Randomised controlled trial to test the impact of increased consumption of wholegrain foods on cardiovascular disease risk (the WHOLEheart study)

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Executive summary

There is an increasingly large body of published evidence from observational studies that demonstrates an association between increased consumption of wholegrain foods and reduced risk of a number of non-communicable diseases such as cardiovascular diseases (CVD), Type 2 diabetes and some cancers. The strength of evidence is strongest for CVD, and this has resulted in a number of health claims in the UK and elsewhere based on the assertion that ‘whole grains are good for your heart’. In the US and Canada this has been further interpreted as a positive need for whole grains in the diet and for these countries there are explicit recommendations for consuming (at least) 3 servings of whole grain per day; equivalent to 48g of whole grain dry matter per day. Denmark has also recently adopted a formal recommendation for daily whole grain-intake of 75g whole grain/10MJ. In the UK there is no such recommendation, although there is a recommendation to eat more whole grains and to consume whole grains whenever possible. Currently the European Food Safety Authority is examining proposals from a number of EU member countries to establish a European consensus on whole grains and health for use on foods. Whilst the evidence for the health benefits of whole grain is considered ‘convincing’, including now a number of meta-analyses, the largest majority of data are derived from cross-sectional and cohort studies. The data from intervention studies are limited. There is a need, therefore, for high quality randomised controlled intervention studies investigating the impact of increased whole grain-intake on markers of disease risk. To date, no studies have investigated consumer perceptions of wholegrain foods, including reasons for and barriers to their consumption. Understanding this area is necessary to develop targeted dietary guidelines and strategies.

The WHOLEheart study was designed to address this issue and specifically to measure the impact of increased whole grain-intake on known markers of CVD risk. The specific aims of the study were to:

1. To test the impact of the inclusion of 60g/day and 120g/day of whole grains into the diets of low whole grain-consuming adults who were overweight, but otherwise healthy in a randomised, controlled dietary intervention on a number of previously documented cardiovascular disease risk factors. The primary outcome measure was change in fasting plasma LDL-cholesterol concentration.

2. To compare self-reported intake of wholegrain foods with the measured concentrations of mammalian lignans in blood and plasma samples, and thereby assess the potential use of lignans as a biomarker of whole grain-intake.

3. To elucidate participant attitudes, priorities, language and framework of understanding of wholegrain foods in order to better understand barriers to whole-grain consumption.

Methods: Approximately 300 overweight, low whole grain-consuming adults, average age 45 years, 49% male, were randomly allocated to 3 intervention groups; Control Group (CG, no change in diet), Intervention Group 1 (IG1, 3 x 20g servings of whole grain per day for 16 weeks), and Intervention Group 2 (IG2, 3 x 20g servings of whole grain per day for 8 weeks followed by 6 x 20g servings of
whole grain for a further 8 weeks). Duplicate samples of fasting blood were collected within 7 days at baseline, at 8 weeks and 16 weeks of intervention for measurement of a range of markers of CVD risk which included: concentration of lipids (total, LDL and HDL cholesterol and triglycerides), markers of insulinaemic response (insulin, glucose, NEFA, QUICKI), markers of inflammatory status (sialic acid, CRP, IL-6, fibrinogen and PAI-1) and markers of endothelial function (ICAM-1, VCAM-1 and E-selectin). Anthropometric measurements (weight, BMI, waist measurement, body fat percentage), 24-hour urine collections, blood pressure and dietary intake (by FFQ and food diary) were recorded at the same time points. Spot urine collections were also recorded at 4 and 12 weeks. One month post-intervention participants completed further diet records by FFQ and attended focus group discussions, the purpose of which was to explore acceptance of the dietary intervention and barriers to whole grain-consumption.

Intervention foods were provided in pre-weighed packages individually apportioned for males and females. These included a selection of wholegrain breakfast cereals, wholewheat pasta and brown rice. Wholewheat bread was also provided. Participants were instructed on how to achieve their target level of intake and were provided with calendars to aid compliance.

**Results:** Dietary intake of whole grains was increased slightly above targets for IG1 and IG2 at 8 weeks (average intake 80g/day) and was marginally below target in IG2 at 16 weeks (115g/day). This change in pattern of food intake was associated with a significant increase in the proportion of daily energy derived from carbohydrates and a small reduction in the proportion of daily energy derived from fat. The intake of dietary fibre was, on average, increased from baseline by approximately 5g per day at 8 weeks for IG1 and IG2, and by 11g per day in IG2 at 16 weeks (p<0.001). Intake of a range of B-vitamins and several minerals was higher in those consuming whole grains (B vitamin (P<0.001 for folate, niacin riboflavin and thiamine), iron (P<0.001), magnesium (P<0.001), manganese (P<0.001) and zinc (P<0.001)). Sodium intake was higher in IG1 and IG2 compared with the CG, but the differences were not consistent between IG1 and IG2 at 8 and 16 weeks. Total energy intake increased slightly in the intervention groups, and fruit was displaced from the diet at the highest level of wholegrain intake (P = 0.045).

Body weight, BMI, waist and hip circumference, blood pressure and percentage of body fat were unaffected by dietary intervention and remained constant across all three intervention groups throughout the 16 weeks of follow-up. The chosen markers of CVD risk, including total and LDL-cholesterol concentrations, measures of insulin sensitivity, haemostatic markers and inflammatory markers were all unaffected by the dietary intervention.

The mammalian lignan, enterolactone, was detected in the majority of plasma samples tested, but enterodiol was only found in a small number of subjects. The relationship between whole grain-intake and plasma enterolactone concentrations was poor, although some subjects showed a dose-response relationship with increasing whole grain-intake.
The focus group data showed that the personal acceptance of wholegrain foods was influenced by taste acceptability and dietary acceptability, mediated by the health beliefs, food experiences and motivation to improve health or weight management. Barriers to consumption were associated with personal issues such as likes and dislikes, product-related issues such as cooking requirements and situational issues such as availability while eating away from the home. In the context of the intervention, incorporation of an average of 3 servings of whole grains per day was considered sustainable by most participants, however, 6 servings of whole grains per day was not considered sustainable.

**Summary and conclusions:** Positive changes towards a more healthful diet were observed in participants who ate more whole grains; in particular increased intake of dietary fibre, an increase in the proportion of daily energy derived from carbohydrates and a reduction in the proportion of daily energy from fat. Intake of some vitamins and minerals was also improved. Increased consumption of whole grain foods in this study did not affect body weight or composition, or alter (positively or negatively) plasma markers of CVD risk. Within the participants there were, however, individuals who demonstrated a positive response to the dietary change, and the reasons why some, but not all participants responded warrants further investigation. There were positive attitudes towards consuming the wholegrain foods mainly at the lower level of intake, although barriers to consumption still existed. These factors should be taken into consideration when promoting whole grain consumption in the future.

**Acknowledgements**

This project was fully funded by the Food Standards Agency. Wholegrain foods used in this study were kindly provided by Cereal Partners UK, Weetabix, Allied Bakeries and PepsiCo. A big thank-you goes out to the participants, who demonstrated great commitment and enthusiasm for the study.
Lay summary

Background

‘Whole grains are good for you’. This is the message currently given by health professionals, nutritionists and, increasingly, food manufacturers worldwide. They make this statement after careful consideration of a large amount of evidence from studies of populations carried out over many years. These so-called ‘observational studies’ include information gathered from many thousands of people where diet is measured and later health outcomes are recorded. These studies are often used by governments and health agencies to develop health eating advice for the population. The results from these studies show strong associations between whole grain-intake and health; those that eat the most whole grains are less likely to suffer from heart diseases, some cancers and to develop Type 2 diabetes compared with those who eat the least amount of whole grains. The government in America thinks that this evidence is so strong that it now advises its citizens to ‘eat at least three servings of whole grain’ every day. Some foods containing whole grain in America and Europe (including Britain) can show a health claim promoting the foods as being ‘good for your heart’. The problem with observational studies is that they are good at showing relationships between diet and health, but they do not say why this effect is seen. Also, other factors such as whether subjects smoke, or do more exercise, or eat lots of other healthy foods can complicate the interpretation of the results. To really show whether a particular type of food or diet pattern is of benefit and why, we need to carry out ‘intervention studies’. These are studies where volunteers are asked to change their diet for a period of time (normally several weeks or months) and scientists look for changes in markers which are known to be related to disease risk.

Rationale and Objectives

The role of the Food Standards Agency is to provide, interpret and disseminate information which can be used to help the UK population to live longer, healthier lives. Diet is very important in this context. If the Agency is to give advice on whether or not it should recommend we eat more whole grains it needs scientific evidence based on well designed dietary interventions. This, then, was the objective of the WHOLEheart study; to carry out a controlled whole grain dietary intervention of sufficient size that it would provide evidence which could be used to underpin the development of future dietary recommendations. The aim was not only to provide quantitative data on possible health benefits for heart disease risk, but also to collect information about attitudes to the whole grains foods from those taking part in the study.

Approach

We recruited about 300 overweight, but otherwise healthy people and randomly allocated them to one of three groups, making sure that the groups were as similar as possible in the numbers of men and women, ages and body sizes (to help reduce variation). One group was asked not to change their diet and to carry on as normal. The second group was asked to eat 3 servings of wholegrain food
(which we provided) every day for 16 weeks – this is the amount recommended by the American health agencies. The final group was asked to eat this amount for 8 weeks and then to double the amount to 6 servings of whole grain per day for the final 8 weeks. At the start of the study, and then at 8 weeks and 16 weeks the volunteers came to clinical research facilities at Newcastle University and MRC Human Nutrition Research, Cambridge where we weighed them, took some other body measurements and also a small blood sample. The volunteers also gave us a 24-hour urine sample. At week 4 and week 12 of the study they also gave us another small urine sample. We measured the diet of the volunteers at the same time points using a food frequency questionnaire so we could identify the foods they were eating and the composition of their diet. After the study had finished some of the volunteers came in to a focus group meeting where they discussed their experiences with one of the investigators.

**Outcome/Key Results Obtained**

The volunteers ate the wholegrain foods as requested and they enjoyed doing so (many were still eating them a month after we stopped providing them). As a result of eating the wholegrain foods their overall diets were healthier – they consumed less energy as fat and more as carbohydrate (this is a key government recommendation). Other positive dietary changes were that the volunteers ate much more dietary fibre and also several important vitamins and minerals. At the same time, whole grain intake increased total energy and sodium intakes. The 6 servings of whole grain a day resulted in participants consuming less fruit (as a result of displacing it from the diet with wholegrain snacks). The volunteers did not change their weight during the study. When we analysed the blood samples, however, despite changing their diet there were no changes in the measurements taken – for example, blood cholesterol, glucose and insulin concentrations when averaged for all of the volunteers were similar at each time point. For some, but not all of the volunteers, these measurements were lower, and further examination of the data may help us understand why some people seem to have benefited but others did not.

**What it means and why it’s important**

The changes in diet composition caused by encouraging the volunteers to eat more wholegrain foods were mostly positive and suggest a whole grain-rich diet can help people to achieve a more healthy diet overall. However, there appeared to be no measurable consequences in terms of blood chemistry and some of the known risk factors for later disease. There are many possible reasons for this – firstly, the number of subjects may have been too small to detect a change. This is unlikely as the study was large and there was no real ‘hint’ of a difference. Secondly, the study may not have been long enough to cause a permanent change in the measurements we took. This is possible, as heart disease takes a long time to develop and it may be that long-term changes in diet will have a greater impact on health. Thirdly, although the volunteers told us they ate the wholegrain foods they may not have done; this is a common problem for diet studies where people prefer their original diet and so find it difficult to change, but (understandably) they tell the researchers that they did as they
were asked. We tried to test this looking for chemicals in the blood that come from grains, however in general they were present in too small amounts to be detected. Finally, we saw that some people’s blood and body measurements did change, and it is possible that there is something in the genes of those people which meant that they were better at responding to wholegrain foods than others.

The intervention, like many scientific studies, has opened up more questions. This study has shown that eating whole grains improves the nutritional quality of the diet, however it does not provide evidence that short term increases in intake replicate the health benefits of long term intake which have been shown in epidemiological studies. Our study showed that people were enthusiastic about eating reasonable amounts (i.e. 3 servings a day) of wholegrain foods once they had overcome their worries about cooking and preparing them, identifying them correctly in the shops and fitting them into their (and their family’s) lifestyle. How whole grains may improve heart health, however, still needs further research.

**Acknowledgements**

This project was fully funded by the Food Standards Agency. Wholegrain foods used in this study were kindly provided by Cereal Partners UK, Weetabix, Allied Bakeries and PepsiCo. A big thank-you goes out to the participants, who demonstrated great commitment and enthusiasm for the study.
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1 Background

Food grains are classified as edible seeds or kernels of cereal plants from the *Gramineae* family of grasses and include wheat, maize (corn), rice, oats, barley, quinoa, sorghum, spelt, rye and popcorn (Seal *et al.*, 2006). Whole grains are classified as the entire edible portion of these seeds and kernels, (i.e. they contain the outer coat, germ and endosperm). Non-*Gramineae* seeds which have similar compositional and nutritional advantages to true grains and are consumed like grains, include wild rice, buckwheat and amaranth, are often also included in the wholegrain category. Grains are composed of three distinct anatomical parts. The outer coat (i.e. bran layer), formed by the plant to protect the seed, is a tough multi-layered structure which contains large quantities of fibre, some B vitamins and phytochemicals. The germ portion is the true embryo of the seed, and contains protein, B vitamins, minerals, phytochemicals, oil and fat soluble vitamins such as Vitamin E. The bulk of the grain, at about 60% of total seed weight, is the starchy endosperm which also contains some protein and trace levels of minerals. The majority of the world’s populations consume some form of cereal grains as their staple source of dietary carbohydrates; for many populations grains also provide the primary source of protein. As a result of the development of new milling and processing technologies, much of the cereal grains that are consumed today are extensively processed or refined before they reach consumers. Intact (i.e. unaltered) ‘whole grains’ form only a very minor part of the diet; they are found in some mueslis and as decoration/texture in specialist breads. While modern milling and refining processes result in significant loss of nutrients and other protective substances present in the bran and germ from cereal grains, some processing of whole grains is necessary in order to increase digestibility, promote nutrient absorption and for the production of palatable and shelf-stable goods (Slavin, 2000; Slavin *et al.*, 2000). Due to a potential for dietary deficiencies of some of the key nutrients lost in the milling process (e.g. calcium, iron and niacin), refined flours are fortified with some minerals and vitamins under mandatory fortification programs, but fibre and the majority of trace components particularly phytochemicals and bio-active molecules are lost from highly refined flours. Aside from stone ground flours, wholemeal flours are reconstituted from the original grain components after milling and these flours are not normally fortified. Thus even wholemeal flours have undergone extensive processing before being used in the manufacture of foods.

There is no universally accepted definition of ‘whole grain’ but the American Association of Cereal Chemists (AACC) produced a definition which has been adopted in the US. This currently reads: ‘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 exist in the intact caryopsis’ (American Association of Cereal Chemists, 2005). There is currently no similar definition for the guidance of UK food manufacturers or consumers, although the IGD have recently proposed a definition for adoption (Institute of Grocery Distribution, 2007). The AACC has established a ‘task force’ which is currently developing a comprehensive definition of whole grains which, it is hoped, can be adopted universally for the benefit of consumers and food manufacturers alike.
Cardiovascular diseases (CVD) are currently the largest cause of mortality in the Western world, accounting for approximately 30% of all deaths worldwide in 2005 (2007). A large body of epidemiological evidence has been collated which demonstrates an apparent link between the highest levels of whole grain-intake and reduced disease risk (e.g. Jacobs et al., 1999; Anderson et al., 2000; Liu, 2003); this evidence is discussed in detail in Section 6.6 below. This evidence has led to the adoption of health claims for foods in the US, UK and Sweden (Seal et al., 2007). The basis of these health claims is that individuals who consume higher amounts of wholegrain foods are more likely to have a healthier heart (see Section 7.2.3 for further details of wholegrain foods and health claims). Further understanding of the impact of wholegrain foods on health and development of more direct health claims for wholegrain foods both require randomised, controlled intervention studies to be carried out to directly assess the effect of wholegrain foods on markers of cardiovascular health.

1.1 Rationale

The proposed intervention study examined whether increasing whole grain-consumption to the minimum levels recommended by the USDA (US Department of Agriculture, 2005) provided measurable improvements in cardiovascular disease risk and whether there were additional benefits with further increases in consumption. The primary outcome was a reduction in plasma LDL cholesterol concentration, but broader health outcomes and potential mechanisms were also be investigated, together with qualitative aspects relevant to consumer choice. The data will contribute to the development of authoritative health claims in the UK and elsewhere. This project is directly relevant to the research required by the Food Standards Agency to improve the health of the nation. It provides a combination of quantitative evidence on which to base public health recommendations, together with qualitative information relating to consumer knowledge and attitudes that may be used to develop strategies to enhance the acceptability of whole grains, especially among non-consumers. Additionally this study developed a new food frequency questionnaire for dietary assessment of whole grain-consumption, and refined the use of enterodiol and enterolactone as biomarkers of whole grain-intake. Together these methodological improvements will facilitate future research in this field and ongoing surveillance of whole grain-consumption.
1.2 Hypotheses

i) Inclusion of specific levels of wholegrain foods into the diet of healthy, overweight participants, who do not currently consume wholegrain foods, will result in a reduction of the concentration of plasma LDL cholesterol, and improve other markers of cardiovascular risk.

ii) The levels of mammalian lignans in human plasma samples will provide a biomarker of whole grain-intake.

iii) Barriers to, and reasons for, consuming wholegrain foods exist in the UK population.

1.3 Aims

1. To test the impact of the inclusion of 60g/day and 120g/day of whole grains into the diets of non-whole grain-consuming adults who are overweight, but otherwise healthy in a randomised, controlled dietary intervention on a number of cardiovascular disease risk factors.

2. To compare self-reported intake of wholegrain foods with the measured concentrations of mammalian lignans in plasma samples, and thereby assess the potential use of lignans as a biomarker of whole grain-intake.

3. To elucidate participant attitudes, priorities, language and framework of understanding of wholegrain foods in order to better understand barriers to whole grain-consumption.
2 Project Objectives

Objectives for the project are listed in Table 1. Full details of the methods used and results obtained (where appropriate) for each objective are given in the sections below.

Table 1: Detailed project objectives of the WHOLEheart study

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<tr>
<th>Objective No.</th>
<th>Objective Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Establishment of Steering Group for the project; protocol refinement; MREC and LREC approval</td>
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<tr>
<td>2</td>
<td>To recruit a total of 300 subjects into the intervention, 150 in each of the 2 collaborating centres: the University of Newcastle (UoN) and the MRC Human Nutrition Research (MRC-HNR). Overweight subjects (BMI &gt;25 kg/m²) will be recruited on the basis of non-consumption of wholegrain foods (&lt;1 portion/d).</td>
</tr>
<tr>
<td>3</td>
<td>To conduct a dietary intervention study aimed at raising consumption of wholegrain foods to 3 portions per day, increasing to 6 portions per day after 8 weeks using a controlled parallel design. Three hundred subjects will be recruited and assigned to a control group or one of two intervention groups for a period of 16 weeks.</td>
</tr>
<tr>
<td>4</td>
<td>To evaluate methods for assessing dietary intake of wholegrain foods and compliance with the intervention using a previously validated food frequency questionnaire and measures of mammalian lignan (enterodiol and enterolactone) concentrations in plasma. The following will be determined in all subjects in both centres at baseline, 8 weeks and 16 weeks of intervention: Plasma enterolactone and enterodiol as bio-markers of whole grain consumption Dietary assessment by validated food frequency questionnaire (subgroup of subjects to complete food diaries)</td>
</tr>
<tr>
<td>5</td>
<td>To evaluate the impact of increased whole grain-consumption on risk factors for cardiovascular disease (CVD) with blood lipid profiles as the primary outcome. Secondary outcome measures will be circulating markers of insulin sensitivity, inflammatory status and endothelial function. The following markers will be analysed in all subjects in both centres at baseline, 8 weeks and 16 weeks of intervention: Fasting lipid profile, including measures of total, LDL and HDL cholesterol, total triglycerides concentration and triglycerides profile, and non-esterified free fatty acids (NEFA). Insulin sensitivity, from measures of fasting glucose, NEFA and insulin concentration. The acute phase protein C-reactive protein, sialic acid, fibrinogen and PAI-1 and the plasma cytokine IL-6, as markers of inflammatory status. Plasma, ICAM-1, VCAM-1 and e-selectin as markers of endothelial function. Seated diastolic and systolic blood pressure.</td>
</tr>
<tr>
<td>6</td>
<td>To evaluate the acceptability of, and barriers to consumption of wholegrain foods used in the intervention study. A sub-sample of subjects from both experimental groups will take part in structured focus-group discussions one month post-intervention to provide information on the acceptability of, and barriers to, increasing consumption of wholegrain foods as a means to improve the healthiness of the diet.</td>
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3 Objective 1: Ethical application and project registration

3.1 Summary

Ethical approval for this project was obtained through the COREC standard process and received favourable approval from Newcastle and North Tyneside Local Research Ethics Committee 1 (reference number 05/Q0905/75). Local Research Ethics Committee approval was also subsequently obtained for the Cambridge group.

Approval was obtained from the Newcastle upon Tyne Hospitals NHS Foundation Trust R&D Department (project reference number 3351).

The Project was registered with the International Standard Randomized Controlled Trial Number Register (ref: CCT-NAPN-13175).

Additional Primary Care Trust Approval was obtained in both centres prior to approaching potential participants through GP surgeries for participant recruitment.
4 Objective 2: Participant recruitment for dietary intervention

4.1 State of the art

Investigations to determine the measurable health benefits of increased consumption of wholegrain foods were required to inform public policy on promoting changes in eating pattern at the population level. Wholegrain foods provided a medium through which substitution of refined grain products could be achieved with minimal changes to broader eating patterns. Overweight subjects were selected for the study population in order to reduce variability in the test population and increase the likelihood of demonstrating change in the principle outcome measure.

4.2 Introduction

A number of large-scale epidemiological studies have clearly demonstrated an association between wholegrain food consumption and a reduced risk of major diseases, including cardiovascular disease (Anderson et al., 2000; Seal, 2006), diabetes (McKeown et al., 2002; Murtaugh et al., 2003; Lutsey et al., 2007) and cancer (Jacobs et al., 1998). While this type of study is useful in demonstrating an association between food components and disease risk they do not demonstrate causality and risk residual confounding. Therefore, hypotheses generated from these studies must be tested in randomised, carefully controlled intervention studies, where the only variable is the inclusion or exclusion of wholegrain foods in the diet.

4.3 Sample size calculation

A feasibility study for this project was previously undertaken at Newcastle University (Jones, 2006). Data from this uncontrolled dietary intervention study are shown in Table 2. These data demonstrated a reduction in both total and LDL-cholesterol concentrations following 8 weeks of a wholegrain intervention at intakes of approximately 70g whole grains per day in 22 male and female subjects. The change in LDL cholesterol concentration was greater than predicted from the Framingham Offspring Study (McKeown et al., 2002) in which a 4% change in fasting LDL cholesterol concentration was observed between the lowest (median intake <1 serving of whole grain per day) and highest (median intake approximately 3 servings of whole grain per day) quintiles of whole grain consumption. Although the number of subjects was not large, it was of sufficient size to indicate not only the potential effectiveness of the wholegrain intervention, but also provided data which could be used to inform the power calculations necessary in estimating subject numbers for further studies.
Table 2: Data collected in a Newcastle population demonstrating changes to plasma cholesterol concentrations over an 8-week wholegrain food intervention

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cholesterol</td>
<td>baseline</td>
<td>4.99</td>
<td>1.117</td>
<td>0.238</td>
<td>4.49</td>
<td>5.48</td>
</tr>
<tr>
<td>(mM)</td>
<td>8 weeks</td>
<td>4.54</td>
<td>0.898</td>
<td>0.191</td>
<td>4.15</td>
<td>4.94</td>
</tr>
<tr>
<td>HDL Cholesterol</td>
<td>baseline</td>
<td>1.58</td>
<td>0.320</td>
<td>0.068</td>
<td>1.44</td>
<td>1.73</td>
</tr>
<tr>
<td>(mM)</td>
<td>8 weeks</td>
<td>1.56</td>
<td>0.406</td>
<td>0.086</td>
<td>1.38</td>
<td>1.74</td>
</tr>
<tr>
<td>LDL Cholesterol</td>
<td>baseline</td>
<td>2.99</td>
<td>0.975</td>
<td>0.208</td>
<td>2.56</td>
<td>3.42</td>
</tr>
<tr>
<td>(mM)</td>
<td>8 weeks</td>
<td>2.55</td>
<td>0.759</td>
<td>0.162</td>
<td>2.21</td>
<td>2.88</td>
</tr>
</tbody>
</table>

These data were used in conjunction with data from a previous FSA-funded project carried out at MRC HNR (Cambridge) (NO2026) to estimate the sample size. Both sets of data were derived from overweight study participants i.e. similar to those selected for the WHOLEheart study, and accordingly give an appropriate estimate of variance.

On the basis of the estimates of variance from the two previous studies, a sample size of 254 subjects (84 per treatment group) was calculated to detect a 10% decrease in LDL cholesterol with a 0.05 significance level and 80% power, assuming an SD of 0.85. Allowing for an estimated dropout rate of 15% (based on similar nutrition intervention studies in the two centres), a target of 100 subjects per treatment group was proposed.

4.4 Recruitment criteria

150 participants were sought in each of the two UK centres (School of Agriculture, Food & Rural Development at Newcastle University and MRC Human Nutrition Research in Cambridge).

Inclusion criteria were:

- Participants, male and female aged 18 – 65 years old
- Not habitually consuming wholegrain foods (estimated as <1.5 servings of whole grain per day)
- Healthy but overweight (BMI of >25.0 kg/m²)

Exclusion criteria were:

- Habitual consumption of wholegrain foods (estimated as >1.5 servings of whole grain per day);
- History of clinical treatment for Type 2 diabetes or hyperlipidaemia
- Currently prescribed NSAIDS, aspirin, steroids or immunosuppresants;
- Allergic or intolerant to study foods;
- Planning to change dietary habits or increase physical activity markedly, or change body weight;
- Habitual heavy smokers (i.e. > 20 cigarettes/day)
- Currently planning pregnancy or have had a baby in the past 12 months
- Having changed weight by >3 kg in the past 1 month
- BMI <25.0 kg/m²
A full list of exclusion drugs is given in Appendix 1. Participants successfully completing the screening telephone questionnaire were sent a previously-validated, 149-item food frequency questionnaire (FFQ) by post with a stamped addressed envelope for return, to assess intake of wholegrain foods. Potential participants found to consume greater than an average of 1.5 servings (30 g) whole grains/day or more by FFQ were excluded. Finally, the BMI of each volunteer was confirmed, by direct measurement, at an induction visit for the study.
5 Objective 3: Intervention design and implementation

Eligible participants were randomly allocated to treatment groups using a minimisation procedure which included age, gender and BMI as factors, in order to ensure comparable populations within each treatment group while still ensuring random allocation. The three treatment groups were:

- **Control Group**, no dietary intervention (i.e. participants were instructed to maintain their habitual diet over 16 weeks, including consuming < 1.5 servings WG/day).
- **Intervention Group 1**, participants were asked to consume an average of 3 servings of whole grains/day for 16 weeks. For the purposes of the intervention, one serving of whole grain was defined as 20g dry weight of whole grain (i.e. the target consumption was 60 g whole grain/day).
- **Intervention Group 2**, participants were asked to consume an average of 3 servings of whole grains/day for 8 weeks, followed by an increase to 6 servings/day (i.e. the target consumption was 120g whole grains/day) over the final 8 weeks of the intervention. The study design is outlined below in Figure 1.

At weeks 0, 8 and 16 duplicate fasting plasma samples (on separate days separated by no more than 7 days) were collected along with a 24 hr urine sample. At the same time-points blood pressure and anthropometric measurements were taken and subjects were asked to complete a FFQ. A spot urine sample and FFQ were also collected at weeks 4 and 12 (see Figure 1).

![Figure 1: Summary of the intervention design for the WHOLEheart study. Spot urine samples and FFQ were collected at week 4 and week 12. Duplicate fasting plasma samples, 24h urine collections and FFQ were collected at weeks 0, 8 and 16 along with anthropometric measurements and blood pressure.](image)

5.1 Dietary intervention strategy

Foods for the dietary intervention were provided by Cereal Partners UK, Weetabix, Allied Bakeries and PepsiCo. All foods provided by Cereal Partners UK (Shredded Wheat Fruitful, Cheerios, porridge...
oats, brown rice and wholewheat pasta) were provided to participants in precisely weighed packs identified separately for male and female participants. Portion sizes for males and females were based on data on portion sizes from the National Diet and Nutrition Survey (Thane, personal communications) and data previously collected in Newcastle (Jones, 2006). Table 3 outlines details of the study foods provided to participants and their whole grain-content. Examples of the study foods are shown in Figure 2 and Figure 3. Foods packaged by CPUK were labelled with study logo and the ‘whole grain symbol’ designed to facilitate participant compliance. Each label indicated the number of servings of whole grain contained within the packet.
Figure 2: Examples of study foods provided to participants in Intervention Group 1 and Intervention Group 2.

Figure 3: Individual packet of wholegrain breakfast cereal showing label and 'whole grain symbols' used to facilitate participant compliance.
Table 3: Whole grain-content of foods provided to the participants for the WHOLEheart study. * denotes cooked weight, whereas all other whole grain-contents have been calculated per 100 g dry weight (Jones, 2006).

<table>
<thead>
<tr>
<th>Product name</th>
<th>Supplied by</th>
<th>Whole grain content/100 g</th>
<th>Portion size</th>
<th>Whole grain weight/portion (whole grain servings/portion)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Wholewheat bread</td>
<td>Allied Bakeries Cereal</td>
<td>54.8</td>
<td>36.5</td>
<td>36.5</td>
</tr>
<tr>
<td>Shredded Wheat</td>
<td>Fruitful Cereal Partners UK</td>
<td>57.6</td>
<td>67</td>
<td>59</td>
</tr>
<tr>
<td>Cheerios</td>
<td>Cereal Partners UK</td>
<td>64.3</td>
<td>43</td>
<td>35</td>
</tr>
<tr>
<td>Porridge oats</td>
<td>Cereal Partners UK</td>
<td>11.2*</td>
<td>254</td>
<td>216</td>
</tr>
<tr>
<td>Brown basmati rice</td>
<td>Cereal Partners UK</td>
<td>34*</td>
<td>220</td>
<td>181</td>
</tr>
<tr>
<td>Wholewheat pasta</td>
<td>Cereal Partners UK</td>
<td>30.9*</td>
<td>257</td>
<td>200</td>
</tr>
<tr>
<td>Weetabix</td>
<td>Weetabix</td>
<td>80.8</td>
<td>41.8</td>
<td>35.9</td>
</tr>
<tr>
<td>Seriously Oaty flavoured porridge</td>
<td>Pepsico</td>
<td>52.8</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Quaker Oat Bar</td>
<td>Pepsico</td>
<td>60</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>SunChips (wholegrain crisps)</td>
<td>Pepsico</td>
<td>69</td>
<td>28.7</td>
<td>28.7</td>
</tr>
</tbody>
</table>

5.2 Recruitment

A total of 1900 potential volunteers, responding to a range of adverts, email alerts, mail drops and GP contacts were screened for participation. Of these, 316 participants (16.6%) were eligible post-induction (251 from Newcastle and 65 from Cambridge). Patterns of recruitment and drop-out are shown in Figure 4 and Figure 5. As the post-induction drop-out rate was higher than predicted (which peaked at 20%, as opposed to the predicted 15%) near the end of the recruitment phase, extra participants were recruited in order to achieve the required number of completers to ensure statistical power.

5.3 Participant drop-outs

A total of 100 participants completed in the Control Group, 85 completed in Intervention Group 1 (3 servings of whole grain a day for 16 weeks) and 81 completed in Intervention Group 2 (3 servings a day for 8 weeks, followed by an increase to 6 servings a day in the subsequent 8 weeks). Thus the number of subjects completing in Intervention Group 3 was marginally below that suggested by the statistical model (n = 84).
The largest proportion of participants (36 of 50) dropped out after their screening visits, but before they had received the instructions specific to their group (i.e. once they had been minimised before the end of their week 0 visits). Therefore knowledge of, or participation in the intervention was not an influencing factor for those participants. These early stage drop-outs were either due to medical reasons (mostly due to difficulties in obtaining blood samples or the participant feeling unwell on taking a blood sample), or personal reasons (the participants could not afford the time commitment). Only 6 out of 50 drop-outs cited intolerance to the study foods as their reason for doing so. The remaining 8 were removed from the study due to medical reasons arising during the intervention (e.g. changing medication, new diagnosis).
Figure 4: Total recruitment figures for the WHOLEheart study
Figure 5: Total recruitment for WHOLEheart study over time
5.4 Summary

Of the 316 participants randomised into the study using the minimisation procedure, 50 participants dropped out. Of these the largest majority (88%) were either excluded (due to medical concerns or current whole grain-intake), or withdrew due to personal circumstances. A total of 166 participants, who were given whole grain intervention foods, completed the study. Only 6 participants (i.e. 3.5% of those who received wholegrain food interventions) were intolerant to the study foods. This suggests a high level of acceptance of wholegrain foods among the target population, and commitment from participants for continuing in the study.
6 Objective 4: Evaluation of methods for assessing dietary intakes of wholegrain foods

6.1 State of the art

There is a need to develop a user-friendly method for quantifying consumption of wholegrain foods for use in population-based studies. Mammalian lignan concentrations in plasma and urine have been suggested as potential bio-markers of whole grain-intake, but these have not been assessed in a UK population under controlled intervention conditions.

6.2 Introduction

6.2.1 Consumer guidelines for whole grain-consumption

The Dietary Guidelines for Americans recommend consuming 3 ounce equivalents of whole grain per day (48g per day) (US Department of Agriculture, 2005). There is no equivalent recommendation for the UK, although the latest Food Standards Agency ‘Eat Well Be Well’ campaign encourages consumers to ‘eat wholegrain varieties of starchy foods whenever you can’ (Food Standards Agency, 2005).

6.2.2 Patterns of whole grain-consumption

Despite an increasing drive by industry and health professionals, based on the current scientific evidence, consumers have been slow to change their eating habits. National surveys of dietary intake, especially in USA, are not always designed to quantitatively measure food item intake, but rather incidence of food item intake. Even accounting for these potential inaccuracies, data pertaining to whole grain-intake in these surveys consistently show intakes which fall well below the target of 3-servings per day. In the Iowa Women's Health Study less than 20% of the women consumed 3 or more servings of wholegrain foods per day (Jacobs et al., 1999). Data for another American cohort of 38-63 year old women are similar (Liu et al., 1999). In the UK, analyses of the National Diet and Nutrition Surveys (NDNS) show that about one third of adults eat no whole grains on a daily basis and only 5% achieve the target of 3-servings per day. The picture is worse in British young people where the median intake of whole grain was only 7g/d and in the US 90% of under eighteens reported whole grain eating occasions of less than one per day (Harnack et al., 2003; Lang et al., 2003; Thane et al., 2005). Whole grain-consumption in the UK appeared to fall between 1986 and 2000 (Thane et al., 2007). The current levels of whole grain-intake may be higher than these estimates, due to a recent campaign to promote consumption of whole grains, both from the industrial and health sectors. Although absolute intakes are low, the range of wholegrain foods consumed is quite broad; recent analyses of National Diet and Nutrition Surveys for young persons and adults (Thane et al., 2005; Thane et al., 2007) showed that of the 347 foods containing >10% whole grain (expressed on a DM
basis as a percentage of the food fresh weight) recorded in food diaries by the participants (Thane et al., 2007) only 101 were >51% whole grain and would therefore qualify to use the whole grain health claim. Food categories covered were dominated by breakfast cereals, breads and baked products, which together accounted for over 90% of all foods containing whole grain eaten in both surveys.

6.2.3 Mammalian lignans

Lignans are biphenolic compounds that occur widely in the fibre layers of various plant species. In terms of human dietary intake, lignans occur in a range of whole grains, seeds, nuts, fruits and vegetables (Kilkkinen et al., 2003). Plant lignans are digested by the gut microbiota into forms that can be absorbed by mammals and appear in the blood stream (i.e. mammalian lignans). Two mammalian lignans have previously been described - enterolactone and enterodiol (Penalvo et al., 2004). The presence of mammalian lignans (particularly enterolactone) in human plasma has been linked to a lower incidence of certain types of cancer and cardiovascular diseases (Adlercreutz, 2007). Dietary intake of plant lignans has previously been demonstrated to be associated with plasma enterolactone concentrations (Kilkkinen et al., 2003; Johnsen et al., 2004) in Scandinavian populations. Wholegrain foods have been demonstrated to be the one dietary factor most strongly associated with plasma enterolactone concentrations (Johnsen et al., 2004), suggesting that whole grain-intake is the major determinant of plasma lignan status. Therefore, measurement of the concentrations of mammalian lignans in human plasma and urine may be a useful tool to monitor whole grain-intake.

6.3 Measurement of participants’ dietary intake

Participant compliance was assessed in three ways. All participants were asked to complete a 149-item WHOLEheart food frequency questionnaire at weeks 0, 8 and 16 of the intervention. A randomly selected sub-set (approximately 30% of participants) also completed 4-day diet diaries at the same time points. Participants on Intervention 1 and Intervention 2 (i.e. those receiving wholegrain foods) were provided with record sheets throughout the 16 weeks (to allow participants to monitor their own whole grain-intake).

Participants were asked to provide 24-h urine samples at weeks 0, 8 and 16. Along with plasma samples, these were analysed for biomarkers of whole grain-consumption (see section on lignan measurement below).

6.4 Intake of wholegrain foods measured by FFQ

Table 4 shows the completion rates for FFQ return. This demonstrates a return rate > 90% throughout the intervention period, although at one month post intervention the return rate fell to 52%.
Table 4: Return rate for Food Frequency Questionnaires (FFQ) throughout the WHOLEheart intervention and 1-month post-intervention. Screening return rate was 100%, as return of an FFQ was mandatory for participant eligibility

<table>
<thead>
<tr>
<th>Time point</th>
<th>Screening</th>
<th>0 weeks (baseline)</th>
<th>8 weeks</th>
<th>16 weeks</th>
<th>1 month post-intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return rate (%)</td>
<td>100</td>
<td>94</td>
<td>93</td>
<td>97</td>
<td>52</td>
</tr>
</tbody>
</table>

Figure 6 shows the reported whole grain-intake of participants at screening and throughout the intervention. These data show that average intake of wholegrain foods within each group was close to the prescribed intake for each intervention group at each stage of the intervention. Average whole grain-intake was less than <20 g/day for control participants throughout the 16 week intervention as expected but there was considerable individual variation, with several subjects reporting consuming much higher amounts at various time-points (including baseline). For those in Intervention Groups 1 and 2, whole grain-intake rose significantly at 8 weeks, and slightly exceeded the target (i.e. 80 g versus the target level of 60 g whole grain/day). At 16 weeks in intervention group 2, whole grain-intake rose further but in this case failed to reach the target of 120g whole grain/d (actual average value was 115 g/day. At both 8 weeks and 16 weeks there was again considerable variability in reported whole grain-intake. One month post intervention whole grain-intake fell in both intervention group 1 and intervention group 2, but did not fall back to pre-intervention levels. A significant increase in the whole grain-intake of the control group (p = 0.05) from screening to one-month post-intervention (from 16.6 g/day to 23.6 g/day) suggests that there may be an increase in the levels of wholegrain food consumed by the general population occurring over the time course of the study, although this effect is small. In addition, the response rate for 1 month post intervention data was only 52%, suggesting that response bias (i.e. those interested in diet and health) may also account for some of the change in whole grain-intake measured. This will be further evaluated when data from 6 and 12 months post intervention are investigated.

Data for dietary changes one month post intervention are not reported here, but will be reported alongside 6 and 12 month post-intervention data when completed (July 2008).
Comparison between FFQ data and data from 4-day diet diaries

A sub-group of participants completed standard 4-day food record diaries in addition to the FFQs. Participants were asked to fill in details of all foods they ate for at least 4 days in the week, one day to include a weekend day, leading up to their week 0, week 8 and week 16 visits (i.e. for the same week as dietary intake was reported for in the FFQs). Estimates of portion sizes were based on average data (Ministry of Agriculture Fisheries and Food, 1993); portion sizes for wholegrain foods were from Newcastle data (Jones, 2006). Food intakes were converted to nutrient intakes using Windiets (Robert Gordon University, Aberdeen). In total, 274 matching food diaries and FFQs were available for analysis.

Daily intake of energy (kJ), total fat (g), total carbohydrate (g), total protein (g), total alcohol (g) and non-starch polysaccharide (g – as estimated by Englyst procedure) were compared between the matched diaries and FFQs by paired Student’s t-test and Bland-Altman bias measures (Ratio of FFQ:diary). Bland-Altman plots were used to compare the two measurement methods, showing the difference between measures against the average of the two measures. Values of 1.0 show good correlation between the two measures. Results of this analysis are displayed in Table 5.
Comparison by paired t-test demonstrated that there was no significant difference in the measured values for daily total energy, protein and alcohol intake. While Bland Altman bias ratios show that both total energy and protein intake had bias ratios close to 1.0, measures of daily alcohol intake were very divergent (SD of bias is much higher than the bias itself). The lack of difference between measurement methods is therefore likely due to this high standard deviation.

Paired-tests suggested significant differences between the FFQ- and diary-measured levels of daily fat, carbohydrate and dietary fibre intakes. Bland Altman bias ratios show that intake of dietary fat (FFQ:diary ratio of 0.94) was, on average, underestimated by 6% using the FFQ (although mean FFQ intake was higher) whereas dietary carbohydrate (1.17) and dietary fibre (1.45) were overestimated.

Dietary fat intake estimated by FFQ is likely to be lower due to the fact that oils used in cooking, and non-butter spreads are not included in the nutrient analysis calculations. In the case of dietary carbohydrates and dietary fibre, the over-estimation may be due to the high numbers of carbohydrate-based (i.e. breads, breakfast cereals, potatoes and other starchy foods) and fibre-rich items (i.e. whole grains, fruits and vegetables) included in the FFQ. This is likely to result in an over-reporting of these items, which would therefore skew measured intakes.

Table 5: Comparison of measured dietary intakes using 7-day food frequency questionnaires (FFQ) and 4-day un-weighted food diaries.

<table>
<thead>
<tr>
<th>Daily intake</th>
<th>Energy (kJ)</th>
<th>Fat (g)</th>
<th>Protein (g)</th>
<th>CHO (g)</th>
<th>NSP(^1) (g)</th>
<th>Alcohol (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diary mean</td>
<td>9312.7</td>
<td>83.5</td>
<td>86.8</td>
<td>256.0</td>
<td>15.0</td>
<td>22.3</td>
</tr>
<tr>
<td>FFQ mean</td>
<td>12477.9</td>
<td>95.4</td>
<td>102.6</td>
<td>360.6</td>
<td>23.9</td>
<td>48.4</td>
</tr>
<tr>
<td>P-value (paired t-test)</td>
<td>0.307</td>
<td>&lt;0.001</td>
<td>0.444</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.379</td>
</tr>
<tr>
<td>Ratio FFQ:diary Bland-Altman bias (bias SD)</td>
<td>1.06</td>
<td>0.94</td>
<td>1.03</td>
<td>1.17</td>
<td>1.45</td>
<td>1.69</td>
</tr>
<tr>
<td></td>
<td>(0.34)</td>
<td>(0.38)</td>
<td>(0.33)</td>
<td>(0.41)</td>
<td>(0.55)</td>
<td>(2.64)</td>
</tr>
</tbody>
</table>

\(^1\)CHO = carbohydrate, \(^2\)NSP – non-starch polysaccharide, as estimated by Englyst procedure.

6.6 Effect of wholegrain intervention on other dietary factors

6.6.1 Impact of wholegrain intervention on daily frequency of food use

Frequency of food use was assessed by FFQ. There were no changes in the daily frequency of food consumption for any group for meat, fish, total dairy, spreads used on bread or non-bread carbohydrates (i.e. pasta, potatoes, rice etc). Data for median changes in intake from baseline in each group are shown in Table 6 and Table 7 for weeks 8 and 16 of the intervention, respectively.

Frequencies of intake for each group at each measurement point are shown in Table 8. The daily frequency of bread consumption increased in Intervention Group 2 at week 8, and tended to be higher in Intervention Group 1 (\(P=0.059\)) at this time point. At week 16 the daily frequency of bread consumption was significantly higher for both intervention groups. The daily frequency of breakfast
cereal consumption was significantly higher in both intervention groups at 8 and 16 weeks compared with baseline. In the Control Group, the frequencies of cereal and snacks consumption were significantly lower at week 8 compared with week 0 but had returned to baseline levels at week 16. The daily frequency of fruit intake was reduced in Intervention Group 2 at week 16, suggesting that the higher levels of whole grain intake in this group had resulted in a displacement of fruit from the diet. This reduced fruit intake mirrors qualitative information obtained from focus group data (see Section 8.4 for full details).

Table 6: Effect of wholegrain food intervention on median change in daily frequency of consumption of different food groups at week 8.

<table>
<thead>
<tr>
<th>Food group</th>
<th>Control</th>
<th>Intervention 1</th>
<th>Intervention 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat</td>
<td>0.000</td>
<td>0.000 (0.787)</td>
<td>-0.007 (0.543)</td>
</tr>
<tr>
<td>Fish</td>
<td>0.000</td>
<td>0.000 (0.499)</td>
<td>0.000 (0.258)</td>
</tr>
<tr>
<td>Breads</td>
<td>-0.070</td>
<td>0.210 (0.058)</td>
<td>0.325 (0.021)</td>
</tr>
<tr>
<td>Breakfast cereals</td>
<td>0.000 (0.001)</td>
<td>0.430 (&lt;0.001)</td>
<td>0.505 (&lt;0.001)</td>
</tr>
<tr>
<td>Potatoes, rice and pasta</td>
<td>0.010</td>
<td>-0.070 (0.492)</td>
<td>-0.005 (0.537)</td>
</tr>
<tr>
<td>Dairy and egg products</td>
<td>-0.003</td>
<td>0.000 (0.492)</td>
<td>-0.001 (0.537)</td>
</tr>
<tr>
<td>Spreads</td>
<td>0.000</td>
<td>0.000 (0.064)</td>
<td>-0.000 (0.881)</td>
</tr>
<tr>
<td>Sweets and snacks</td>
<td>-0.150 (0.001)</td>
<td>-0.140 (0.502)</td>
<td>-0.400 (0.726)</td>
</tr>
<tr>
<td>Fruit</td>
<td>0.000</td>
<td>-0.280 (0.213)</td>
<td>-0.140 (0.236)</td>
</tr>
<tr>
<td>Vegetables</td>
<td>-0.37</td>
<td>-0.215 (0.796)</td>
<td>0.140 (0.161)</td>
</tr>
</tbody>
</table>

Changes in daily frequency of consumption of Intervention Group 1 and Intervention Group 2 were compared with changes in Control Group values by non-parametric, two-sample Wilcoxon rank sum test. Changes in frequencies of food consumption that were significantly different from the control values (P<0.05) are highlighted in red. Changes in values for the Control Group that differed from baseline values are shown in blue.
Table 7: Effect of wholegrain food intervention on median change in daily frequency of consumption of different food groups at week 16.

<table>
<thead>
<tr>
<th>Food group</th>
<th>Control</th>
<th>Intervention 1</th>
<th>Intervention 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat</td>
<td>0.000</td>
<td>-0.140 (0.577)</td>
<td>-0.005 (0.924)</td>
</tr>
<tr>
<td>Fish</td>
<td>0.000</td>
<td>0.000 (0.418)</td>
<td>0.000 (0.646)</td>
</tr>
<tr>
<td>Breads</td>
<td>-0.140</td>
<td>0.140 (0.038)</td>
<td>1.56 (&lt;0.001)</td>
</tr>
<tr>
<td>Breakfast cereals</td>
<td>0.000</td>
<td>0.430 (&lt;0.001)</td>
<td>0.570 (&lt;0.001)</td>
</tr>
<tr>
<td>Potatoes, rice and pasta</td>
<td>0.000</td>
<td>0.000 (0.514)</td>
<td>-0.140 (0.731)</td>
</tr>
<tr>
<td>Dairy and egg products</td>
<td>0.000</td>
<td>0.137 (0.273)</td>
<td>0.007 (0.991)</td>
</tr>
<tr>
<td>Spreads</td>
<td>0.000</td>
<td>0.000 (0.294)</td>
<td>0.000 (0.945)</td>
</tr>
<tr>
<td>Sweets and snacks</td>
<td>-0.009</td>
<td>-0.140 (0.851)</td>
<td>-0.075 (0.792)</td>
</tr>
<tr>
<td>Fruit</td>
<td>0.005</td>
<td>-0.140 (0.613)</td>
<td>-0.140 (0.045)</td>
</tr>
<tr>
<td>Vegetables</td>
<td>-0.160</td>
<td>-0.150 (0.320)</td>
<td>0.035 (0.136)</td>
</tr>
</tbody>
</table>

Changes in daily frequency of consumption of Intervention Group 1 and Intervention Group 2 were compared with changes in Control Group values by non-parametric, two-sample Wilcoxon rank sum test. Changes in frequencies of food consumption that were significantly different from the control values (P<0.05) are highlighted in red.
Table 8: Daily frequency of consumption of food consumption in study groups throughout the intervention

<table>
<thead>
<tr>
<th>Food group</th>
<th>Median frequency of food consumption per day (SD)</th>
<th>Median frequency of food consumption per day (SD)</th>
<th>Median frequency of food consumption per day (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Int. 1</td>
<td>Int.2</td>
</tr>
<tr>
<td>Meat</td>
<td>1.28 (0.76)</td>
<td>1.28 (0.81)</td>
<td>1.28 (0.69)</td>
</tr>
<tr>
<td>Fish</td>
<td>0.28 (0.44)</td>
<td>0.42 (0.33)</td>
<td>0.28 (0.34)</td>
</tr>
<tr>
<td>Breads</td>
<td>1.57 (1.39)</td>
<td>1.33 (1.57)</td>
<td>1.36 (1.16)</td>
</tr>
<tr>
<td>Breakfast cereals</td>
<td>0.79 (0.72)</td>
<td>0.43 (0.51)</td>
<td>0.57 (0.48)</td>
</tr>
<tr>
<td>Potatoes, rice and pasta</td>
<td>1.28 (0.62)</td>
<td>1.28 (0.52)</td>
<td>1.28 (0.49)</td>
</tr>
<tr>
<td>Dairy and egg products</td>
<td>2.85 (1.14)</td>
<td>2.71 (1.13)</td>
<td>3.15 (1.41)</td>
</tr>
<tr>
<td>Milk frequency</td>
<td>2.00 (0.99)</td>
<td>2.00 (1.06)</td>
<td>2.00 (1.11)</td>
</tr>
<tr>
<td>Spreads</td>
<td>1.00 (1.16)</td>
<td>0.93 (1.15)</td>
<td>1.00 (1.26)</td>
</tr>
<tr>
<td>Sweets and snacks</td>
<td>1.67 (2.26)</td>
<td>1.96 (2.16)</td>
<td>2.00 (2.97)</td>
</tr>
<tr>
<td>Fruit</td>
<td>1.63 (1.38)</td>
<td>1.43 (1.55)</td>
<td>1.79 (1.87)</td>
</tr>
<tr>
<td>Vegetables</td>
<td>3.38 (1.66)</td>
<td>3.41 (1.59)</td>
<td>2.70 (2.01)</td>
</tr>
</tbody>
</table>

Changes in daily frequency of consumption of Intervention Group 1 and Intervention Group 2 from baseline (week 0) were compared with changes from baseline (week 0) by non-parametric, two-sample Wilcoxon rank sum test. Control values from week 8 and week 16 were compared with those at baseline. Changes in frequencies of food consumption that were significantly different from their comparator values (P<0.05) are highlighted in bold italics.
6.6.2 Impact of wholegrain intervention on nutrient intake

Total daily nutrient intake was assessed from each FFQ by comparing daily food frequency to the average nutrient content per portion, and using average portion sizes of each item on the questionnaire. The changes in median daily intakes of energy and major nutrients intakes in the three intervention groups at week 8 and week 16 time-points are shown in Table 9 and Table 10. Significant differences from the Control Group are highlighted in red. Median values at each measurement point are shown in Table 11.

Participants on the wholegrain interventions significantly increased their daily intakes of a number of B vitamins (i.e. folate, niacin, riboflavin and thiamine), minerals (i.e. iron, magnesium, manganese and zinc), dietary fibre and total carbohydrate compared with the Control Group. At the same time, intervention participants tended to have a significantly higher intake of total energy and sodium than at baseline compared with control participants. For control participants, a significant reduction in B vitamin intake was noted at both 8- and 16-week time-points (see Table 9 and Table 10). This reduction may have exacerbated the apparent increase in B vitamin intake in the intervention groups.
Table 9: Median change from baseline in daily nutrient intakes at week 8 for each study group. Changes in daily nutrient intakes of Intervention Group 1 and Intervention Group 2 were compared with changes in the Control Group by non-parametric, two-sample Wilcoxon rank sum test. Nutrient intakes that were significantly different from the control values (P<0.05) are highlighted in red. Values for the Control Group that differed from baseline values are shown in blue.

<table>
<thead>
<tr>
<th>Daily intake</th>
<th>Control</th>
<th>Intervention 1</th>
<th>Intervention 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy intake (kJ)</td>
<td>-430</td>
<td>379 (0.015)</td>
<td>-399 (0.3126)</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>-1.97</td>
<td>22.6 (0.004)</td>
<td>14.8 (0.026)</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>-3.17</td>
<td>6.15 (0.014)</td>
<td>1.75 (0.125)</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>-2.87</td>
<td>0.245 (0.162)</td>
<td>-8.12 (0.815)</td>
</tr>
<tr>
<td>Alcohol (g)</td>
<td>0.000</td>
<td>0.000 (0.820)</td>
<td>0.000 (0.510)</td>
</tr>
<tr>
<td>% energy carbohydrate</td>
<td>0.348</td>
<td>1.241 (0.049)</td>
<td>1.838 (0.020)</td>
</tr>
<tr>
<td>% energy protein</td>
<td>0.108</td>
<td>0.123 (0.944)</td>
<td>0.845 (0.209)</td>
</tr>
<tr>
<td>% energy fat</td>
<td>0.262</td>
<td>-1.884 (0.033)</td>
<td>-2.113 (0.003)</td>
</tr>
<tr>
<td>% energy alcohol</td>
<td>0.000</td>
<td>0.000 (0.5594)</td>
<td>0.000 (0.4339)</td>
</tr>
<tr>
<td>Dietary fibre (g)</td>
<td>-0.144</td>
<td>4.69 (&lt;0.001)</td>
<td>6.23 (&lt;0.001)</td>
</tr>
<tr>
<td>Added sugar (g)</td>
<td>-5.438 (0.008)</td>
<td>-1.498 (0.084)</td>
<td>-3.888 (0.624)</td>
</tr>
<tr>
<td>TRE (µg)</td>
<td>-4.17</td>
<td>-14.1 (0.709)</td>
<td>-8.80 (0.331)</td>
</tr>
<tr>
<td>Folate (µg)</td>
<td>-22.7 (0.022)</td>
<td>29.4 (0.001)</td>
<td>23.6 (0.001)</td>
</tr>
<tr>
<td>Niacin (mg)</td>
<td>-1.27 (0.042)</td>
<td>4.36 (&lt;0.001)</td>
<td>3.50 (&lt;0.001)</td>
</tr>
<tr>
<td>Riboflavin (mg)</td>
<td>-0.089 (0.008)</td>
<td>0.258 (&lt;0.001)</td>
<td>0.175 (&lt;0.001)</td>
</tr>
<tr>
<td>Vitamin B6 (mg)</td>
<td>-0.045 (0.033)</td>
<td>0.103 (0.011)</td>
<td>0.046 (0.085)</td>
</tr>
<tr>
<td>Thiamin (mg)</td>
<td>-0.051 (0.043)</td>
<td>0.351 (&lt;0.001)</td>
<td>0.343 (&lt;0.001)</td>
</tr>
<tr>
<td>Vitamin C (mg)</td>
<td>-9.34</td>
<td>1.89 (0.229)</td>
<td>5.10 (0.165)</td>
</tr>
<tr>
<td>Vitamin E (mg)</td>
<td>-0.245</td>
<td>0.173 (0.300)</td>
<td>0.225 (0.392)</td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>-33.9</td>
<td>41.1 (0.028)</td>
<td>5.51 (0.202)</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>-0.925 (0.009)</td>
<td>2.65 (&lt;0.001)</td>
<td>2.45 (&lt;0.001)</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>-12.2</td>
<td>68.8 (&lt;0.001)</td>
<td>79.3 (&lt;0.001)</td>
</tr>
<tr>
<td>Manganese (mg)</td>
<td>-0.219 (0.035)</td>
<td>1.56 (&lt;0.001)</td>
<td>1.75 (&lt;0.001)</td>
</tr>
<tr>
<td>Sodium (mg)</td>
<td>-175</td>
<td>266 (0.023)</td>
<td>36.4 (0.074)</td>
</tr>
<tr>
<td>Zinc (mg)</td>
<td>-0.24</td>
<td>1.36 (&lt;0.001)</td>
<td>1.14 (&lt;0.001)</td>
</tr>
</tbody>
</table>

1 as measured by Englyst procedure. TRE = Total Retinol Equivalents.
Table 10: Median change from baseline in daily nutrient intakes at week 16 for each study group. Changes in daily nutrient intakes of Intervention Group 1 and Intervention Group 2 were compared with changes in the Control Group by non-parametric, two-sample Wilcoxon rank sum test. Nutrient intakes that were significantly different from the control values (P<0.05) are highlighted in red. Values for the Control Group that differed from baseline values are shown in blue.

<table>
<thead>
<tr>
<th>Daily intake</th>
<th>Control</th>
<th>Intervention 1</th>
<th>Intervention 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy intake (kJ)</td>
<td>-679</td>
<td>387 (0.073)</td>
<td>587 (0.005)</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>-14.8</td>
<td>37.1 (0.007)</td>
<td>53.8 (&lt;0.001)</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>-4.25</td>
<td>5.05 (0.061)</td>
<td>6.99 (0.001)</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>-4.05</td>
<td>-2.96 (0.546)</td>
<td>-1.63 (0.695)</td>
</tr>
<tr>
<td>Alcohol (g)</td>
<td>0.000</td>
<td>0.000 (0.191)</td>
<td>0.000 (0.632)</td>
</tr>
<tr>
<td>% energy carbohydrate</td>
<td>-0.047</td>
<td>3.303 (0.002)</td>
<td>4.204 (&lt;0.001)</td>
</tr>
<tr>
<td>% energy protein</td>
<td>-0.143</td>
<td>0.288 (0.268)</td>
<td>0.428 (0.087)</td>
</tr>
<tr>
<td>% energy fat</td>
<td>0.114</td>
<td>-1.241 (0.089)</td>
<td>-3.934 (&lt;0.001)</td>
</tr>
<tr>
<td>% energy alcohol</td>
<td>0.000</td>
<td>-0.116 (0.0841)</td>
<td>-0.048 (0.072)</td>
</tr>
<tr>
<td>Dietary fibre (g)¹</td>
<td>0.438</td>
<td>5.70 (&lt;0.001)</td>
<td>11.0 (&lt;0.001)</td>
</tr>
<tr>
<td>Added sugar (g)</td>
<td>-3.73</td>
<td>-2.28 (0.500)</td>
<td>-2.15 (0.557)</td>
</tr>
<tr>
<td>TRE (µg)</td>
<td>-42.1</td>
<td>-0.143 (0.241)</td>
<td>-8.80 (0.331)</td>
</tr>
<tr>
<td>Folate (µg)</td>
<td>-17.6 (0.034)</td>
<td>51.7 (0.001)</td>
<td>41.8 (&lt;0.001)</td>
</tr>
<tr>
<td>Niacin (mg)</td>
<td>-2.45 (0.030)</td>
<td>4.18 (&lt;0.001)</td>
<td>8.18 (&lt;0.001)</td>
</tr>
<tr>
<td>Riboflavin (mg)</td>
<td>-0.125 (0.048)</td>
<td>0.269 (&lt;0.001)</td>
<td>0.388 (&lt;0.001)</td>
</tr>
<tr>
<td>Vitamin B6 (mg)</td>
<td>-0.085</td>
<td>0.237 (0.031)</td>
<td>0.087 (0.104)</td>
</tr>
<tr>
<td>Thiamin (mg)</td>
<td>-0.080 (0.037)</td>
<td>0.346 (&lt;0.001)</td>
<td>0.678 (&lt;0.001)</td>
</tr>
<tr>
<td>Vitamin C (mg)</td>
<td>-11.36</td>
<td>5.20 (0.596)</td>
<td>-11.6 (0.299)</td>
</tr>
<tr>
<td>Vitamin E (mg)</td>
<td>-0.615</td>
<td>-0.100 (0.275)</td>
<td>0.298 (0.205)</td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>-27.3</td>
<td>48.6 (0.045)</td>
<td>17.6 (0.321)</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>-0.914</td>
<td>2.90 (&lt;0.001)</td>
<td>5.67 (&lt;0.001)</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>-17.9</td>
<td>71.0 (&lt;0.001)</td>
<td>139 (&lt;0.001)</td>
</tr>
<tr>
<td>Manganese (mg)</td>
<td>-0.209</td>
<td>1.68 (&lt;0.001)</td>
<td>3.47 (&lt;0.001)</td>
</tr>
<tr>
<td>Sodium (mg)</td>
<td>-241</td>
<td>23.7 (0.098)</td>
<td>450 (&lt;0.001)</td>
</tr>
<tr>
<td>Zinc (mg)</td>
<td>-0.784</td>
<td>1.57 (&lt;0.001)</td>
<td>1.14 (&lt;0.001)</td>
</tr>
</tbody>
</table>

¹as measured by Englyst procedure. TRE = Total Retinol Equivalents.
Table 11: Median estimated daily nutrient intake over time.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Control</th>
<th>Baseline</th>
<th>Int. 1</th>
<th>Int. 2</th>
<th>Control</th>
<th>Week 8</th>
<th>Int. 1</th>
<th>Int. 2</th>
<th>Control</th>
<th>Week 16</th>
<th>Int. 1</th>
<th>Int. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy intake (kJ)</td>
<td>8300 (3027)</td>
<td>7889 (3148)</td>
<td>8268 (2712)</td>
<td>7742 (2757)</td>
<td>8409 (2764)</td>
<td>8468 (2826)</td>
<td>7747 (2813)</td>
<td>8133 (2443)</td>
<td>9268 (3140)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>251 (102)</td>
<td>237.6 (86)</td>
<td>255 (90)</td>
<td>231 (94)</td>
<td>271 (85)</td>
<td>268 (81)</td>
<td>238 (92)</td>
<td>260 (80)</td>
<td>308 (106)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole grains (g)</td>
<td>16.7 (16.7)</td>
<td>14.9 (20.0)</td>
<td>15.8 (18.9)</td>
<td>12.0 (22.4)</td>
<td>75.0 (27.5)</td>
<td>82.5 (31.1)</td>
<td>14.7 (19.8)</td>
<td>76.6 (33.2)</td>
<td>119.5 (48.9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein (g)</td>
<td>72.6 (25.7)</td>
<td>66.8 (26.2)</td>
<td>68.6 (21.7)</td>
<td>66.1 (25.7)</td>
<td>77.0 (23.6)</td>
<td>75.4 (24.7)</td>
<td>69.7 (24.0)</td>
<td>74.0 (21.3)</td>
<td>81.0 (27.9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat (g)</td>
<td>60.0 (25.5)</td>
<td>57.1 (29.1)</td>
<td>58.9 (23.6)</td>
<td>56.1 (23.6)</td>
<td>57.2 (23.1)</td>
<td>58.7 (30.8)</td>
<td>57.3 (25.0)</td>
<td>54.3 (21.1)</td>
<td>57.4 (24.2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol (g)</td>
<td>19.3 (28.0)</td>
<td>17.9 (35.9)</td>
<td>18.0 (26.9)</td>
<td>17.8 (24.1)</td>
<td>18.3 (26.7)</td>
<td>14.4 (25.2)</td>
<td>16.9 (25.7)</td>
<td>14.4 (24.7)</td>
<td>18.3 (27.7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% energy CHO</td>
<td>49.1 (7.5)</td>
<td>48.8 (7.8)</td>
<td>50.5 (6.7)</td>
<td>49.9 (7.1)</td>
<td>50.8 (6.9)</td>
<td>51.7 (7.6)</td>
<td>49.6 (7.0)</td>
<td>52.8 (6.7)</td>
<td>54.4 (7.4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% energy protein</td>
<td>14.8 (2.7)</td>
<td>15.5 (3.0)</td>
<td>14.7 (2.5)</td>
<td>15.1 (2.7)</td>
<td>15.7 (2.7)</td>
<td>14.9 (2.5)</td>
<td>14.8 (2.6)</td>
<td>15.8 (2.8)</td>
<td>15.4 (2.6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% energy fat</td>
<td>27.1 (4.9)</td>
<td>28.1 (5.5)</td>
<td>27.0 (5.1)</td>
<td>27.7 (5.3)</td>
<td>26.5 (4.2)</td>
<td>25.1 (6.0)</td>
<td>27.1 (5.2)</td>
<td>25.3 (4.0)</td>
<td>23.8 (4.4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% energy alcohol</td>
<td>6.5 (7.5)</td>
<td>6.4 (9.9)</td>
<td>6.0 (7.3)</td>
<td>6.1 (7.8)</td>
<td>5.8 (7.2)</td>
<td>5.2 (7.2)</td>
<td>6.5 (7.9)</td>
<td>5.1 (7.1)</td>
<td>5.2 (7.0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dietary fibre (g)</td>
<td>16.7 (6.2)</td>
<td>16.5 (6.2)</td>
<td>15.7 (7.3)</td>
<td>15.5 (5.5)</td>
<td>22.3 (6.6)</td>
<td>22.6 (7.8)</td>
<td>16.0 (5.8)</td>
<td>22.5 (6.9)</td>
<td>26.2 (9.4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Added sugar (g)</td>
<td>53.6 (38.2)</td>
<td>53.1 (28.5)</td>
<td>52.6 (44.1)</td>
<td>46.5 (29.7)</td>
<td>50.2 (34.5)</td>
<td>50.1 (36.1)</td>
<td>54.4 (29.6)</td>
<td>49.7 (29.4)</td>
<td>50.5 (30.5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRE (µg)</td>
<td>568 (400)</td>
<td>506 (384)</td>
<td>452 (308)</td>
<td>525 (369)</td>
<td>499 (346)</td>
<td>489 (439)</td>
<td>526 (351)</td>
<td>506 (347)</td>
<td>385 (406)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Folate (µg)</td>
<td>306 (103)</td>
<td>272 (102)</td>
<td>278 (118)</td>
<td>269 (93)</td>
<td>267 (99)</td>
<td>286 (115)</td>
<td>257 (98)</td>
<td>296 (87.1)</td>
<td>311 (107)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Niacin (mg)</td>
<td>25.4 (8.2)</td>
<td>22.4 (8.0)</td>
<td>23.0 (9.1)</td>
<td>22.4 (7.7)</td>
<td>25.6 (8.2)</td>
<td>25.7 (8.6)</td>
<td>22.6 (7.7)</td>
<td>26.2 (7.6)</td>
<td>30.2 (10.2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riboflavin (mg)</td>
<td>1.5 (0.6)</td>
<td>1.3 (0.6)</td>
<td>1.4 (0.6)</td>
<td>1.3 (0.5)</td>
<td>1.4 (0.5)</td>
<td>1.5 (0.5)</td>
<td>1.3 (0.5)</td>
<td>1.4 (0.5)</td>
<td>1.6 (0.5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin B6 (mg)</td>
<td>2.4 (0.7)</td>
<td>2.2 (0.8)</td>
<td>2.1 (0.8)</td>
<td>2.2 (0.6)</td>
<td>2.1 (0.7)</td>
<td>2.2 (0.7)</td>
<td>2.2 (0.7)</td>
<td>2.2 (0.6)</td>
<td>2.2 (0.7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thiamin (mg)</td>
<td>1.7 (0.6)</td>
<td>1.7 (0.5)</td>
<td>1.6 (0.6)</td>
<td>1.4 (0.5)</td>
<td>1.9 (0.6)</td>
<td>2.0 (0.6)</td>
<td>1.5 (0.6)</td>
<td>1.9 (0.5)</td>
<td>2.2 (0.7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin C (mg)</td>
<td>119 (67)</td>
<td>122 (70)</td>
<td>98 (80)</td>
<td>115 (63)</td>
<td>111 (59)</td>
<td>96 (90)</td>
<td>111 (59)</td>
<td>119 (67)</td>
<td>91 (64)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin E (mg)</td>
<td>6.1 (2.3)</td>
<td>5.8 (2.6)</td>
<td>6.0 (2.2)</td>
<td>5.7 (2.0)</td>
<td>6.2 (2.0)</td>
<td>5.9 (2.5)</td>
<td>5.7 (1.9)</td>
<td>5.8 (2.0)</td>
<td>5.8 (2.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>548 (245)</td>
<td>510 (202)</td>
<td>559 (186)</td>
<td>505 (203)</td>
<td>501 (200)</td>
<td>532 (194)</td>
<td>490 (206)</td>
<td>499 (163)</td>
<td>552 (240)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>12.9 (4.5)</td>
<td>12.8 (4.8)</td>
<td>13.3 (5.3)</td>
<td>11.6 (4.2)</td>
<td>15.1 (4.7)</td>
<td>14.4 (4.2)</td>
<td>11.8 (4.5)</td>
<td>13.8 (4.2)</td>
<td>17.1 (5.6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>310 (101)</td>
<td>296 (106)</td>
<td>312 (93)</td>
<td>294 (87)</td>
<td>365 (117)</td>
<td>314 (113)</td>
<td>277 (99)</td>
<td>368 (100)</td>
<td>447 (140)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manganese (mg)</td>
<td>3.6 (1.2)</td>
<td>3.6 (1.6)</td>
<td>3.6 (1.4)</td>
<td>3.3 (1.3)</td>
<td>5.2 (1.7)</td>
<td>5.8 (1.8)</td>
<td>3.4 (1.4)</td>
<td>5.4 (1.8)</td>
<td>7.0 (2.5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium (mg)</td>
<td>2820 (1128)</td>
<td>2663 (1329)</td>
<td>2926 (959)</td>
<td>2533 (1114)</td>
<td>2847 (1153)</td>
<td>3095 (1246)</td>
<td>2643 (1329)</td>
<td>2815 (1032)</td>
<td>3344 (1404)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc (mg)</td>
<td>8.3 (3.4)</td>
<td>7.4 (3.2)</td>
<td>8.0 (2.4)</td>
<td>7.6 (3.5)</td>
<td>9.9 (3.2)</td>
<td>9.5 (2.9)</td>
<td>7.8 (3.1)</td>
<td>9.3 (2.8)</td>
<td>11.2 (3.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 as measured by Englyst procedure. TRE = Total Retinol Equivalents.
6.7 Effect of wholegrain intervention on plasma/urinary lignans

6.7.1 Measurement of mammalian lignans

Plasma and urine concentrations of the mammalian lignans enterolactone and enterodiol were assessed by HPLC using previously reported methods (Nurmi et al., 2003; Penalvo et al., 2004). Briefly, samples were subjected to enzymatic hydrolysis with a mixture of β-glucuronidase and sulphatase for 16 h at 37°C. The organic phase of the resulting solution was then extracted with diethyl ether and dried. The resulting material was purified through ion exchange columns, dried and re-constituted in HPLC solvent prior to analysis.

6.7.2 Plasma and urinary lignans

For the majority of samples analysed, plasma enterodiol concentrations were below detection limits, and are therefore not reported here. The relationship between dietary whole grain-intake (g/d) and plasma enterolactone concentrations is shown in Figure 7.

Figure 7: Relationship between measured plasma enterolactone concentration and reported whole grain-intake. Linear regressions for each treatment group are shown as dashed lines, and were all non-significant. Period 1, 2 and 3 are week 0, week 8 and week 16 time-points respectively. Groups 1, 2 and 3 are Control, Intervention Group 1 and Intervention Group 2 respectively.
The range in plasma enterolactone concentrations was large and was not related to whole grain-intake calculated from FFQs. Linear regression analysis across treatments and within treatment groups showed no significant relationship between the parameters. Group means for plasma enterolactone concentration are shown in Table 12. There were no differences between treatment groups or between time points within treatment groups. However, within Intervention Groups 1 and 2 there were individuals in which plasma enterolactone concentrations rose during the wholegrain intervention (i.e. they ‘responded’ positively to increased whole grain-intake. Further interrogation of the data are required to explore the nature of the individual participants to separate ‘responders’ and ‘non responders’; for example, whether this was due to consumption of a particular wholegrain food. Data for urinary lignans were also very varied and similar lack of response was observed at the group level. Further investigation of these data is required.

Table 12: Plasma enterolactone concentration (ng/ml) in participant at baseline, 8 and 16 weeks of wholegrain intervention.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Intervention 1</th>
<th>Intervention 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>21.46 (3.548)</td>
<td>20.08 (3.955)</td>
<td>32.39 (3.985)</td>
</tr>
<tr>
<td>8 Weeks</td>
<td>21.07 (3.570)</td>
<td>23.68 (4.016)</td>
<td>24.79 (3.955)</td>
</tr>
<tr>
<td>16 Weeks</td>
<td>26.46 (3.570)</td>
<td>22.37 (3.896)</td>
<td>24.85 (3.868)</td>
</tr>
</tbody>
</table>

6.8 Summary

Energy intake and protein were similar when measured by FFQ and 4-day diet diary. The FFQ appeared to over estimate CHO and fibre intake; this was likely to be due to the foods within the FFQ which included a large number of wholegrain products and fruit and vegetable items. In contrast, on average, fat intakes were underestimated by the FFQ method.

Plasma enterolactone concentrations were not related to reported whole grain-intakes estimated from FFQ. There was considerable variation in the data obtained. Similar wide variations and inconsistencies with urinary lignan concentrations were determined. Some individuals may be classified as ‘responders’, with higher enterolactone concentrations with increased whole grain-intake, but this requires further investigation.

Wholegrain food intake had both positive and negative impacts on dietary intake. In particular, participants on the intervention groups consumed higher amounts of dietary fibre, B vitamins (i.e. folate, niacin, riboflavin, vitamin B6, thiamin) and minerals (iron, magnesium, manganese and zinc). However wholegrain food consumption was also linked to an increase in daily energy and sodium intake, and led to a displacement of fruit from the diet for those participants consuming the highest levels of whole grain.
7 Objective 5: Evaluation of the impact of whole grain-consumption on CVD risk factors

7.1 State of the art

Circulating plasma total and LDL-cholesterol concentrations are major predictors of CVD risk. There is a need to evaluate the impact of increasing whole grain-consumption on this key outcome measure. There are no prospective studies which have evaluated the effects of increasing whole grain-consumption on changes in lipid profile or other markers of CVD risk.

7.2 Introduction

7.2.1 Whole grains and cardiovascular disease risk

Analyses of large-scale epidemiological and cohort studies, mostly from North America but also including Scandinavia, have consistently demonstrated an association between whole grain-consumption and disease risk. These data show strong inverse relationships with increasing levels of whole grain-intake and relative risk of developing chronic diseases such as coronary heart diseases, Type 2 diabetes and some cancers (Chatenoud et al., 1998; Jacobs et al., 1998; Liu, 2003; Montonen et al., 2003; Murtaugh et al., 2003). The strongest relationships have been found for cardiovascular disease (CVD) (Anderson et al., 2000; Seal, 2006) where a risk reduction of between 20 and 40% has been reported for CVD between the highest and lowest percentiles of whole grain-intake. These studies benefit from large numbers of subjects and there is generally good statistical interrogation of the data, including appropriate adjustments made for associated confounding factors (as most whole grain consumers are more likely to have a generally healthy lifestyle than non whole grain consumers (Anderson et al., 2000; Seal, 2006)).

Factors such as plasma cholesterol concentrations (Godsland et al., 1987; Grundy & Denke, 1990), fasting insulin and glucose concentrations (Stout, 1979; Jarrett, 1984), blood pressure (Wood et al., 1997) and anthropometric measures such as BMI and body fat percentage (Despres et al., 1990; Seidell & Flegal, 1997) have all been demonstrated to be strongly associated with relative risk of subsequent cardiovascular disease. As a result, these factors are ideal biomarkers to measure whether or not wholegrain foods affect risk of cardiovascular disease.

7.2.2 Mechanisms of action

While epidemiological evidence described briefly above is a powerful indicator of the inverse correlation between whole grain-intake and cardiovascular disease risk, this evidence does not demonstrate causality. To date, there is no evidence from controlled dietary intervention studies with large numbers of subjects showing clear benefit of increased consumption of wholegrain foods on markers of disease risk. As a result supposed mechanisms of action are at this time speculative.
Due to a lack of causal evidence many plausible, yet speculative explanations have been proposed including the increased intake of antioxidant substances, bio-active components such as plant lignans, phytooestrogens, soluble and insoluble fibre, phytates and phenolics. Intakes of many of these components have also been suggested to improve immune function, antioxidant status, endothelial function and blood pressure, tumour suppression, and inflammation all of which are linked to chronic diseases. In a recent observational study Qi et al. (2006) showed that intakes of whole grain were associated with decreased concentrations of systemic inflammation in diabetic women in a cross sectional study. These results were mirrored in a study of similar design (Lutsey et al., 2007), where a negative correlation between whole grain-intake and markers of insulin sensitivity was also noted. Within this study, whole grain-intake was not associated with reduced blood pressure or plasma HDL- or LDL cholesterol concentrations. In a recent cross-sectional study, the highest intakes of wholegrain foods were inversely associated with plasma concentrations of homocysteine and markers of glycaemic control (i.e. insulin, C-peptide and leptin). Inverse associations were also noted between whole grain-intake and plasma total, HDL and LDL cholesterol. No association was noted between whole grain-intake and inflammatory markers (i.e. C-reactive protein, fibrinogen and interleukin 6) (Jensen et al., 2006). A few studies published recently have shown benefit of incorporating whole grains into the diet of ‘at risk’ subjects but the numbers of subjects are very small. For example, Behall et al. (2006) showed that wholegrain foods whether high in soluble or insoluble fibre reduced blood pressure in mildly hypercholesterolemic men and women (n = 25). In a randomized, non-blinded, crossover dietary intervention (n = 34), which took place over two 6-week periods, markers of both inflammation and insulin sensitivity were not affected by inclusion of whole grain in the diet compared to refined grain intake (Andersson et al., 2007).

Wholegrain food-consumption has also been linked to weight management and obesity control, but most of the evidence is from cohort studies with self-reported weight and has not been confirmed in either weight loss studies or long term intervention studies.

For some grains such as oats, barley and rye which contain significant quantities of soluble fibres their effects on CVD may be due to their proven hypocholesterolaemic properties. The cholesterol-lowering effects of oats have been well documented and a health claim is authorised, both in America (Food and Drink Administration, 2002) and in the UK (Joint Health Claims Initiative, 2004), based on the presence of the soluble fibre, β-glucan. A similar claim for barley has also now been approved in the US (Food and Drink Administration, 2005a). The benefit of soluble arabinoxylans in rye in lowering cholesterol has also been observed in a number of studies (Leinonen et al., 1999).

Although some wholegrain foods have a lower glycaemic index (GI) than refined grain alternatives, this is not true for all wholegrain foods. For example wholemeal bread has the same GI as white bread. Thus some wholegrain foods may have an impact on glycaemic load and consequently on postprandial glucose and insulin responses (Jenkins et al., 1988). Studies in healthy subjects have shown that postprandial plasma insulin responses are significantly lower after the consumption of a whole grain rye bread compared with a white wheat bread (Juntunen et al., 2003a; Juntunen et al.,
2003b) but potential benefits on the development of Type 2 diabetes or the metabolic syndrome need further investigation.

7.2.3 Whole grain health claims

The Food and Drink Administration (FDA) was the first organisation to authorise the use of a health claim for use on wholegrain products in the US in 1999 (Food and Drink Administration, 1999). The claim was modified in 2003 to read: ‘Diets rich in wholegrain foods and other plant foods, and low in saturated fat and cholesterol, may help reduce the risk of heart disease’ (Food and Drink Administration, 2005b). Products using the claim must contain >51% whole grain by weight per reference amount customarily consumed (RACC). In order to use the health claim, and consider the food as a ‘wholegrain food’ the wholegrain ingredients must be present in sufficient quantity to characterise the food (hence the dominant or first ingredient in the ingredient list must be a whole grain), and the food must provide a minimum of 16g whole grain/RACC (Richardson, 2003). Similar health claims have been approved in the UK (by the Joint Health Claims Initiative) in 2002 (Joint Health Claims Initiative, 2002) and the Swedish Nutrition Foundation in 2003 (Swedish Nutrition Foundation, 2003).

7.3 Measurement of CVD risk factors

Table 13 shows the mean age, gender and BMI of participants at baseline. These data were used to minimise participants. BMI, waist measurements and blood pressure were assessed by standard methodologies (see for example, Savage et al., 2003). Body composition, including body fat percentage, was assessed using a Tanita BC-418 segmental body composition analyzer [Tanita Corporation of America Inc, Illinois, USA] (Jebb et al., 2000). Analysis of fasting measures of plasma fibrinogen and PAI-1 were conducted at the Department of Clinical Biochemistry at Addenbrookes Hospital. All other measures of plasma CVD risk markers were analysed at the Nutritional Biochemistry Laboratory at MRC HNR. Details of the methods used for all measures analysed or subsequently calculated are shown in Table 14.

Table 13: Baseline characteristics of the 3 WHOLEheart study groups. The data are presented for study completers only.

<table>
<thead>
<tr>
<th></th>
<th>Age (± SEM)</th>
<th>% male</th>
<th>BMI (± SEM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>45.6 (± 1.0)</td>
<td>49.0</td>
<td>30.0 (± 0.4)</td>
</tr>
<tr>
<td>Intervention 1</td>
<td>45.9 (± 1.1)</td>
<td>50.0</td>
<td>30.0 (± 0.4)</td>
</tr>
<tr>
<td>Intervention 2</td>
<td>45.7 (± 1.1)</td>
<td>51.2</td>
<td>30.3 (± 0.5)</td>
</tr>
</tbody>
</table>
Table 14: Markers of CVD risk analysed in fasting plasma samples. All measurements were made at week 0, week 8 and week 16 of the intervention period. NEFA = non-esterified fatty acids, CRP = C-reactive protein, IL-6 = interleukin-6, ICAM-1 = intercellular adhesion molecule 1, VCAM-1 = vascular cell adhesion molecule 1, PAI-1 = plasminogen activator inhibitor

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Detection method</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lipid profile</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cholesterol</td>
<td>Enzymatic colorimetric assay</td>
<td>(Wesenberg et al., 2000)</td>
</tr>
<tr>
<td>HDL cholesterol</td>
<td>Colorimetric assay</td>
<td>(Wesenberg et al., 2000)</td>
</tr>
<tr>
<td>LDL cholesterol</td>
<td>Indirect calculation (Friedwald equation), based on measured levels of triglycerides, total and HDL cholesterol</td>
<td>(Nandeesha et al., 2006)</td>
</tr>
<tr>
<td>Triglycerides</td>
<td>Enzymatic colorimetric assay</td>
<td>(Amsel et al., 2001)</td>
</tr>
<tr>
<td>NEFA</td>
<td>Enzymatic colorimetric assay using commercially available kit (Roche, Cat # 11 383 175 001)</td>
<td>(Shimizu et al., 1980)</td>
</tr>
<tr>
<td><strong>Insulin sensitivity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td>Colorimetric assay</td>
<td>(Savoca et al., 2006)</td>
</tr>
<tr>
<td>Insulin</td>
<td>Fluorometric immunoassay using commercially available kit (Dako Ltd, Cat # B080-101)</td>
<td>(Andersen et al., 1993)</td>
</tr>
<tr>
<td>Modified QUICKI</td>
<td>Indirect measurement based on measured glucose, insulin and NEFA levels</td>
<td>(Katz et al., 2000; Rabasa-Lloret et al., 2003)</td>
</tr>
<tr>
<td><strong>Endothelial function</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICAM-1</td>
<td>Colorimetric sandwich ELISA using commercially available kit (R&amp;D Systems Cat no SBBE1B)</td>
<td>(Register et al., 2004)</td>
</tr>
<tr>
<td>VCAM-1</td>
<td>Colorimetric sandwich ELISA using commercially available kit (R&amp;D Systems Cat no SVC00)</td>
<td>(Garton et al., 2003)</td>
</tr>
<tr>
<td>E-selectin</td>
<td>Colorimetric sandwich ELISA using commercially available kit (R&amp;D Systems Cat no SBBE2B)</td>
<td>(Ruchaud-Sparagano et al., 1998)</td>
</tr>
<tr>
<td><strong>Inflammatory status</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sialic acid</td>
<td>Enzymatic colorimetric assay using commercially available kit (Roche Diagnostics, cat no 10 784 192 001)</td>
<td>(Webber et al., 2006)</td>
</tr>
<tr>
<td>CRP</td>
<td>Particle-enhanced, turbidimetric immunoassay</td>
<td>(Roberts et al., 2001)</td>
</tr>
<tr>
<td>IL-6</td>
<td>Colorimetric sandwich ELISA using commercially available kit (Diaclone Cat no 850.035.096)</td>
<td>(Wehlin et al., 2004)</td>
</tr>
<tr>
<td>Fibrinogen</td>
<td>Modified Clauss methodology</td>
<td>(Al-Barjas et al., 2006)</td>
</tr>
<tr>
<td>PAI-1</td>
<td>Colorimetric sandwich ELISA using commercially available kit (Technoclone Technozym® PAI-1 Actibind®)</td>
<td>(Pannekoek et al., 1986)</td>
</tr>
</tbody>
</table>
7.4 Statistical analysis

All variables (except waist and body fat percentage) were log transformed. A random intercepts model was used to account for the correlated nature of longitudinal measures. The model was constrained (see Figure 8 below) to reflect the study design. The intervention groups were then compared with the control group at follow-up by taking the average of 2 month and 4 month data and by averaging groups 2 and 3, i.e. 0.5 • (D + (E + F/2)). This is the most powerful way of detecting a statistically significant difference should a difference exist. The difference between both geometric means and 95% confidence intervals were compared. If the 95% confidence intervals fell around 0, then no further analysis was carried out, as the P value would be above 0.05.

Figure 8: Theoretical mixed effects model (random intercepts, on the log scale) for analysis of WHOLEheart outcome measures. Plasma LDL concentration is used in this graph as an example. Int 3then3 is Intervention Group 1, 3 servings of whole grain per day for whole 16 week period; Int 3then6 is Intervention Group 2, 3 servings of whole grain for 8 weeks followed by 6 servings per day for the second 8 week period.
7.5 Effect of wholegrain intervention on risk factors for CVD

Despite the observation from dietary records that dietary compliance was good for those consuming the wholegrain foods, there were no significant differences observed for any of the chosen markers of cardiovascular risk between the wholegrain intervention groups and the Control Group. These data are summarised in Table 15, which displays the mean values of each parameter measured for each group at all time-points. Median differences from Control group are described in the following sections.

Table 15: Mean values of all outcome measures for WHOLEheart study. Results are displayed as geometric means for each group at each time-point during the intervention.

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Control group</th>
<th>Intervention 1</th>
<th>Intervention 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Week</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td><strong>Anthropometry</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>86.48</td>
<td>86.65</td>
<td>86.56</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>29.99</td>
<td>29.96</td>
<td>30.03</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>32.4</td>
<td>32.3</td>
<td>32.5</td>
</tr>
<tr>
<td>Systolic BP (mm Hg)</td>
<td>128.7</td>
<td>128.1</td>
<td>126.5</td>
</tr>
<tr>
<td>Diastolic BP (mm Hg)</td>
<td>79.1</td>
<td>78.4</td>
<td>77.3</td>
</tr>
<tr>
<td><strong>Lipid profile</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cholesterol (mmol/l)</td>
<td>5.18</td>
<td>5.24</td>
<td>5.29</td>
</tr>
<tr>
<td>HDL cholesterol (mmol/l)</td>
<td>1.29</td>
<td>1.33</td>
<td>1.33</td>
</tr>
<tr>
<td>LDL cholesterol (mmol/l)</td>
<td>3.12</td>
<td>3.15</td>
<td>3.21</td>
</tr>
<tr>
<td>Triglycerides (mmol/l)</td>
<td>1.43</td>
<td>1.41</td>
<td>1.36</td>
</tr>
<tr>
<td>NEFA (mmol/l)</td>
<td>0.48</td>
<td>0.47</td>
<td>0.48</td>
</tr>
<tr>
<td><strong>Insulin sensitivity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucose (mmol/l)</td>
<td>5.53</td>
<td>5.53</td>
<td>5.53</td>
</tr>
<tr>
<td>Insulin (pmol/l)</td>
<td>59</td>
<td>62</td>
<td>59</td>
</tr>
<tr>
<td>Modified QUICKI</td>
<td>0.387</td>
<td>0.384</td>
<td>0.387</td>
</tr>
<tr>
<td><strong>Endothelial function</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>ICAM-1 (ng/ml)</td>
<td>224.7</td>
<td>226.9</td>
<td>233.1</td>
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<tr>
<td>VCAM-1 (ng/ml)</td>
<td>671.9</td>
<td>662.1</td>
<td>690.8</td>
</tr>
<tr>
<td>E-selectin (ng/ml)</td>
<td>31.6</td>
<td>30.2</td>
<td>32.8</td>
</tr>
<tr>
<td><strong>Inflammatory status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sialic acid (mg/dl)</td>
<td>67.12</td>
<td>67.44</td>
<td>66.99</td>
</tr>
<tr>
<td>CRP (mg/l)</td>
<td>2.42</td>
<td>2.75</td>
<td>2.92</td>
</tr>
<tr>
<td>IL-6 (pg/ml)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Fibrinogen (g/L)</td>
<td>3.06</td>
<td>3.03</td>
<td>3.08</td>
</tr>
<tr>
<td>PAI-1 (ng/ml)</td>
<td>12.06</td>
<td>13.35</td>
<td>11.89</td>
</tr>
</tbody>
</table>
7.5.1 Effect of wholegrain intervention on fasting lipid profile

Fasting lipid profile measurements were taken in duplicate (at separate visits within 7 days of each other) at weeks 0, 8 and 16 of the intervention. These duplicate measures had Spearman’s correlation value of above 0.75, demonstrating a good reproducibility between measurements at each time point. Table 16 shows the effect of wholegrain intervention on fasting lipid profiles, calculated following the statistical model outlined in Section 7.4. There were no significant differences (P> 0.05) for any of the measured outcomes, with all 95% confidence intervals including 0.

Table 16: Effect of wholegrain intervention on fasting lipid profile measures compared with the Control Group. For further details of the statistical model used, see section 7.4. All “means” used in the analysis were geometric means.

<table>
<thead>
<tr>
<th>Difference (%) from Control Group mean (95% Cis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cholesterol</td>
</tr>
<tr>
<td>HDL</td>
</tr>
<tr>
<td>LDL (calculated)</td>
</tr>
<tr>
<td>Triglycerides</td>
</tr>
</tbody>
</table>

These data are at variance with the data from the feasibility study reported in Section 4.3 in which plasma LDL-cholesterol concentrations fell in response to increased intake of wholegrain foods. The feasibility study was an uncontrolled intervention also based on substitution of wholegrain foods in the diet. Participants in this preliminary study were provided with a similar range of wholegrain foods to those used in the WHOLEheart study, but they were also given healthy eating advice focussed on including whole grains in their diet, and information about other wholegrain foods available at that time. The subjects were asked to include whichever foods they chose and were asked to include them in their diet to a prescribed amount (c. 70 g/day). It is possible that participants may have used participation in this study as a platform to consume a healthier diet and/or live a healthier lifestyle. As a result, other factors may have influenced plasma cholesterol concentrations. Since there was no control group in that study, we cannot exclude seasonal or other factors in affecting the outcome.

Increased intake of whole grain in this study was associated with an overall lower intake of dietary fat, but this fall was relatively small (2% of daily energy), which on its own may not have been sufficient to affect cholesterol concentrations. In addition, dietary carbohydrate intake was increased and, overall, subjects in both intervention groups consumed more energy during the intervention. The frequency of intake of breads and breakfast cereals were increased at 8 and further at 16 weeks suggesting that the intervention had resulted in additional food consumption and a change in the overall diet pattern. Thus the subjects had not followed a substitution intervention only changing refined grain foods for wholegrain foods as requested.
7.5.2 Effect of wholegrain intervention on markers of insulin sensitivity

Measures of fasting insulin and glucose were taken in duplicate (at separate visits within 7 days of each other) at weeks 0, 8 and 16 of the intervention. Duplicates were once again consistent with each other at all time-points, with Spearman’s correlation values of above 0.70.

Table 17 shows the effect of wholegrain intervention on the measured markers of insulin sensitivity, calculated following the statistical model outlined in 7.4. There were no significant differences (P>0.05) for any of the measured outcomes.

Table 17: Effect of wholegrain intervention on markers of insulin sensitivity compared with the Control Group. For further details of the statistical model used, see section 7.4. NEFA = non-esterified fatty acids, QUICKI = quantitative insulin-sensitivity check index (Katz et al., 2000), R.QUICKI = revised quantitative insulin-sensitivity check index (Rabasa-Lhoret et al., 2003). All “means” used in analysis were geometric means.

<table>
<thead>
<tr>
<th></th>
<th>Difference (%) from Control group mean (95% CIs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td>-0.82% (-1.95%, 0.32%)</td>
</tr>
<tr>
<td>Insulin</td>
<td>1.84% (-4.12%, 8.17%)</td>
</tr>
<tr>
<td>NEFA</td>
<td>-3.11% (-9.26%, 3.47%)</td>
</tr>
<tr>
<td>QUICKI</td>
<td>-0.30% (-1.26%, 0.66%)</td>
</tr>
<tr>
<td>R.QUICKI</td>
<td>0.62% (-0.96%, 2.22%)</td>
</tr>
</tbody>
</table>

7.5.3 Effect of wholegrain intervention on markers of inflammatory status

Single measures of fasting sialic acid, CRP, IL-6, fibrinogen and PAI-1 plasma concentrations were taken at weeks 0, 8 and 16 of the intervention. Table 18 shows the effect of wholegrain intervention on markers of inflammatory status, calculated following the statistical model outlined in section 7.4. There were no significant differences (P>0.05) for any of the measured outcomes. Approximately 70% of all IL-6 measurements from the intervention period were below the minimum detectable value, and as a result no statistical analysis was possible.

Table 18: Effect of wholegrain intervention on markers of inflammatory status compared with the Control Group. For further details of the statistical model used, see section 7.4. CRP = C-reactive protein, IL-6 = interleukin-6, PAI-1 = plasminogen activator inhibitor-1. All “means” used in analysis were geometric means.

<table>
<thead>
<tr>
<th></th>
<th>Interventions are higher at follow-up on average (95% CI) by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sialic acid</td>
<td>0.44% (-1.21%, 2.12%)</td>
</tr>
<tr>
<td>CRP</td>
<td>-1.20% (-12.32%, 11.32%)</td>
</tr>
<tr>
<td>IL-6</td>
<td>N/A</td>
</tr>
<tr>
<td>Fibrinogen</td>
<td>1.31% (-2.03%, 4.76%)</td>
</tr>
<tr>
<td>PAI-1</td>
<td>-2.78% (-22.12%, 21.36%)</td>
</tr>
</tbody>
</table>
7.5.4 Effect of wholegrain intervention on markers of endothelial function

Single measures of fasting plasma ICAM-1, VCAM-1 and E-selectin concentrations were taken at weeks 0, 8 and 16 of the intervention. Table 19 shows the effect of wholegrain intervention on markers of endothelial function, calculated following the statistical model outlined in 7.4. There were no significant differences (P> 0.05) for any of the measured outcomes.

Table 19: Effect of wholegrain intervention on markers of endothelial function compared with the Control Group. For further details of the statistical model used, see section 7.4. ICAM-1 = intercellular adhesion molecule-1, VCAM-1 = vascular cell adhesion molecule 1. All “means” used in analysis are geometric means.

<table>
<thead>
<tr>
<th>Markers of Endothelial Function</th>
<th>Interventions are higher at follow-up on average (95% CI) by</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICAM-1</td>
<td>-0.66% (-2.93%, 1.66%)</td>
</tr>
<tr>
<td>VCAM-1</td>
<td>-0.81% (-3.39%, 1.83%)</td>
</tr>
<tr>
<td>E-selectin</td>
<td>-1.46% (-5.17%, 2.40%)</td>
</tr>
</tbody>
</table>

7.5.5 Effect of wholegrain intervention on blood pressure and weight

Seated blood pressure was measured in duplicate (i.e. two same day measurements 5 minutes apart) at weeks 0, 8 and 16 of the intervention. Single measures of body weight were taken at the same time-points. Table 20 shows the effect of wholegrain intervention on seated blood pressure, weight, waist circumference and body fat percentage, calculated following the statistical model outlined in 7.4. There were no significant differences (P> 0.05) for any of the measured outcomes.

Table 20: Effect of wholegrain intervention on seated blood pressure, body weight, waist circumference and body fat percentage compared with the Control Group. For further details of the statistical model used, see section 7.4. All “means” used in analysis are geometric means

<table>
<thead>
<tr>
<th>Blood Pressure, Weight, Waist, Body Fat</th>
<th>Interventions are higher at follow-up on average (95% CI) by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic BP</td>
<td>-0.73% (-2.17%, 0.73%)</td>
</tr>
<tr>
<td>Diastolic BP</td>
<td>-0.18% (-1.99%, 1.66%)</td>
</tr>
<tr>
<td>Weight</td>
<td>-0.01% (-0.49%, 0.46%)</td>
</tr>
<tr>
<td>Waist</td>
<td>0.1cm (-0.7, 0.9)</td>
</tr>
<tr>
<td>Body fat %</td>
<td>0 (-0.4, 0.4)</td>
</tr>
</tbody>
</table>

7.6 Summary

Despite the observation from dietary records that dietary compliance was good for those consuming the wholegrain foods, there were no significant differences observed for any of the chosen markers of cardiovascular risk between the whole grain intervention groups and the Control Group. The aim of the intervention was to encourage participants to substitute refined grain foods for whole grain alternatives. However, reported dietary energy intake tended to be higher in intervention groups compared with the Control Group suggesting that the subjects were consuming the whole grain...
intervention foods in addition to their normal (habitual) diet, and there were changes in the pattern of foods consumed. Despite this apparent increase in energy consumption, body weight, waist circumference and body fat percentage did not change during the intervention. Reasons for this apparent contradiction in the data are unknown.
8 Objective 6: Evaluation of consumer attitudes towards wholegrain foods

8.1 State of the art

Wholegrain foods are currently consumed by a small minority of the population. There is a need to explore the underlying psychosocial aspects of food choice in relation to wholegrain foods in order to develop effective strategies for promoting their uptake at the population level.

8.2 Introduction

The WHOLEheart study provided a unique opportunity to explore the acceptability of incorporating whole grains into the diet. These were either absent in volunteers’ diets prior to the study or present in small quantities (a requirement of inclusion for the study; see section 4.4 of this report). Typically ‘acceptance studies’ have focussed on either:

- ‘conceptual acceptance’ or the factors relating to the pre-trial understanding of novel foods and technologies at the abstract or conceptual level, such as research examining genetically modified foods (Kuznesoff & Ritson, 1996; Grove-White, 1997) or irradiated foods (Bruhn, 1995)

or

- ‘taste acceptance’ or the factors relating to the taste testing of novel or ingredient-modified foods (de Graaf, 2007). Within these experimental designs subjects are often asked to express a preference between a number of alternative foods. However, ultimate incorporation of a food into the diet is dependent upon a range of personal, product and situational factors (Birch, 1979).

The WHOLEheart study enabled an examination beyond taste acceptance to examine the personal, product and situational factors associated with ‘dietary acceptance’ or the post-trial incorporation of a novel food or ingredient into existing dietary patterns.

8.3 The focus group method

8.3.1 Introduction to focus groups

Exploring volunteer attitudes towards wholegrain foods and experiences of participation in the WHOLEheart study required a qualitative data generation methodology. The focus group technique was employed for its appropriateness in exploring attitudes, beliefs and perceptions (Stewart &
Focus groups are defined as group discussions led by a moderator in a permissive, non-threatening environment (Krueger, 2000). Group discussions work when the discussants have common interests and interact with one another (Goldman, 1962). These interactive exchanges whereby participants ask one another questions, swap anecdotes and describe personal experiences enables the researcher to access broader range of issues than would be typical with individual interviews (Kitzinger, 1994).

### 8.3.2 Focus group recruitment

To ensure Goldman’s ‘community of interests’ (Goldman, 1962), participants were recruited into either a ‘control’ or ‘intervention’ group according to their volunteer status during the study. When a critical mass of approximately 6-8 volunteers within the control or intervention groups had completed the study they were invited to attend a focus group approximately one month later. Focus groups progressed with a commitment from at least 4 volunteers. Unforeseen circumstances preventing attendance meant some groups took place with fewer individuals. To accommodate this scenario, focus groups were held more frequently than anticipated and all groups were held in Newcastle-upon-Tyne. Lower recruitment numbers in Cambridge made viable 1 month follow-up focus groups unattainable. A total of 13 one month follow-up focus groups were conducted with 4 control groups and 9 intervention groups, with a total of 53 volunteers. Group profiles are shown in Table 21.

<table>
<thead>
<tr>
<th>Group Number</th>
<th>Number of participants</th>
<th>Gender</th>
<th>Group</th>
<th>Intervention</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>F</td>
<td></td>
<td>1 (3 units)</td>
</tr>
<tr>
<td>1:1 N</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>Control</td>
<td>7.02.06</td>
</tr>
<tr>
<td>1:2 N</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Int</td>
<td>9.02.06</td>
</tr>
<tr>
<td>1:3 N</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>Int</td>
<td>23.03.06</td>
</tr>
<tr>
<td>1:4 N</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>Int</td>
<td>10.08.06</td>
</tr>
<tr>
<td>1:5 N</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>Int</td>
<td>22.08.06</td>
</tr>
<tr>
<td>1:6 N</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>Control</td>
<td>31.10.06</td>
</tr>
<tr>
<td>1:7 N</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>Int</td>
<td>2.11.06</td>
</tr>
<tr>
<td>1:8 N</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>Int</td>
<td>15.05.07</td>
</tr>
<tr>
<td>1:9 N</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>Control</td>
<td>17.05.07</td>
</tr>
<tr>
<td>1:10 N</td>
<td>8</td>
<td>2</td>
<td>6</td>
<td>Int</td>
<td>22.05.07</td>
</tr>
<tr>
<td>1:11 N</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>Control</td>
<td>19.06.07</td>
</tr>
<tr>
<td>1:12 N</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>Int</td>
<td>10.07.07</td>
</tr>
<tr>
<td>1:13 N</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>Int</td>
<td>26.07.07</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>53</strong></td>
<td><strong>22</strong></td>
<td><strong>31</strong></td>
<td><strong>4</strong></td>
<td><strong>9</strong></td>
</tr>
</tbody>
</table>

Table 21: Focus group profiles for the WHOLEheart study. Focus groups were carried out approximately 1-month after participants had completed their 16-week intervention for the study. Focus groups included either control participants, or a mixture of participants from Intervention 1 (I1) and Intervention 2 (I2), here displayed as “Int”. For full details of the 3 intervention groups, see section 5.
8.3.3 Focus group process

The focus groups were held in a small function room at Newcastle University and participants were provided with light refreshments. The discussions followed a questioning route outlined in the semi-structured interview guides in Appendix 3. Intervention volunteers were asked questions relating to their motivations for volunteering in the study, general experience of the study, experiences of incorporating both 3 and where appropriate 6 units of whole grains into their daily diet, and perceptions of potential whole grain dietary recommendations. Discussions on whole grain dietary recommendations were based upon the assumption that there may be a health benefit derived from substituting 3 units of wholegrain foods into the diet. Control participants’ questions mirrored intervention subjects’ questions by exploring motivations for volunteering in the study, knowledge of whole grains, experiences of the study, general food behaviours and general dietary recommendations (including potential whole grain-consumption recommendations of 3 units per day). Control group participants were also shown examples of foods given to intervention participants as prompts to discussions on whole grains and serving sizes. The discussions lasted approximately one and a half hours and were audio-recorded.1

8.3.4 Analysis of focus group discussions

Full transcriptions were made from the audio-recordings and the computer assisted qualitative data analysis software NVivo7 was used to manage the data set and facilitate the analysis through its coding and retrieval functions. The analysis closely followed the procedures recommended by Strauss and Corbin (1998). Therefore, detailed coding or the affixing of ‘labels’ to data (or pieces of narrative) which had an inherent meaning, was followed by the grouping of these codes into categories. Using the ‘constant comparison’ technique of comparing and cross-referencing particular codes within and between the focus groups, the properties or dimensions of the categories were developed. Through this iterative process, the categories were integrated to provide an interpretation of ‘personal acceptance of whole grains’, ‘barriers to acceptance’ and ‘whole grain dietary recommendations’ from which policy considerations were derived. This process is shown diagrammatically in Figure 9.

1 It is usual practice to remunerate focus group participants in lieu of their time devoted to attending such discussions. The WHOLEHeart focus group participants attended without additional financial compensation (study incentives were paid on completion of their dietary intervention one month earlier). This is noteworthy because of the high percentage of volunteers willing to attend focus groups at both research sites in Newcastle and Cambridge. This indicates the very strong volunteer commitment to the study (which became apparent in the focus group discussions).
The data analysis process means that the following interpretive results are grounded in or derived from the experiences of the WHOLEheart volunteers and quotes are used to illustrate key points.

### 8.4 Personal Acceptance of Wholegrain Foods

Acceptance of whole grains is dependent upon a number of deeply personal factors namely the taste of the individual foods (taste acceptance) and the degree to which wholegrain foods are compatible with existing dietary patterns and meal ingredients (dietary acceptance). These two key personal acceptance concepts are mediated by health beliefs, food experience and motivations for dietary change. These concepts are shown schematically in Figure 10 and are discussed sequentially.

---

**Figure 9: Process involved in the analysis of focus group discussions (adapted from descriptions of Strauss and Corbin (1998), Spiggle (1994) and Miles & Huberman (1994)).**

<table>
<thead>
<tr>
<th>Components</th>
<th>Procedures</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Reduction</td>
<td>Coding</td>
<td>Description</td>
</tr>
<tr>
<td></td>
<td>Categorisation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Abstraction</td>
<td></td>
</tr>
<tr>
<td>Data Display</td>
<td>Comparison</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dimensionalisation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Integration</td>
<td></td>
</tr>
<tr>
<td>Conclusions and Verification</td>
<td>Interpretation</td>
<td>Explanation/ Interpretation</td>
</tr>
<tr>
<td></td>
<td>Iteration</td>
<td></td>
</tr>
</tbody>
</table>
Taste Acceptance

Like

Dislike/reject

Dietary Acceptance

Compatible with meal patterns and ingredients

Incompatible with meal patterns and/or ingredients - reject

Underlying Constructs

- Health beliefs
- Experience
- Dietary motivations

Figure 10: Key factors underlying acceptance of wholegrain foods in the diet

8.4.1 Taste Acceptance

Personal acceptance of the wholegrain foods was initially based upon ‘taste’. Where the taste of products was enjoyed, the foods were retained within the diet for the period of the study. Included in the variety of wholegrain foods available for substitution into participants’ diets were a range of breakfast cereals, wholemeal bread, wholegrain rice and wholemeal pasta. For participants required to consume 6 units of wholegrain foods per day, individually wrapped oat-based snack bars and wholegrain crisps (as a substitute for potato-based crisps or tortilla chips) were also available. Most of the intervention discussants sampled the range of foods on offer and personal preferences for branded foods were cited. Equally a number of foods were rejected based upon a dislike of the food’s gustatory qualities. This is unsurprising and to be expected given the personal nature of ‘taste’.

Two outcomes of taste acceptability were particularly noteworthy within this study. First, many participants expressed surprise at liking the taste of wholegrain foods that they had prejudged to be ‘tasteless’ or recalled (on the basis of previous trial) to be personally inferior in taste to alternatives.

“I remember years ago having wholemeal pasta and it was like… it was disgusting, it was very, very soggy … but I think they must have improved the wholemeal pasta because it’s very similar [to white pasta] I think now, in texture. I mean the rice is pretty different but I actually think it’s got a nice taste of its own.” FG13 F

Recollections of inferior tasting ‘brown rice’ or ‘brown pasta’ were also echoed by control group participants suggesting commercial opportunities to encourage taste testing.

Second, a preference for certain wholegrain foods was established over time. Repeated and necessary consumption of a new wholegrain food (in particular where participants were part of the 6 per day trial) resulted in participants developing a liking referred to as “learning to like” the wholegrain
foods on offer. Although some participants were relieved to finish the study particularly those on 6 units of whole grains per day and didn't eat particular wholegrain foods they may have been over-exposed to, they found themselves returning to the wholegrain varieties out of preference. Experimental research particularly involving children (Birch, 1979) and their exposure to unfamiliar vegetables have demonstrated an increase in liking and intake as a consequence of repeated exposure to the vegetables (Wardle et al., 2003a; Wardle et al., 2003b). One female participant from focus group discussion 13 described the role of her exposure to whole grains (up to 6 units per day) as “retraining my palate”.

8.4.2 Dietary Acceptance

Although the WHOLEheart Study was based upon a substitution diet requiring participants to replace non-wholegrain foods with wholegrain equivalents within their existing dietary patterns to the desired ‘unit’ level, in practice four different behaviours were observed. Incorporating wholegrain foods into volunteer diets occurred via:

- Direct substitution of whole grain with non-whole grain (refined/white) counterparts, e.g. wholegrain rice and wholewheat pasta with refined white rice and pastas.
- The exchange of wholegrain foods for foods that would not be considered straightforward substitutes e.g. breakfast cereals such as Cheerios eaten as a snack food instead of biscuits.
- The incorporation of new foods into the diet that were previously absent.
- Structural changes within the daily dietary pattern, in particular the incorporation of ‘breakfast’.

Thus ‘dietary acceptance’ of wholegrain foods was dependent upon two key interrelated factors: The structure of daily meals referred to as ‘meal patterns’.

The similarity, degree of closeness or compatibility of substituting novel wholegrain foods with existing items in participants’ diets referred to as ‘meal ingredients’.

These factors can be explained by contrasting the experiences of participants eating both 3 and 6 units of wholegrain foods per day.

8.4.3 Meal Patterns

Consumption of 3 units of wholegrain foods per day was viewed as highly achievable, particularly for participants who were accustomed to eating breakfast. Breakfast was the main vehicle by which participants achieved both 3 a day and in particular 6 a day units into their diet. For example, a wholegrain breakfast cereal and 2 slices of wholewheat toast accounted for between 3 to 4 units depending upon the type of breakfast cereal. Here wholegrain breakfast cereals or breads were often a direct substitute for non-wholegrain cereals, toast or sandwiches. Breakfast eaters with this prior meal profile often described having to avoid exceeding their 3 a day limit which could be satisfied at
the breakfast meal. For other breakfast eaters, there was an exchange of bread or cereal for non-carbohydrate based breakfasts such as yoghurt and fruit.

The importance of breakfast to the consumption of wholegrain foods was demonstrated by participants incorporating breakfast into their daily meal routine which was absent or intermittent prior to the study. Eating breakfast was driven by a personal commitment to honour the demands of the study. It provided a reasonably easy vehicle for satisfying the 3 a day requirements and was explained as a ‘necessity’ for participants who were selected to eat 6 portions a day. In addition, eating three servings of whole grain at the earliest convenience in the day released the participants from ‘counting’ portions for the rest of the day.

The change to meal patterns through the incorporation of breakfast had a number of self-reported benefits to participants whilst on 3 units of whole grains a day. These included improved personal organisation by finding the time to eat breakfast, higher energy levels and greater satiety thereby reducing mid-morning snacking. Most of the individuals who introduced breakfast into their daily meal structure reported retaining it beyond completion of the study. The motivations for doing so included the aforementioned self-reported benefits, the routine of eating breakfast which had become established during the study and also the personal belief that breakfast was consistent with a healthy lifestyle.

“I lost a pound when I was on the study because I was trying to keep my weight but since I’ve finished the study I’ve lost nearly a stone… I do put it down to eating better … if I had breakfast, it meant I was getting up a little bit earlier to have my breakfast, and then I had the energy instead of getting the bus to work … I walk to work. And now I walk to and from work four times a week” FG13 F

The structure of daily meal patterns also impacted dietary acceptance. Eating regular programmed meals such as a breakfast, a mid-day meal, and an evening meal, facilitated the consumption of three and particularly six units of wholegrain foods per day. Many working participants described having routinised meal times during their working week, when it was relatively easy to plan meals and incorporate whole grains into the diet. Deviating from ‘normal’ routines of preparing meals inside the home was cited as disruptive:

“I found that, if you went out for the day or something disrupted your routine, oh it was difficult to catch up if you got behind” FG5

Participants often described their weekend meal planning as more relaxed and spontaneous and therefore harder to achieve daily whole grain-consumption requirements. Some participants described their own habitual weekend meal events such as a fried breakfast or traditional Sunday lunch and they commented upon the fact that these meals would not ordinarily contain wholegrain foods or ingredients.
8.4.4 Meal Ingredients

The degree to which whole grains were directly substitutable within the diet impacted in particular the experience of eating 6 units of whole grains per day. Eating ‘six a day’ was described as “much more difficult than three” and “a struggle” and was perceived to negatively impact both diet and general health. For many people, the consumption of 3 units of whole grain per day largely involved a substitution of white or refined foods with wholegrain alternatives. With the consumption of 6 units per day there was a greater need to incorporate supplementary units of whole grains into the diet, which was achieved by a variety of means. Some participants exchanged foods within their existing dietary repertoire with wholegrain alternatives, such as dried breakfast cereals as a mid-morning snack alternative. Some participants simply ‘over-ate’ to ‘make-up’ the daily or weekly unit count.

“If I didn’t want supper I was sort of forcing myself to have a slice of bread or have more cereal actually to make up the ones… you know?” FG3

Therefore supplementary slices of bread, bowls of cereal or wholegrain snack products were eaten at periods such as prior to bedtime or between meals, when food would not normally have been eaten. In addition, people were eating foods that were absent from their pre-Study daily repertoire such as wholegrain crisps and cereal snack bars to “make-up the units”.

For other people anxious not to over-eat there was a displacement of foods that were perceived as ‘healthier’. For example, a number of participants eating six units of whole grains per day noted that they ate fewer fruits and vegetables than normal to compensate for their higher carbohydrate intake. This was perceived to be a less healthy diet. As a consequence participants felt their diets were unbalanced as illustrated in the following discussion excerpt from focus group 4:

The three portions was fine. The six was a slog. And I think, at the end of it, I just though oh, thank goodness that’s over. So I think going up to the six was counter-productive for me.

What were you having to do that was different to eat the six units?
I was eating more carbohydrates full stop than I normally would. And I found that I was getting bored because to try and get that level of whole grain into your diet… I was sort of skewing what I would normally eat. We would normally have a much more varied diet but I didn’t… I didn’t really have the appetite to take the other on top of, you know. It just became very boring to get the six in.

What were you dropping from your diet to eat the six units?
Well, just some of the other nice… sometimes some of the carbohydrates that… I wasn’t eating as much potato or anything like that, em, some of the vegetables and things as well, you know, and the fruit. Because in the mornings I would have a couple of bits of fruit but I was having cereal instead of it so that was all changed.
Eating a greater quantity of wholegrain foods also had the effect of increasing the intake of ‘complementary’ foods particularly ‘fats and oils’, such as milk with breakfast cereals, butter or a fat-based spread on bread, oils or oil based dressings on pasta or rice, and particularly cheese with pasta.

For participants with a self-reported varied diet prior to the study, eating 6 units of whole grains per day meant their diet was less varied and less enjoyable as a consequence. For participants who self-reported a limited repertoire of foods prior to the study, eating 6 units of whole grains per day often exacerbated their narrow dietary range. Examples of more restrictive diets included participants who only liked one or two of wholegrain foods on offer and ate those almost exclusively.

Participants eating six units of whole grains per day described a greater number of negative health effects including bloating, weight gain, and stomach discomfort and for some restricted bowel movements which was counterintuitive to those concerned. One female participant described maintaining or slightly losing weight whilst on ‘6 a day’ but commented on her waist size increasing through bloating. This scenario was familiar to many other participants on ‘6 a day’. A few participants also commented upon being unable to maintain ‘6 a day’ whilst recovering from an illness, their “body’s telling them” this wasn’t the food necessary to recover.

There was only a minority of participants who felt comfortable eating six units of whole grains per day. For these people, it was through direct substitution of wholegrain foods for non-wholegrain alternatives that enabled them achieve this higher whole grain-intake.

The self-reported benefits of eating ‘6 a day’ included the control over the diet in terms of ‘planning meals’ to incorporate six units of whole grains per day (which was lost following completion of the study) and eating less healthy snack foods between meals or prior to bedtime. Despite these benefits, eating six units of whole grains a day was from a dietary perspective unsustainable for most participants.

“I enjoyed it because it saved me thinking what… what to eat because I knew I had to keep to these and now I’m not on the study now I find it difficult.” FG6

8.4.5 Motivation, Beliefs and Experience

Taste and dietary acceptance was mediated by participants’ health beliefs, food perceptions and experience. These three factors were themselves influenced by participants’ motivations for volunteering for the study.

The motivations of individuals volunteering for the WHOLEheart Study predominantly included: 1) curiosity; 2) altruism; and 3) self-interest, often in combination. Early volunteers to the Study expressed a personal interest in food and diet related issues and stated a personal curiosity about the study. There was also an element of altruism from people who wanted to ‘do something useful’ or ‘help out’, particularly where volunteers had a personal or professional understanding of the problems associated with recruitment for research programmes. A number of participants were motivated to
‘give something back’ to society and viewed WHOLEHeart as an opportunity to contribute to knowledge generation that would be useful to the wider population. A significant number of participants were also motivated by self-interest particularly personal health concerns “I was about to hit 60 and I thought well if there’s anything wrong with me they might find it!” (FG6). For some volunteers the timing of newspaper adverts, mail drops or company intranet notices requesting Study volunteers coincided with a heightened awareness of health problems affecting family, close friends or own weight management issues. Less serendipitous were personal letters from GP’s suggesting recipients may be interested in the Study and its associated health checks because of GP or participants’ own genetic or diet-related health concerns.

“I actually got a letter from my G.P. as being somebody who was, although was very fit and healthy, was overweight and then obviously just the concerns like for your health and so this brilliant letter from the G.P. that brought it [knowledge about the study] to me. And obviously, em, other people have done lots of research and you feel as if you should give something back, to be a bit of a guinea pig for somebody else”. FG13

The altruistic nature of volunteers was also evident in the high proportion of volunteers who had been involved in blood, and/or plasma donation or wanted to donate but were ineligible for medical reasons.

The motivations of volunteers are important because they impacted the mindset of volunteers to the Study. For example, many participants thought they would use the Study to kick start eating more healthily. They were however prevented from doing so by the Study’s requirements of participants to follow the same diet during the Study as they did prior to the Study with the exception of substituting whole grains where appropriate. Many of these health motivated individuals made dietary changes following completion of the intervention. These changes included eating breakfast regularly, bolstered by the belief it contributed towards a healthy diet and the sustained consumption of wholegrain foods.

“being on this study helped retrain my palate, made me think more about what I was eating, gave me the energy in the morning because I was eating breakfast too but I do, I feel better in myself.” FG13

Personal knowledge about food intake was made transparent by the self-completion of food diaries. This activity sensitised participants to their overall dietary profile and made them more attentive to their food intake either by reinforcing the belief that their diet was healthy or making them aware that there were bad dietary habits. For participants volunteering for the Study on the basis of personal health concerns, the food diary bolstered a resolve to make changes to their diet on completion of their involvement with the study.

2 These dietary changes have been identified in 6 and 12 month post-intervention focus groups and will be reported on completion of that follow-up study.
“I found I was much more conscious of what I put into my mouth because I was aware of what I was eating [through food diary completion]. … before I would have snacked but it would have been invisible. Whereas now I felt like I was watching what I was doing to make sure I was getting me six portions. FG12

8.4.6 Summary

The personal acceptance of wholegrain foods is influenced by taste acceptability and dietary acceptability, mediated by the health beliefs, food experiences and motivation to improve health or weight management. Table 22 below summarises the perceived impact of incorporating 3 and 6 units of whole grain into the diet for volunteers on this study.

Table 22: Perceived impact of incorporating ‘3’ and ‘6’ units of wholegrain foods per day into the diet

<table>
<thead>
<tr>
<th>Ease of incorporation into the diet</th>
<th>‘3’ a day</th>
<th>‘6’ a day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relatively easy (particularly if ate breakfast)</td>
<td>very difficult/ a &quot;struggle&quot;</td>
</tr>
<tr>
<td></td>
<td>Sometimes “hold back” from overeating</td>
<td>often a need to “make-up” 6 units</td>
</tr>
<tr>
<td></td>
<td>Sustainable in long term</td>
<td>unsustainable in long term</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Perceived impact on diet</th>
<th>‘3’ a day</th>
<th>‘6’ a day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>psychologically believe diet is healthier</td>
<td>Less healthy diet</td>
</tr>
<tr>
<td></td>
<td>eating fewer ‘unhealthy’ snacks</td>
<td>displacement of fruit and vegetables with whole grains</td>
</tr>
<tr>
<td></td>
<td>eating breakfast</td>
<td>less varied diet</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Perceived impact on general health (when stated)</th>
<th>‘3’ a day</th>
<th>‘6’ a day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Higher energy levels</td>
<td>Physically sluggish</td>
</tr>
<tr>
<td></td>
<td>Some bloating</td>
<td>Bloating</td>
</tr>
<tr>
<td></td>
<td>Greater feelings of satiety</td>
<td>Weight gain</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>General perceptions</th>
<th>‘3’ a day</th>
<th>‘6’ a day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Mostly positive</td>
<td>• Predominantly negative</td>
</tr>
<tr>
<td></td>
<td>• Generally sustainable quantity to eat daily</td>
<td>• Unsustainable quantity to eat daily</td>
</tr>
</tbody>
</table>
8.5 Barriers to whole grain-consumption

8.5.1 Introduction

The preceding discussion on personal acceptance of wholegrain foods highlights the personal factors affecting participants’ sustained incorporation of wholegrain foods into the diet. The personal liking of a wholegrain food or its compatibility with meal patterns or as a meal ingredient does not however assure incorporation into the diet. There are a number of barriers potentially preventing sustained intake of wholegrain foods. These include personal, product and situational factors as shown in Figure 11 and are discussed in turn.

Figure 11: Barriers to whole grain-consumption

- **Personal**
  - Taste
  - Preferences of family members
  - Motivation
  - Illness
  - Boredom
  - Cooking skills
  - Time

- **Product**
  - Cooking times
  - Availability
  - Price
  - Aesthetic vs. health

- **Situational**
  - Meal occasion
  - Access
    - Restaurants
    - Holidays
    - Work
  - Work patterns
  - Food purchaser
8.5.2 Personal barriers

Personal and family taste preferences
A personal dislike of the taste of wholegrain foods is one obvious reason for rejecting wholegrain foods from the diet. However, in the event that particular wholegrain foods are liked and enjoyed, they may not be incorporated into the diet if they are disliked by other family members within their household. A lack of personal control over food purchasing and cooking was also cited as a further barrier.

“We used to (eat brown rice). I liked it but the wife buys white... she does all the buying and many a time I'll say ‘What have you bought this for?’ Look what it's got in.” FG1

This is particularly the case with wholegrain rice and wholewheat pasta. Many volunteers described having to cook two separate evening meals during the study (particularly on 6 units per day), one for themselves which contained whole grains and one for other family members who preferred white or refined alternatives. For many volunteers the preparation of two meals was not sustained beyond the duration of the study. The consumption of breakfast cereals was less problematic. Participants described having multiple choices of cereals to satisfy the preferences of different family members, so substituting or incorporating wholegrain breakfast cereal alternatives simply complemented the suite of cereals available to eat.

Difficulties were also experienced by participants living alone, where they were unaccustomed to cooking meals for themselves. Thus preparing wholegrain pasta or rice based dishes contravened their cooking and eating habits, as shown in the excerpt below.

“I'm single and that makes me lazy cooking, because I was shocked at how few vegetables I actually eat. Now that's partly to do with shift work because I can't be bothered to make a meal before I go into work. I just don't”.

“You're the same as me. My husband works away so I eat the rubbish they prepare at work and then because... I'm just lazy and I won't make a proper meal; I make something quick or that's in one pan only and even boiling vegetables doesn't take long, em, but I think you might find a difference between people who are in families or couples and in single people because we live differently”. FG11(Control)

Motivation
The motivation to eat healthily is another factor affecting sustained consumption of wholegrain foods. There was a general agreement that wholegrain foods are nutritionally superior to white or refined alternatives because they were more ‘natural’. However, many participants claimed to have neither the motivation nor the discipline to alter their dietary habits. For some participants, better than
expected health indicators (weight, BMI etc) was a sign they could continue with present eating patterns.

**Illness**

As mentioned when discussing ‘taste acceptability’ some participants considered whole grain-consumption not conducive to recovery after an illness. Whole grains would therefore not be eaten during a period of recuperation.

**Variety**

Variety in the foods consumed was cited as desirable by participants. For many participants, the consumption of wholegrain foods, particularly six units per day restricted their diets. The boredom of eating the same foods meant that this level of consumption of whole grains would not be maintained, although certain foods such as wholegrain rice and wholewheat pasta may be substituted periodically.

**Cooking Skills**

Many participants described having to refresh their cooking skills to prepare whole grain-based meals. In particular there was much discussion about how to cook wholegrain (referred to as ‘brown’) rice and how to alleviate the boredom of constantly eating wholegrain rice and wholewheat pasta dishes with different sauces and accompaniments.

**Time**

The time taken to prepare meals from ingredients was also cited as a barrier to permanently incorporating wholegrain rice and pasta into the diet. Although many participants attempted to do this during the study, busy schedules meant eating very late in the evening. This time factor leads onto the product-related barriers.

### 8.5.3 Product-Related Barriers

**Cooking times and product availability**

As mentioned, cooking times were cited as a barrier to sustained use of wholegrain rice in particular. For time restricted individuals or those working irregular hours or shifts, the main meal of the day was often cited as a ready-made meal. It was observed by participants that there were few ready made meals containing wholegrain foods and this lack of availability would restrict their consumption of whole grains in the future.

The general availability of wholegrain foods was described as ‘restrictive’ by many of the volunteers at the beginning of the study. This criticism was less obvious amongst participants joining the study in its later stages, and some participants commented positively on the variety of wholegrain foods available in when they looked for them in their local supermarkets (such as wholewheat tortillas, wholewheat pita breads, wholewheat couscous etc.)

**Price**

For a number of participants price was cited as a barrier to wholegrain food consumption. Many participants described their enjoyment of the wholemeal branded bread during the study. When they sought the bread in their local supermarkets they noted the price was significantly more expensive.
than the non-wholegrain bread they used to purchase. For a few of the participants the price was prohibitive to bread purchase. For other participants, there were complaints about the cost but they continued to purchase the bread because they preferred its taste.

*Food aesthetics versus health*

Much of the preceding discussion has focussed on the perceived health qualities of wholegrain foods and the assumption that whole grains are nutritionally superior to white or refined alternatives. A minority of participants stated that food also had aesthetic qualities and they might use particular ingredients to enhance the visual appeal of the food served rather than its nutritional content. For example, white rice was considered visually more stimulating in risottos than brown rice, particularly when served to guests.

"I also found brown basmati rice which was a very easy substitution...the only time I would go back to using white is for the aesthetic value of the food, not for the taste of it. I don't think taste-wise it's any different. So, you know, if I was making like a white risotto I would use white rice but I couldn't find any wholewheat risotto rice. Em, you know, if I needed white rice for the look of the dish" FG12

### 8.5.4 Situational Barriers

**Meal Occasion**

As mentioned above certain meal occasions were not deemed appropriate to whole grain-consumption. For example, the traditional Sunday lunch did not contain whole grains, and sometimes health was not the priority when preparing meals for guests.

**Access**

Access to whole grains eaten out of the home was also cited as a barrier to its consumption. Many participants commented upon the lack of wholegrain foods available in restaurants, fast food outlets or take-away food facilities. The lack of restaurants serving wholegrain ingredients was cited as curtailing the social life of some participants whilst on the study. Travelling out of the United Kingdom was also cited as problematic for sourcing wholegrain foods. Many participants described taking breakfast cereals and oat-based snack bars on holiday or business trips to ensure they maintained their unit requirements. It was implicit amongst participants that this behaviour would not be maintained outside the study. A lack of access to wholegrain foods at work canteens was also a problem for some participants on the study. Packed lunches containing wholegrain foods were therefore substituted for company provided lunches.

"I found going on holiday was terrible. I mean if there is such a thing as wholemeal bread in Portugal I’ve yet to find it! So when that happened [travelling outside the UK] em, I mean, just took whole [grain] cereal packets with me."FG6

**Work patterns**

A number of participants worked irregular and/or shift based hours, or worked in an environment where their eating patterns were erratic. This tended to mean participants ‘ate on the hoof’, often convenience (non-wholegrain) foods. One young male participant in a control group cited concerns
about his chaotic eating patterns. He could not envisage how to improve his health through diet due to his work situation and instead was ‘compensating’ by increasing cardiovascular exercise.

Food Purchaser

A common barrier to the sustained consumption of wholegrain foods was the lack of influence the WHOLEheart Study participants had over food purchasing and or cooking decisions, which were often undertaken by a spouse, partner or parent. The delegation of these tasks meant little influence was exerted over food purchasing and preparation.

8.5.5 Summary

The above discussion shows there are a number of barriers to the sustained intake of wholegrain foods, not withstanding participants liking of such foods or desire to eat more of them.

8.6 Whole grain dietary recommendations

8.6.1 Introduction

Communicating potential whole grain dietary recommendations requires an understanding of consumer perceptions of wholegrain foods in general and exploring the information requirements of the target population for wholegrain foods. The motivations of individuals volunteering for the WHOLEheart Study indicate they maybe atypical of the population at large, representing a sub-stratum of individuals interested in food and health and with a generally altruistic nature. However, volunteer experiences give an insight into their requirements of dietary recommendations. Participants were asked if they would consider eating 3 units of wholegrain foods per day if it was established there would be benefits to lowering cholesterol. The ensuing discussion focussed on factors relevant to evidence and self-relevance, the benefits of wholegrain foods and wholegrain knowledge and information.

8.6.2 Evidence and self-relevance

Evidence of the cholesterol lowering benefits of whole grains was cited by participants as important to the communication of dietary recommendations to eat three units of whole grains per day. However, attending to such messages depended in part upon the self-relevance of the ‘cholesterol lowering message’. Many participants suggested their ‘cholesterol was not a problem’. Those participants concerned about high cholesterol levels assumed they would make changes to their diets as well as potentially taking medication. This multi-method approach to lowering cholesterol was also reflected in other foods that may be eaten, such as those specifically promoting cholesterol lowering properties (the Benecol brand was often cited as an example of this). Wholegrain foods were however viewed as having other additional benefits not offered by cholesterol only lowering foods.
8.6.3 Perceived benefits of wholegrain foods

Participants cited a number of benefits to the wholegrain foods they had eaten. Whole grains were viewed as a “natural” food, a desirable attribute over functional foods. This ‘naturalness’ reinforced an intuitive belief that wholegrain foods had a superior nutritional quality to white or refined alternatives, offering attributes such as fibre to aid digestion. Psychologically participants felt that by eating wholegrain foods they were contributing to improving their health.

“If it’s psychological because when you’re eating the wholemeal you feel… you feel as if you’re feeling good, do you know what I mean? You think, oh it’s wholemeal, great, I feel great, you know.” FG8

8.6.4 Whole grain-knowledge and information

A number of participants expressed surprise at the range of foods that could be categorised as ‘whole grain’. Participants on the intervention could cite a greater range of wholegrain foods than control participants. The Study clearly had an educational impact to the extent that intervention subjects stated feeling better informed about wholegrain foods having completed the study. They also highlighted general misunderstandings that they had about wholegrain foods prior to the study and misunderstandings about wholegrain foods that were observed in others.

“If asked me husband to bring a loaf of wholemeal bread in from work because I didn’t have time so he bought a loaf of brown… just brown bread, and I looked and I thought, that’s not wholemeal. He says it is, it’s brown bread. I says brown bread isn’t wholemeal. So it just shows you, that’s a prime example.” FG8

There was also a call for more detailed information on portion sizes. With the exception of wholewheat pasta, many participants considered the portion sizes of some breakfast cereals and the wholegrain rice to be smaller than they would ordinarily have served themselves. This led to an overall comment by some participants who were concerned about their overweight that their portion sizes may be generally too large.

“Well it’s unbelievable because I have porridge every morning and, God, I must have been having three helpings before this and now I’ve got a proper little cup now so I can measure now exactly. It’s porridge and prunes… sort of breakfast.

So being on the study’s made you aware of the portion sizes?
Yeah. Well over… over… eating too much really, the portion size.

Yes, particularly with rice and pasta I found. When I’m sort of… I weighed the packet and I realised that when I did rice… when I had been doing rice normally, it was obviously much more … so now I know what one portion weighs so I just double that for my husband and I. And it is less than we were eating before”.

FG8
“The first time I got the bag of supplies I was on my lunchtime so I went back to the office and of course everyone in the office knew I was on this thing so we all unpacked them and we were all horrified at how little a serving of rice was…what I know is I clearly have more … my portion sizes are expanded in comparison to what I would think a serving is."FG12

“Do you know what I find nice about this [individually packaged wholegrain foods]? It shows me how much I should eat because maybe I think that’s where I go wrong, it’s not so much what I eat, it’s the sheer quantity of food”. FG1 (Control)

Following discussions about the boredom and lack of variety associated with eating 6 units of wholegrain foods per day, a number of participants suggested providing recipes and menus containing wholegrain foods that would also incorporate other recommended foods such as fruit and vegetables.

“It’s about em, trying to follow health recommendations because I try and eat a large portion of fruit and veg also. So, I mean, I know that the government recommend five portions of fruit and veg a day but I tend to err on the cautious side and have about six to eight per day. Em, so if you try and incorporate six servings of, em, whole grain and try and eat very… low levels of red meat and eat chicken and all that… oh it was just overwhelming. I just needed somebody to produce me a recipe book that could help me have decent foods. I was having very odd combinations of meals that I just thought never in real life would I actually put this combo of food together. Em, so if it comes out in the study that actually the six portions a day is what we should do, I’m gonna find that very hard. I might write the cookbook though! Ha ha.” FG12 F

One potential problem with a wholegrain dietary recommendation to eat three units per day was the sense of saturation of such health messages and scepticism about their value. Many participants agreed there was a general understanding of what constitutes a healthy diet but acknowledged there were a variety of reasons impeding peoples’ ability to achieve this. In the face of numerous and often conflicting health messages participants’ likelihood to change their diets depended upon their motivation to do so (in part informed by their health beliefs and interpretation of their own body’s needs) and what was personally achievable (in the context of barriers to alter dietary intake).

“I mean if you swamp people with too much information and they’re trying to balance this, calories, with that and it can become a nightmare can’t it? But I think, what I try to do is try to eat three meals and try and balance it as best I can”. FG7
“Yeah, I know. But I wouldn’t make a conscious effort to go back but you’d feel like you… it could be like, em, these government, em, initiatives where they don’t actually mean anything, you know, you just feel like oh here’s another one, so it might lose a bit of faith in it but em…” FG8

8.6.5 Summary

Wholegrain foods have a number of benefits beyond the potential for lowering cholesterol. These benefits are intuitive and as such have high face validity. Practical requirements for information relating to wholegrain foods were highlighted by participants and these are discussed in the context of policy considerations.

8.7 Discussion

This qualitative study set out to examine the acceptance of and barriers to whole grain-intake. Understanding the factors contributing to whole grain-acceptance has highlighted policy considerations for encouraging the consumption of wholegrain foods. These considerations are discussed below.

Acceptance of wholegrain foods is linked to both 1) ‘taste acceptance’ or 2) the degree of liking for the product and ‘dietary acceptance’ or the degree to which the wholegrain food is complimentary with existing meal patterns and the degree of substitutability with existing foods. Assuming individuals both like wholegrain foods and could incorporate them into existing dietary patterns, there are a number of barriers that may hinder wholegrain food consumption. These barriers are related to personal factors, product factors and situational factors. The relationship is shown in Figure 12.

![Figure 12: Factors affecting the acceptance of wholegrain foods](image)
9 General discussion and conclusions

9.1 Wholegrain intervention

An appropriate number of participants were recruited for the study despite needing to screen a much larger number of potential participants than had been originally anticipated. This was primarily due to a higher proportion of people consuming more than 1.5 servings of whole grain per day. This was greater than predicted from existing data on whole grain-intake in the UK, and may reflect the manufacture and promotion of an increasing range of wholegrain products since the latest NDNS data was published. Reported dietary intakes revealed that the study was successful in increasing whole grain-intake to 3 and 6 serving/day through provision of a range of wholegrain products.

Since commencing this contract there have been a number of additional publications supporting the associations between increased whole grain-intake and reduction in disease risk; these include data relating to the metabolic syndrome (Sahyoun et al. 2006) and a new meta analysis of the relationship between whole grain-intake and CVD (Mellen et al. 2007). There have also been a small number of intervention studies with ‘at risk’ subjects (see section 7.2.2). In some cases data on inflammatory markers and glucose/insulin measurements show improvements with higher intakes of whole grain. In contrast, this 'WHOLEheart’ controlled intervention study found no effect of increasing whole grain-consumption on a broad range of CVD risk factors in a group of overweight, but otherwise healthy adults consuming either 3 or 6 servings of wholegrain foods each day. While the wholegrain intervention resulted in increased dietary fibre, B vitamin and mineral intake, it was also associated with negative effects on the diet, such as increased total energy intake and possibly increased sodium intake, as well as a reduction in the frequency of fruit intake with the highest levels of whole grain consumed (120g/day). However, body weight and blood pressure did not change throughout the intervention.

The disparity in the findings from the observational data and this intervention study warrant further consideration and may arise as a consequence of methodological and/or biological effects. We sought wherever possible to reduce the sources of methodological errors. Intervention studies may sometimes fail to show the expected effect because the subjects fail to comply with the dietary prescription or because of unexpected changes in the control group. However, the dietary analysis suggests that in this study, aided by the provision of specific foodstuffs, compliance to the prescription in each group was good. Intervention studies may sometimes be underpowered to detect a significant effect, but this was a large study and no clear trend was observed. The study may have been of insufficient duration to detect an effect, but comparison of the results at 8 and 16 weeks did not suggest a consistent trend which may have become significant with further time. Thus it may be more likely that this is a biological explanation.
In this highly controlled intervention study foods were provided in a very specific and structured manner which may not reflect the habitual consumption of wholegrain foods seen in observational studies. The range of products was restricted and subjects had to make conscious changes in other parts of their diet in order to incorporate the study foods as prescribed. Hence in some cases subjects report consuming additional bowls of cereal or substituting wholegrain foods for other items, particularly fruit, especially at the highest levels of whole grain-intake. The net effect is that the diet of high wholegrain consumers in this intervention study may be very different to that of high wholegrain consumers in observational studies, where ‘elective’ whole grain-intake is a marker of a healthy diet and lifestyle that cannot be easily controlled in observational studies.

Finally, the difference may be a consequence of the study population. This study focused specifically on a group of overweight people, likely to be at increased risk of cardiovascular disease. It is possible that a short period of exposure to a diet high in whole grain is insufficient to change the lifetime disease trajectory.

9.2 Consumer perceptions of wholegrain foods

Encouraging dietary change requires sensitivity to individual differences in product taste and the degree to which new foods will fit into existing dietary patterns. In the case of this study, the incorporation of an average of 3 servings of whole grains per day was considered sustainable by most participants, 6 servings of whole grains per day considered unsustainable by many participants. Thus a dietary recommendation based on consumption of 6 servings of whole grain per day is unlikely to be achieved due to an incompatibility with dietary acceptance for a number of individuals. In contrast, a recommendation to eat three servings of whole grain per day is likely to be more achievable. However, barriers to whole grain-consumption and information requirements clearly need to be understood and addressed to facilitate incorporation of even this level of whole grain into the diet.

The following list identifies key policy considerations based upon the preceding analysis.

- Messages communicating recommendations for wholegrain food consumption need to be self-relevant to individuals, by for example focusing on benefits to individuals.
- Wholegrain foods are perceived to have a number of benefits, including ‘naturalness’, high fibre content which is perceived as a positive aid to digestion, superior gustatory qualities to white or refined alternatives, feelings of satiety and improving energy levels. In addition, there is a ‘psychological comfort’ from the perception that eating whole grains is ‘the right thing to do’. These factors are intuitive and provide a stronger rationale for eating whole grains than potential cholesterol lowering properties.
- Practical support for incorporating wholegrain foods into the diet include recommending that people eat breakfast (with some whole grain-content), providing clear information on the foods classified as whole grain and suggesting recipes containing whole grains.
- Encouraging consumer sampling or tasting of whole grains was shown to alter negative preconceptions about whole grains tasting inferior to white or refined counterparts.
- Encouraging the development of new wholegrain foods both to satisfy individual taste differences and to accommodate demands for products that complement time-compromised
lifestyles such as whole grain based ready made meals, would help improve barriers to availability.

- Based on the assumption people have a basic understanding of the constituents of a healthy diet, individuals could be challenged to keep food diaries to undertake their own diagnosis and potentially control of their diets to substantiate the health claims to help generate effective public health messages aimed at increasing consumption.

9.3 Implications for public health policy

This study adds a note of caution to the interpretation of observational data on whole grains and health, but it does not undermine more general efforts to promote whole grains as part of a healthy diet for the population as a whole across the life-course. This study supports the assertion that diets rich in whole grain are associated with other improvements in dietary habits, notably reductions in the proportion of fat, increases in fibre and in some micronutrients. The marginal decrease in fruit intake observed was not associated with significant decreases in the nutrients measured and is likely to have been a consequence of the pressure to consume the prescribed wholegrain foods.

This study shows the feasibility of increasing whole grain-intake, to at least 3 servings per day and possibly more. It shows the importance of wholemeal bread and wholegrain breakfast cereals as key food groups. The benefit of regular consumption of ‘improved quality’ breakfasts in reducing obesity and chronic diseases has recently been emphasised (Timlin & Pereira, 2007).

The qualitative data supports development of effective strategies for behaviour change. Consumer perceptions of whole grain as a healthy alternative were generally positive and achieving the dietary targets for the intervention was possible, although the highest level of whole grain-intake was seen as difficult by some participants. Factors affecting acceptance and purchasing behaviours were clearly identified and highlight the need for interventions targeting these individual (personal) needs.

9.4 Future Research

A number of areas for future research have been identified. Further intervention studies are required, perhaps using a study design more closely aligned to habitual consumption patterns, The range of wholegrain foods provided reflected the range of products currently available to the UK market and the majority of foods were wheat-based. The participants were given free choice as to which foods they wished to consume, and so it is possible that the target consumption of whole grains was achieved in very different ways by different volunteers, particularly in those increasing their intake from 3 to 6 servings of whole grain per day. The wholegrain foods were substituted into the diet as replacement for refined grain alternatives. Thus differences between intakes of some components may have both increased and/or decreased within the same food type. For example, changing from cornflakes as a breakfast cereal to Shredded Wheat would result in a lowering in intake of some micronutrients when moving from the refined, fortified product to the whole grain unfortified product,
but a significant increase in dietary fibre intake and a reduction in glycaemic index of the meal. Thus dietary changes are likely to be confounded by the types of foods selected by the participants, and the chemical characteristics of the foods themselves. This clearly requires further investigation.

The analysis to date has been conducted on an intention to treat basis. Post hoc analyses will explore the characteristics of participants who exhibited positive improvements in risk markers. The inter-individual variability may have been due to subtle differences in the baseline characteristics of the participants, or differences in genetic background, although this may be difficult to determine with smaller numbers of subjects in the different sub-groups.

Other laboratory-based studies are warranted to shed light on the potential mechanism of action of whole grains in improving health. This knowledge will help to formulate more specifically targeted intervention studies. Detailed studies using metabolomic approaches are already underway.
10 Appendix 1 – WHOLEheart study exclusion medications

Oral Hypolipidaemics

**Fibrates**
Benzafibrate (Benzalip), Ciprofibrate (Modalim), Fenofibrate (Lipantil) and Gemfibrozil (Lopid)

**Statins**
Atorvastatin (Lipitor), Fluvastatin (Lescol), Pravastatin (Lipostat), Rosuvastatin (Crestor) and Simvastatin (Zocor)

**Anion-exchange resins**
Colestyramine (Questran or Questran light) and Colestipol hydrochloride

Systemic Corticosteroids

**Glucocorticoids**
Prednisolone, Betamethasone (Betnelan, Betnesol), Cortisone acetate, Deflazacort (Calcort), Dexamethasone (Decadron), Hydrocortisone (Efcortesol, Hydrocortone, Solu-Cortef), Methylprednisolone (Medrone, Solu-medrone) and Traimcinolone

Fludrocortisone

**Androgens**
Restandol, Testosterone Enantate, Sustainon, Virormone, Mesterolone

**Anti-epileptics**
Phenytoin (Epanutin)

**Anti-Bacterial Macrolides**
Erythromycin (Erymax, Erythrocin and Erythroped), Azithromycin (Zithromax), Clarithromycin (Klaricid) and Telithromycin (Ketec)

Other

**Thyroid hormones**
Levothyroxine sodium/Thyroxine sodium and Liothyronine (Tertoxin, Triiodothyronine)

**Regular or prescribed aspirin use**

**Haemostatic drugs**

**Anti-coagulants**
Warfarin, Acenocoumarol or Nicoumalone (Sinthrome) and Phenindione

**Anti-platelets**
Clopidogrel (Plavix), Dipyridamole (Persantin)
Appendix 2 – example of study calendar provided to volunteers for 3 servings of whole grain per day

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12 Appendix 3 – Focus group interview guide

Volunteer (Control) Experiences of the WHOLEheart Intervention

1. **Introduction**
   - Thank participants for agreeing to attend this focus group
   - Explain focus group process (asked to share reflections and experiences of participating in the WHOLEheart study. No right or wrong answers.)
   - commitment to confidentiality (Any responses reported as coming from a group (1), not individual)
   - use of a tape recorder to accurately capture what was said
   - Introduce Mary administrative support and note taker, introduce myself, discussant introductions

2. **Reasons for volunteering in the study**
   I am interested to learn how you became involved as a volunteer in this project
   - How did you hear about the project?
   - What interested you about the project?
   - Have you volunteered for other similar studies?

3. **Experience of participation in the intervention study**
   I am interested to learn how you found the experience of participating in this study
   - What did you expect when you joined the study?
   - What was your actual experience of volunteering in the study?
   - Was there any aspect that you particularly enjoyed?
   - Was there any aspect that you particularly disliked?
   - Would you consider volunteering for a similar food intervention study again?

4. **Whole grain (knowledge)**
   The study was interested in the impact of carbohydrates on cardiovascular disease risk. One carbohydrate that was of particular interest was wholegrain foods.
   - Have you heard of the term 'wholegrain' foods?
   - Where have you heard of the term wholegrain foods?
   - What do you understand wholegrain foods to be?
   - Can you give examples?

5. **Whole grain (acceptability)**
Wholegrain foods have been described as foods where the main component (over 51%) are wholegrain ingredients, whole grains typically being the unrefined grain such as wheat, rice, maize, barley, rye and oats. Typical wholegrain foods include breakfast cereals such as shredded wheat, cheerios, and porridge, wholemeal bread, brown rice and brown pasta.

- Do you eat wholegrain foods as part of your everyday diet?
- What sort of wholegrain foods do you typically eat?
- For those that eat them, what is it that you like about them? (probe/expand)
- For those that don’t eat them what is it that is unattractive about them? (probe/expand)

6. Wholegrain intervention

It is recommended that people eat three servings of wholegrain foods per day as part of a healthy balanced diet. Some participants were asked to eat such foods as part of this study.

Here are some examples:

- Do you think you would have found it easy to substitute these foods into your own diet and achieve the 3 portions per day?
- What would have made it easy?
- What would have made it difficult?

A small group of participants were asked to increase their consumption to 6 servings per day.

- Do you think you would have found it easy to substitute these foods into your own diet and achieve the 6 portions per day?
- What would have made it easy?
- What would have made it difficult?

7. Wholegrain dietary recommendations

If it was recommended that you try to increase consumption of these wholegrain foods to 3 servings per day, would you try to do so?

- What would encourage you to do so?
- What might stop you from doing so?
- Do you ever seek out dietary information?
- Where do you get your dietary information from?

8. Closing comments

- questions and comments
- thank discussants
Volunteer (Mixed Intervention) Experiences of the WHOLEheart Intervention

1. **Introduction**
   - Thank participants for agreeing to attend this focus group
   - Explain focus group process (asked to share reflections and experiences of participating in the WHOLEheart study. No right or wrong answers.)
   - commitment to confidentiality (Any responses reported as coming from a group (1), not individual)
   - use of a tape recorder to accurately capture what was said
   - Introduce Mary administrative support and note taker, introduce myself, discussant introductions

2. **Reasons for volunteering in the study**
   I am interested to learn how you became involved as a volunteer in this project
   - How did you hear about the project?
   - What interested you about the project?
   - Have you volunteered for other similar studies?

3. **Experience of participation in the intervention study**
   I am interested to learn how you found the experience of participating in this study
   - What did you expect when you joined the study?
   - What was your actual experience of volunteering in the study?
   - Was there any aspect that you particularly enjoyed?
   - Was there any aspect that you particularly disliked?
   - Would you consider volunteering for a similar food intervention study again?

4. **Whole grain (knowledge)**
   The study was interested in the impact of carbohydrates on cardiovascular disease risk. One carbohydrate that was of particular interest was wholegrain foods.
   - Had you heard of the term ‘wholegrain’ foods before this study?
   - If so, where did you hear of the term wholegrain foods?
   - What do you understand wholegrain foods to be?
   - Can you give examples?
5. Whole grain (acceptability)
Wholegrain foods have been described as foods where the main component (over 51%) are wholegrain ingredients, whole grains typically being the unrefined grain such as wheat, rice, maize, barley, rye and oats. Typical wholegrain foods include breakfast cereals such as Shredded Wheat, Cheerios, and porridge, wholemeal bread, brown rice and brown pasta.
- Did you eat wholegrain foods as part of your everyday diet before the study?
- What sort of wholegrain foods do you typically eat?

6. Wholegrain intervention
You all started the intervention trying to incorporate 3 servings into your daily diet.
- What was your experience of doing this?
- Did anything make it particularly easy?
- Did anything make it particularly difficult?

A small group of you were asked to increase your consumption to 6 servings per day.
- What was your experience of doing this?
- Did anything make it particularly easy?
- Did anything make it particularly difficult?

7. Wholegrain dietary recommendations
It is recommended that people eat three servings of wholegrain foods per day as part of a healthy balanced diet.
- What would encourage you to do so?
- What might stop you from doing so?
- Do you ever seek out dietary information?
- Where do you get your dietary information from?

8. Closing comments
- questions and comments
- thank discussants
13 References


Kitzinger J (1994) The methodology of focus groups: The importance of interaction between research participants. Sociology of Health and Illness 16, 103 - 121.


Mellen, P.B., Walsh, T.F., Herrington, D.M (2008) Whole grain intake and... 


