	7966	Tracker Bar Peanut	M-Jones et al	Tracker Roasted Nut Bar 13% Oat flakes	13			oat
				Other ingredients	87	=13*0.911	**11.8**	
17	7967	Tracker Bar Chocolate Chip	NC: Sainsbury's online store, accessed May 2013	Tracker ChocChip Bar 13% Oat flakes	13			oat
					87	=13*0.911	**11.8**	
18	8044	Cereal bars made with oats only	NC: Jordan's website, accessed May 2013	Jordan's Frusli, Raisin and Hazelnuts - 24% Oat flakes	24			oat

				Other ingredients	76	=24*0.911	21.9	
			NC: Jordan's website, accessed May 2013	Jordan's Frusli, Wild Berry - 33% Oat flakes	33			
				Other ingredients	67	=33*0.911	30.1	
			NC: Nature Valley website, accessed May 2013	Nature Valley Granola Bar, Oats and honey - 56% Rolled Oats	56			
				Other ingredients	44	=56*0.911	51	
			NC: Nature Valley website, accessed May 2013	Nature Valley Granola Bar, Oats and Choc - 56% Rolled Oats	51			
				Other ingredients	49	=51*0.911	46.5	
			NC: Tesco online store, accessed May 2013	Tesco Honey and Oaty granola bar - 49% Oats	49			
				Other ingredients	51	=49*0.911	44.6	
			NC: Quaker website, accessed May 2013	Oat So Simple golden syrup bar- 51% Rolled Oats	51			
				Other ingredients	49	=51*0.911	46.5	
				Average of all Oat Bars		=(21.9+30.1+51+46.5+44.6+46.5)/6	**40.1**	
19	8124	Kellogg's Optivia Cereal Bar	NC: Kfoodtest website, accessed May 2013	Optivia Raisin Bar- 38% Cereals (assuming equal proportions of each)				wheat/oat/rice 33/33/33
				Whole Oats	12.67			
				Brown Rice	12.67			
				Whole Wheat	12.67	=(12.67*0.911)+(12.67*0.861)+(12.67*0.86)		
				Other ingredients	62		**33.3**	
20	8160	Flapjack with chocolate, purchased	S-Jones et al	As for #261 Flapjacks, purchased			**34.7**	oat
21	8165	Kellogg's Special K Bliss Cereal Bar	NC: My supermarket website, accessed May 2013	Special K Bliss bar- 33% Cereals (assuming equal proportions of each)				wheat
				Rice- Not WG	6.6			
				Rice flour- Not WG	6.6			
				Wholewheat	6.6			
				Wheat flour-Not WG	6.6			
				Oat flour-Not WG	6.6			
				Other ingredients	67	=6.6*0.86	**5.7**	
22	8442	Kellogg's NutriGrain Oat Baked Bars	NC: Tesco online store, accessed May 2013	Average of three flavours				oat
				Crunchy Oat granola honey-61% WG Oats	61			
				Other ingredients	39	=61*0.911	55.6	
			NC: Tesco online store, accessed May 2013	Crunchy Oat granola cinnamon-67% WG Oats	67			
				Other ingredients	33	=67*0.911	61	
			NC: Tesco online store, accessed May 2013	Crunchy Oat granola choc chip-54% WG Oats	54			
				Other ingredients	46	=54*0.911	49.2	
				Average of the three		=(55.6+61+49.2)/3	**55.3**	
23	8989	Digestives, Reduced Fat		McVities light digestive biscuits				wheat

			NC: Sainsbury's online store, accessed May 2013	Wheat flour- 60%	60			
				Wholemeal Wheat flour-13%	13			
				Other ingredients	27	=13*0.86	**11.2**	
24	9472	Digestives, Reduced Fat, half coated in chocolate	NC: Tesco online store, accessed May 2013	McVities's Light digestives				wheat
				Wheat flour-48% Not WG	48			
				Wholemeal Wheat flour-11%	11			
				Other ingredients	29	=11*0.86	**9.5**	
25	9770	Oatmeal cookies	NC: Sainsbury's online store, accessed May 2013	Oat and treacle cookies- Oats 32%	32			oat
				Other ingredients	68	=(32*0.911)	**29.1**	
26	9881	Yogurt, full fat with cereal/crumble	NC: Sainsbury's online store, accessed May 2013	Average of following yoghurts				wheat
				Muller Crunch Corner, 3 flavours 10% cereal				
				Muller Crunch Corner, 4 flavours 11% cereal				
				Rachel's organic and granola yohurt-11% granola				
				Activita breakfast pot, 2 flavours 10.6% cereal				
				Average of all 10.62% cereal				
				Assume cereal/crispy muesli type cereal 55.6% dry WG/65% wet WG		=10.62*0.556	**5.9**	
27	10064	Flapjacks, reduced fat	S-Jones et al	As for #261 Flapjacks, purchased			**34.7**	oat
28	10130	Kellogg's NutriGrain Elevenses Bars, any, not carrot	NC: Tesco website, accessed May 2013	Average of four flavours				wheat/oat
				Nutri-grain elevenses raisin bakes-36% cereals				50/50
				Rolled Oats	18			
				Wheat flour	18			
				Other ingredients	64	=18*0.911	16.4	
			NC: Tesco website, accessed May 2013	Nutri-grain elevenses choc hip bakes-32% cereals				
				Rolled Oats	16			
				Wheat flour	16			
				Other ingredients	68	=16*0.911	14.6	
			NC: Tesco website, accessed May 2013	Nutri-grain elevenses golden oat bakes-35% cereals				
				Rolled Oats	17.5			
				Wheat flour	17.5			
				Other ingredients	65	=17.5*0.911	15.9	

			NC: Tesco website, accessed May 2013	Nutri-grain elevenses ginger bakes 41% cereals				
				Rolled Oats	20.5			
				Wheat flour	20.5			
				Other ingredients	59	=20.5*0.911	18.7	
				Average of the flavours		=(16.4+14.6+15.9+18.7)/4	**16.4**	
29	10181	Organix Carrot Cake Cereal Bar	NC: Organix website, accessed May 2013	Organix Goodies raspberry and apple soft oaty bars (very similar)				oat
				WG Oats -46%	46			
				Other ingredients	54	=46*0.911	**41.9**	
30	10184	Organix Flavoured Baby Rice Cakes	NC: Organix website, accessed May 2013	Organix rice cakes Average of 5 flavours				rice
				Stage 2 (7months+) 3 flavours-85% WG rice	85			
				Other ingredients	15	=85*0.861	73.2	
			NC: Organix website, accessed May 2013	Stage 2 (7months+) raspberry and blueberry-78% WG rice	78			
				Other ingredients	22	=78*0.861	67.2	
			NC: Organix website, accessed May 2013	Stage 2 (7months+) apple-79% WG rice	79			
				Other ingredients	21	=79*0.861	68	
				Average of the flavours		=(3*73.2+67.2+68)/5	**71**	
31	10187	Kellogg's Special K Cereal Bars, Fruit with yogurt topping only	NC: Tesco online store, accessed May 2013	Special K red berry cereal bar-45% Special K				wheat
				Special K cereal, 12% WG dry, 14% WG wet	45			
				Other ingredients	55	=45*0.12	5.4	
			NC: Tesco online store, accessed May 2013	Special K peach and apricot cereal bar-44% Special K	44			
				Other ingredients	56	=44*0.12	5.3	
				Average of the two		=(5.4+5.28)/2	**5.3**	
32	10207	Organix Fruit Cereal Bars, not carrot/chocolate	NC: Organix website, accessed May 2013	Average of three flavours				oat
				Oragnix Goodies strawberry and apple-48% WG Oats	48			
				Other ingredients	52	=48*0.911		
			NC: Organix website, accessed May 2013	Oragnix Goodies apricot-44% WG Oats	44			
				Other ingredients	56	=44*0.911		
			NC: Organix website, accessed May 2013	Oragnix Goodies raspberry and apple-48% WG Oats	48			
				Other ingredients	52	=48*0.911		
				Average of the flavours		=(43.7+40.1+43.7)/3	**42.5**	

33	10216	Kellogg's Special K Mini Breaks	NC: Tesco online store, accessed May 2013	Special K mini breaks original				wheat/
				WG barley flakes-27%	27			barley
				Whole Wheat-5%	5			15/85
				Other ingredients	68	=(27*0.883)+(5*0.86)	**28.1**	
34	10260	Kellogg's NutriGrain Soft Oaties Cookies	S-Jones et al	As for #5770 Cereal bar, fruit-filled e.g. Kellogg's NutriGrain			**12.8**	oat
35	10286	Kellogg's NutriGrain Elevenses Carrot Cake Bar	NC: My supermarket website, accessed May 2013	Nutri-grain elevenses carrot cake bake-35% cereal, assume equal proportions				oat
				Rolled Oats	17.5			
				Wheat flour-Not WG	17.5			
				Other ingredients	65	=17.5*0.911	**15.9**	
36	10300	Ryvita Goodness Bars	NC: My supermarket website, accessed May 2013	Average of two flavours				rye
				Ryvita Goodness mixed berry-28% WG Rye flakes	28			
				Other ingredients	72	=28*0.85	23.8	
				Ryvita Goodness apple and sultana 24% WG Rye flakes	24			
				Other ingredients	76	=24*0.85	20.4	
				Average of the flavours		=(23.8+20.4)/2	**22.1**	
37	10326	Fruit and Grain Cereal Bar, supermarket own brand (ASDA)	NC: ASDA online store, accessed May 2013	Asda (chosen by you) Fruit and Grain soft baked bars, 4 flavours				oat
				All flavours, Rolled Oats-5.3%	5.3			
				Other ingredients	94.7	=5.3*0.911	**4.8**	
38	10329	Organix Cookie Bites	NC: My supermarket website, accessed May 2013	Organix Organic no junk orange cookie bites				wheat/oat
				WG Wheat flour	29			75/25
				WG Oats	9			
				Other ingredients	62	=(29*0.86)+(9*0.911)	33.1	
			NC: My supermarket website, accessed May 2013	Organix Organic no junk cocoa cookie bites				
				WG Wheat flour	26			
				WG Oats	9			
				Other ingredients	65	=(26*0.86)+(9*0.911)	30.6	
				Average of the flavours		=(33.1+30.56)/2	**31.8**	
39	10329	Organix Goodiess Biscuit, 12 Month+, WholeGrain flour only	NC: Organix website, accessed May 2013	Orgainx Goodies Animal biscuits				wheat
				WG Wheat flour	31			
				Other ingredients	69	=31*0.86	26.7	

			NC: Organix website, accessed May 2013	Organix Goodies Alphabet biscuits				
				WG Wheat flour	29			
				Other ingredients	71	=29*0.86	24.9	
				Average of the flavours		=(26.7+24.9)/2	**25.8**	
40	10467	Nestlé Oats and More Cereal Bars	NC: My supermarket website, accessed May 2013	Nestle Oats and More Chocolate bar-46.2% cereal grains				oat/wheat
				WG Oat flakes	31.4			90/10
				WG Wheat	2.42			
				Rice- Not WG	2.42			
				Oat Bran-Not WG	2.7			
				Other ingredients	61.06	=(31.4*0.911)+(2.42*0.86)	30.7	
			NC: My supermarket website, accessed May 2013	Nestle Oats and More Strawberry bar-42.8% cereal grains				
				WG Oat flakes	29.1			
				WG Wheat	2.24			
				Rice- Not WG	2.24			
				Oat Bran- Not WG	2.5			
				Other ingredients	63.92	=(29.1*0.911)+(2.24*0.86)	28.4	
				Average of the flavours		=(30.7+28.4)/2	**29.6**	
41	10523	Popcorn, homemade with olive oil	S-Jones et al	As for #2268 Popcorn, plain or salted			**54.9**	maize
42	10536	Weetabix Ltd., Weetabix Oaty Bars	NC: Weetabix website, accessed May 2013	Weetabix Oaty bars milk chocolate				oat/wheat
				Whole Oats-29%	29			90/10
				Whole Wheat-3.2%	3.2			
				Other ingredients	67.8	=(29*0.911)+(3.2*0.86)	29.2	
			NC: Weetabix website, accessed May 2013	Weetabix Oaty bars white chocolate				
				Whole Oats-29%	29			
				Whole Wheat-3.2%	3.2			
				Other ingredients	67.8	=(29*0.911)+(3.2*0.86)	29.2	
			NC: Weetabix website, accessed May 2013	Weetabix Oaty bars strawberry				
				Whole Oats-27%	27			
				Whole Wheat-2.8%	2.8			
				Other ingredients	70.2	=(27*0.911)+(2.8*0.86)	27	
				Average of the flavours		=(29.17+29.17+27)/3	**28.4**	
43	10578	Kellogg's Fibre Plus Cereal Bars	NC: Amazon website, accessed June 2013	Kellogg's Fibre plus milk chocolate bar				oat
				Oats-20%	20			
				Other ingredients	80	=20*0.911	**18.2**	
44	10584	Belvita breakfast biscuits	NC: Sainsbury's online store, accessed May 2013	Belvita biscuits, 4 flavours with WG details				wheat/oat/ barley/rye
				Milk and Cereal				35/40/ 15/10
				Wheat flour-Not WG	51.3			
				Oat flakes	8.5			
				WG Wheat	6.1			
				WG Barley flour	2.7			
				WG Rye flour	2			
				WG Spelt flour	1			

				Other ingredients	28.4	=(8.5*0.911)+(6.1*0.86)+(2.7*0.883)+(2*0.85)+(1*0.8898)	18	
			NC: Sainsbury's online store, accessed May 2013	Fruit and Fibre				
				Wheat flour-Not WG	35.1			
				Oat flakes	18.8			
				WG Wheat	1			
				WG Barley flour	1			
				WG Rye flour	1			
				WG Spelt flour	1			
				Other ingredients	42.1	=(18.8*0.911)+(1*0.86)+(1*0.883)+(1*0.85)+(1*0.8898)	20.6	
			NC: Sainsbury's online store, accessed May 2013	Crunchy Oats				
				Wheat flour-Not WG	26.8			
				Oat flakes	19.4			
				WG Wheat	1			
				WG Barley flour	1			
				Malted Rye flakes	19.4			
				WG Spelt flour	1			
				Other ingredients	31.4	=(19.4*0.911)+(1*0.86)+(1*0.883)+(19.4*0.85)+(1*0.8898)	36.8	
			NC: Sainsbury's online store, accessed May 2013	Cranberry				
				Wheat flour-Not WG	25.6			
				Oat flakes	21.8			
				WG Wheat	1			
				WG Barley flour	1			
				Malted Rye flakes	20.5			
				WG Spelt flour	1			
				Other ingredients	29.1	=(21.8*0.911)+(1*0.86)+(1*0.883)+(20.5*0.85)+(1*0.8898)	39.9	
				Average of the flavours		=(18+20.6+36.8+39.9)/4	**28.8**	
45	10770	Popcorn plain, no added fat, sugar or salt	S-Jones et al	As for #2268 Popcorn, plain or salted			**54.9**	Maize

Cakes, buns, pastries and deserts								
1	167	Wholemeal malt loaf	M-Jones et al	Average of two malt loaf recipes, BBC website				wheat
				Recipe 1: Wholemeal flour	350			
				Other ingredients	599			
			M&W CoF, Milk bread	Assume 10.5% weight loss in cooking				
				Total cooked weight	849.35	=((350*0.86)/849.355)*100	35.4	
				Recipe 2: Wholemeal flour	225			
				Other ingredients	716.25			
			M&W CoF, Milk bread	Assume 10.5% weight loss in cooking				
				Total cooked weight	842.41	=((225*0.86)/842.41875)*100	23	
				Average of the two recipes		=(35.4+23)/2	**29.2**	
2	342	Jam/treacle tart, Wholemeal	M-Jones et al	Shortcrust pastry 300g-60.24% Wholemeal flour	180.72			wheat
				Other ingredients	300			
			M&W CoF recipe	0% weight loss in cooking				
				Total cooked weight	600	=((180.72*0.86)/600)*100	**25.9**	
3	372	Wholemeal scones, plain	M-Jones et al, M&W CoF	Wholemeal flour	200			wheat
				Other ingredients	200			
			M&W CoF recipe	14% weight loss in cooking				
				Total cooked weight	344	=((200*0.86)/344)*100	**50**	
4	376	Swiss roll/sponge, no fat, w'meal, jam filling	M-Jones et al, M&W CoF	Wholemeal flour	70			wheat
				Other ingredients	333			
			M&W CoF recipe	13.8% weight loss in cooking				
				Total cooked weight	347.38	=((70*0.86)/347.386)*100	**17.3**	
5	407	Wholemeal fruit bun	M-Jones et al	Wholemeal flour	450			wheat
				Other ingredients	420			
			M&W CoF recipe, Hot cross bun	Assuming 15% weight loss in cooking				
				Total cooked weight	739.5	=((450*0.86)/739.5)*100	**52.3**	
6	3189	Wholemeal fruit scones	M-Jones et al, M&W CoF	Wholemeal flour	200			wheat
				Sultanas	50			
				Other ingredients	200			

			M&W CoF recipe	14% weight loss in cooking				
				Total cooked weight	387	=((200*0.86)/387)*100	**44.4**	
7	5862	Dumplings with plain and Wholemeal flour and marg	M-Jones et al, Thane et al	Wholemeal flour	180			wheat
				Other ingredients	355			
				52.7% weight gain in cooking				
				Total cooked weight	816.94	=((180*0.86)/816.9486)*100	**18.9**	
8	7675	Hot cross buns, Wholemeal	M-Jones et al, M&W	Wholemeal flour	450			wheat
				Other ingredients	666			
			M&W recipe	15% weight loss in cooking				
				Total cooked weight	948.6	=((450*0.86)/948.6)*100	**40.8**	
9	7690	Wholemeal fruit cake, purchased	M-Jones et al, M&W CoF	Recipe page 122 Wholemeal fruit cake			**14.4**	wheat
10	9363	Oatcakes, pancake-type, not biscuit	M-Jones et al, M&W CoF	Using Tortillas recipe- Oatmeal	266			oat
				Water	150			
				Salt	2.5			
			M&W CoF, Tortillas recipe	17.3% weight loss in cooking				
				Total cooked weight	346.09	=((266*0.911)/346.1)*100	**70**	

M-Jones et al: Matched to Jones et al (2007); S: Similar to Jones et al (2007); NC: New calculation:source; M&W: McCance & Widdowson's Composition of Foods, 6th Edition; M&W CoF: McCance & Widdowson's Composition of Foods, Cereal and Cereal products 3rd supplement: CPUK: Cereal Partners UK.

Appendix B Whole grain content of foods consumed in the NDNS 2008-2011

Table B.1 Whole grain dry matter percentage of whole grain foods reported in four-day diet diaries from the NDNS rolling programme 2008-2011

NDNS Food Number	Food Name	Whole grain dry matter per 100g as consumed
5	Barley, Whole Grain, boiled in water	30.4
4	Barley, Whole Grain, dried	88.3
10584	Belvita breakfast biscuits	28.8
8910	Boulders breakfast cereal, supermarket own brand (Tesco)	18.9
7624	Bran flakes, with sultanas, supermarket own brand	40.4
7623	Bran flakes, without sultanas, supermarket own brand	54.2
112	Bread, granary	49.0
113	Bread, granary, toasted	57.4
7617	Bread, Oatmeal	11.8
7618	Bread, Oatmeal, toasted	13.9
117	Bread, pitta, Wholemeal	65.3
114	Bread, rye	54.1
115	Bread, rye, toasted	63.4
4168	Bread, white and Wholemeal best of both, eg Hovis	24.9
3904	Bread, white and Wholemeal with added wheatgerm	24.9
133	Bread, Wholemeal	54.8
7614	Bread, Wholemeal, slimmers only, eg Nimble	54.8
3172	Bread, Wholemeal, slimmers', toasted	64.1
138	Bread, Wholemeal, toasted	64.1
10009	Brown Basmati Rice, cooked	34.0
10008	Brown Basmati Rice, raw	86.1
10011	Brown easycook Italian/American rice, cooked	34.0
10010	Brown easycook Italian/American rice, raw	86.1
5770	Cereal bar, fruit-filled eg Kellogg's NutriGrain	12.8
8044	Cereal bars made with oats only	40.1
3457	Chapati, Wholemeal with olive oil	58.8
3937	Chapati, Wholemeal, made with blended vegetable oil	58.8
8603	Chapati, Wholemeal, made with sunflower oil	58.8
7656	Chewy cereal snack bar	21.0
10280	Cow and Gate Sun, Moon and Stars cereal 1 Year+	56.0
4068	Crackerbread, Wholemeal, Ryvita	83.4
258	Crispbread extra light	84.2
256	Crispbread, rye	84.2
7653	Crispbread, rye, with sesame seeds	81.6
8120	Crispbread, Whole Grain and seeded	81.6
213	Crunchy Clusters-type cereal without nuts	55.9
5328	Crunchy/crispy muesli-type cereal	55.9
5202	Crunchy/Mixed cereal with choc and/or toffee, supermarket own brand (Sainsbury's)	55.9
8989	Digestives, Reduced Fat	11.2
260	Digestives, half coated in chocolate	7.7
259	Digestives, plain	13.8

9472	Digestives, Reduced Fat, half coated in chocolate	9.5
7658	Digestives, with oats & chocolate, ½ coated	38.3
7657	Digestives, with oats, plain, eg Hob Nobs	51.1
10302	Dorset cereal with fruit	46.7
3415	Dorset cereal with fruit & nuts	46.7
5862	Dumplings with plain and Wholemeal flour and marg	18.9
7769	Eggy bread, Wholemeal, milk, blended oil	10.0
8160	Flapjack with chocolate, purchased	34.7
5752	Flapjack, with Oats & flour, dipped in chocolate	34.7
357	Flapjacks, homemade	34.7
261	Flapjacks, purchased	34.7
10064	Flapjacks, reduced fat	34.7
7616	French stick, granary	49.0
5327	Fruit ‘n’ fibre, own brand	59.3
10326	Fruit and Grain Cereal Bar, supermarket own brand (ASDA)	4.8
8315	Harvest Morn raisin bran cereal (supermarket own brand, Aldi)	40.4
10660	Heinz Stage 3/4 breakfast cereal for babies	72.9
7325	High-fibre Ryvita	84.2
10160	Hipp Organic creamed porridge, dry weight	25.5
10258	Hipp-a-bisc Toddler cereal	80.8
3008	Honey & nut branflakes, supermarket own brand (Safeway)	49.0
10468	Honey Monster Honey Waffle breakfast cereal	21.3
7675	Hot cross buns, Wholemeal	40.8
10440	Instant hot Oat cereal, honey flavoured, dry weight eg: Ready Brek	37.4
10515	Instant hot Oat cereal, not flavoured, dry weight eg: Oatsosimple	90.1
10514	Instant hot Oat cereal, not flavoured, dry weight eg: Ready Brek	52.8
5329	Instant Oat cereal with fruit and/or nuts, dry weight, e.g. Oat So Simple	64.7
9348	Instant Oat cereal, made up with water	11.2
342	Jam/treacle tart, Wholemeal	25.9
8086	Kellogg’s Crunchy nut clusters	40.1
5204	Kellogg’s Frosted Wheats	71.4
229	Kellogg’s Fruit ‘n’ Fibre	59.3
6822	Kellogg’s Just Right, ½-fat muesli	28.7
7051	Kellogg’s Raisin Wheats	62.8
223	Kellogg’s Special K	12.0
8013	Kellogg’s Special K berries any fruit addition not choc or yogurt	10.3
8014	Kellogg’s Special K bliss with choc or yogurt pieces	12.0
2970	Kellogg’s Special K with red berries	10.3
202	Kellogg's Bran flakes	54.2
10762	Kellogg's Choc 'n' Roll breakfast cereal	39.0
10578	Kellogg's Fibre Plus Cereal Bars	18.2
8486	Kellogg's Honey Nut Loops	54.9
228	Kellogg's MultiGrain Start	28.7
10130	Kellogg's NutriGrain Elevenses Bars, any, not carrot	16.4
10286	Kellogg's NutriGrain Elevenses Carrot Cake Bar	15.9
8442	Kellogg's NutriGrain Oat Baked Bars	55.3
10260	Kellogg's NutriGrain Soft Oaties Cookies	12.8
10132	Kellogg's Optivia berry breakfast cereal	55.3

8124	Kellogg's Optivia Cereal Bar	33.3
10125	Kellogg's Rice Krispies multiGrain breakfast cereal	23.7
8165	Kellogg's Special K Bliss Cereal Bar	5.7
10187	Kellogg's Special K Cereal Bars, Fruit with yogurt topping only	5.3
10596	Kellogg's Special K fruit and nut clusters	14.9
8140	Kellogg's Special K medley cereal	14.9
10216	Kellogg's Special K Mini Breaks	28.1
10330	Kellogg's Special K Oats and honey	40.0
10355	Kellogg's Special K Sustain cereal	55.1
10305	Malt Wheat cereal, Shreddies Type, supermarket own brand	80.0
3259	Millet, boiled	30.4
8155	Mini Crispbread snacks flavoured, Ryvita Minis	73.1
214	Muesli without sugar	65.4
8118	Muesli, 55% fruit, supermarket own brand	46.7
6836	Muesli, no added sugar with extra fruit and nuts	46.7
173	Muffins, English, Wholemeal or bran	61.4
10123	Multi Grain Hoops breakfast cereal, supermarket own brand	47.4
8117	MultiGrain Crispbread	74.0
8019	Multiseed Bread, Wholemeal	49.0
10204	Multiseed Bread, Wholemeal, toasted	57.4
8441	Nestlé Almond Oats and More	58.7
8712	Nestlé Clusters	43.0
8383	Nestlé Coco Shreddies	48.2
8409	Nestlé Cookie Crisp cereal	29.8
9032	Nestlé Curiously Cinnamon, formerly Cinnamon Grahams	27.9
8182	Nestlé Frosted Shreddies	48.4
8169	Nestlé Golden Nuggets	27.6
9275	Nestlé Honey Nut Cheerios	52.8
6824	Nestlé Honey Nut Shredded Wheat	67.1
8163	Nestlé Honey Oats and More	62.3
7637	Nestlé Multi Cheerios	64.3
5199	Nestlé Nesquik chocolate cereal	38.4
10467	Nestlé Oats and More Cereal Bars	29.6
10254	Nestlé Raisin Oats and More	54.1
221	Nestlé Shredded Wheat	86.0
8190	Nestlé Shredded Wheat Fruitful, mini fruit	57.6
10511	Nestlé Shreddies, not frosted not coco	80.0
4084	Oat & bran flakes, no additions, supermarket own brand	54.2
8156	Oat Granola	48.8
267	Oatcakes	78.4
9363	Oatcakes, pancake-type, not biscuit	70.0
9770	Oatmeal cookies	29.1
23	Oatmeal, raw	91.1
2687	Oats with losses on boiling	91.1
24	Oats, rolled, quick cook	91.8
10181	Organix Carrot Cake Cereal Bar	41.9
10329	Organix Cookie Bites	31.8
10184	Organix Flavoured Baby Rice Cakes	71.0

10207	Organix Fruit Cereal Bars, not carrot/chocolate	42.5
10329	Organix Goodiess Biscuit, 12 Month+, WholeGrain flour only	25.8
8595	Paratha, Wholemeal	27.2
36	Pasta spaghetti, Wholemeal boiled	30.9
35	Pasta, spaghetti, Wholemeal, dried	89.5
10358	Plum Baby Four Grain porridge with plum and banana	35.2
10770	Popcorn plain, no added fat, sugar or salt	54.9
4408	Popcorn salted, Microwave or purchased	54.9
10523	Popcorn, homemade with olive oil	54.9
2268	Popcorn, plain or salted (made with oil/fat)	54.9
2269	Popcorn, sweet	16.9
10473	Porridge made with 1% milk	11.2
8756	Porridge made with 1/2 semi-skimmed milk 1/2 water, no added salt	11.3
9549	Porridge made with 1/2 skimmed milk 1/2 water	11.2
9555	Porridge made with bran and semi-skimmed milk	10.2
7646	Porridge made with bran and skimmed milk, added salt	10.2
3210	Porridge with soya milk, sweetened	11.2
3211	Porridge with soya milk, unsweetened	11.2
3797	Porridge, made up with semi-skimmed milk	11.2
215	Porridge, made up with water (with salt)	11.2
10284	Porridge, made up with water, no added salt	11.2
217	Porridge, made up with Whole milk & water (with salt)	11.2
216	Porridge, made up with Whole milk (with salt)	11.2
10338	Porridge, made up with Whole milk, no added salt	11.2
3925	Porridge, made with skimmed milk, no sugar	11.2
210	Post Grapenuts	43.9
10424	Quinoa, cooked	28.4
219	Ready Brek, as served	10.2
2675	Ready Brek, dry weight	52.8
7642	Ready Brek, flavoured with semi-skimmed milk	9.1
8005	Ready Brek, flavoured, dry weight	37.4
7641	Ready Brek, flavoured, with Whole milk	9.1
3421	Ready Brek, made up with skimmed milk	10.2
7640	Ready Brek, plain, made with skimmed milk	10.2
10017	Red rice, cooked	21.2
49	Rice, brown, boiled	34.0
169	Roll, granary/brown/wheatgerm, toasted	57.4
7620	Rolls, brown/granary/wheatgerm, crusty	49.0
7621	Rolls, brown/granary/wheatgerm, soft	49.0
8142	Rolls, white and Wholemeal blend	24.9
161	Rolls, Wholemeal	54.8
172	Rolls, Wholemeal, toasted	64.1
18	Rye flour (100%)	85.0
10300	Ryvita Goodness Bars	22.1
10022	Self raising Wholemeal flour	86.0
10510	Shreddies supermarket own brand, not frosted/coco, not Nestlé	80.0
222	Shreddies, any brand, not frosted	80.0
3603	Soda bread, Wholemeal	58.5

3431	Soda bread, Wholemeal, toasted	68.5
10374	Special Flakes breakfast cereal, supermarket own brand (Tesco)	18.9
203	Sultana Bran, bran flakes with sultanas	40.4
376	Swiss roll/sponge, no fat, w’meal, jam filling	17.3
7876	Tortilla Chips	63.4
10070	Tortilla Chips in sunseed/high oleic sunflower oil, Doritos	63.4
10754	Tortilla wrap, Wholemeal	66.1
7967	Tracker Bar Chocolate Chip	11.8
7966	Tracker Bar Peanut	11.8
275	Twiglets	66.2
10182	Walkers Sunbites	59.2
212	Weetabix Ltd., Alpen muesli with added sugar	59.3
7629	Weetabix Ltd., Alpen Tropical Fruit, Muesli with extra fruit	46.7
8183	Weetabix Ltd., Crunchy Bran	27.5
9207	Weetabix Ltd., Disney breakfast cereals	56.0
10457	Weetabix Ltd., Disney breakfast cereals	56.0
8103	Weetabix Ltd., Oatabix	88.4
225	Weetabix Ltd., Weetabix	80.8
6132	Weetabix Ltd., Weetabix Fruitibix	66.7
3875	Weetabix Ltd., Weetabix Mini's chocolate crisp, Previously known as Chocolate Weetabix Mini Crunch	66.7
10536	Weetabix Ltd., Weetabix Oaty Bars	28.4
7632	Weetabix Ltd., Weetos	23.2
10234	Whole Earth perfect balance cereal	43.9
276	Wholemeal biscuit, plain or flavoured	77.9
2643	Wholemeal flour with losses	86.0
10021	Wholemeal flour, bread making	86.0
407	Wholemeal fruit bun	52.3
7690	Wholemeal fruit cake, purchased	14.4
3189	Wholemeal fruit scones	44.4
167	Wholemeal malt loaf	29.2
7652	Wholemeal or farmhouse crackers	20.8
372	Wholemeal scones, plain	50.0
6823	Wholewheat Flakes, no sultanas	54.2
9208	Wholewheat Spaghetti canned in tomato sauce	15.2
10013	Wild rice, cooked	26.1
9881	Yogurt, full fat with cereal/crumble	5.9
706	Yogurt, Low fat with muesli/nuts	6.3

Appendix C Cereal Food Questionnaire

CONFIDENTIAL

1000 FAMILIES
from Newcastle

CEREAL FOOD QUESTIONNAIRE

Newcastle University

COMPLETING THE QUESTIONNAIRE

HOW TO FILL IN THE QUESTIONNAIRE

There are different types of questions in this booklet. ***Most of them can be answered by ticking a box.*** *Please do not leave any question unanswered and try to answer all questions as accurately and honestly as possible. People and families are very different and there are no 'right' or 'wrong' answers.*

For example In the **last year**, did you usually eat breakfast cereal ?

☑ Yes ☐ No

Questions 1 to 4 relate to your diet during the ***LAST YEAR****.*

For each food there is an amount shown, either a 'medium serving' or a common household unit such as a slice or bowl. Please indicate how often, on average, you have eaten the specified amount of each food ***during the LAST YEAR*** *by placing a tick in one of the options available.*

For example

Someone who usually ate cornflakes for breakfast on weekdays and had a cooked breakfast with two pieces of white toast every Saturday, as well as ate soup with a white bread roll once a week would complete the questions as follows:

	Average use last year								
Cereals (One bowl)	Never or less than once a month	1 to 3 times a month	Once a week	2 to 4 times a week	5 to 6 times a week	Every day	2 to 3 times a day	4 to 5 times a day	6 or more times a day
(c) Non-sugar coated cereals *e.g. Cornflakes, Rice Crispies*	☐	☐	☐	☐	☑	☐	☐	☐	☐
Bread and Savoury Biscuits (One slice or one biscuit)									
(a) White bread and rolls, white pita bread **(per slice/roll)**	☐	☐	☐	☑	☐	☐	☐	☐	☐

Note*: The combination of two slices of toast and one bread roll per week equates to 3 servings per week indicated by ticking '2 to 4' times per week.*

If you make a mistake please cross over the incorrect answer and ticket the correct box

(a) White bread and rolls, white pita bread **(per slice/roll)**	☐	☐	☐	☒	☑	☐	☐	☐	☐

If you need any help filling in the questionnaire please contact:

The Newcastle Thousand Families Study Team
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Newcastle University
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NE1 4LP

Telephone 0191 282 1353
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PLEASE TURN OVER

Q1 Please estimate your average consumption of **bread and savoury biscuits** during the **last year**, taking care to complete every line. **(Complete every line - tick one box per line)**

Bread and Savoury Biscuits (One slice or one biscuit)	Average use last year: Never or less than once a month	1 to 3 times a month	Once a week	2 to 4 times a week	5 to 6 times a week	Every day	2 to 3 times a day	4 to 5 times a day	6 or more times a day
(a) White bread and rolls, white pita bread **(per slice/roll)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(b) Brown bread and rolls **(per slice/roll)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(c) Wholemeal bread and rolls **(per slice/roll)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(d) Half and Half/50:50 white and wholemeal bread and rolls **(per slice/roll)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(e) Wholemeal pita bread **(each)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(f) Granary bread and rolls **(per slice/roll)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(g) Rye bread and rolls **(per slice/roll)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(h) Oatmeal bread and rolls **(per slice/roll)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(i) Garlic bread **(per serving)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(j) Naan bread, chapatti **(each)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(k) Tortilla wraps **(each)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(l) Wholemeal Tortilla wraps **(each)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(m) Other speciality breads **(each)** (please state and tick for frequency) 1.	☐	☐	☐	☐	☐	☐	☐	☐	☐
2.	☐	☐	☐	☐	☐	☐	☐	☐	☐
(n) Cream crackers, cheese biscuits **(each)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(o) Crispbread, *e.g. Ryvita* **(one)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(p) Oatcakes **(one)**	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q2 Please estimate your average consumption of **potatoes, rice and pasta** during the **last year**, taking care to complete every line. **(Complete every line - tick one box per line)**

Potatoes, Rice and Pasta (Medium Serving)	Average use last year: Never or less than once a month	1 to 3 times a month	Once a week	2 to 4 times a week	5 to 6 times a week	Every day	2 to 3 times a day	4 to 5 times a day	6 or more times a day
(a) Boiled, mashed, instant, or jacket potatoes **(about ⅓ of a plate)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(b) Chips **(side order with meal,** chip-shop portions count as 2**)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(c) Roast potatoes **(3-5 potatoes)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(d) Potato salad **(per small tub, 2 tablespoons)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(e) White rice **(½ plateful, or in a dish e.g. rice salad, risotto)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(f) Brown rice **(½ plateful, or in a dish e.g. rice salad, risotto)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(g) White or green pasta *e.g. spaghetti, macaroni, noodles,* **(½ plate)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(h) Wholemeal pasta *e.g. spaghetti, macaroni, noodles,* **(½ plate)**	☐	☐	☐	☐	☐	☐	☐	☐	☐

Question 2 continues on the next page...

Question 2 continued from Page 2 ("Please estimate your average consumption of **potatoes, rice and pasta** during the **last year**, taking care to complete every line")...

Potatoes, Rice and Pasta (Medium Serving)	Average use last year: Never or less than once a month	1 to 3 times a month	Once a week	2 to 4 times a week	5 to 6 times a week	Every day	2 to 3 times a day	4 to 5 times a day	6 or more times a day
(i) Tinned pasta *e.g. spaghetti, ravioli, macaroni*, **(½ standard tin)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(j) Tinned Wholemeal pasta *e.g. spaghetti, ravioli, macaroni*, **(½ standard tin)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(k) Lasagne, cannelloni, moussaka made with white or green pasta **(as individual meal)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(l) Lasagne, cannelloni, moussaka made with wholemeal pasta **(as individual meal)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(m) Pizza **(10" = 1, 12" = 2, 12+"= 3 -4)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(n) Quinoa **(½ plateful, or in a dish e.g. salad)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(o) Wholegrain dishes not mentioned (please state and tick for frequency)									
1.	☐	☐	☐	☐	☐	☐	☐	☐	☐
2.	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q3 Please estimate your average consumption of **cereals** during the **last year**, taking care to complete every line. **(Complete every line - tick one box per line)**

Cereals (One bowl)	Average use last year: Never or less than once a month	1 to 3 times a month	Once a week	2 to 4 times a week	5 to 6 times a week	Every day	2 to 3 times a day	4 to 5 times a day	6 or more times a day
(a) Porridge, Readybrek, Oat So Simple	☐	☐	☐	☐	☐	☐	☐	☐	☐
(b) Sugar coated cereals *e.g. Sugar Puffs, Cocoa Pops, Frosties*	☐	☐	☐	☐	☐	☐	☐	☐	☐
(c) Non-sugar coated cereals *e.g. Cornflakes, Rice Crispies*	☐	☐	☐	☐	☐	☐	☐	☐	☐
(d) Muesli	☐	☐	☐	☐	☐	☐	☐	☐	☐
(e) Bran containing cereals *e.g. All Bran*	☐	☐	☐	☐	☐	☐	☐	☐	☐
(f) Multigrain cereals *e.g. Cheerios*	☐	☐	☐	☐	☐	☐	☐	☐	☐
(g) Branflakes	☐	☐	☐	☐	☐	☐	☐	☐	☐
(h) Weetabix	☐	☐	☐	☐	☐	☐	☐	☐	☐
(i) Shredded Wheat, Shreddies, Frosted/Raisin Wheats	☐	☐	☐	☐	☐	☐	☐	☐	☐
(j) Special K	☐	☐	☐	☐	☐	☐	☐	☐	☐
(k) Wholegrain cereals with fruit *e.g. Sultana Bran, Fruit n Fibre, Optivia*	☐	☐	☐	☐	☐	☐	☐	☐	☐
(l) Flake and cluster cereals *e.g. Clusters, Oats and More*	☐	☐	☐	☐	☐	☐	☐	☐	☐
(m) Crunchy cluster cereal *e.g. Crunchy Nut Clusters*	☐	☐	☐	☐	☐	☐	☐	☐	☐
(n) Other Wholegrain cereals (please state and tick for frequency)									
1.	☐	☐	☐	☐	☐	☐	☐	☐	☐
2.	☐	☐	☐	☐	☐	☐	☐	☐	☐

PLEASE TURN OVER

Q4 Please estimate your average consumption of **sweets and snacks** during the **last year**, taking care to complete every line. **(Complete every line - tick one box per line)**

Sweets and Snacks (Medium Serving)	Average use last year: Never or less than once a month	1 to 3 times a month	Once a week	2 to 4 times a week	5 to 6 times a week	Every day	2 to 3 times a day	4 to 5 times a day	6 or more times a day
(a) Sweet biscuits, chocolate, *e.g. Penguin, Kit-Kat* **(one) Excluding (1) and (2) below**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(1) chocolate digestive **(one)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(2) chocolate hob nob **(one)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(b) Sweet biscuits, plain, *e.g. Nice, ginger, rich tea, crunch cream* **(one) Excluding (1) and (2) below**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(1) plain digestive **(one)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(2) plain hob nob **(one)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(c) Breakfast biscuits, *e.g. Belvita* **(one)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(d) Soft cereal bars, *e.g. NutriGrain* **(one)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(e) Crunchy cereal bars, *e.g. Alpen, Special K* **(one)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(f) Flapjacks **(each)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(g) Crisps or other packet snacks, *e.g. Wotsits* **(one packet)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(h) Wholegrain snacks, e.g. *Walkers Sunbites* **(one packet)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(i) Tortilla crisps, *e.g. Doritos, Nachos* **(one packet)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(j) Popcorn **(one packet)**	☐	☐	☐	☐	☐	☐	☐	☐	☐
(k) Other wholegrain biscuits, cereal bars, crisps (please state and tick for frequency) 1.	☐	☐	☐	☐	☐	☐	☐	☐	☐
2.	☐	☐	☐	☐	☐	☐	☐	☐	☐
(l) Home made cakes, *e.g. fruit sponge* **(medium slice)**									
(1) made with white flour	☐	☐	☐	☐	☐	☐	☐	☐	☐
(2) made with wholemeal flour	☐	☐	☐	☐	☐	☐	☐	☐	☐
(m) Ready made cakes, *e.g. fruit sponge* **(medium slice)**									
(1) made with white flour	☐	☐	☐	☐	☐	☐	☐	☐	☐
(2) made with wholemeal flour	☐	☐	☐	☐	☐	☐	☐	☐	☐
(n) Home baked buns / pastries, e.g. scones **(each)**									
(1) made with white flour	☐	☐	☐	☐	☐	☐	☐	☐	☐
(2) made with wholemeal flour	☐	☐	☐	☐	☐	☐	☐	☐	☐
(o) Ready made buns / pastries, *e.g. croissants, doughnuts* **(each)**									
(1) made with white flour	☐	☐	☐	☐	☐	☐	☐	☐	☐
(2) made with wholemeal flour	☐	☐	☐	☐	☐	☐	☐	☐	☐
(p) Home baked fruit pies, tarts, crumbles **(per individual pie/medium serving)**									
(1) made with white flour	☐	☐	☐	☐	☐	☐	☐	☐	☐
(2) made with wholemeal flour	☐	☐	☐	☐	☐	☐	☐	☐	☐

Question 4 continues on the next page...

Question 4 continued from Page 4 ("Please estimate your average consumption of **sweets and snacks** during the **last year**, taking care to complete every line")...

Sweets and Snacks (Medium Serving)	Average use last year: Never or less than once a month	1 to 3 times a month	Once a week	2 to 4 times a week	5 to 6 times a week	Every day	2 to 3 times a day	4 to 5 times a day	6 or more times a day
(q) Ready made fruit pies, tarts, crumbles **(per individual pie/medium serving)**									
(1) made with white flour	☐	☐	☐	☐	☐	☐	☐	☐	☐
(2) made with wholemeal flour	☐	☐	☐	☐	☐	☐	☐	☐	☐
(r) Home baked sponge puddings **(medium slice)**									
(1) made with white flour	☐	☐	☐	☐	☐	☐	☐	☐	☐
(2) made with wholemeal flour	☐	☐	☐	☐	☐	☐	☐	☐	☐
(s) Ready made sponge puddings **(medium slice)**									
(1) made with white flour	☐	☐	☐	☐	☐	☐	☐	☐	☐
(2) made with wholemeal flour	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q5 In the **last year**, did you usually eat breakfast cereal (excluding any porridge mentioned earlier)?

☐ Yes ☐ No

If YES...

(i) Which brand and type of breakfast cereal, including muesli, did you usually eat? *If you ate more than three types, list the three types that you ate most often.*

	Brand (*e.g. Kellogg's*)	Type (*e.g. Corn Flakes*)
(a)		
(b)		
(c)		

PLEASE TURN OVER

Q6 Did you complete the 1000 Families from Newcastle, Health and Lifestyle Questionnaire **in 2009** (age 62)?

☐ Yes ☐ No

If YES...

(i) How much do you think your eating habits have changed since 2009?

☐ No changes have occurred

☐ Small changes have occurred

☐ Major changes have occurred

Instruction **If NO CHANGES HAVE OCCURRED, please ignore the following question.**

We would like to know the reasons for your dietary changes. In the following question please indicate all the things that you think may explain your change in eating patterns.

(ii) Please tick as many of the things listed that you think explain your change in eating habits since 2009? **(Tick all that apply)**

☐ Change in the food you like or dislike

☐ Your enjoyment of food

☐ Concerns about safety/content of foods e.g. food scares/ organic foods

☐ The type and variety of foods available

☐ Price of foods

☐ Advertising of food products

☐ Desire to maintain health

☐ Your body weight

☐ Ill health or disability prevents you from cooking for yourself

☐ Dental problems

☐ Religion

☐ Ethical/ political concerns

☐ The knowledge you have about food

☐ Cooking ability/ skill

☐ Ease of shopping

☐ Kitchen equipment

☐ Special diet **(Please specify)** ______

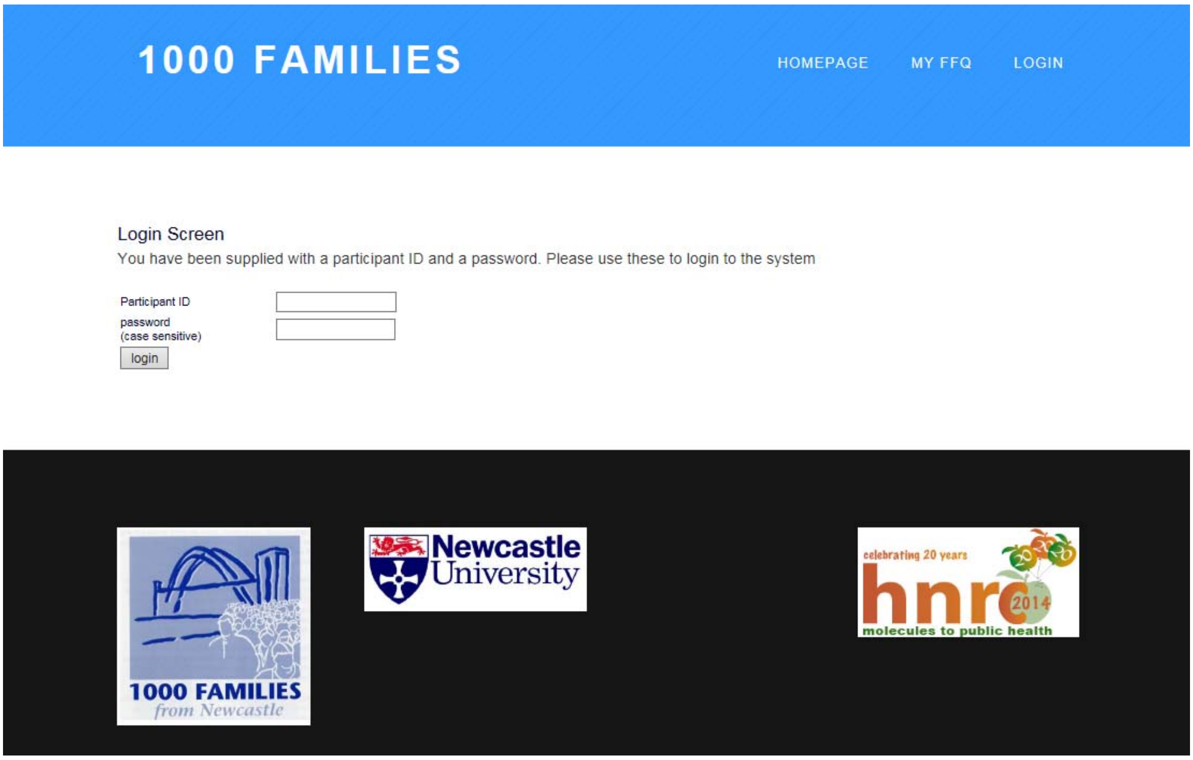
☐ Health problem **(Please specify)** ______

☐ Other **(Please specify)** ______

END - THANK YOU VERY MUCH FOR TAKING THE TIME TO COMPLETE THIS QUESTIONNAIRE

Appendix D Online Cereal Foods Questionnaire

Screen shots of the online version of the Cereal Food Questionnaire created by Steven Hall. Participants were given login details and could not move onto the following page until all questions had been answered.



1000 FAMILIES HOMEPAGE MY FFQ LOGIN

Participant ID: 9999

Click Here to complete your questionnaire.

HOW TO COMPLETE THE QUESTIONNAIRE

There are different types of questions this questionnaire. Most of them can be answered by clicking one button ◉ . Please do not leave any question unanswered and try to answer all questions as accurately and honestly as possible. People and families are very different and there are no 'right' or 'wrong' answers.

For example: In the last year, did you usually eat breakfast cereal?
◉ Yes ○ No

Questions 1 to 4 relate to your diet during the LAST YEAR.

For each food there is an amount shown, either a 'medium serving' or a common household unit such as a slice or bowl. Please indicate how often, on average, you have eaten the specified amount of each food during the LAST YEAR by clicking one of the options available.

For example: Someone who usually ate cornflakes for breakfast on weekdays and had a cooked breakfast with two pieces of white toast every Saturday, as well as ate soup with a white bread roll once a week would complete the questions as follows.

Cereals (One bowl)	Never or less than once a month	1 to 3 times a month	Once a week	2 to 4 times a week	5 to 6 times a week	Every day	2 to 3 times a day	4 to 5 times a day	6 or more times a day
(c) Non-sugar coated cereals e.g. Cornflakes, Rice Crispies	○	○	○	○	◉	○	○	○	○
Bread and Savoury Biscuits (One slice or one biscuit)	**Never or less than once a month**	**1 to 3 times a month**	**Once a week**	**2 to 4 times a week**	**5 to 6 times a week**	**Every day**	**2 to 3 times a day**	**4 to 5 times a day**	**6 or more times a day**
(a) White bread and rolls, white pitta bread (one slice/roll)	○	○	○	◉	○	○	○	○	○

1000 FAMILIES HOMEPAGE MY FFQ LOGIN

Participant ID: 9999

Q1: Please estimate your average consumption of bread and savoury biscuits during the last year, taking care to complete every line. (Complete every line - tick one box per line)

Bread and Savoury Biscuits (One slice or one biscuit)	Never or less than once a month	1 to 3 times a month	Once a week	2 to 4 times a week	5 to 6 times a week	Every day	2 to 3 times a day	4 to 5 times a day	6 or more times a day
(a) White bread and rolls, white pitta bread (one slice/roll)	○	○	◉	○	○	○	○	○	○
(b) Brown bread and rolls(one slice/roll)	◉	○	○	○	○	○	○	○	○
(c) Wholemeal bread and rolls(one slice/roll)	○	○	◉	○	○	○	○	○	○
(d) Half and Half/50:50 white and wholemeal bread and rolls (one slice/roll)	○	○	○	◉	○	○	○	○	○
(e) Wholemeal pitta bread (each)	○	◉	○	○	○	○	○	○	○
(f) Granary bread and rolls (one slice/roll)	○	◉	○	○	○	○	○	○	○
(g) Rye bread and rolls (one slice/roll)	○	◉	○	○	○	○	○	○	○
(h) Oatmeal bread and rolls (one slice/roll)	○	◉	○	○	○	○	○	○	○
(i) Naan bread, chapatti (each)	○	○	◉	○	○	○	○	○	○
(j) Tortilla wraps (each)	○	○	◉	○	○	○	○	○	○
(k) Wholemeal tortilla wraps (each)	○	○	◉	○	○	○	○	○	○
(l) Other speciality breads (each) (please state and tick for frequency)									
1: other bread	◉	○	○	○	○	○	○	○	○
2: Test 2nd Bread	◉	○	○	○	○	○	○	○	○
(m) Cream crackers, cheese biscuits (each)	○	○	○	○	○	○	○	○	◉
(n) Wholemeal crackers (per cracker)	○	○	○	○	○	○	○	○	◉
(o) Crispbread, e.g. Ryvita (one)	○	○	○	○	○	○	○	○	◉
(p) Oatcakes (per cake)	○	○	○	○	○	○	○	○	◉

next reset

1000 FAMILIES

HOMEPAGE MY FFQ LOGIN

Participant ID: 9999

Q2 Please estimate your average consumption of rice and pasta during the last year, taking care to complete every line.
(Complete every line - tick one box per line)

Rice and Pasta (Medium Serving)	Never or less than once a month	1 to 3 times a month	Once a week	2 to 4 times a week	5 to 6 times a week	Every day	2 to 3 times a day	4 to 5 times a day	6 or more times a day
(a) White rice (½ plateful, or in a dish e.g. rice salad, risotto)	○	◉	○	○	○	○	○	○	○
(b) Brown rice (½ plateful, or in a dish e.g. rice salad, risotto)	◉	○	○	○	○	○	○	○	○
(c) White or green pasta e.g. spaghetti, macaroni, noodles, (½ plate)	○	○	○	○	○	◉	○	○	○
(d) Wholemeal pasta e.g. spaghetti, macaroni, noodles, (½ plate)	◉	○	○	○	○	○	○	○	○
(e) Tinned pasta e.g. spaghetti, ravioli, macaroni, (½ standard tin)	◉	○	○	○	○	○	○	○	○
(f) Tinned Wholemeal pasta e.g. spaghetti, ravioli, macaroni, (½ standard tin)	◉	○	○	○	○	○	○	○	○
(g) Lasagne, cannelloni, moussaka made with white or green pasta (as individual meal)	○	○	○	○	○	◉	○	○	○
(h) Lasagne, cannelloni, moussaka made with wholemeal pasta (as individual meal)	◉	○	○	○	○	○	○	○	○
(i) Pizza (10" = 1, 12" = 2, 12+"= 3 -4)	◉	○	○	○	○	○	○	○	○
(j) Quinoa (½plateful, or in a dish e.g. salad)	◉	○	○	○	○	○	○	○	○
(k) Wholegrain dishes not mentioned (please state and tick for frequency)									
1: test	○	○	○	○	○	◉	○	○	○
2: test2	○	○	○	○	○	◉	○	○	○

next reset back

1000 FAMILIES

HOMEPAGE MY FFQ LOGIN

Participant ID: 9999

Q3: Please estimate your average consumption of cereals during the last year, taking care to complete every line.
(Complete every line - tick one box per line)

Cereals (One bowl)	Never or less than once a month	1 to 3 times a month	Once a week	2 to 4 times a week	5 to 6 times a week	Every day	2 to 3 times a day	4 to 5 times a day	6 or more times a day
(a) Porridge, Readybrek, Oat So Simple	○	○	○	○	○	○	○	○	◉
(b) Sugar coated cereals e.g. Sugar Puffs,Cocoa Pops, Frosties	○	○	○	○	○	○	○	○	◉
(c) Non-sugar coated cereals e.g. Cornflakes, Rice Crispies	○	○	○	○	○	○	○	○	◉
(d) Muesli	○	○	○	○	○	○	○	○	◉
(e) Bran containing cereals e.g. All Bran	○	○	○	○	○	○	○	○	◉
(f) Multigrain cereals e.g. Cheerios	○	○	○	○	○	○	○	○	◉
(g) Bran Flakes	○	○	○	○	○	○	○	○	◉
(h) Weetabix	○	○	○	○	○	○	○	○	◉
(i) Shredded Wheat, Shreddies, Frosted/Raisin Wheats	○	○	○	○	○	○	○	○	◉
(j) Special K	○	○	○	○	○	○	○	○	◉
(k) Wholegrain cereals with fruit e.g. Sultana Bran, Fruit n Fibre, Optivia	○	○	○	○	○	○	○	○	◉
(l) Flake and cluster cereals e.g. Clusters, Oats and More	○	○	○	○	○	○	○	○	◉
(m) Crunchy cluster cereal e.g. Crunchy Nut Clusters	○	○	○	○	○	○	○	○	◉
(n) Other Wholegrain cereals (please state and tick for frequency)									
1:	○	○	○	○	○	○	○	○	○
2:	○	○	○	○	○	○	○	○	○

next reset back

Q4: Please estimate your average consumption of sweets and snacks during the last year, taking care to complete every line. (Complete every line - tick one box per line)

Sweets and Snacks (Medium Serving)	Never or less than once a month	1 to 3 times a month	Once a week	2 to 4 times a week	5 to 6 times a week	Every day	2 to 3 times a day	4 to 5 times a day	6 or more times a day
(a) Sweet biscuits, chocolate, e.g. Penguin, Kit-Kat (one) Excluding (1) and (2) below	○	◉	○	○	○	○	○	○	○
(1) chocolate digestive (one)	○	○	◉	○	○	○	○	○	○
(2) chocolate hob nob (one)	○	○	◉	○	○	○	○	○	○
(b) Sweet biscuits, plain, e.g. Nice, ginger, rich tea, crunch cream (one) Excluding (1) and (2) below	○	○	○	○	○	◉	○	○	○
(1) plain digestive (one)	○	○	○	○	○	◉	○	○	○
(2) plain hob nob (one)	○	○	○	○	○	◉	○	○	○
(c) Breakfast biscuits, e.g. Belvita (one)	◉	○	○	○	○	○	○	○	○
(d) Soft cereal bars, e.g. NutriGrain (one)	○	◉	○	○	○	○	○	○	○
(e) Crunchy cereal bars, e.g. Alpen, Special K (one)	◉	○	○	○	○	○	○	○	○
(f) Flapjacks (each)	○	◉	○	○	○	○	○	○	○
(g) Crisps or other packet snacks, e.g. Walkers crisps, Wotsits (one packet)	○	○	◉	○	○	○	○	○	○
(h) Wholegrain snacks, e.g. Walkers Sunbites (one packet)	○	○	○	○	◉	○	○	○	○
(i) Tortilla crisps, e.g. Doritos, Nachos (one packet)	○	○	○	○	○	◉	○	○	○
(j) Popcorn (one packet)	◉	○	○	○	○	○	○	○	○
(k) Other wholegrain biscuits, cereal bars, crisps (please state and tick for frequency)									
1:	○	○	○	○	○	○	○	○	○
2:	○	○	○	○	○	○	○	○	○
(l) Home made cakes, e.g. fruit sponge (medium slice)									
(1) made with white flour	○	◉	○	○	○	○	○	○	○
(2) made with wholemeal flour	◉	○	○	○	○	○	○	○	○
(m) Ready made cakes, e.g. fruit sponge (medium slice)									
(1) made with white flour	○	○	◉	○	○	○	○	○	○
(2) made with wholemeal flour	○	○	◉	○	○	○	○	○	○
(n) Home baked buns / pastries, e.g. scones (each)									
(1) made with white flour	○	◉	○	○	○	○	○	○	○

1000 FAMILIES

HOMEPAGE MY FFQ LOGIN

Participant ID: 9999

Q5: (a) In the last year, did you usually eat breakfast cereal (excluding porridge mentioned earlier)?

◉ Yes ○ No

if YES.....

(1) Which brand and type of breakfast cereal, including muesli, did you usually eat? If you ate more than three types, list the three types that you ate most often.

	Brand (e.g. Kellogg's)	Type (e.g. Corn Flakes)
(a)	kelloggs	branflakes
(b)	tesco	rice crispies
(c)		

next reset back

1000 FAMILIES

HOMEPAGE MY FFQ LOGIN

Participant ID: 9999

Q6: (a) Did you complete the last 1000 Families from Newcastle, Health and Lifestyle Questionnaire (this was sent to you when you were aged 61-63)?

◉ Yes ○ No

---

if YES.....

(b) How much do you think your eating habits have changed since completing the last questionnaire?

○ No Changes have occured ◉ Small changes have occured ○ Major changes have occured

---

if NO CHANGES HAVE OCCURED, please go on to question 7.

We would like to know the reasons for your dietary changes. In the following question please indicate all the things that you think may explain your eating patterns.

(c) Please tick as many of the things listed that you think explain your change in eating habits? (tick all that apply)

- ☐ Change in the food you like or dislike
- ☐ Your enjoyment of food
- ☐ Concerns about safety/content of foods e.g. food scares/orgainc foods
- ☐ The type and variety of foods available
- ☑ Price of foods
- ☐ Advertising of food products
- ☐ Desire to maintain health
- ☐ Your body weight
- ☐ Ill health or disability prevents you from cooking yourself
- ☑ Dental problems
- ☐ Religion

1000 FAMILIES

HOMEPAGE MY FFQ LOGIN

Participant ID: 9999

Thank you for completing the 1000 Families Questionnaire.

You can can edit your responses at anytime by clicking MY FFQ on the top menu.

1000 FAMILIES from Newcastle

Newcastle University

celebrating 20 years hnrc 2014 molecules to public health

Appendix E Food portion size details

The following tables detail food consumption data from NDNS years 1 to 4 diet diaries for adults 19+ years. The foods consumed have been allocated into the appropriate question from the cereal foods questionnaire. The relative contribution of each food consumed is calculated and used to weight the average (mean/median) portion size consumed. Information from the MAFF Food portion sizes book is included (as this has been used in the NDNS) as well as branded product information where available. Finally consumer habit information from diet diaries is also included (for example where two portions are consumed in one serving e.g. biscuits).

Table E.1: Portion size details for breads and savory biscuits, questionnaire question 1

Question in cereal foods questionnaire	NDNS diet diary records 2008-2012: NDNS Food Code	Food Name	Frequency consumed	Relative contribution %	Portion size (g): Mean	Multiplier (mean)	Median	Multiplier (median)	Comments	Weighted portion size (g): Mean	Median	Final decided potion size
Bread and savoury biscuits (One slice or one biscuit)												
(a)White bread and rolls, white pitta bread (one slice/roll) - Not whole grain												
(b)Brown bread & rolls (one slice/roll)	102	*BROWN BREAD NO ADDED BRAN*	224	41.10	64.84	26.65	72.00	29.59	FPSB: Brown bread included with wholemeal; small slice fresh 25g, toasted 23g, medium slice fresh 36g, toasted 31g, large slice fresh 44g, toasted 40g. Wholemeal roll crusty or soft 48g. CH: 2 slices or one roll per serving.	**59.65**	**57.82**	One slice/roll 36g
	107	*BROWN BREAD TOASTED*	138	25.32	47.86	12.12	43.87	11.11				
	110	*WHEATGERM BREAD EG HOVIS WHEATGERM BREAD*	14	2.57	60.40	1.55	66.96	1.72				
	111	*WHEATGERM BREAD, TOASTED*	20	3.67	52.27	1.92	62.00	2.28				
	118	*BREAD VIT-BE*	1	0.18	36.00	0.07	36.00	0.07				
	162	*BREAD VITBE FRIED BLENDED OIL*	1	0.18	24.84	0.05	24.84	0.05				
	169	*ROLL GRANARY BROWN WHEATGERM TOASTED*	2	0.37	56.07	0.21	56.07	0.21				
	7620	*ROLLS BROWN GRANARY WHEATGERM CRUSTY*	7	1.28	65.74	0.84	48.00	0.62				
	7621	*BROWN, GRANARY, WHEATGERM ROLLS, SOFT, NOT F*	124	22.75	61.41	13.97	43.00	9.78				
	8177	*HI BRAN BREAD*	5	0.92	58.03	0.53	63.90	0.59				
	8178	*HIBRAN BREAD TOASTED*	5	0.92	77.78	0.71	75.64	0.69				
	10459	*GLUTEN FREE BROWN BREAD*	4	0.73	140.25	1.03	154.00	1.13				
		Total	545									
(c)Wholemeal bread & rolls (one slice/roll)	133	*BREAD WHOLEMEAL*	1001	43.60	68.75	29.97	72.00	31.39		**61.21**	**61.36**	One slice/roll 36g
	138	*BREAD WHOLEMEAL TOASTED*	777	33.84	52.17	17.66	49.50	16.75				
	161	*ROLLS, WHOLEMEAL, NOT F*	179	7.80	70.80	5.52	63.00	4.91				
	172	*ROLLS WHOLEMEAL TOASTED*	2	0.09	98.00	0.09	98.00	0.09				
	3172	*WHOLEMEAL BREAD, SLIMMERS, TOAST*	27	1.18	25.36	0.30	23.46	0.28				
	6463	*WHOLEMEAL BREAD SESAME SEEDS SUNFLOWER SEEDS OLIVE*	1	0.04	100.00	0.04	100.00	0.04				
	7614	*BREAD WHOLEMEAL SLIMMERS EG NIM*	69	3.01	31.08	0.93	26.22	0.79				
	8019	*MULTISEED BREAD WHOLEMEAL*	145	6.32	68.70	4.34	72.00	4.55				
	10204	*MULTISEED BREAD WHOLEMEAL TOAST*	95	4.14	57.00	2.36	62.00	2.57				
		Total	2296									
(d)Half and Half/50:50 white & wholemeal bread & rolls (one slice/roll)	3904	*WHITE & WHOLEMEAL BREAD WITH ADDED WHEATGERM*	193	39.47	83.27	32.87	80.00	31.57	FPSB: Hovis best of both medium slice 38g, thick slice 47g BP: Hovis best of both rolls 62g	**68.73**	**67.41**	One slice/roll 36g
	4168	*HOVIS, BEST OF BOTH WHITE BREAD WITH ADDED WHEATGERM, TOAST*	206	42.13	56.38	23.75	54.00	22.75				
	8142	*WHITE & WHOLEMEAL BREAD ROLLS*	5	1.02	88.20	0.90	63.00	0.64				
	10775	*BREAD, 50% WHITE & 50% WHOLEMEAL*	38	7.77	83.25	6.47	80.00	6.22				
	10777	*BREAD, 50% WHITE & 50% WHOLEMEAL TOAST*	46	9.41	49.09	4.62	64.80	6.10				
	10779	*BREAD ROLLS,50% WHITE & 50% WHOLE*	1	0.20	63.00	0.13	63.00	0.13				
		Total	489									
(e)Wholemeal pitta bread (each)	117	*BREAD PITTA WHOLEMEAL*	49	100.0	110.36	110.36	85.00	85.00	FPSB: pitta, small 75g, large 95g	**110.4**	**85.00**	One pitta 85g
		Total	49									

Comments column contains information from the foods standard agency's Food Portion Size Book (FPSB), detail on consumption habits (CH) from NDNS diet diaries, portion sizes from manufacturers for specific branded products (BP) and detail on any foods excluded. F: Fortified, UF: Unfortified

(f)Granary bread & rolls (one slice/roll)	112	*BREAD GRANARY*	399	56.12	63.27	35.50	72.00	40.41		62.14	65.27	One slice/roll 36g
	113	*GRANARY BREAD, TOASTED*	158	22.22	53.05	11.79	62.00	13.78				
	7616	*GRANARY FRENCH STICK*	21	2.95	95.24	2.81	100.00	2.95				
	169	*ROLL GRANARY BROWN WHEATGERM TOASTED*	2	0.28	56.07	0.16	56.07	0.16				
	7620	*ROLLS BROWN GRANARY WHEATGERM CRUSTY*	7	0.98	65.74	0.65	48.00	0.47				
	7621	*BROWN, GRANARY, WHEATGERM ROLLS, SOFT, NOT F*	124	17.44	64.41	11.23	43.00	7.50				
		Total	711									
(g)Rye bread & rolls (one slice/roll)	114	*BREAD RYE*	36	73.47	32.68	24.01	29.75	21.86	FPSB: Rye bread average slice 25g	34.32	30.61	One slice 33g
	115	*RYE BREAD, TOASTED*	13	26.53	38.86	10.31	33.00	8.76				
		Total	49									
(h)Oatmeal bread & rolls (one slice/roll)	7617	*OATMEAL BREAD*	68	72.34	74.55	53.93	80.60	58.31	CH: two slices per serve	73.15	78.22	One slice 36g
	7618	*BREAD OATMEAL TOASTED*	26	27.66	69.50	19.22	72.00	19.91				
		Total	94									
(i)Naan bread, chapatti (each)	143	*CHAPATI BROWN NO FAT*	40	24.10	101.06	24.35	110.00	26.51	FPSB: Chapati white or brown average no fat 55g, with fat 60g. Naan filled 155g, plain 160g.	109.0	112.0	One 55g
	144	*CHAPATIS WHITE IN BUTTER GHEE*	9	5.42	86.67	4.70	60.00	3.25				
	145	*CHAPATIS WHITE IN VEGETABLE GHEE*	2	1.20	16.00	0.19	16.00	0.19				
	146	*CHAPATI WHITE MADE WITHOUT FAT*	11	6.63	60.50	4.01	55.00	3.64				
	7622	*NAAN BREAD PLAIN*	95	57.23	125.65	71.91	120.00	68.67				
	8670	*WHITE CHAPATTI MADE WITH SUNFLOWER OIL*	9	5.42	71.43	3.87	180.00	9.76				
		Total	166									
(j) Tortilla wraps (each) - Not whole grain												
(k)Wholemeal wraps (each)	10754	*WHOLEMEAL WHEAT TORTILLA WRAPS*	5	100.0	89.92	89.92	72.00	72.00		89.92	72.00	One wrap 72g
		Total	5									
(m) Cream crackers, cheese biscuits (each) - Not whole grain												
(n)Wholemeal crackers	7652	*WHOLEMEAL CRACKERS OR FARMHOUSE CRACKERS*	54	100.0	19.97	19.97	17.60	17.60	FPSB: Farmhouse cracker 8g. CH: 2/3 per serve	19.97	17.60	One cracker 8g
		Total	54									
(o)Crispbread, e.g. Ryvita (one)	256	*CRISPBREAD RYE*	116	47.54	12.15	5.78	20.00	9.51	FPSB:Wholemeal crispbread 5g, ryvita 10g, cracker bread 10g. CH :2,3,4 per serve. BP: Ryvita crackerbread 5g slice. Ryvita crispbread 10g slice.	18.34	21.07	One 10g
	258	*CRISPBREADS EXTRA LIGHT*	33	13.52	17.94	2.43	16.50	2.23				
	4068	*CRACKERBREAD, WHOLEMEAL, RYVITA*	15	6.15	8.33	0.51	10.00	0.61				
	7325	*HIGH FIBRE RYVITA*	4	1.64	34.00	0.56	33.00	0.54				
	7653	*CRISPBREAD RYE WITH SESAME/ SUNFLOWER SEEDS*	43	17.62	29.24	5.15	28.50	5.02				
	7654	*C'BREAD NOTRYVITA POP/SES SEED*	13	5.33	27.23	1.45	24.00	1.28				
	8117	*MULTIGRAIN CRISPBREAD*	16	6.56	30.25	1.98	22.00	1.44				
	8120	*CRISPBREADS WHOLEGRAIN & SEEDED*	4	1.64	28.98	0.48	26.00	0.43				
		Total	244									
(p)Oatcakes (per cake)	267	*OATCAKES*	65	100.0	28.81	28.81	26.00	26.00	FPSB: round 13g, triangle 17g. CH:2/3 per serve	28.81	26.00	One cake 15g
		Total	65									

Comments column contains information from the foods standard agency's Food Portion Size Book (FPSB), detail on consumption habits (CH) from NDNS diet diaries, portion sizes from manufacturers for specific branded products (BP) and detail on any foods excluded. F: Fortified, UF: Unfortified

Table E.2: Portion size details for rice and pasta, questionnaire question 2

Question in cereal foods questionnaire	NDNS diet diary records 2008-2012: NDNS Food Code	Food Name	Frequency consumed	Relative contribution %	Portion size (g): Mean	Multiplier (mean)	Median	Multiplier (median)	Comments	Weighted portion size (g): Mean	Median	Final decided potion size
Rice and pasta (medium serving)												
(a)White rice (½ plateful, or in a dish e.g. rice salad, risotto) - Not whole grain												
(b)Brown rice (½ plateful, or in a dish e.g. rice salad, risotto)	49	*RICE, BROWN, BOILED*	29	30.53	145.10	44.30	175.00	53.42	FPSB: medium serve 180g. BP: microwave packs are 250g with ½ portion per serve.	134.5	126.3	Average portion 135g
	10009	*BROWN BASMATI RICE, COOKED*	14	14.74	179.60	26.47	180.00	26.53				
	10010	*BROWN EASYCOOK RICE, RAW*	4	4.21	3.90	0.16	3.90	0.16				
	10011	*BROWN EASYCOOK RICE, COOKED*	48	50.53	126.22	63.78	91.65	46.31				
		Total (not including raw weights)	95									
(c)White or green pasta e.g. spaghetti, macaroni, noodles, (½ plate)	27	*PASTA MACARONI BOILED*	7	0.68	110.75	0.76	115.00	0.79	White/green pasta & noodles not whole grain calculation to inform portion size of WM pasta. FPSB: macaroni 230g boiled, Instant noodle pack 280g boiled, spaghetti 220g boiled, Tortellini portion 320g.	191.8	194.8	Average portion for ½ plate 200g
	30	*PASTA NOODLES BOILED*	35	3.42	159.00	5.43	200.00	6.84				
	32	*PASTA NOODLES EGG BOILED*	60	5.86	140.00	8.20	145.00	8.50				
	34	*PASTA SPAGHETTI BOILED WHITE*	716	69.92	189.76	132.68	189.00	132.15				
	819	*MACARONI CHEESE NOT CANNED*	6	0.59	196.25	1.15	166.25	0.97				
	2726	*TAGLIATELLE CARBONARA, REDUCED FAT, READY MEAL*	2	0.20	310.00	0.61	310.00	0.61				
	3994	*PASTA, EGG, FRESH, FILLED WITH CHEESE ONLY, BOILED*	5	0.49	309.00	1.51	340.00	1.66				
	3995	*PASTA, EGG, FRESH, FILLED WITH CHEESE & TOMATO ONLY*	3	0.29	155.00	0.45	150.00	0.44				
	3996	*PASTA, EGG, FRESH, FILLED, WITH MUSHROOMS, BOILED*	4	0.39	185.50	0.72	220.00	0.86				
	4002	*PASTA & SAUCE MIXES, DRY*	12	1.17	78.13	0.92	87.50	1.03				
	4003	*PASTA & SAUCE MIXES, COOKED*	15	1.46	315.37	4.62	450.00	6.59				
	5166	*SUPERNOODLES BATCHELORS AS SERVED*	59	5.76	255.14	14.70	270.00	15.56				
	5888	*PASTA WITH VEG BAKE WITH SAUCE*	2	0.20	285.00	0.56	285.00	0.56				
	6139	*CHEESE & VEGETABLE PASTA*	1	0.10	400.00	0.39	400.00	0.39				
	6393	*CHICKEN & PASTA READY MEALS, STEAMED, MICROWAVED*	2	0.20	400.00	0.78	400.00	0.78				
	6785	*MACARONI CHEESE SEMI SKIM MILK & REDUCED FAT SPREAD*	1	0.10	220.00	0.21	220.00	0.21				
	8011	*MACARONI CHEESE READYMEAL LOW FA*	1	0.10	294.00	0.29	294.00	0.29				
	8049	*MACARONI CHEESE PURCHASED READY MEAL*	7	0.68	391.86	2.68	400.00	2.73				
	8093	*PASTA, EGG, FRESH, FILLED WITH CHEESE & VEGETABLES BOILED*	17	1.66	182.65	3.03	150.00	2.49				
	8128	*TOMATO & MOZZARELLA PASTA BAKE PURCHASED*	5	0.49	276.80	1.35	344.00	1.68				
	8175	*TORTELLINI WITH CHEESE*	1	0.10	150.00	0.15	150.00	0.15				
	8361	*RAVIOLI NOT CANNED*	7	0.68	173.21	1.18	150.00	1.03				
	8666	*TAGLIATELLE CARBONARA READY MEAL*	2	0.20	381.50	0.75	381.50	0.75				
	9098	*SPAGHETTI CAEBRBONARA*	4	0.39	325.00	1.27	275.00	1.07				
	9099	*PASTA SALAD SAINSBURYS ITALIAN STYLE*	15	1.46	110.87	1.62	100.00	1.46				
	9371	*PASTA, EGG, FRESH, PLAIN BOILED*	31	3.03	154.05	4.66	135.10	4.09				
	9824	*FRESH EGG PASTA RAVIOLI (FILLED)*	4	0.39	285.00	1.11	295.00	1.15				
		Total	1024									
(d)Wholemeal pasta e.g. spaghetti, macaroni, noodles, (½ plate)	36	*PASTA SPAGHETTI, WHOLEMEAL BOILED*	41	100.00	192.74	192.74	175.00	175.00	FPSB: wholemeal pasta medium serve 220g Using detail for white pasta as above	192.7	175.0	Average portion for ½ plate 200g
		Total	41									
(e)Tinned pasta e.g. spaghetti, ravioli, macaroni, (½ standard tin)	38	*PASTA MACARONI CANNED IN CHEESE SAUCE*	5	9.09	341.06	31.01	400.00	36.36	FPSB: Canned mac cheese 210g, ravioli 220g, spaghetti bolognaise	217.7	224.6	Average portion for ½ can 200g
	39	*PASTA RAVIOLI CANNED IN TOMATO SAUCE*	4	7.27	402.50	29.27	400.00	29.09				
	40	*PASTA SPAGHETTI CANNED IN BOLOGNESE SAUCE*	3	5.45	280.00	15.27	215.00	11.73				

Comments column contains information from the foods standard agency's Food Portion Size Book (FPSB), detail on consumption habits (CH) from NDNS diet diaries, portion sizes from manufacturers for specific branded products (BP) and detail on any foods excluded. F: Fortified, UF: Unfortified

	41	*PASTA,SPAGHETTI, CANNED IN TOMATO SAUCE*	34	61.82	191.85	118.60	200.00	123.64	large 430g, small 210g, spaghetti in tomato sauce 125g. BP: Heinz and supermarket cans 410g, 400g, 395g, 385g.			
	7602	*SPAGHETTI, CANNED IN TOMATO SAUCE, REDUCED SUGAR*	6	10.91	128.03	13.97	130.00	14.18				
	8611	*PASTA SHAPES IN TOMATO SAUCE FORT. WITH VITS/MINS*	2	3.64	213.25	7.75	213.25	7.75				
	10773	*PASTA SHAPES IN TOMATO SAUCE FORT. WITH VITS/MINS*	1	1.82	100.00	1.82	100.00	1.82				
		Total	55									
(f)Tinned wholemeal pasta e.g. spaghetti, ravioli, macaroni, (½ standard tin) – None consumed by NDNS adults so using the portion size for non-wholemeal tinned pasta above part (e).												Average portion for ½ can 200g
(g)Lasagne, cannelloni, made with white/green pasta (individual meal)	Lasagne dishes made at home are split into ingredients see appendix XX for further detail on the calculation for all meals 7601.											
	7601	*ALL MEALS CONTAINING 7601 PASTA LASAGNE WHITE BOILED*	43	87.76	563.01	494.07	573.00	502.84	FPSB: Lasagne portion 420g, cannelloni portion 304g	**530.6**	**542.6**	Average individual meal 500g
	4023	*SPINACH & RICOTTA CANNELLONI, READY MEAL EG SAINSBURY'S*	6	12.24	298.33	36.53	325.00	39.80				
		Total	49									
(h)Lasagne, cannelloni, moussaka made with wholemeal pasta (as individual meal) – None consumed by NDNS adults so using the portion size for lasagne above part (g)												Average individual meal 500g
(i)Pizza (10" = 1, 12" = 2, 12+"= 3 -4) – Not whole grain												
(j)Quinoa (½plateful/ dish)	10424	*QUINOA COOKED*	2	100.00	150.00	150.00	150.00	150.00		**150.0**	**150.0**	Average portion 150g

Comments column contains information from the foods standard agency's Food Portion Size Book (FPSB), detail on consumption habits (CH) from NDNS diet diaries, portion sizes from manufacturers for specific branded products (BP) and detail on any foods excluded. F: Fortified, UF: Unfortified

Table E.3: Portion size details for cereals, questionnaire question 3

Question in cereal foods questionnaire	NDNS Food Code	Food Name (NDNS diet diary records 2008-2012)	Frequency consumed	Relative contribution %	Portion size (g): Mean	Multiplier (mean)	Median	Multiplier (median)	Comments	Weighted portion size (g): Mean	Median	Final decided potion size
Cereals (One bowl)												
(a)Porridge, Readybrek, Oat So Simple	215	*PORRIDGE MADE WITH WATER & ADDED SALT*	51	12.14	160.57	19.50	160.00	19.43	FPSB: Porridge small 110g, medium 160g, large 210g. CH: consumed as either small 130g or medium 180g.	**166.9**	**163.6**	One serve average 170g
	216	*PORRIDGE MADE WITH WHOLE MILK & ADDED SALT*	13	3.10	183.08	5.67	210.00	6.50				
	217	*PORRIDGE MADE WITH WHOLE MILK & WATER & ADDED SALT*	5	1.19	160.00	1.90	160.00	1.90				
	219	*READY BREK AS SERVED*	8	1.90	161.25	3.07	180.00	3.43				
	3210	*PORRIDGE WITH SOYA MILK,SWEETENED*	1	0.24	160.00	0.38	160.00	0.38				
	3211	*PORRIDGE WITH SOYA MILK,UNSWEETENED*	3	0.71	100.00	0.71	100.00	0.71				
	3421	*READY BREK WITH SKIMMED MILK*	10	2.38	164.50	3.92	180.00	4.29				
	3797	*PORRIDGE MADE SEMISKIMMED MILK*	127	30.24	163.30	49.38	160.00	48.38				
	3925	*PORRIDGE SKIMMED MILK NO SUGAR*	14	3.33	170.71	5.69	160.00	5.33				
	7640	*INSTANT HOT OAT CEREAL, PLAIN, WITH SEMI-SKIMMED MILK, EG. READY BREK, OATSO SIMPLE*	16	3.81	212.81	8.11	180.00	6.86				
	7642	*R.BREK FLAV. SEMI SKIM*	1	0.24	180.00	0.43	180.00	0.43				
	7646	*PORRIDGE MADE WITH BRAN & SKIMMED MILK & ADDED SALT*	1	0.24	360.00	0.86	360.00	0.86				
	8756	*PORRIDGE MADE 1/2 SEMI-SKIM MILK 1/2 WATER NO ADDED SALT*	52	12.38	169.13	20.94	160.00	19.81				
	9348	*INSTANT OAT CEREAL MADE UP WITH WATER*	8	1.90	190.63	3.63	180.00	3.43				
	9549	*PORRIDGE MADE WITH 1/2 SKIMMED MILK & 1/2 WATER*	8	1.90	152.50	2.90	160.00	3.05				
	9555	*PORRIDGE MADE W BRAN & SEMI SKIMMED MILK & WATER*	3	0.71	143.33	1.02	160.00	1.14				
	10284	*PORRIDGE MADE UP WITH WATER NO SALT ADDED*	77	18.33	170.48	31.26	160.00	29.33				
	10338	*PORRIDGE MADE WITH ALL WHOLE MILK NO ADDED SALT*	21	5.00	143.29	7.16	160.00	8.00				
	10473	*PORRIDGE MADE WITH 1% MILK*	1	0.24	160.00	0.38	160.00	0.38				
	2675	*INSTANT HOT OAT CEREAL, NOT FLAVOURED, DRY WEIGHT F EG READY BREK*	3	1.64	18.67	0.41	25.00	0.41	These are dry weight sachet servings. So not included in portion calculation			
	5329	*INSTANT OAT CEREAL WITH FRUIT &/ OR NUTS EG. OATSO SIMPLE BAKED APPLE, DRY WEIGHT*	75	40.98	35.19	14.42	36.00	14.75				
	8005	*READY BREK FLAVOURED, DRY WEIGHT*	5	2.73	29.00	0.79	23.00	0.63				
	10514	*INSTANT HOT OAT CEREAL, NOT FLAVOURED, DRY WEIGHT, F EG READY BREK*	7	3.83	44.56	1.70	40.00	1.53				
	10515	*INSTANT HOT OAT CEREAL, NOT FLAVOURED, DRY WEIGHT,NOT F WG OATSO SIMPLE*	93	50.82	29.00	14.74	27.00	13.72				
		Total (not including raw weights)	420									
(b)Sugar coated cereals e.g. Sugar Puffs,Cocoa Pops, Frosties	204	*COCO POPS KELLOGGS ONLY*	27	6.98	30.84	2.15	30.00	2.09	Average cornflake type cereals FPSB: small 20g, medium 30g, large 50g BP: sugar puffs, coco pops, Frosties, crunchy nut, ricicles, choco squares,	**37.50**	**34.00**	One serve average 40g
	224	*HONEY COATED PUFFED WHEAT INC. QUAKER SUGAR PUFFS & OWN BRAND*	68	17.57	37.28	6.55	30.00	5.27				
	227	*FROSTIES-KELLOGGS ONLY*	68	17.57	37.06	6.51	30.00	5.27				
	232	*CRUNCHY NUT CORNFLAKES KELLOGGS & OWN BRAND*	60	15.50	40.15	6.22	40.00	6.20				
	4331	*RICICLES (KELLOGGS)*	6	1.55	32.50	0.50	30.00	0.47				
	7052	*ASDA CHOCO SQUARES CEREAL F*	5	1.29	31.00	0.40	30.00	0.39				
	7626	*FROSTED CORNFLAKES, OWN BRAND*	19	4.91	37.37	1.83	30.00	1.47				
	8138	*CHOCOLATE BREAKFAST CEREAL UF*	4	1.03	50.00	0.52	50.00	0.52				
	8151	*ASDA GOLDEN BALLS CEREAL F*	6	1.55	43.33	0.67	45.00	0.70				
	8159	*KELLOGGS COCOPOPS COCOROCKS*	7	1.81	14.00	0.25	16.00	0.29				

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	8483	*COCOA POPS OWN BRAND*	8	2.07	32.50	0.67	30.00	0.62	golden balls all 30g.			
	10257	*NEW DAY HONEY HOOPS CEREAL F*	2	0.52	30.00	0.16	30.00	0.16				
	10320	*HARVEST MORN HONEY NUT CORNFLAKES*	2	0.52	30.00	0.16	30.00	0.16				
	10369	*LITTLE MAN CHOCO MOON BREAKFAST CEREAL F*	1	0.26	30.00	0.08	30.00	0.08	Average cornflake type cereals FPSB: small 20g, medium 30g, large 50g.			
	10512	*CRUNCHY NUT CORNFLAKES KELLOGGS ONLY*	71	18.35	42.42	7.78	40.00	7.34				
	10513	*CRUNCHY NUT CORNFLAKES OWN BRAND*	32	8.27	34.44	2.85	33.75	2.79				
	10848	*MORNFLAKE CHOCOLATEY SQUARES*	1	0.26	74.00	0.19	74.00	0.19				
		Total	387									
(c)Non-sugar coated cereals e.g. Cornflakes, Rice Crispies	205	*CORNFLAKES KELLOGG'S ONLY*	328	52.82	32.53	17.18	30.00	15.85	Average cornflake type cereals in FPSB is small portion 20g, medium 30g, large 50g which looks like it covers all of these.	**31.40**	**29.97**	One serve average 30g
	206	*CORNFLAKES OWN BRAND*	99	15.94	30.89	4.92	30.00	4.78				
	218	*PUFFED WHEAT, NOT HONEY COATED*	11	1.77	19.09	0.34	20.00	0.35				
	220	*RICE KRISPIES KELLOGGS ONLY*	91	14.65	29.84	4.37	30.00	4.40				
	3546	*CRUNCHY RICE & WHEAT FLAKES*	16	2.58	25.04	0.65	30.00	0.77				
	7630	*RICE KRISPIES OWN BRAND*	37	5.96	31.80	1.89	30.00	1.79				
	8460	*MALTED FLAKE BREAKFAST CEREAL OWN BRAND, F*	17	2.74	30.47	0.83	30.00	0.82				
	10125	*KELLOGGS RICE KRISPIES MULTIGRAIN*	5	0.81	31.60	0.25	30.00	0.24				
	10156	*CORNFLAKES UF, INCLUDING ORGANIC*	7	1.13	28.57	0.32	30.00	0.34				
	10197	*CORNFLAKE TYPE CEREALS FROSTED UF*	6	0.97	35.00	0.34	35.00	0.34				
	10322	*MORRISONS TRIM FLAKES*	4	0.64	45.00	0.29	45.00	0.29				
		Total	621									
(d) Muesli	212	*MUESLI E.G. ALPEN WITH ADDED SUGAR NOT KELLOGGS COUNTRY STORE*	129	29.12	41.30	12.03	40.00	11.65	FPSB: Muesli not crunchy small 30g, medium 50g, large 80g FPSB: Muesli crunchy small 40g, medium 60g, large 100g BP: packaging 45g serve	**41.06**	**35.31**	One serve average 40g
	214	*MUESLI, NO ADDED SUGAR*	120	27.09	39.85	10.79	30.00	8.13				
	5328	*CRUNCHY/CRISPY MUESLI TYPE CEREAL WITH NUTS*	71	16.03	37.23	5.97	30.00	4.81				
	6836	*MUESLI, NO ADDED SUGAR EXTRA FRUIT & NUTS*	66	14.90	37.94	5.65	37.00	5.51				
	7629	*MUESLI WITH ADDED SUGAR, WITH EXTRA FRUIT & NUTS E.G. SAINSBURY'S LUXURY MUESLI*	18	4.06	52.92	2.15	50.00	2.03				
	8118	*MUESLI WITH 55% FRUIT*	27	6.09	35.77	2.18	30.00	1.83				
	10302	*DORSET CEREAL MUESLI WITH FRUIT ONLY*	12	2.71	84.38	2.29	50.00	1.35				
		Total	443									
(e) Bran containing cereals e.g. All Bran	201	*ALL BRAN KELLOGGS ONLY*	62	64.58	26.91	17.38	32.50	20.99	FPSB: all-bran type cereals small 30g, medium 40g, large 60g. CH: table spoon of bran FPSB is 7g	**26.78**	**23.36**	One serve average 30g
	8183	*WEETABIX CRUNCHY BRAN - PREVIOUSLY ALPEN CRUNCHY BRAN*	7	7.29	21.53	1.57	21.00	1.53				
	8315	*HARVEST MORN RAISIN BRAN CEREAL F*	1	1.04	30.00	0.31	30.00	0.31				
	8482	*ALL BRAN TYPE CEREAL, E.G. TESCO BRAN, NESTLE, ALPEN CRUNCHY BRAN*	26	27.08	27.75	7.51	9.31	2.52				
		Total	96									
(f) Multigrain cereals e.g. Cheerios	7632	*WEETOS, CHOCOLATE COVERED RINGS*	9	7.69	36.67	2.82	30.00	2.31	FPSB: 1 tablespoon Cheerios 5g, BP: Weetos, Cheerios and honey loops 30g	**32.63**	**31.80**	One serve average 33g
	7637	*NESTLE CHEERIOS MULTIGRAIN, NOT HONEY NUT*	68	58.12	30.81	17.90	30.00	17.44				
	8486	*HONEY LOOPS, KELLOGGS ONLY*	6	5.13	28.33	1.45	25.00	1.28				
	9275	*NESTLE HONEY CHEERIOS*	12	10.26	30.83	3.16	30.00	3.08				
	10123	*MULTIGRAIN HOOPS BREAKFAST CEREAL SUPERMARKET BRAND*	12	10.26	41.67	4.27	50.00	5.13				
	10468	*HONEY MONSTER HONEY WAFFLE BREAKFAST CEREAL F*	10	8.55	35.32	3.02	30.00	2.56				
		Total	117									
(g) Bran Flakes	202	*BRANFLAKES KELLOGGS ONLY*	99	44.00	32.02	14.09	30.00	13.20	FPSB: corn flake type cereal-small 20g, medium 30g, large 50g. 1 tablespoon bran flakes 8g. BP: Kelloggs 30g	**29.92**	**30.27**	One serve average 30g
	4084	*OAT & BRAN FLAKES NO ADDITIONS OWN BRAND EG ASDA*	9	4.00	16.67	0.67	20.00	0.80				
	7623	*BRAN FLAKES, OWN BRAND, NOT KELLOGGS*	102	45.33	27.37	12.41	30.00	13.60				
	7624	*BRANFLAKES WITH SULTANAS, OWN BRAND*	15	6.67	41.33	2.76	40.00	2.67				
		Total	225									

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(h) Weetabix	225	*WEETABIX & OTHER WHOLEWHEAT BISKS FORTIFIED*	483	88.30	40.40	35.67	40.00	35.32	FPSB: Weetabix 1 bisk 20g. BP: Weetabix 2 bisks 37.5g. Weetabix crispy minis 40g, Oatibix 2 bisks 48g.	**41.00**	**40.00**	One serve average 40g
	3875	*WEETABIX MINI'S CHOCOLATE CRISP - PREVIOUSLY KNOWN AS CHOCOLATE WEETABIX MINI CRUNCH*	15	2.74	46.84	1.28	40.00	1.10				
	6132	*WEETABIX MINIBIX WITH FRUIT & NUTS, NOT CHOCOLATE, BANANA OR HONEY*	18	3.29	37.89	1.25	40.00	1.32				
	8103	*WEETABIX OATIBIX ONLY*	31	5.67	49.42	2.80	40.00	2.27				
		Total	547									
(i) Shredded Wheat, Shreddies, Frosted/Raisin Wheats	221	*SHREDDED WHEAT, INCLUDES NESTLE & OWN BRAND, NO ADDITIONS*	186	55.52	41.49	23.04	44.00	24.43	FPSB: Shredded Wheat portion (2) 45g, 22g each. Shredded Wheat Mini small 35g, medium 45g, large 70g. BP:2 Shredded Wheat 45g, mini, frosted, honey nut & Shreddies, all 40g. Raisin wheats 45g.	**43.51**	**43.33**	One serve average 45g
	222	*SHREDDIES ANY BRAND NOT FROSTED NOT COCO*	13	3.88	39.62	1.54	35.00	1.36				
	5204	*KELLOGGS FROSTED WHEATS*	6	1.79	40.00	0.72	40.00	0.72				
	6824	*HONEY NUT SHREDDED WHEAT, NESTLE*	10	2.99	39.50	1.18	40.00	1.19				
	7051	*RAISIN WHEATS, KELLOGGS*	1	0.30	25.00	0.07	25.00	0.07				
	8182	*FROSTED MALTED WHEAT CEREAL, EG. FROSTED SHREDDIES*	5	1.49	45.00	0.67	45.00	0.67				
	8383	*NESTLE COCO SHREDDIES*	2	0.60	45.00	0.27	45.00	0.27				
	8190	*SHREDDED WHEAT FRUITFUL MINIWHEAT & OWN BRANDS. NOT KELLOGGS RAISIN WHEATS*	29	8.66	45.90	3.97	40.00	3.46				
	10305	*LIDL BIXIES SHREDDIES TYPE CEREAL F*	3	0.90	41.67	0.37	45.00	0.40				
	10510	*SHREDDIES OWN BRAND, NOT FROSTED, NOT COCO, NOT NESTLE, NOT LIDL*	46	13.73	50.04	6.87	45.00	6.18				
	10511	*SHREDDIES NESTLE ONLY, NOT FROSTED NOT COCO*	34	10.15	47.35	4.81	45.00	4.57				
		Total	335									
(j) Special K	223	*SPECIAL K KELLOGG'S*	151	70.89	30.77	21.82	30.00	21.27	BP: Special K 30g, with red berries 30g, bliss 30g	**30.23**	**28.92**	One serve 30g
	2970	*SPECIAL K WITH RED BERRIES*	24	11.27	31.96	3.60	30.00	3.38				
	8013	*SPECIAL K BERRIES ANY FRUIT ADDITION NOT CHOC OR YOGURT*	11	5.16	30.64	1.58	30.00	1.55				
	8014	*SPECIAL K BLISS WITH CHOC OR YOGURT*	16	7.51	26.25	1.97	20.00	1.50				
	8140	*KELLOGGS SPECIAL K MEDLEY CEREAL*	4	1.88	25.00	0.47	25.00	0.47				
	10330	*KELLOGGS SPECIAL K OATS & HONEY*	5	2.35	22.00	0.52	20.00	0.47				
	10355	*KELLOGGS SPECIAL K SUSTAIN CEREAL*	2	0.94	30.00	0.28	30.00	0.28				
		Total	213									
(k)Wholegrain cereals with fruit e.g. Sultana Bran, Fruit n Fibre, Optivia	203	*SULTANA BRAN KELLOGGS ONLY*	9	3.69	36.67	1.35	30.00	1.11	BP: Sultana Bran, Fruit & Fibre, Just Right all 40g. Tesco own brand cereals all 30g. Post Grapenuts & Dorset cereals 45g.	**38.15**	**36.05**	One serve average 40g
	229	*FRUIT & FIBRE KELLOGGS ONLY*	43	17.62	39.49	6.96	40.00	7.05				
	5327	*FRUIT & FIBRE OWN BRAND F (NOT VIT D)*	97	39.75	40.12	15.95	40.00	15.90				
	210	*GRAPENUTS*	3	1.23	15.67	0.19	3.50	0.04				
	3415	*DORSET CEREAL WITH FRUIT & NUTS*	48	19.67	41.15	8.09	30.00	5.90				
	6822	*JUST RIGHT, KELLOGGS (1/2 FAT MUESLI)*	15	6.15	38.67	2.38	50.00	3.07				
	6823	*WHEATFLAKES, NO SULTANAS, WHOLEWHEAT FLAKES*	4	1.64	26.75	0.44	14.00	0.23				
	10132	*OPTIVITA BERRY BREAKFAST CEREAL*	13	5.33	30.00	1.60	30.00	1.60				
	10374	*TESCO SPECIAL FLAKES BREAKFAST CEREAL F WITH VIT E*	8	3.28	26.25	0.86	25.00	0.82				
	10813	*KELLOGGS OPTIVITA NUTS & OATS BREAKFAST CEREAL*	4	1.64	20.00	0.33	20.00	0.33				
		Total	244									
(l) Flake and cluster cereals e.g. Clusters, Oats and More	8156	*OAT GRANOLA*	16	31.37	29.29	9.19	30.00	9.41	BP: Oats and more 40g	**24.62**	**27.05**	One serve average 25g
	8163	*NESTLE HONEY OATS & MORE FORTIFIED*	15	29.41	27.11	7.97	30.00	8.82				
	8441	*NESTLE ALMOND OATS & MORE CEREAL F*	11	21.57	25.00	5.39	30.00	6.47				
	10254	*NESTLE OATS & MORE RAISIN CEREAL*	9	7.83	26.39	2.07	30.00	2.35				
		Total	51									
(m) Crunchy cluster cereal e.g. Crunchy Nut Clusters	213	*CRUNCHY CLUSTERS TYPE CEREAL WITHOUT NUTS*	87	75.65	37.01	28.00	30.00	22.70	FPSB: Clusters 30g. BP: Crunchy nut clusters & Special K clusters 45g. Nestle clusters 30g.	**38.56**	**32.17**	One serve average 40g
	5202	*CRUNCHY/MIXED CEREAL WITH CHOC &/OR TOFFEE EG. SAINSBURYS TRIPLE CHOCOLATE CRISP*	6	5.22	34.52	1.80	34.90	1.82				
	8086	*CRUNCHY NUT CLUSTERS KELLOGGS*	7	6.09	74.29	4.52	60.00	3.65				
	8712	*NESTLE CLUSTERS BREAKFAST CEREAL*	6	5.22	23.33	1.22	20.00	1.04				
	10596	*KELLOGGS SPECIAL K F&NUT CLUSTERS*	7	6.09	40.79	2.48	40.00	2.43				
	10885	*KELLOGGS SPECIAL K HONEY CLUSTER*	2	1.74	30.50	0.53	30.50	0.53				
		Total	115									

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Table E.4 Portion size details for sweets and snacks, questionnaire question 4

Question in cereal foods questionnaire	NDNS diet diary records 2008-2012: NDNS Food Code	Food Name	Frequency consumed	Relative contribution %	Portion size (g): Mean	Multiplier (mean)	Median	Multiplier (median)	Comments	Weighted portion size (g): Mean	Median	Final decided potion size
Sweets and snacks (medium serving)												
a) Sweet biscuits, chocolate, e.g. Penguin, Kit-Kat (one) Excluding (1) and (2) below – Not Wholegrain												
(1) chocolate digestive (one)	260	*DIGESTIVES HALF COATED IN CHOCOLATE*	226	99.56	34.38	34.23	36.00	35.84	FPSB: 1 biscuit 18g. CH: 2 biscuits per serve	**34.38**	**36.00**	One biscuit 18g
	9472	*DIGESTIVES HALF COATED IN CHOCOLATE, REDUCED FAT*	1	0.44	34.00	0.15	34.00	0.15				
		Total	227									
(2) chocolate hob nob (one)	7658	*DIGESTIVES WITH OATS, CHOCOLATE 1/2 COATED E.G. HOBNOBS*	36	100.00	32.78	32.78	32.00	32.00	FPSB: 1 biscuit 16g. CH: 2 biscuits per serve	**32.78**	**32.00**	One biscuit 16g
		Total	36									
(b) Sweet biscuits, plain, e.g. Nice, ginger, rich tea, crunch cream (one) Excluding (1) and (2) below –Not Wholegrain												
(1) plain digestive (one)	259	*DIGESTIVE PLAIN*	363	96.03	30.68	29.46	30.00	28.81	FPSB: 1 biscuit 15g. CH: 2 biscuits per serve	**30.80**	**30.00**	One biscuit 15g
	8989	*REDUCED FAT BISCUITS INCLUDING DIGESTIVES, RICH TEAS & HOBNOBS*	15	3.97	33.80	1.34	30.00	1.19				
		Total	378									
(2) plain hob nob (one)	7657	*DIGESTIVES WITH OATS PLAIN E.G. HOB NOBS RUSTICS*	52	77.61	29.22	22.68	28.00	21.73	FPSB: 1 biscuit 14g. CH: 2 biscuits per serve	**30.24**	**28.45**	One biscuit 14g
	8989	*REDUCED FAT BISCUITS INCLUDING DIGESTIVES, RICH TEAS & HOBNOBS*	15	22.39	33.80	7.57	30.00	6.72				
		Total	67									
(c) Breakfast biscuits, e.g. Belvita (one)	10584	*BELVITA BREAKFAST BISCUITS F*	23	100.00	39.13	39.13	50.00	50.00	BP: Belvita 12.5g each in packs of 4.	**39.13**	**50.00**	One biscuit 12.5g
		Total	23									
(d) Soft cereal bars, e.g. NutriGrain (one)	5770	*NUTRI GRAIN BARS/NUTRI-GRAIN TWIST*	21	87.50	37.00	32.38	37.00	32.38	BP: All Nutrigrain bars 37g as are asda/aldi bars	**37.00**	**37.00**	One bar 37g
	10326	*ASDA FRUIT & GRAIN BARS F*	2	8.33	37.00	3.08	37.00	3.08				
	10426	*ALDI HARVEST MORN FRUIT & GRAIN BAR*	1	4.17	37.00	1.54	37.00	1.54				
		Total	24									
(e) Crunchy cereal bars, e.g. Alpen, Special K (one)	3882	*KELLOGG'S CEREAL+MILK BARS ONLY EG KELLOGG'S RICE KRISPIE,COCO POPS,FROSTIES,C'FLAKES CEREAL+MILK*	8	2.46	25.00	0.62	22.00	0.54	BP: Kelloggs bars range from 20-25g. Harvest Chewee bars 22g. Tracker bars 37g single, 26g multipack. Rice krispie square 36g, 34g or 28g packs. Special K original and bliss 22g, mini breaks 24g packs. Nutrigrain raisin bakes 45g. Elevenses carrot cake bar 40g. Ryvita goodness bar 23g. Asda bars 22g. CH: some eat 2 bars per serve	**32.96**	**30.18**	One bar average 32g
	6883	*CEREAL BAR WITH FRUITS, NO NUTS, UF*	30	9.23	32.42	2.99	30.00	2.77				
	7656	*HARVEST CHEWEEE CEREAL BARS ONLY, F*	23	7.08	25.91	1.83	22.00	1.56				
	7966	*TRACKER BAR PEANUT*	13	4.00	31.07	1.24	26.00	1.04				
	7967	*TRACKER BAR CHOCOLATE CHIP*	15	4.62	29.67	1.37	26.00	1.20				
	8022	*CEREAL BARS REDUCED FAT ONLY UF*	13	4.00	22.38	0.90	21.00	0.84				
	8044	*CEREAL BARS MADE WITH OATS ONLY UF*	18	5.54	39.00	2.16	42.00	2.33				
	8070	*KELLOGGS RICE KRISPIES SQUARES ALL*	3	0.92	30.33	0.28	28.00	0.26				
	8165	*KELLOGGS SPECIAL K BLISS CEREAL BAR F*	12	3.69	21.67	0.80	22.00	0.81				
	8442	*KELLOGGS NUTRIGRAIN OAT BAKED BARS*	6	1.85	50.00	0.92	50.00	0.92				
	8616	*SAINSBURYS FRUIT & YOGURT BALANCE BAR F*	1	0.31	25.00	0.08	25.00	0.08				
	10057	*CEREAL BARS WITH FRUIT, NO NUTS, COATED, UF*	30	9.23	32.53	3.00	32.50	3.00				
	10058	*CEREAL BARS WITH NUTS, NO FRUIT, NOT COATED, UF*	12	3.69	39.42	1.46	34.50	1.27				
	10059	*CEREAL BARS WITH FRUIT & NUTS, NOT COATED, UF*	39	12.00	36.44	4.37	30.00	3.60				
	10060	*CEREAL BARS WITH FRUIT & NUTS, COATED, UF*	49	15.08	38.39	5.79	35.00	5.28				
	10130	*NUTRIGRAIN ELEVENSES BARS, F, ANY, NOT CARROT*	12	3.69	45.00	1.66	45.00	1.66				
	10187	*SPECIAL K CEREAL BARS, FRUIT WITH YOGURT TOPPING ONLY*	11	3.38	25.30	0.86	23.00	0.78				
	10216	*SPECIAL K MINI BREAKS*	11	3.38	26.18	0.89	24.00	0.81				
	10259	*TESCO SPECIAL FLAKE CEREAL BAR WITH CHOCOLATE CHIPS FORTIFIED*	1	0.31	21.00	0.06	21.00	0.06				
	10286	*NUTRIGRAIN ELEVENSES CARROT CAKE BAR*	2	0.62	40.00	0.25	40.00	0.25				

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	10300	*RYVITA GOODNESS BARS*	10	3.08	30.67	0.94	23.00	0.71				
	10536	*WEETABIX OATY BARS*	1	0.31	23.00	0.07	23.00	0.07				
	10708	*ASDA VITALITY CEREAL BAR*	5	1.54	27.50	0.42	22.00	0.34				
		Total	325									
(f) Flapjacks (each)	357	*FLAPJACKS, HOMEMADE*	7	14.00	43.03	6.02	40.20	5.63	FPSB: Boots 70g, large 90g, yoghurt coated 50g.	**45.40**	**36.04**	Average serve 45g
	261	*FLAPJACKS, PURCHASED*	27	54.00	42.64	23.03	30.00	16.20				
	5752	*OAT FLAPJACK DIPPED IN CHOCOLATE (RECIPE)*	2	4.00	77.70	3.11	77.70	3.11				
	8160	*FLAPJACKS WITH CHOCOALTE, PURCHASED*	13	26.00	43.23	11.24	35.00	9.10				
	10064	*FLAPJACKS, REDUCED FAT, PURCHASED*	1	2.00	100.00	2.00	100.00	2.00				
		Total	50									
(g) Crisps or other packet snacks, e.g. Walkers crisps, Wotsits (one packet) – Not Wholegrain												
(h)Wholegrain snacks, e.g. Walkers Sunbites (one packet)	275	*TWIGLETS*	3	11.54	31.67	3.65	25.00	2.88	FPSB: Twiglets 25/50/100g. BP: Twiglets 24/150g bags. Rvyita mini 24/30g. Sunbites 25g. CH: 25 or 45g serves	**26.42**	**26.35**	One packet 25g
	8155	*MINI CRISPBREAD SNACKS FLAVOURED, E.G. RYVITA MINIS*	7	26.92	27.43	7.38	30.00	8.08				
	10182	*WALKERS SUNBITES*	16	61.54	25.00	15.38	25.00	15.38				
		Total	26									
(i) Tortilla crisps, e.g. Doritos, Nachos (one packet)	7876	*TORTILLA CHIPS*	35	34.31	36.49	12.52	15.00	5.15	FPSB: Tortilla chips 50/100g. BP: Doritos 30g	**38.66**	**24.95**	One packet 40g
	10070	*TORTILLA CHIPS IN SUNSEED OR HIGH OLEIC SUNFLOWER OIL, E.G.DORITOS*	67	65.69	39.79	26.14	30.00	19.71				
		Total	102									
	2268	*POPCORN HOMEMADE NO ADDED SALT*	6	24.00	115.55	27.73	100.00	24.00	FPSB: 25/75g BP: Tescos online range 70-200g bags	**91.41**	**57.38**	One packet average 90g
	4408	*POPCORN SALTED E.G. MICROWAVE OR PURCHASED*	15	60.00	95.20	57.12	50.00	30.00				
	10523	*HOMEMADE POPCORN WITH OLIVE OIL*	1	4.00	30.00	1.20	30.00	1.20				
	10770	*POPCORN PLAIN NO ADDED FAT, SUGAR OR SALT*	3	12.00	44.65	5.36	18.13	2.18				
		Total	25									

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Table E.5 Portion size details for sweets and snacks (cakes and deserts), questionnaire question 4 continued

Question in cereal foods questionnaire	NDNS diet diary records 2008-2012: NDNS Food Code	Food Name	Frequency consumed	Relative contribution %	Portion size (g): Mean	Multiplier (mean)	Median	Multiplier (median)	Comments	Weighted portion size (g): Mean	Median	Final decided potion size
Sweets & snacks (medium serving)												
(l) Homemade cakes, e.g. fruit sponge (medium slice) (1) made with white flour	9803	APPLE CAKE MADE WITH BUTTER	2	1.03	33.75	0.35	33.75	0.35	FPSB: Banana cake 85g, cherry cake 42g, coconut cake 40g, fruit cake 90g, rich fruit cake 70g, cheesecake slice 120g, cheesecake individual 90g, chocolate cake 65g, sponge cake 58g, sponge cake with filling/icing 60g, chocolate cupcake 40g, fairy cake 28g, gateau 85g, swiss roll 30g, fruit malt loaf 35g, tiramisu 90g.	**53.07**	**49.17**	Medium slice average 60g
	302	BANANA CAKE, HOMEMADE	1	0.52	50.00	0.26	50.00	0.26				
	7686	CHERRY CAKE	4	2.06	34.50	0.71	32.00	0.66				
	9768	COCONUT CAKE HOMEMADE	1	0.52	30.00	0.15	30.00	0.15				
	9306	FRUIT CAKE HOMEMADE WITH MARG	3	1.55	105.00	1.62	90.00	1.39				
	334	FRUIT CAKE PLAIN HOMEMADE	22	11.34	50.09	5.68	40.00	4.54				
	3647	FRUIT CAKE,DIABETIC,NO FAT	1	0.52	90.00	0.46	90.00	0.46				
	333	ICED RICH FRUIT CAKE HOMEMADE	4	2.06	61.50	1.27	61.50	1.27				
	331	RICH FRUIT CAKE HOMEMADE NOT ICED	2	1.03	79.00	0.81	79.00	0.81				
	6216	CARROT CAKE HOMEMADE, NO ICING	10	5.15	40.00	2.06	40.00	2.06				
	3899	CARROT CAKE WITH SOFT CHEESE ICING, HOMEMADE	2	1.03	33.23	0.34	33.23	0.34				
	305	CARAMEL SHORTCAKE HOMEMADE	1	0.52	37.00	0.19	37.00	0.19				
	509	CHEESECAKE BAKED HOMEMADE	3	1.55	80.00	1.24	80.00	1.24				
	389	WELSH CHEESECAKE	1	0.52	43.00	0.22	43.00	0.22				
	8576	CHOCOLATE CAKE NO FAT, FILLING, ICING	1	0.52	40.15	0.21	40.15	0.21				
	8713	CHOCOLATE CAKE PUFA MARG HOMEMADE NO FILLING/ICING	1	0.52	65.00	0.34	65.00	0.34				
	3905	CHOCOLATE SPONGE CAKE MADE WITH BUTTER, HOMEMADE BUTTER ICING	1	0.52	50.00	0.26	50.00	0.26				
	3091	CHOCOLATE SPONGE CAKE MADE WITH REDUCED FAT SPREAD, HOMEMADE	1	0.52	65.00	0.34	65.00	0.34				
	8858	LEMON SPONGE CAKE MADE WITH PUFA MARG ICED	2	1.03	40.00	0.41	40.00	0.41				
	308	SPONGE CAKE CHOCOLATE WITH MARG NOT PUFA, BUTTER ICING, HOMEMADE	20	10.31	52.78	5.44	49.00	5.05				
	8647	SPONGE CAKE HOMEMADE, PUFA MARG, JAM & GLACE ICING	2	1.03	50.00	0.52	50.00	0.52				
	9556	SPONGE CAKE M WITH PUFA & WATER ICING	1	0.52	40.00	0.21	40.00	0.21				
	9548	SPONGE CAKE MADE WITH BUTTER	4	2.06	47.75	0.98	45.50	0.94				
	5377	SPONGE CAKE MARG LEMON & ICING	2	1.03	40.00	0.41	40.00	0.41				
	8680	SPONGE CAKE PUFA MARG HOMEMADE NO FILLING NO ICING	2	1.03	40.00	0.41	40.00	0.41				
	8508	SPONGE CAKE WITH JAM & BUTTERCREAM FILLING, HOMEMADE	7	3.61	61.43	2.22	40.00	1.44				
	374	SPONGE CAKE WITH MARG, JAM FILLING, HOMEMADE	8	4.12	42.50	1.75	40.00	1.65				
	2644	SPONGE CAKE WITH MARG, NOT CHOCOLATE, HOMEMADE	4	2.06	50.00	1.03	50.00	1.03				
	378	SPONGE NOT W/MEAL NOT CHOC WITH MARG BUTTER ICING	12	6.19	41.67	2.58	40.00	2.47				
	5534	VIC. SPONGEWITH FONDANT ICING & BUTTER CREAM FILL	17	8.76	63.35	5.55	60.00	5.26				
	413	VICTORIA SANDWICH WITH JAM FILLING & ICING	25	12.89	50.20	6.47	45.00	5.80				
	5158	CHOCOLATE CHIP MUFFINS HOMEMADE	4	2.06	74.38	1.53	74.38	1.53				
	309	CHOCOLATE CUP CAKES HOMEMADE	1	0.52	180.00	0.93	180.00	0.93				
	9788	SIMNEL CAKE	2	1.03	68.00	0.70	68.00	0.70				
	8551	CHOCOLATE GATEAU WITH FRESH CREAM HOMEMADE	2	1.03	106.25	1.10	106.25	1.10				
	387	WALNUT GATEAUX	1	0.52	64.00	0.33	64.00	0.33				
	8507	SWISS ROLL WITH JAM & CREAM FILLING	3	1.55	23.40	0.36	20.10	0.31				
	376	SWISS ROLL/SPONGE NO FAT JAM FILLING	1	0.52	20.00	0.10	20.00	0.10				
	6266	TIRAMISU	4	2.06	75.00	1.55	75.00	1.55				
	2795	BANANA BREAD, HOMEMADE	1	0.52	26.00	0.13	26.00	0.13				
	320	DATE & WALNUT LOAF	1	0.52	26.00	0.13	26.00	0.13				

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	3037	*FRUIT LOAF MADE WITH TEA, NO FAT*	5	2.58	36.70	0.95	35.00	0.90				
	345	*LARDY CAKE*	1	0.52	78.00	0.40	78.00	0.40				
	388	*WALNUT LOAF*	1	0.52	70.00	0.36	70.00	0.36				
		Total	194									
(2) made with wholemeal flour – Non consumed so use white flour cake portion size												
(m) Readymade cakes, e.g. fruit sponge (medium slice) (1) made with white flour	3992	*CAKE BARS, NOT CHOCOLATE, INDIVIDUAL, PURCHASED*	2	0.23	91.50	0.21	91.50	0.21	FPSB: Almond slice 35g, Battenburg slice 32g, sponge cake no fat with cream purchased 58g, cheesecake individual 90g, cheesecake slice 120g, American muffins purchased 85g, cupcakes 39g, chocolate cupcake 40g, fairy cake 28g, coconut cake slice 40g, fruit cake purchased 60g, fruit cake rich 70g, gateau 85/90g, gingerbread 50g, malt loaf slice 35g, chocolate cake with buttercream 35/65g, chocolate fudge slice 98g, sponge cake with filling 60g, madeira cake slice 40g, Swiss roll slice 30g, tiramisu 90g.	**63.13**	**58.41**	Medium slice average 60g
	8161	*CHOCOLATE CAKE BAR WITH CHOCOLATE CHIPS PURCHASED*	5	0.56	55.20	0.31	66.00	0.37				
	5201	*CHOCOLATE COATED CAKE BARS, INDIVIDUAL, PURCHASED*	25	2.82	35.41	1.00	32.00	0.90				
	4042	*ALMOND SLICES; ALMOND FINGERS, PURCHASED*	10	1.13	51.15	0.58	40.00	0.45				
	304	*BATTENBURG, PURCHASED*	3	0.34	38.00	0.13	32.00	0.11				
	8016	*CHOCOLATE BROWNIE NO NUTS PURCHASED*	33	3.72	72.13	2.68	85.00	3.16				
	8069	*LEMON SLICES ICING LOW FAT PURCHASED ONLY*	2	0.23	41.00	0.09	41.00	0.09				
	6061	*LOWER FAT CAKE SLICES PURCHASED*	8	0.90	49.50	0.45	48.00	0.43				
	10548	*ROCKY ROAD/TIFFIN*	5	0.56	47.50	0.27	45.00	0.25				
	5722	*CARROT CAKE ICED PURCHASED*	19	2.14	58.66	1.26	50.00	1.07				
	10073	*CARROT CAKE NO ICING, PURCHASED*	7	0.79	28.50	0.22	21.00	0.17				
	5474	*CHEESECAKE LOW FAT FRUIT TOPPING PURCHASED*	11	1.24	110.00	1.36	100.00	1.24				
	588	*CHEESECAKE PACKET MIX AS SERVED INC FRUIT TOPPING*	4	0.45	95.00	0.43	100.00	0.45				
	510	*CHEESECAKE WITH FRUIT, PURCHASED, FROZEN OR CHILLED (NOT INDIVIDUAL, NOT LOW FAT)*	26	2.93	121.68	3.56	115.63	3.39				
	6962	*CHEESECAKE, FRUIT, INDIVIDUAL FULL FAT, PURCHASED*	13	1.46	96.42	1.41	100.00	1.46				
	8626	*CHEESECAKE, PLAIN/CHOCOLATE/ COFFEE/ CARAMEL, PURCHASED, FROZEN OR CHILLED, NO FRUIT*	31	3.49	100.73	3.52	110.00	3.84				
	10074	*AMERICAN MUFFINS LOW FAT, PURCHASED, ANY FLAVOUR*	3	0.34	97.50	0.33	130.00	0.44				
	3987	*AMERICAN MUFFINS, NOT CHOCOLATE*	36	4.05	84.40	3.42	85.00	3.45				
	307	*CHINESE GLUTINOUS RICE FLOUR CAKES*	1	0.11	20.00	0.02	20.00	0.02				
	4014	*CHOCOLATE MUFFINS, LOW FAT*	3	0.34	18.67	0.06	14.00	0.05				
	7687	*CUPCAKES PURCHASED, ANY FLAVOUR*	25	2.82	41.87	1.18	40.00	1.13				
	7689	*FAIRY CAKE, PLAIN, ICED, PURCHASED*	23	2.59	38.78	1.00	28.00	0.73				
	8555	*FAIRY CAKES CHOCOLATE NOT ICED PURCHASED*	1	0.11	28.00	0.03	28.00	0.03				
	8367	*FAIRY CAKES PLAIN NOTICED PURCHASED*	24	2.70	47.99	1.30	40.00	1.08				
	329	*FANCY ICED CAKES*	20	2.25	42.28	0.95	33.50	0.75				
	6597	*MUFFINS AMERICAN, CHOCOLATE, PURCHASED*	38	4.28	86.31	3.69	85.00	3.64				
	7688	*COCONUT CAKE PURCHASED*	6	0.68	33.33	0.23	32.50	0.22				
	8105	*FRUIT CAKE PLAIN PURCHASED*	44	4.95	53.68	2.66	45.00	2.23				
	8568	*FRUIT CAKE RICH ICED WITH MARZIPAN PURCHASED*	6	0.68	58.67	0.40	53.00	0.36				
	332	*FRUIT CAKE RICH PURCHASED*	13	1.46	75.12	1.10	70.00	1.02				
	7694	*GATEAU CHOCOLATE (SPONGE) PURCHASED EG BLACK FOREST*	6	0.68	70.75	0.48	64.00	0.43				
	8550	*GATEAUX NOT CHOCOLATE (SPONGE) FROZEN OR CHILLED*	5	0.56	79.60	0.45	85.00	0.48				
	5603	*RICH CHOCOLATE GATEAU, PURCHASED*	6	0.68	97.00	0.66	109.00	0.74				
	10075	*DATE & WALNUT LOAF PURCHASED*	2	0.23	28.13	0.06	28.13	0.06				
	109	*FRUIT LOAF PURCHASED, TOASTED*	10	1.13	62.10	0.70	62.00	0.70				
	108	*FRUIT LOAF, PURCHASED*	39	4.39	61.33	2.69	35.00	1.54				
	7691	*GINGERBREAD/GINGERCAKE PURCHASED*	20	2.25	53.15	1.20	40.00	0.90				
	9020	*GOLDEN SYRUP CAKE PURCHASED*	1	0.11	96.67	0.11	96.67	0.11				
	149	*MALT LOAF FRUIT PURCHASED*	46	5.18	70.34	3.64	70.00	3.63				
	150	*MALT LOAF, TOASTED*	2	0.23	66.00	0.15	66.00	0.15				
	8672	*CARAMEL SHORTCAKE PURCHASED*	22	2.48	46.36	1.15	38.50	0.95				

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	10519	*CAKE WITH JAM & BUTTERCREAM PURCHASED*	16	1.80	66.08	1.19	60.00	1.08				
	8122	*CAKE, NOT CHOCOLATE, WITH ICING BUTTERCREAM, PURCHASED*	32	3.60	71.36	2.57	60.00	2.16				
	3082	*CHOCOLATE CAKE NO FILLING OR ICING, PURCHASED*	7	0.79	45.93	0.36	48.00	0.38				
	8017	*CHOCOLATE CAKE WITH FILLING & ICING PURCHASED ONLY*	25	2.82	67.90	1.91	65.00	1.83				
	3897	*CHOCOLATE FUDGE CAKE, PURCHASED*	13	1.46	53.77	0.79	50.00	0.73				
	349	*MADEIRA CAKE*	6	0.68	51.33	0.35	50.00	0.34				
	375	*SPONGE CAKE FATLESS PURCHASED INCLUDING SPONGE FINGERS*	5	0.56	33.26	0.19	28.00	0.16				
	381	*SPONGE CAKE MIX PACKET AS SERVED*	2	0.23	45.00	0.10	45.00	0.10				
	8600	*SPONGE CAKE WITH FAT NO FILLING NO ICING PURCHASED*	8	0.90	41.31	0.37	37.00	0.33				
	5448	*SPONGE CAKE WITH JAM & GLACE ICING, NOT CHOC, PURCHASED*	9	1.01	65.56	0.66	60.00	0.61				
	379	*SPONGE CAKE/ SWISS ROLL, NOT CHOCOLATE, FRESH CREAM & JAM FILLING, PURCHASED*	39	4.39	48.40	2.13	45.00	1.98				
	380	*SPONGE JAM FILLED PURCHASED*	15	1.69	35.04	0.59	30.00	0.51				
	9374	*TORTES NOT CHOCOLATE BASED PURCHASED FROZEN*	3	0.34	109.58	0.37	120.00	0.41				
	10307	*CHOCOLATE SPONGE/SWISS ROLL WITH FRESH CREAM & CHOCOLATE SAUCE*	7	0.79	98.00	0.77	86.00	0.68				
	8562	*CHOCOLATE SWISS ROLL WITH BUTTERCREAM PURCHASED*	34	3.83	68.18	2.61	65.00	2.49				
	383	*SWISS ROLL INDIVIDUAL CHOCOLATE COATED PURCHASED*	40	4.50	31.94	1.44	20.00	0.90				
	8564	*SWISS ROLL WITH FILLING, PURCHASED*	12	1.35	47.50	0.64	30.00	0.41				
	9533	*TIRAMISU, PURCHASED*	9	1.01	94.97	0.96	90.00	0.91				
		Total	888									
(2) made with wholemeal flour	167	*WHOLE MEAL MALT LOAF*	1	20.00	105.00	21.00	105.00	21.00	FPSB: malt loaf slice 35g, fruit cake purchased 60g	**53.00**	**53.00**	
	7690	*WHOLEMEAL FRUIT CAKE PURCHASED*	4	80.00	40.00	32.00	40.00	32.00				
		Total	5									
(n) Home baked buns / pastries, e.g. scones (each) (1) made with white flour	303	*CHELSEA BUNS NOT WHOLEMEAL*	9	8.18	112.22	9.18	78.00	6.38	FPSB: Chelsea bun 78g, Eccles cakes 45g, chocolate éclair homemade 90g, scones 48g, rock cake 45g, rum baba 198g, welsh cakes 28g, profiteroles 155g	**59.23**	**49.45**	One bun/ pastry/ scone average 60g
	326	*ECCLES CAKES*	8	7.27	42.19	3.07	45.00	3.27				
	328	*CHOCOLATE ECLAIR WITH ARTIFICIAL CREAM*	1	0.91	90.00	0.82	90.00	0.82				
	367	*CHEESE SCONES NOT WHOLEMEAL*	12	10.91	38.00	4.15	42.00	4.58				
	369	*PLAIN SCONES*	53	48.18	61.26	29.52	48.00	23.13				
	370	*ROCK CAKES*	3	2.73	37.50	1.02	45.00	1.23				
	371	*POTATO SCONES*	1	0.91	57.00	0.52	57.00	0.52				
	584	*RUM BABA; SAVARIN*	2	1.82	142.75	2.60	142.75	2.60				
	5686	*PLAIN SCONES MADE WITH BUTTER*	5	4.55	37.80	1.72	37.92	1.72				
	7680	*ECLAIRS & PROFITEROLES, CHOCOLATE ICING, FRESH CREAM, HOMEMADE*	2	1.82	60.00	1.09	60.00	1.09				
	7692	*WELSH CAKES*	11	10.00	43.27	4.33	28.00	2.80				
	8607	*FRUIT SCONE MADE WITH PUFA MARGARINE*	3	2.73	45.13	1.23	48.00	1.31				
		Total	110									
(2) made with wholemeal flour	407	*WHOLEMEAL FRUIT BUN*	12	48.00	58.24	27.95	60.00	28.80	FPSB: Currant bun 60g, hot cross bun 50g, wholemeal scone 50g, Scone 48g	**53.51**	**54.36**	
	7675	*HOT CROSS BUNS, CURRANT BUNS, WHOLEMEAL*	8	32.00	50.00	16.00	50.00	16.00				
	372	*WHOLEMEAL SCONES PLAIN*	3	12.00	48.00	5.76	48.00	5.76				
	3189	*WHOLEMEAL FRUIT SCONES*	2	8.00	47.50	3.80	47.50	3.80				
		Total	25									
(o) Readymade buns / pastries, e.g. croissants, doughnuts (each)	10273	*CHOCOLATE CHIP BRIOCHE ROLLS PURCHASED*	12	1.65	38.75	0.64	36.88	0.61	FPSB: Currant bun 60g, Eccles cakes 45g, hot cross bun 50g, iced bun 65g, croissant:	**66.78**	**63.42**	One bun/ pastry/ scone average 60g
	8123	*CURRANT BUNS PURCHASED, NOT WHOLEMEAL, NOT TEACAKES*	99	13.60	58.89	8.01	50.00	6.80				
	10076	*ECCLES CAKES PURCHASED*	10	1.37	86.54	1.19	69.50	0.95				
	5843	*FRESH CREAM BUN WITH JAM, PURCHASED*	1	0.14	78.00	0.11	78.00	0.11				

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(1) made with white flour	10454	HOT CROSS BUNS LIGHT/LOW CALORIE PURCHASED	8	1.10	86.25	0.95	70.00	0.77	chocolate 60g, mini 35g, plain 60g, doughnut: apple filled 85g, custard filled 75g, iced 75g, jam 75g, large 130g, ring 60g, apple turnover 100g, choux bun 112g, Danish pastry: large 180g, small 110g, chocolate éclair purchased 35g, profiteroles 155g, apple strudel 115g, baklava 100g, scones 48g/50g, teacakes 55/60g BP: Sara Lee desert 66.5g			
	8125	ICED BUN PURCHASED	14	1.92	57.79	1.11	52.75	1.01				
	8366	CROISSANT WITH A SAVOURY FILLING	2	0.27	105.00	0.29	105.00	0.29				
	8176	CROISSANT WITH SWEET FILLING	4	0.55	158.75	0.87	92.50	0.51				
	166	CROISSANTS PLAIN NOT FILLED	74	10.16	69.77	7.09	60.00	6.10				
	8111	PAIN AU CHOCOLATE/CHOCOLATE CROISSANT	37	5.08	65.26	3.32	60.00	3.05				
	8432	REDUCED FAT CROISSANTS	2	0.27	77.00	0.21	77.00	0.21				
	323	DOUGHNUT RING, NOT ICED OR GLAZED, PURCHASED	21	2.88	50.86	1.47	60.00	1.73				
	325	DOUGHNUTS FRESH CREAM FILLED	9	1.24	75.00	0.93	75.00	0.93				
	324	DOUGHNUTS JAM FILLED, WITH OR WITHOUT GLAZE, PURCHASED	50	6.87	83.57	5.74	75.00	5.15				
	7678	DOUGHNUTS WITH CONFECTIONERS CUSTARD FILLING	11	1.51	73.30	1.11	75.00	1.13				
	7679	ICED OR GLAZED RING DOUGHNUTS	28	3.85	76.82	2.95	75.00	2.88				
	9026	APPLE TURNOVER FLAKY PASTRY PURCHASED	10	1.37	98.93	1.36	100.00	1.37				
	7677	CHOUX BUN FILLED FRESH CREAM, ICED	3	0.41	88.33	0.36	90.00	0.37				
	386	CUSTARD SLICE / VANILLA SLICE, PURCHASED	12	1.65	116.33	1.92	113.00	1.86				
	318	DANISH PASTRIES	41	5.63	86.53	4.87	92.00	5.18				
	327	ECLAIRS & PROFITEROLES, CHOCOLATE ICING, FRESH CREAM FILLING, PURCHASED, FRESH OR FROZEN	51	7.01	56.08	3.93	60.00	4.20				
	313	FRESH CREAM HORN / CREAM SLICE	10	1.37	63.40	0.87	60.00	0.82				
	9141	FRUIT FILLED STRUDELS, PURCHASED	10	1.37	62.15	0.85	130.00	1.79				
	4556	GREEK PASTRIES E.G. BAKLAWA	11	1.51	73.00	1.10	67.00	1.01				
	6385	RICH CHOCOLATE DANISH DESERT EG SARA LEE	1	0.14	80.00	0.11	80.00	0.11				
	10518	PLAIN SCONES PURCHASED	16	2.20	72.66	1.60	64.50	1.42				
	368	SCONES, FRUIT, NOT WHOLEMEAL, PURCHASED	87	11.95	49.64	5.93	48.00	5.74				
	3780	SCONES,FRUIT,REDUCED FAT PURCHASED	1	0.14	27.00	0.04	27.00	0.04				
	384	TEACAKES	36	4.95	62.94	3.11	60.00	2.97				
	385	TEACAKES, TOASTED	57	7.83	60.61	4.75	55.00	4.31				
		Total	728									
(2) made with wholemeal flour – Non consumed so use white flour portion size												
(p) Home baked fruit pies, tarts, crumbles (per individual pie/medium serving) (1) made with white flour	502	APPLE CRUMBLE NOT WHOLEMEAL	22	16.54	157.27	26.02	170.00	28.12	FPSB: crumble (any fruit) 170g, mince pie 55/90g, fruit pie: average 110g, deep fried 80d, small 54g, large 100g, cherry bakewell 46g, custard tart 94/140g, fruit tart/flan 95g, treacle tart 35g, jam tart 34/90g.	**94.30**	**96.79**	Individual pie/ medium serving average 80g
	503	FRUIT CRUMBLE NOT APPLE NOT WHOLEMEAL	7	5.26	154.29	8.12	170.00	8.95				
	2783	RHUBARB CRUMBLE WITH OATS & PUFA MARGARINE	1	0.75	170.00	1.28	170.00	1.28				
	9934	BLACKCURRANT CRUMBLE	1	0.75	170.00	1.28	170.00	1.28				
	353	MINCE PIES NOT WHOLEMEAL INDIVIDUAL	1	0.75	55.00	0.41	55.00	0.41				
	521	FRUIT PIE 1 CRUST PASTRY MARG	1	0.75	4.20	0.03	4.20	0.03				
	524	FRUIT PIE 1 CRUST (MARG & CCF)	1	0.75	100.00	0.75	100.00	0.75				
	526	FRUIT PIE 2 CRUST PASTRY MARG	2	1.50	110.00	1.65	110.00	1.65				
	536	BL'CURR PIE 2 CRUST (MARG)	1	0.75	120.00	0.90	120.00	0.90				
	3308	MINCE PIES PUFF PASTRY	3	2.26	73.33	1.65	55.00	1.24				
	5398	APPLE PIE MADE WITH ALL BUTTER PASTRY	4	3.01	98.75	2.97	120.00	3.61				
	6820	MINCE PIES WITH SWEETENED BUTTER PASTRY	1	0.75	55.00	0.41	55.00	0.41				
	9686	MINCE PIES SWEET INDIVIDUAL W SHORTCRUST	31	23.31	66.53	15.51	55.00	12.82				
	9717	APPLE PIE WITH PURCHASED SHORTCRUST PASTRY	20	15.04	89.00	13.38	100.00	15.04				
	301	BAKEWELL TART; FRANGIPANE TART; HOMEMADE	2	1.50	113.60	1.71	113.60	1.71				
	311	COCONUT TART	5	3.76	91.32	3.43	90.00	3.38				
	341	JAM TARTS NOT WHOLEMEAL HOMEMADE INDIVDUAL	7	5.26	43.71	2.30	34.00	1.79				
	343	JAM TREACLE TART TWO CRUST	1	0.75	45.00	0.34	45.00	0.34				

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	346	*LEMON CURD TART*	13	9.77	63.73	6.23	68.00	6.65				
	5546	*CHOCOLATE FUDGE TART MADE WITH SHORTCRUST PASTRY*	2	1.50	90.00	1.35	90.00	1.35				
	7700	*FLAN FRUIT WITH RICH SHORTCRUST PASTRY*	2	1.50	90.15	1.36	90.15	1.36				
	8704	*APPLE BAKEWELL TART*	2	1.50	65.41	0.98	65.41	0.98				
	8758	*JAM TART INDIVIDUAL MADE WITH ALL MARG HOMEMADE*	1	0.75	34.00	0.26	34.00	0.26				
	9643	*BAKEWELL TART PASTRY MADE W ALL MARG*	3	2.26	88.75	2.00	111.25	2.51				
		Total	133									
(2)made with wholemeal flour	342	*JAM TREACLE TART WHOLEMEAL*	1		68.00		68.00		FPSB: treacle tart 35g, jam tart 34/90g			
		Total	1									
(q) Readymade fruit pies, tarts, crumbles (per individual pie/medium serving) (1) made with white flour	6966	*CRUMBLE, FRUIT, PURCHASED*	13	4.80	130.84	6.28	120.00	5.76	FPSB: crumble (any fruit) 170g, apple pie purchased: Burger King 78g, Kentucky 81g, McDonald 115g, fruit pie: average 110g, deep fried 80d, small 54g, large 100g, purchased 150g, lemon meringue pie 95g, custard tart 94/140g, fruit tart/flan 95g, treacle tart 35g, jam tart 34/90g.	**85.34**	**76.26**	Individual pie/ medium serving average 80g
	9573	*CRUMBLE TOPPING-NOT WHOLEMEAL READY MIXED UNCOOKED*	4	1.48	28.04	0.41	25.88	0.38				
	520	*FRUIT PIE INDIVIDUAL PASTRY TOP & BOTTOM*	40	14.76	80.31	11.85	72.00	10.63				
	586	*FRUIT PIE/FRIED EG. MC DONALDS*	2	0.74	115.00	0.85	115.00	0.85				
	6965	*BANOFFEE PIE, PURCHASED*	9	3.32	93.78	3.11	85.00	2.82				
	6967	*APPLE PIE, DOUBLE CRUST, PURCHASED (CHILLED, FROZEN OR AMBIENT)*	35	12.92	108.75	14.05	120.00	15.50				
	7708	*LEMON MERINGUE PIE, PURCHASED*	8	2.95	106.19	3.13	95.00	2.80				
	9893	*CHERRY PIE, TWO CRUSTS, PURCHASED*	14	5.17	117.86	6.09	110.00	5.68				
	316	*CUSTARD TART INDIVIDUAL*	22	8.12	120.32	9.77	94.00	7.63				
	340	*JAM TARTS PURCHASED*	17	6.27	40.12	2.52	34.00	2.13				
	541	*CUSTARD TART LARGE*	4	1.48	61.50	0.91	61.50	0.91				
	572	*TREACLE TART*	2	0.74	95.00	0.70	95.00	0.70				
	4429	*ICED CHERRY BAKEWELL TART, LARGE OR SMALL , PURCHASED*	44	16.24	60.19	9.77	43.00	6.98				
	7684	*STRAWBERRY TARTLETS FRESH CREAM, SHORTCRUST PASTRY, PURCHASED*	8	2.95	54.94	1.62	54.00	1.59				
	10077	*MINCE PIES PURCHASED*	47	17.34	79.76	13.83	66.00	11.45				
	10447	*RICH CHOCOLATE TART PURCHASED*	2	0.74	60.00	0.44	60.00	0.44				
		Total	271									
(2) made with wholemeal flour – Non consumed so use white flour portion size												
(r) Home baked sponge puddings (medium slice) (1) made with white flour	505	*BREAD PUDDING*	6	9.38	166.67	15.63	190.00	17.81	FPSB: Bread pudding 190g, bread & butter pudding 170g, Christmas pudding 100g, sponge pudding 100/110/300g	**127.3**	**128.3**	Medium slice average 120g
	507	*BREAD & BUTTER PUDDING*	11	17.19	180.41	31.01	170.00	29.22				
	511	*CHRISTMAS PUDDING HOMEMADE*	6	9.38	87.50	8.20	87.50	8.20				
	542	*EVES PUDDING*	4	6.25	109.38	6.84	110.00	6.88				
	567	*STEAMED SPONGE PUDDING PLAIN*	6	9.38	158.33	14.84	170.00	15.94				
	568	*STEAMED SPONGE PUDDING WITH DRIED FRUIT*	1	1.56	110.00	1.72	110.00	1.72				
	569	*STEAMED SPONGE PUDDING WITH SYRUP OR JAM*	12	18.75	110.83	20.78	110.00	20.63				
	583	*FRUIT FLAN SPONGE BASE*	6	9.38	107.08	10.04	105.00	9.84				
	5749	*ORANGE & LEMON SPONGE PUDDING BAKED*	1	1.56	53.00	0.83	53.00	0.83				
	6312	*CHOCOLATE SPONGE PUDDING WITH CHOCOLATE SAUCE*	8	12.50	97.92	12.24	100.00	12.50				
	7713	*SPOTTED DICK*	3	4.69	110.00	5.16	100.00	4.69				
		Total	64									
(2) made with wholemeal flour – Non consumed so use white flour portion size												
(s)Readymade sponge puddings (medium slice) (1) made with white flour	512	*CHRISTMAS PUDDING PURCHASED*	9	25.00	94.83	23.71	100.00	25.00	FPSB: Christmas pudding 100g, sponge pudding canned 300g	**114.5**	**115.8**	Medium slice average 120g
	566	*SPONGE PUDDING CANNED (ANY)*	2	5.56	150.00	8.33	150.00	8.33				
	3834	*JAM ROLY-POLY PURCHASED*	2	5.56	100.00	5.56	100.00	5.56				
	9673	*SUMMER PUDDING FROM SAFEWAY*	2	5.56	165.00	9.17	165.00	9.17				
	10318	*STICKY TOFFEE PUDDING PURCHASED*	17	47.22	113.53	53.61	110.00	51.94				
	10581	*CHOCOLATE SPONGE PUDDINGS WITH CHOCOLATE SAUCE CENTRE, PURCHASED*	4	11.11	127.50	14.17	142.50	15.83				
		Total	36									
(2) made with wholemeal flour – Non consumed so use white flour portion size												

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Appendix F Nutrient intakes estimated from FFQ in the NTFS

Table F.1 Nutrient intakes at 50-year follow-up from EPIC-Norfolk FFQ

	Males (n=246)					Females (n=295)				
	Mean	SD	Percentile			Mean	SD	Percentile		
Nutrient Intakes			25th	50th	75th			25th	50th	75th
Energy (kcal)	2165.6	730.3	1666.4	2051.7	2546.2	1961.5	964.1	1525.3	1846.3	2220.0
Energy (MJ)	9.1	3.1	7.0	8.6	10.7	8.3	4.1	6.4	7.8	9.3
Protein (g/10MJ)	97.7	17.4	84.8	95.7	107.8	105.2	18.9	92.7	104.7	117.2
Total Fat (g/10MJ)	91.2	16.2	79.4	92.4	102.5	87.9	16.7	77.0	87.7	97.9
Saturated Fat (g/10MJ)	34.8	8.3	28.6	35.7	40.2	32.9	8.9	26.6	32.5	37.5
PUFA (g/10MJ)	16.4	4.8	13.0	15.7	19.0	17.2	5.2	13.5	16.5	20.1
MUFA g/10MJ)	32.0	7.1	27.7	31.7	35.7	30.0	6.9	25.2	26.6	34.3
Carbohydrate (g/10MJ)	272.0	44.6	243.7	274.3	301.0	293.8	37.9	268.0	293.9	320.3
Total Sugars (g/10MJ)	129.6	37.4	103.7	127.1	149.3	142.7	36.8	118.7	144.9	164.0
Alcohol (g/10MJ)	21.3	24.0	4.7	11.4	30.7	9.2	12.1	1.1	4.9	12.3
Calcium (mg/10MJ)	1100.4	295.6	909.1	1089.5	1279.4	1201.6	316.7	971.5	1192.2	1396.0
Carotene-total (g/10MJ)	3357.4	1609.8	2174.7	3241.1	4288.7	4342.5	1975.4	2840.2	4098.0	5530.5
Cholesterol (mg/10MJ)	339.0	91.2	276.4	338.7	399.6	328.7	95.3	261.3	323.5	392.5
Copper (mg/10MJ)	1.4	0.5	1.1	1.3	1.7	1.5	0.4	1.2	1.4	1.7
Fibre (g/10MJ)	18.4	5.9	14.5	17.1	21.8	22.0	6.8	16.8	21.3	26.0
Folate (mcg/10MJ)	352.5	86.7	293.0	341.0	408.2	387.4	102.4	315.7	376.4	445.6
Iron (mg/10MJ)	13.4	2.6	11.6	12.9	14.6	14.7	3.3	12.3	14.5	16.6
Iodine (mcg/10MJ)	162.7	48.9	127.3	158.3	195.0	185.6	53.3	149.9	183.9	215.8
Magnesium (mg/10MJ)	379.0	80.4	324.7	367.6	427.5	411.2	86.0	349.5	406.1	463.2
Manganese (mg/10MJ)	4.0	1.2	3.1	3.8	4.7	4.5	1.5	3.5	4.4	5.4
Niacin (mg/10MJ)	27.5	6.7	23.0	26.4	31.6	29.5	7.4	24.5	29.6	34.0
Nitrogen (g/10MJ)	15.7	2.8	13.7	15.3	17.4	16.9	3.0	15.0	17.0	18.9
Potassium (mg/10MJ)	4388.3	969.4	3765.6	4315.9	4877.9	4740.1	927.2	4067.2	4717.9	5258.3
Phosphorus (mg/10MJ)	1673.1	276.0	1463.8	1652.3	1860.4	1810.9	302.7	1617.1	1804.6	1987.0
Sodium (mg/10MJ)	3251.6	613.3	2804.1	3186.7	3621.1	3423.4	647.8	3015.8	3348.3	3735.6
Selenium (mcg/10MJ)	78.3	18.7	65.9	76.2	88.8	86.1	23.8	69.4	83.9	100.9
Vitamin A (mcg/10MJ)	822.9	824.2	345.9	505.2	1176.1	728.6	702.2	300.9	464.0	1030.6
Vitamin B1 (mg/10MJ)	1.8	0.4	1.5	1.7	2.0	2.0	0.4	1.7	2.0	2.3
Vitamin B2 (mg/10MJ)	2.4	0.6	1.9	2.3	2.7	2.6	0.6	2.1	2.6	3.0
Vitamin B6 (mg/10MJ)	2.6	0.6	2.3	2.6	3.0	2.9	0.6	2.5	2.8	3.3
Vitamin B12 (mcg/10MJ)	8.0	3.6	5.7	7.4	9.7	8.6	3.8	6.0	7.7	10.5
Vitamin C (mg/10MJ)	120.3	68.6	73.2	103.4	146.8	153.8	68.3	105.2	142.1	191.2
Vitamin D (mcg/10MJ)	3.8	1.8	2.7	3.5	4.7	4.2	2.0	2.9	3.8	5.2
Vitamin E (mg/10MJ)	15.5	5.3	11.1	15.0	18.7	16.5	5.1	12.8	15.5	19.6
Zinc (mg/10MJ)	10.8	2.1	9.3	10.7	12.3	11.7	2.2	10.3	11.6	13.1

Table F.2 Food group intakes at 50-year follow-up from EPIC-Norfolk FFQ

	Males (n=194)					Females (n=232)				
	Mean	SD	Percentile			Mean	SD	Percentile		
Food group intakes			25th	50th	75th			25th	50th	75th
Cereals & cereal products (g/d)	241.6	128.0	150.6	222.6	296.6	242.6	218.3	159.2	210.9	279.7
Milk & milk products (g/d)	386.4	206.3	219.0	331.6	535.5	397.4	199.4	273.7	357.5	517.8
Eggs & egg dishes (g/d)	20.7	16.6	7.0	21.5	21.5	17.2	14.4	7.0	14.0	21.5
Fats & oils (g/d)	33.7	26.8	14.7	27.2	45.8	27.6	35.2	13.8	22.0	33.8
Meat & meat products (g/d)	128.5	68.6	79.8	118.7	164.4	109.2	71.3	66.3	98.9	138.6
Fish & fish products (g/d)	41.6	36.5	19.3	35.4	51.9	41.5	31.7	20.2	35.2	56.2
Fruit (g/d)	197.7	203.6	66.3	152.8	252.9	220.1	167.4	103.4	197.4	285.5
Vegetables (g/d)	240.1	127.9	155.0	222.0	296.8	269.0	130.8	181.9	247.2	330.5
Potatoes (g/d)	106.9	57.4	71.4	95.3	128.7	101.1	58.5	62.6	89.0	131.9
Nuts & seeds (g/d)	4.1	12.9	0.0	2.1	4.2	2.6	8.2	0.0	0.0	2.1
Soups & sauces (g/d)	54.7	52.2	25.8	42.0	64.6	56.2	68.9	25.8	41.3	68.3
Sugars, preserves & snacks (g/d)	47.2	40.2	20.3	38.2	59.8	46.4	44.7	17.7	35.5	63.1
Alcoholic beverages (g/d)	378.3	482.9	61.3	180.8	365.5	88.6	148.2	8.8	43.5	118.9
Non-alcoholic beverages (g/d)	1100.4	386.7	868.3	1086.2	1341.2	1139.9	431.0	898.4	1133.8	1370.1

Table F.3 Nutrient intakes at 60-year follow-up from EPIC-Norfolk FFQ

	Males (n=194)					Females (n=232)				
	Mean	**SD**	**Percentile**			**Mean**	**SD**	**Percentile**		
Nutrient Intakes			**25th**	**50th**	**75th**			**25th**	**50th**	**75th**
Energy (kcal)	1591.7	518.0	1216.2	1500.7	1841.2	1519.2	432.5	1177.2	15069.2	1796.3
Energy (MJ)	6.7	2.2	5.1	6.3	7.8	6.4	1.8	5.0	6.4	7.5
Protein (g/10MJ)	112.0	21.0	100.2	110.0	122.8	120.1	21.5	105.9	119.1	131.9
Total Fat (g/10MJ)	89.1	15.0	78.5	88.8	98.5	85.7	15.3	75.3	86.1	94.9
Saturated Fat (g/10MJ)	33.7	7.8	28.7	33.5	38.8	32.0	8.6	26.4	31.7	37.0
PUFA (g/10MJ)	15.3	4.2	12.3	14.8	17.7	15.7	4.5	12.4	15.0	18.2
MUFA g/10MJ)	32.2	6.5	28.1	32.3	36.1	30.3	6.2	26.1	30.2	33.6
Carbohydrate (g/10MJ)	270.8	44.0	245.0	272.1	299.0	282.9	38.8	256.3	281.5	309.4
Total Sugars (g/10MJ)	137.3	38.2	110.5	138.3	160.6	148.7	38.6	123.9	145.1	171.5
Alcohol (g/10MJ)	16.4	19.6	3.1	10.5	19.3	9.3	12.5	0.9	5.7	12.8
Calcium (mg/10MJ)	1223.0	395.8	962.1	1189.9	1424.6	1318.9	354.2	1054.5	1284.5	1551.6
Carotene-total (g/10MJ)	4700.7	2626.7	2773.6	4263.6	5991.3	5883.4	2560.9	4177.1	5584.6	7234.9
Cholesterol (mg/10MJ)	374.5	116.6	297.1	370.5	436.8	370.7	109.3	297.6	362.5	427.1
Copper (mg/10MJ)	1.5	0.5	1.2	1.4	1.7	1.6	0.6	1.3	1.5	1.8
Fibre (g/10MJ)	21.3	7.1	16.3	20.6	26.1	24.2	6.3	20.2	24.2	28.1
Folate (mcg/10MJ)	319.2	122.8	235.4	301.3	393.7	358.8	122.0	284.1	339.4	427.6
Iron (mg/10MJ)	14.9	3.2	12.8	14.7	16.9	16.0	3.3	13.8	15.8	17.4
Iodine (mcg/10MJ)	200.5	66.8	159.5	188.9	231.7	222.5	64.9	175.7	215.3	260.5
Magnesium (mg/10MJ)	417.8	83.2	358.5	411.7	477.3	446.2	84.7	390.8	436.0	501.3
Manganese (mg/10MJ)	4.4	1.4	3.4	4.3	5.1	4.8	1.4	3.8	4.8	5.7
Niacin (mg/10MJ)	30.8	7.6	25.6	30.4	35.3	32.8	8.3	27.0	32.0	38.2
Nitrogen (g/10MJ)	18.0	3.4	16.0	17.6	19.6	19.3	3.4	17.0	19.1	21.0
Potassium (mg/10MJ)	4909.8	930.6	4357.3	4727.6	5442.8	5315.4	1034.0	4610.6	5274.7	5910.5
Phosphorus (mg/10MJ)	1898.5	322.2	1674.4	1863.6	2074.0	2028.0	308.9	1826.0	2023.8	2220.1
Sodium (mg/10MJ)	3550.1	817.6	3017.4	3434.7	4018.9	3620.7	653.9	3137.4	3581.6	4057.9
Selenium (mcg/10MJ)	83.2	22.7	68.5	77.5	93.4	90.9	24.8	74.8	86.6	103.7
Vitamin A (mcg/10MJ)	793.2	784.9	333.3	467.9	1148.5	786.0	985.3	321.6	427.7	740.2
Vitamin B1 (mg/10MJ)	2.0	0.4	1.8	2.0	2.2	2.2	0.4	2.0	2.2	2.4
Vitamin B2 (mg/10MJ)	2.8	0.7	2.3	2.7	3.2	2.9	0.6	2.4	2.9	3.3
Vitamin B6 (mg/10MJ)	3.1	0.6	2.7	3.1	3.5	3.4	0.7	2.9	3.4	3.8
Vitamin B12 (mcg/10MJ)	9.7	4.0	7.3	8.6	11.6	11.0	4.8	7.8	10.0	13.2
Vitamin C (mg/10MJ)	148.6	72.8	92.3	140.3	187.7	192.6	83.3	136.6	182.3	234.8
Vitamin D (mcg/10MJ)	4.2	2.0	2.9	3.9	5.1	5.0	2.4	3.4	4.4	6.0
Vitamin E (mg/10MJ)	14.4	4.2	11.6	14.3	16.6	15.1	4.3	11.8	14.7	17.8
Zinc (mg/10MJ)	12.7	2.4	11.3	12.5	14.1	13.6	2.4	12.0	13.5	15.2

Table F.4 Food group intakes at 60-year follow-up from EPIC-Norfolk FFQ

	Males (n=194)					**Females (n=232)**				
	Mean	**SD**	**Percentile**			**Mean**	**SD**	**Percentile**		
Food group intakes			**25th**	**50th**	**75th**			**25th**	**50th**	**75th**
Cereals & cereal products (g/d)	163.2	89.8	97.6	150.6	208.0	172.0	86.5	106.4	158.5	221.2
Milk & milk products (g/d)	341.6	198.6	168.4	308.5	456.4	360.5	176.3	217.1	338.7	463.3
Eggs & egg dishes (g/d)	17.5	13.7	7.0	17.5	21.5	16.2	14.9	7.0	14.0	21.5
Fats & oils (g/d)	18.3	13.7	10.7	14.7	21.8	18.0	12.3	10.0	14.5	23.9
Meat & meat products (g/d)	113.2	70.8	67.1	101.0	143.7	103.5	58.2	63.1	94.6	132.6
Fish & fish products (g/d)	37.9	27.8	19.3	33.5	47.5	40.5	24.6	23.7	36.3	51.6
Fruit (g/d)	174.2	137.5	60.9	147.5	265.4	215.4	138.2	121.3	198.1	289.8
Vegetables (g/d)	234.1	128.2	149.7	207.6	291.7	277.4	119.0	192.1	268.9	347.0
Potatoes (g/d)	81.4	45.8	47.1	80.2	110.7	81.1	51.1	53.8	71.4	107.9
Nuts & seeds (g/d)	5.1	7.6	0.0	2.1	4.2	4.6	9.2	0.0	2.1	4.2
Soups & sauces (g/d)	55.7	46.8	29.4	40.1	70.6	60.5	52.3	25.9	43.1	88.1
Sugars, preserves & snacks (g/d)	34.0	28.1	12.9	27.6	45.5	28.7	23.3	13.2	22.7	39.2
Alcoholic beverages (g/d)	214.1	332.7	34.0	123.8	227.5	65.3	92.9	5.3	53.8	98.8
Non-alcoholic beverages (g/d)	881.7	390.6	609.1	908.3	1148.4	837.8	420.4	508.5	855.0	1108.6

Appendix G Regression diagnostics plots for final linear regression models

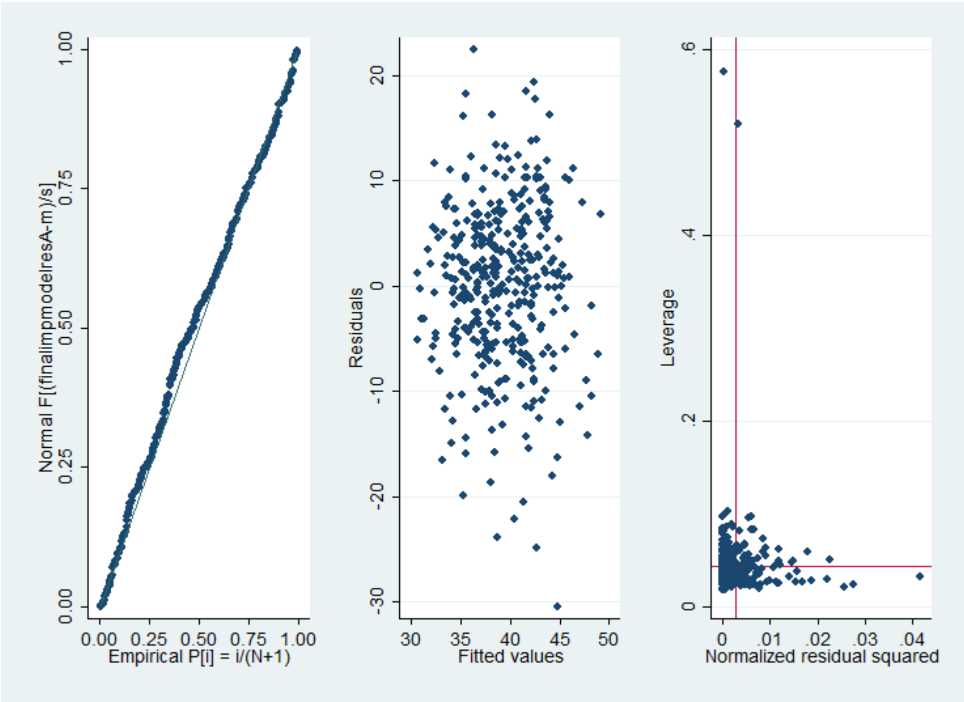

Figure G.1 Linear regression model of the association between whole grain intake (independent/predictor) and body fat percentage (dependent/outcome) at 50-year follow-up adjusted for sex, CVD medication, total energy intake, smoking status, achieved education level and SES.

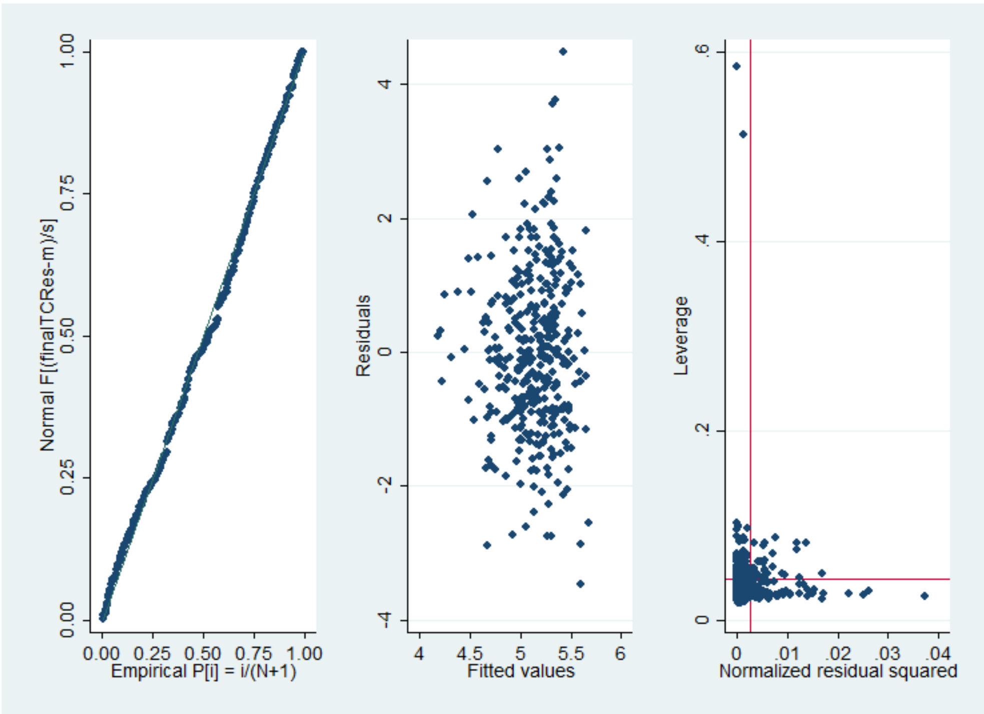

Figure G.2 Linear regression model of the association between whole grain intake and total cholesterol at 50-year follow-up adjusted for sex, CVD medication, total energy intake, smoking status, achieved education level and SES.

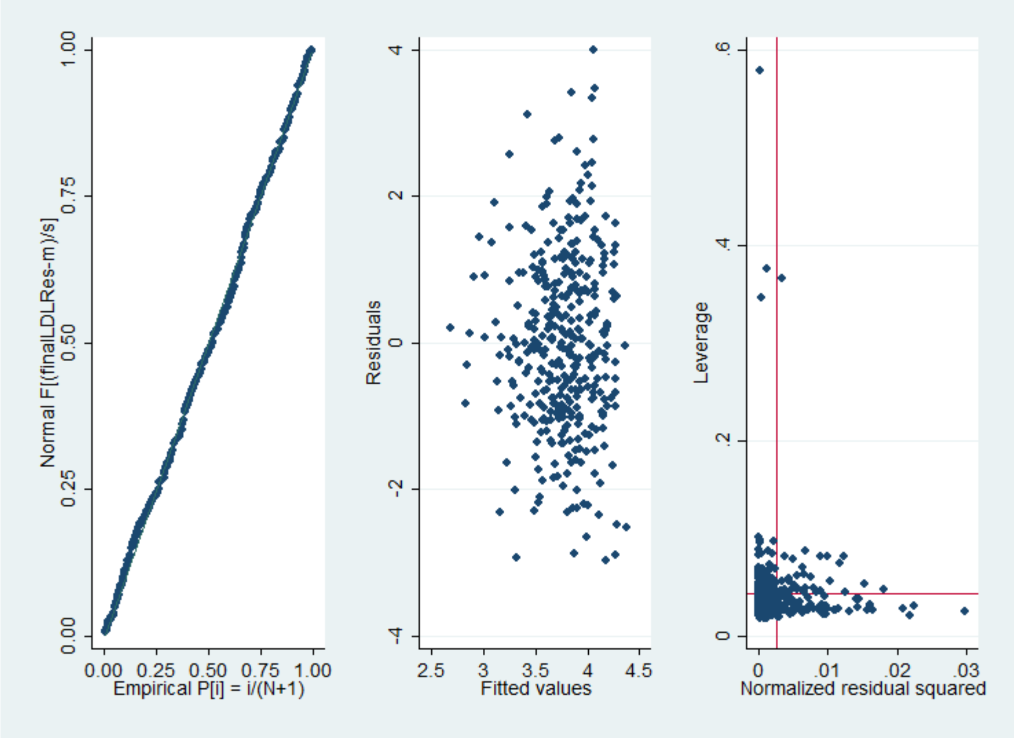

Figure G.3 Linear regression model of the association between whole grain intake and LDL cholesterol at 50-year follow-up adjusted for sex, CVD medication use, total energy intake, smoking status, achieved education level and SES.

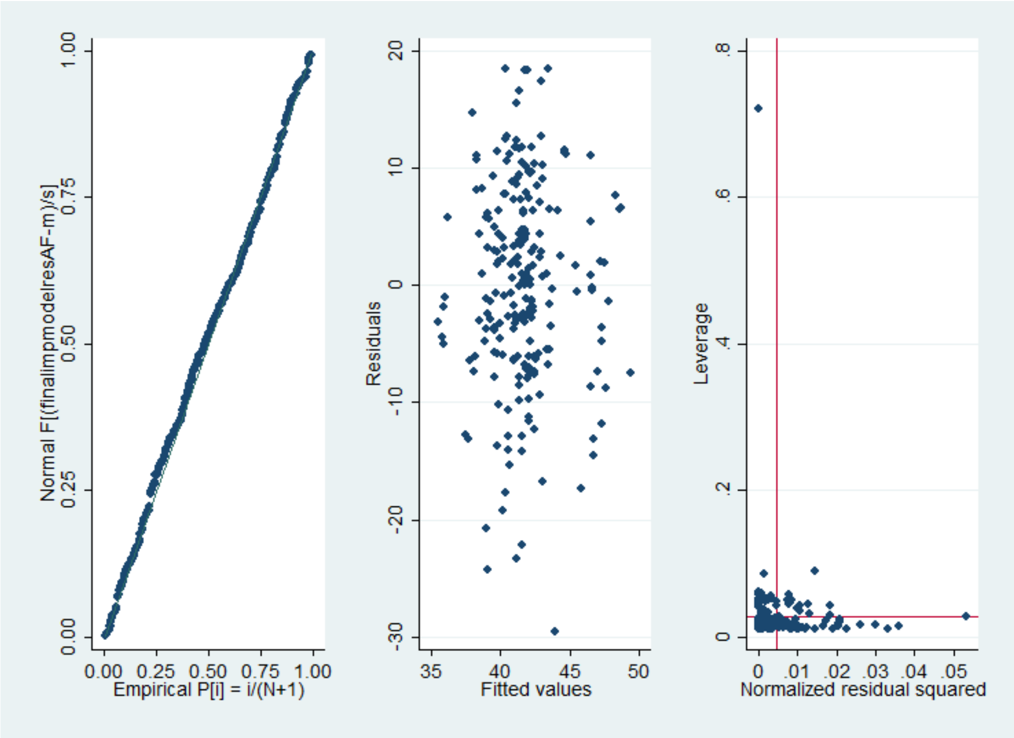

Figure G.4 Linear regression model of the association between whole grain intake and body fat percentage in females only at 50-year follow-up adjusted for sex, CVD medication use, total energy intake, and smoking status.

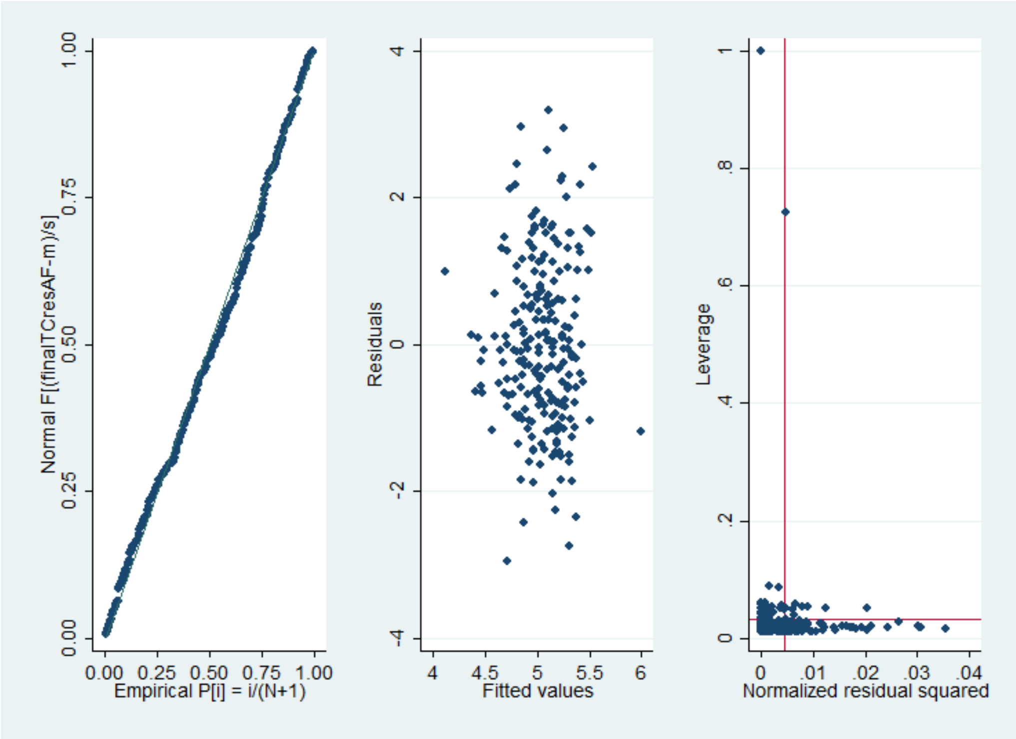

Figure G.5 Linear regression model of the association between whole grain intake and total cholesterol in females only at 50-year follow-up adjusted for sex, CVD medication use, total energy intake, and smoking status.

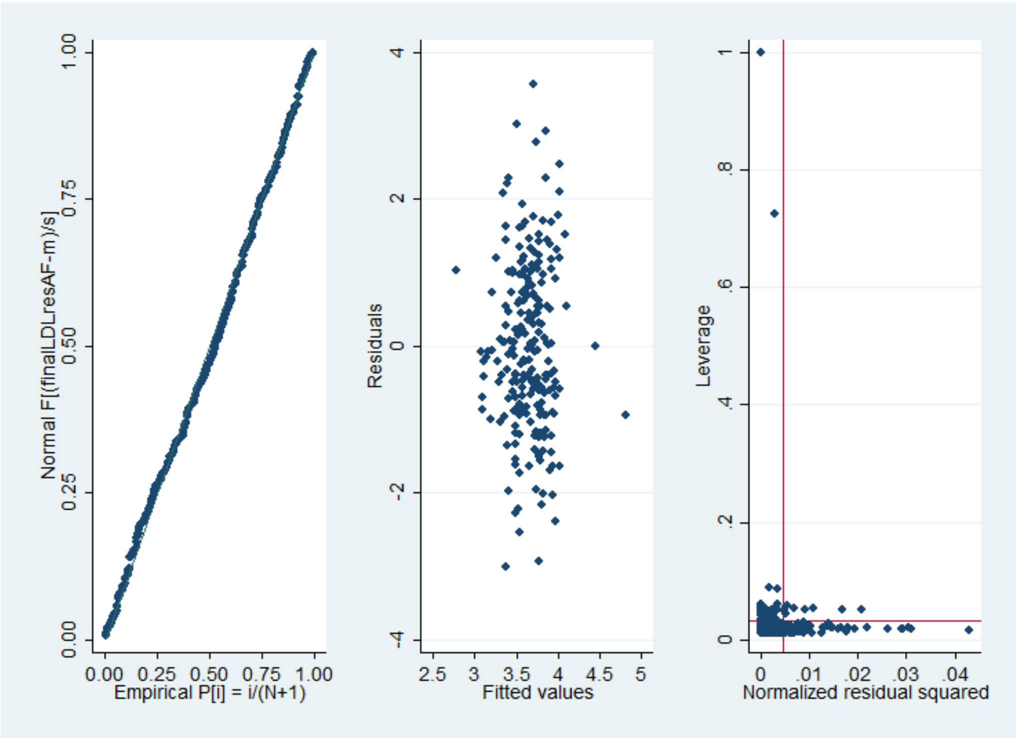

Figure G.6 Linear regression model of the association between whole grain intake and LDL cholesterol in females only at 50-year follow-up adjusted for sex, CVD medication use, total energy intake, and smoking status.

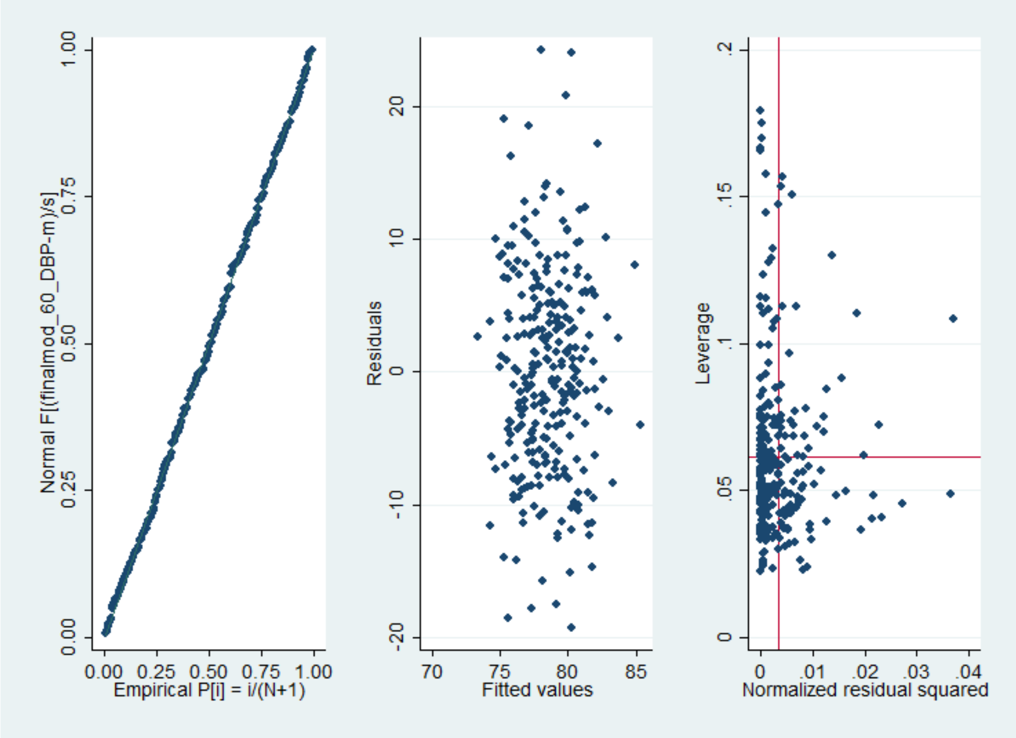

Figure G.7 Linear regression model of the association between whole grain intake and diastolic blood pressure at 60-year follow-up adjusted for sex, CVD medication use, total energy intake, smoking status, achieved education level and SES.

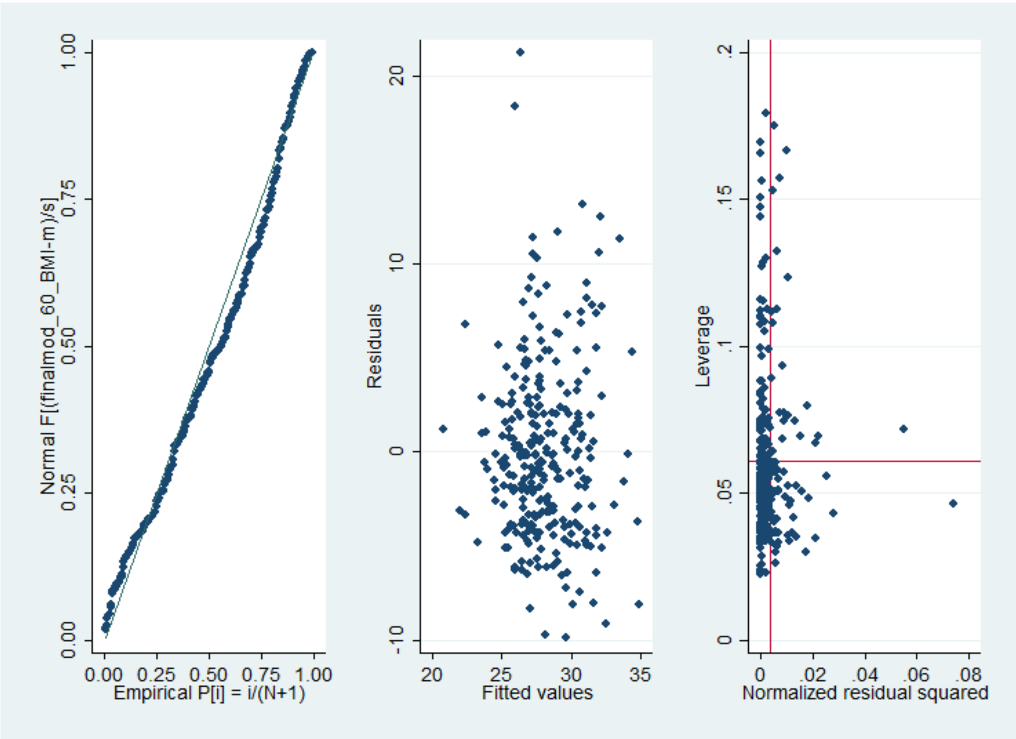

Figure G.8 Linear regression model of the association between whole grain intake and BMI at 60-year follow-up adjusted for sex, CVD medication use, total energy intake, smoking status, achieved education level and SES.

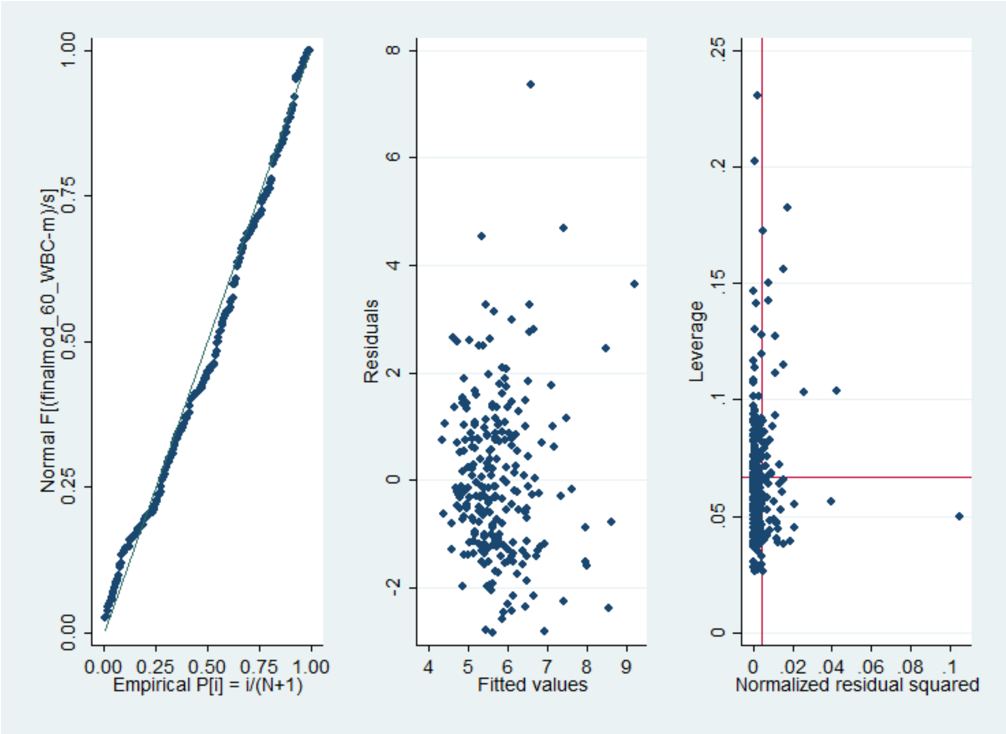

Figure G.9 Linear regression model of the association between whole grain intake and white blood cell count at 60-year follow-up adjusted for sex, CVD medication use, total energy intake, smoking status, achieved education level and SES.

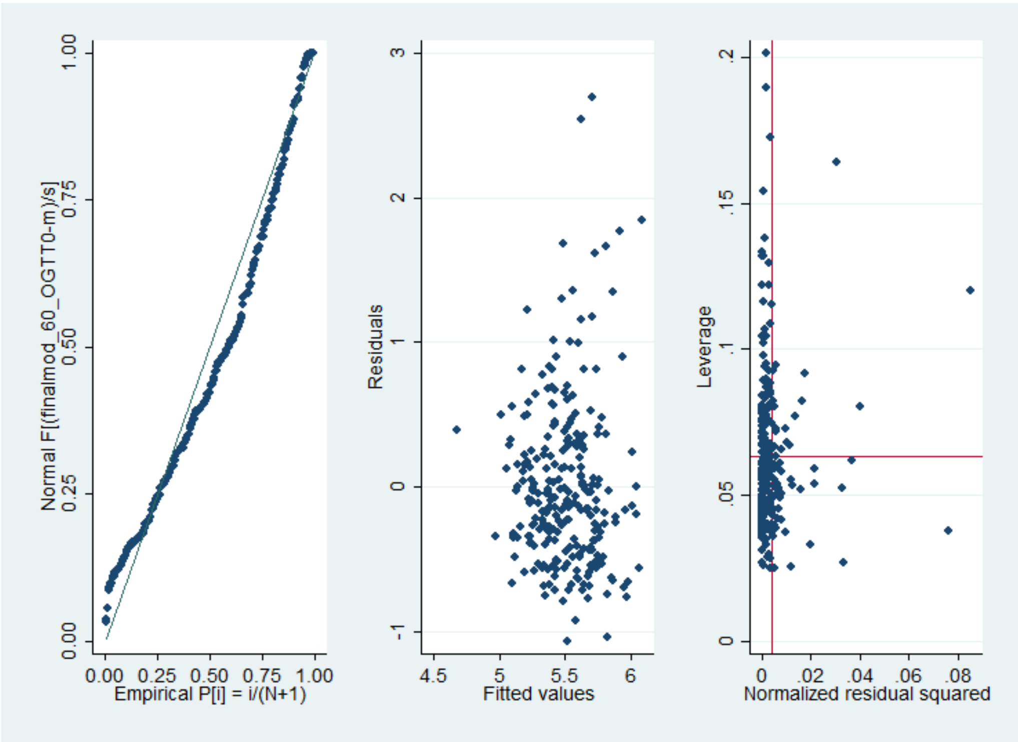

Figure G.10 Linear regression model of the association between whole grain intake and fasting glucose at 60-year follow-up adjusted for sex, CVD medication use, total energy intake, smoking status, achieved education level and SES.

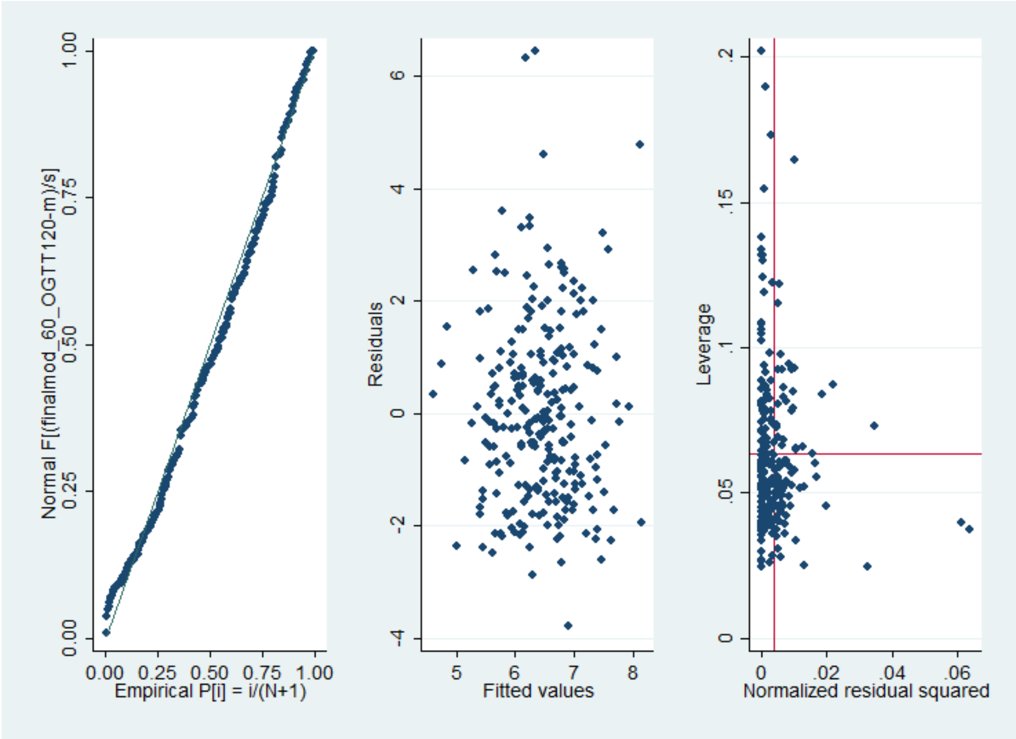

Figure G.11 Linear regression model of the association between whole grain intake and 2-hour glucose at 60-year follow-up adjusted for sex, CVD medication use, total energy intake, smoking status, achieved education level and SES.

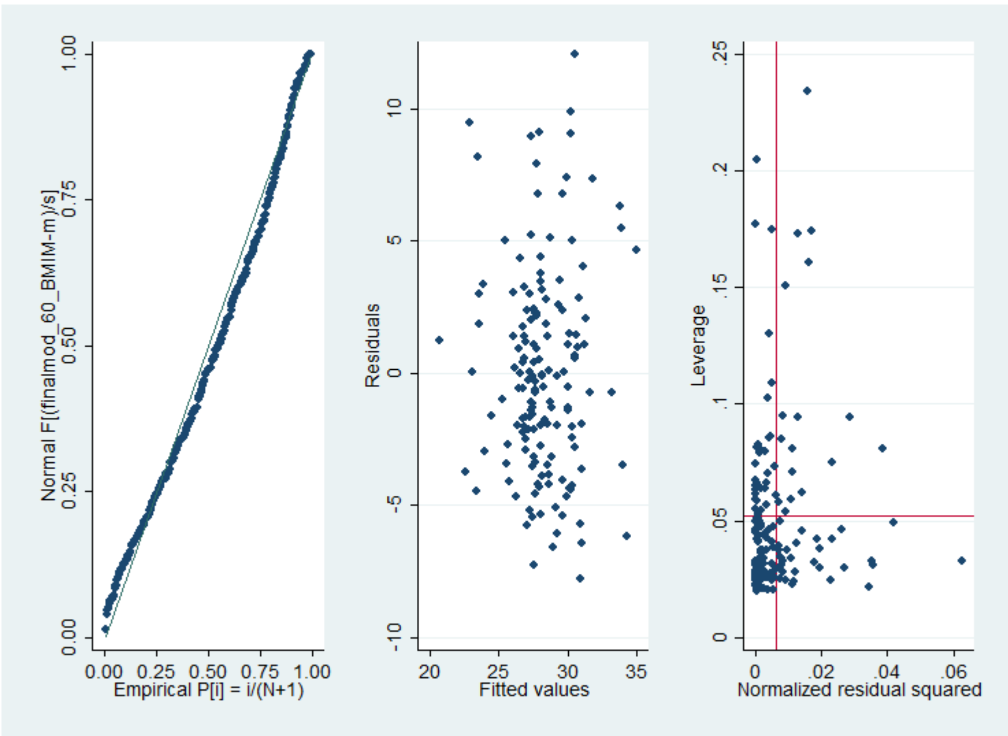

Figure G.12 Linear regression model of the association between whole grain intake and BMI in males only at 60-year follow-up adjusted for sex, CVD medication use, total energy intake, smoking status, achieved education level and SES.

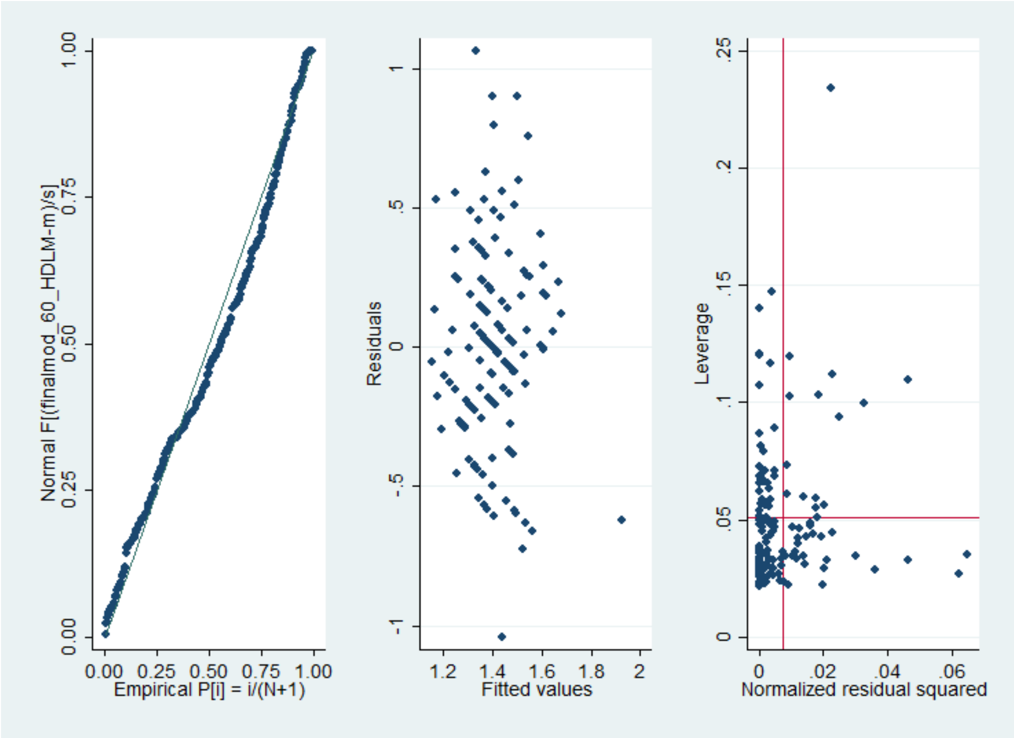

Figure G.13 Linear regression model of the association between whole grain intake and HDL cholesterol in males only at 60-year follow-up adjusted for sex, CVD medication use, total energy intake, smoking status, achieved education level and SES.

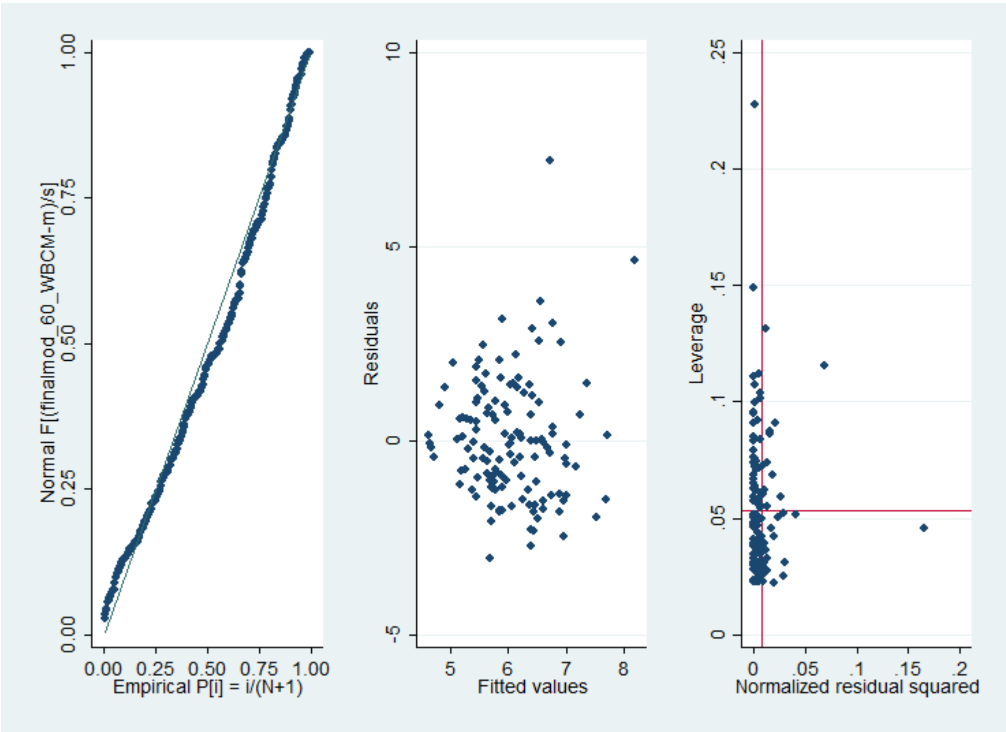

Figure G.14 Linear regression model of the association between whole grain intake and white blood cell count in males only at 60-year follow-up adjusted for sex, CVD medication use, total energy intake, smoking status, achieved education level and SES.

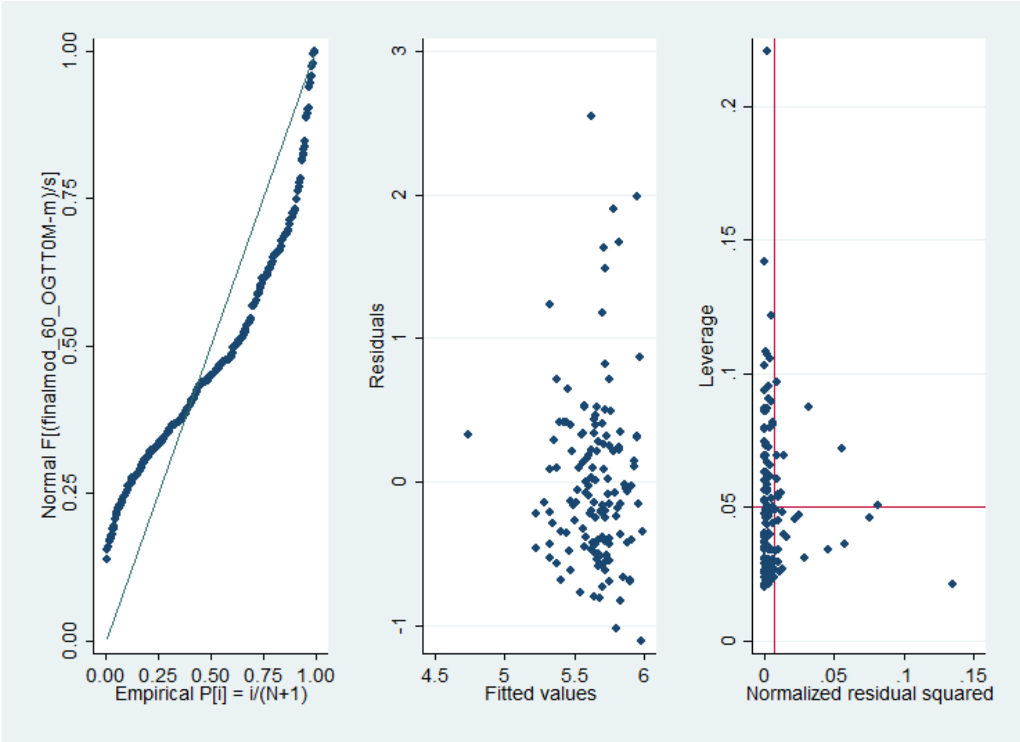

Figure G.15 Linear regression model of the association between whole grain intake and fasting glucose in males only at 60-year follow-up adjusted for sex, CVD medication use, total energy intake, smoking status, achieved education level and SES.

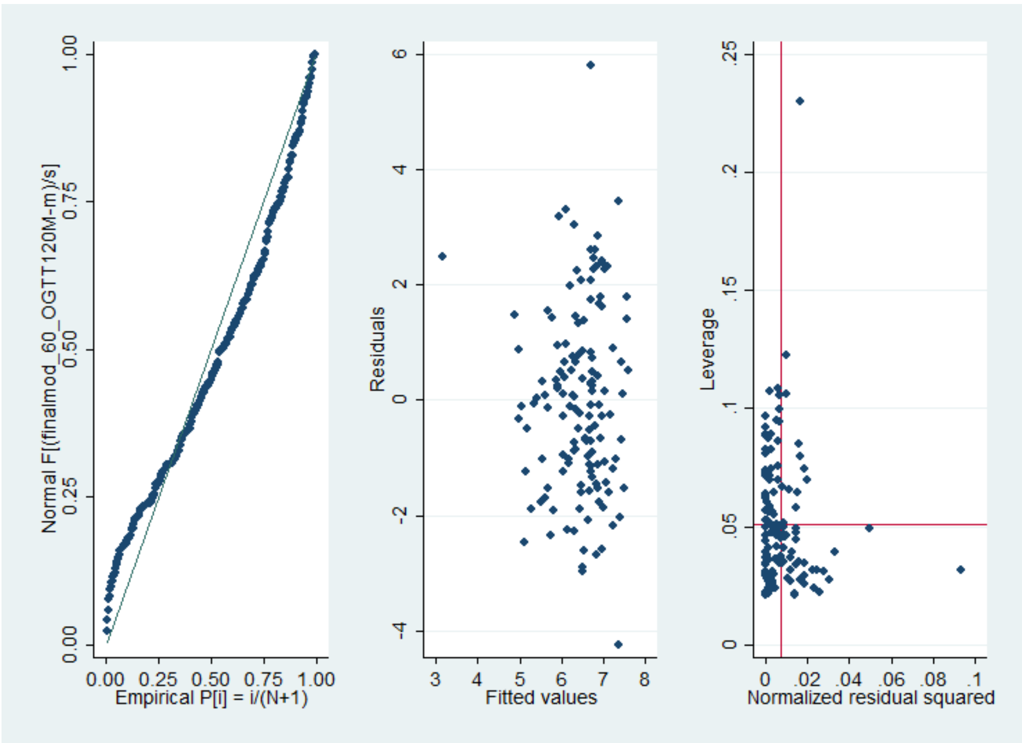

Figure G.16 Linear regression model of the association between whole grain intake and 2-hour glucose in males only at 60-year follow-up adjusted for sex, CVD medication use, total energy intake, smoking status, achieved education level and SES.

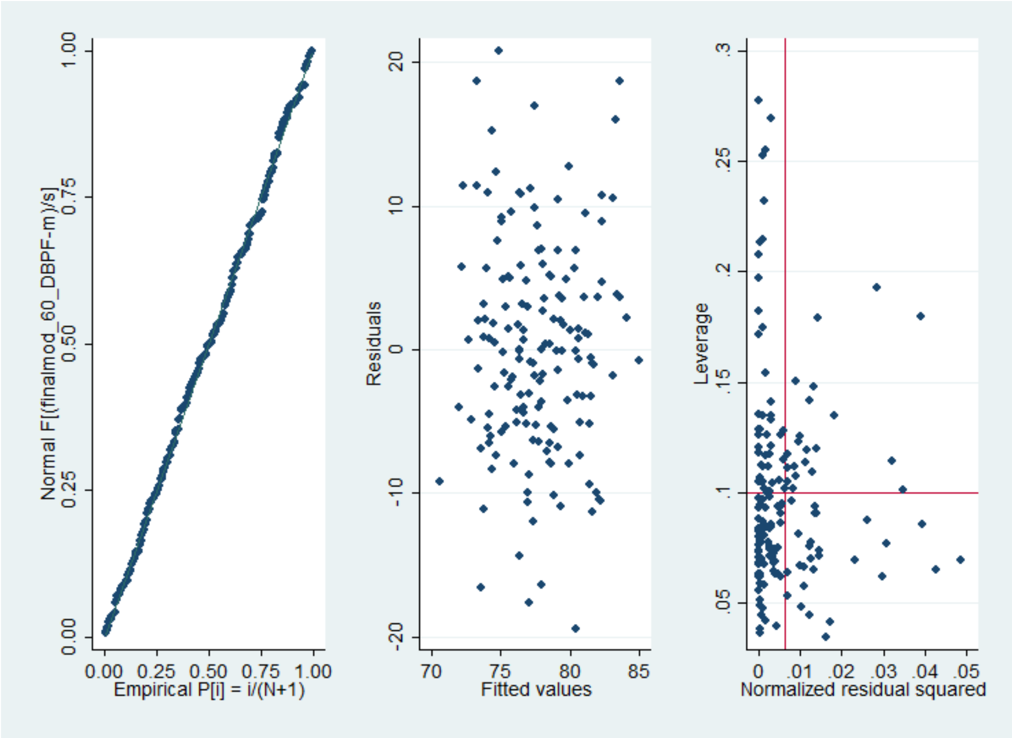

Figure G.17 Linear regression model of the association between whole grain intake and diastolic blood pressure in females only at 60-year follow-up adjusted for sex, CVD medication use, total energy intake, smoking status, achieved education level and SES.

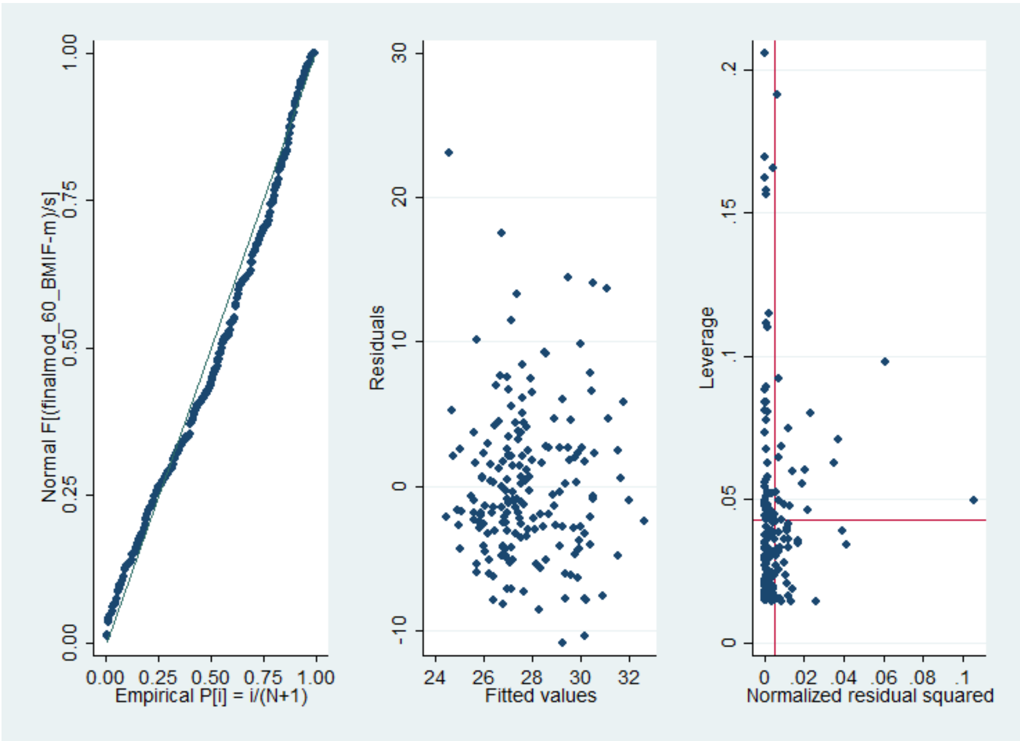

Figure G.18 Linear regression model of the association between whole grain intake and BMI in females only at 60-year follow-up adjusted for sex, CVD medication use, total energy intake, smoking status, achieved education level and SES.