# Evaluating an intervention to increase cereal fiber intake in children: a randomized controlled feasibility trial.

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Abbreviations: AR – Plasma Alkylresorcinol

BCT – behaviour change techniques

HOMA – Homeostasis Model Assessment

IQR – Interquartile range

95% CI – 95% confidence interval

***Abstract***

Background: Observational studies have shown that higher cereal fiber intake is associated with reduced type 2 diabetes risk. However, it remains uncertain whether this association is causal.

Objective: This study evaluated the feasibility of an intervention to increase cereal fiber intake in children using breakfast cereals.

Methods: The study was a two-arm parallel group randomized controlled trial in 9-10-year-old children, who received free supplies of high fiber breakfast cereals (>3.5 gram/portion) or low fiber breakfast cereals (<1.0 gram/portion) to eat daily for one month with behavioral support to promote adherence. Children provided baseline and one-month fasting blood samples, physical measurements and 24-hour dietary recalls. The primary outcome was the group difference in change in plasma total alkylresorcinol (AR) concentration; secondary outcomes were group differences in nutrient intakes and adiposity indices. Analyses (complete case and multiple imputation) were conducted by regressing final AR on baseline AR in models adjusted for sex, ethnicity, age and school (random effect).

Results: 272 children were randomized (137 low fiber, 135 high fiber) and 193 (71%) provided fasting blood samples at baseline and follow-up. Among randomized participants, median (IQR) baseline AR was 43.1 nmol/L (24.6, 85.5 nmol/L) and median (IQR) cereal fiber intake was 4.5g (2.7, 6.4g), 87% reported consuming the cereal on most or all days. Compared to changes in the low fiber group, the high-fiber group had greater increases in AR (40.7 nmol/L; 95% CI 21.7, 59.8 nmol/L, $p<0.0001$) and in reported cereal fiber intake (2.9g/d; 95% CI 2.0, 3.7g, $p<0.0001$). There were no appreciable differences in other secondary outcomes.

Conclusions: We have developed a simple and acceptable nutritional intervention which increases markers of daily cereal fiber intake in children. This intervention could be used to test whether increases in cereal fiber intake in children might reduce insulin resistance.

Key words: Cereal fiber, children, type 2 diabetes risk, feasibility trial, dietary intervention.

## *Introduction*

Foods high in dietary fiber have long been considered an important component of human diets and beneficial for good health, particularly gastrointestinal health. However since the mid-20$^{th}$ century observations that societies with very high fiber diets had very low chronic disease risk (1) created interest in the possibility that dietary fiber may have wider health protection benefits. Over the past few decades, large prospective observational studies have reported that adults with high fiber diets have lower risks of a range of chronic diseases including cardiovascular disease, obesity, some cancers and type 2 diabetes (2-6), in strongly graded associations (7). In common with many other Western societies, intake of fiber in the UK is well below recommended levels (30g fiber/day in adults, 20g/day in children). National surveys have shown that adults need to increase their fiber intakes by around 50% for men and 75% for women to meet recommendations for good health, in children with lower recommendations they would need to increase intakes by over a third, with greater increases needed in children from lower socioeconomic groups (8). A population-wide intervention to increase dietary fiber intake could therefore have substantial public health benefits.

Recent systematic reviews and large-scale meta-analyses have suggested that for reducing risks of type 2 diabetes higher intakes of cereal fiber may be particularly important compared with fiber from fruit or vegetables (7, 9, 10). However, compelling experimental evidence of a causal relationship between cereal fiber and type 2 diabetes is limited (11). Moreover, inconsistent definitions, doses and durations have made reviewing the available evidence problematic (12). Trials which have focused specifically on increasing fiber intakes to reduce diabetes risk have tended to be small with limited statistical power and often lacking objective data on adherence (13, 14). In contrast, large diabetes prevention trials have often

aimed to change multiple aspects of the diet and other health behaviors to achieve the greatest potential reduction in disease risk (15, 16), making it difficult to examine the causal role of individual dietary components. This limitation in the literature has been noted by several large-scale systematic reviews (7, 17). Well designed, large scale trials are urgently needed to robustly test the impact of cereal fiber on the risks of type 2 diabetes and its precursors (18). Before embarking on such a study, it is essential to develop interventions which are well tolerated and which lead to appreciable increases in cereal fiber intake.

We have previously shown that children who consume high fiber breakfast cereals have lower insulin resistance (assessed using fasting insulin and Homeostasis Model Assessment [HOMA]) than children who ate a low fiber breakfast (19), suggesting that the association between cereal fiber and emerging type 2 diabetes risk may be apparent in childhood. Improving diet quality in children offers the potential to establish healthy dietary habits which may persist into later life (20). However, there is currently little evidence in children on the effects of increasing cereal fiber intake on emerging type 2 diabetes risk. We therefore developed and evaluated a dietary intervention aiming to increase cereal fiber intake over a one-month period in 9-10-year-old children. Measuring dietary fiber intake is challenging; we therefore used a biomarker of whole-wheat fiber intake (fasting plasma total alkylresorcinol [AR]) to test whether the intervention had been successful in its primary aim to bring about a sustained change in dietary cereal fiber intake. Dietary recalls were collected to examine any further changes in dietary intakes and biological markers were included to estimate secondary effects of dietary change (body composition and type 2 diabetes risk markers, e.g. insulin resistance). If shown to be effective, such an intervention could be used in future studies to examine the effect of increasing cereal fiber intake on insulin resistance and glycaemic control.

## *Subjects and Methods*

### Study overview

The CeReal nUtritioN for Child Health (CRUNCH) study was a two-armed parallel group randomized controlled feasibility trial investigating whether providing a free supply of high fiber breakfast cereal (high fiber group) to children currently consuming a low fiber breakfast cereal, would increase cereal fiber intake over a one-month period. As a feasibility trial for a larger full-scale trial, the one-month duration of the trial was chosen to represent a sustained dietary change of sufficient duration to bring about a change in metabolic outcomes such as fasting insulin and insulin resistance (21). The comparison group (low fiber group) were also given a free supply of breakfast cereal but which had a low fiber content. The study was based on use of commercially available high-fiber and low-fiber cereals, widely available from UK supermarkets (see Supplementary Table 1 for details of cereals and their fiber contents). All participants received support and encouragement based on behavior change techniques (BCTs), detailed below. Ethical approval was granted by the St George's University Ethics Committee (SGREC17.0007). Written, informed parental consent was obtained separately for the initial assessments which included a question on child allergies (detailed below) and for the feasibility trial; child assent was also obtained for all participants at entry to the study.

### Participants and initial procedures

A total of 23 London Primary schools agreed to take part in the study (70% response rate) between September 2017 and June 2018. All Year 5 pupils in those schools (aged 9-10 years) were invited to take part in initial eligibility assessments including a brief questionnaire on their current breakfast habits (including the name of their current breakfast cereal) and a taste test, which included all the breakfast cereals (both low and high fiber) that

would be offered in the feasibility trial. They were also asked about parental and grandparental place of birth, used to define child ethnicity. Participants were asked to rate the palatability of each cereal they tasted on a five-level Likert scale, with the following anchors; awful, not good, alright, good, brilliant. Data from these initial assessments were used to identify children eligible for the trial. Inclusion criteria were: currently eating a breakfast cereal with a low fiber content (<1-gram cereal fiber per portion), scoring at least one of the high fiber and one of the low fiber cereals in the highest two Likert scale categories and no relevant food allergies. This was to ensure that trial participants would be given breakfast cereals that they had previously tasted and found to be palatable. Children with diabetes were excluded from participation. Eligible children were given a briefing session about the trial by a member of the research team and were then given invitation letters and consent forms for the feasibility trial to take home to their parents/carers.

Randomization and interventions

After baseline assessment, eligible participants consenting to take part in the trial were individually randomized to either receive a one-month free supply of high fiber breakfast cereals (>3.5 grams fiber per portion) or a one-month free supply of low fiber breakfast cereals (<1 gram of fiber per portion). Randomization was carried out using the King's Clinical Trials Unit (KCTU) online randomization service, stratified by school and using a block size of two to maintain balanced randomization within schools. The study co-ordinator (not blinded) implemented the randomization on the same day by preparing a two-week supply of the high or low fiber cereal preferred by each child in the taste test in plain packaging. This was given out to each child at school ready to be taken home; children were not informed which cereal group they had been allocated to.

Intervention Procedures

Participants in both the high fiber and low fiber groups were seen by the trial co-ordinator on the day of baseline assessments, to provide a supply of the allocated cereal and to implement behavioral intervention procedures underpinned by the Social Cognitive Theory of behavior change (22) which were coherent with standard BCT taxonomy (23) and were designed to encourage daily breakfast cereal consumption (Supplementary Table 2).

The participants were given a 'Participant Pack' at the end of the school day which included; a two-week supply of their allocated cereal, a breakfast diary, a wall chart and stickers (to chart their progress), pens, pencils, fridge magnets and badges. These items were used to provide reminders for the children to increase their adherence and engagement with the study. Participating children were asked to eat the cereal provided for them every day for one month and to record in their breakfast diary what they ate for breakfast, including non-allocated items. They were given information on how to contact the research team, including via a study website (www.crunch.sgul.ac.uk) which had a message box they could use. The trial coordinator visited each school after one week and ran a quiz about breakfast and general nutrition, to keep the participants interested in and engaged with the study. During this visit participants were asked whether the allocated cereal was still acceptable and the supply adequate; additional or replacement cereals were provided where needed. A further two-week supply of cereal was delivered to the children (via the primary school) half way through the trial to take home.

Outcome measures

Assessments were made at baseline and after one month by research outcome assessors, who were blind to group allocation. On each occasion, each child was asked to provide a blood sample taken after an overnight fast and was asked about the last time of eating and drinking; s/he was then provided with breakfast. Measurements of height, weight and body fatness

(using a Tanita body composition analyser BC-418 MA Tanita Inc. Tokyo, Japan) were made, followed by a 24 hour recall dietary assessment using the Intake24 software programme (www.intake24.co.uk). On the one month visit, children were also given a short questionnaire which included a question asking how often they had eaten the breakfast cereal, with the following four options; every day, most days, some days and never/hardly ever, and if they had enjoyed taking part with the following five options: I did not enjoy it at all, I did not really enjoy it, it was alright, I enjoyed taking part, I really enjoyed it.

The primary outcome was change in total plasma alkylresorcinol (AR) concentration (which is the sum of C17:0, C19:0, C21:0, C23:0 and C25:0 homologues), a biomarker of whole grain wheat and rye intakes, measured from fasting blood samples taken at baseline and at follow-up. Secondary outcomes included change in cereal fiber intakes measured through self-reported 24 hour recalls and changes in dietary intakes of total energy, carbohydrates, fat and protein intakes, body weight and body composition. Fasting measurements of plasma insulin, glucose and blood lipids were made to inform the design of potential future outcome trials. Participants were defined as fasting if they reported consuming nothing other than water on the morning of assessment and had a plasma insulin concentration of less than 25 mU/L.

Laboratory analysis: Blood samples were centrifuged and aliquoted within 6 hours of collection; aliquots were then deep frozen at -70$^{o}$C and transferred to central laboratories for measurement within 12 months of collection. Plasma total AR was measured using a LC-MS/MS method as described by Ross et al (24). Both baseline and follow-up samples from each child were analyzed in the same batch. Intra- and inter batch coefficient of variation were both < 10%. Plasma total and HDL-cholesterol and glucose were measured using an automated analyzer (c311, Roche Diagnostics UK); HbA1c was measured in whole blood

using the same analyser. Plasma insulin was measured with an automated immunoassay method (411, Roche Diagnostics UK), which does not cross-react with proinsulin.

Study size and Statistical analysis

We estimated 100 participants with complete data in each group were required to have 90% power at the 1% significance level, to detect a difference of 0.7 SD in AR level at the end of the trial between the high fiber and low fiber groups. We over-recruited by 35% to allow for withdrawals and for non-adherence with the requirement for fasting.

All analyses were carried out using STATA/SE software (Stata/SE 14 for Windows; StataCorp LP, College Station, TX, USA). Multilevel linear regression models were fitted using the *mixed* procedure to examine the effect of the high fiber breakfast cereal intervention on levels of fasting AR and secondary outcomes compared to controls who received low fiber breakfast cereal, and Wald's test examined statistical significance. Fasting AR at follow-up was regressed on fasting AR at baseline and intervention group, to estimate change in AR between intervention groups efficiently while allowing for regression to the mean; school was adjusted for as a random effect in all analyses. The effect of further adjustment for participant characteristics including sex, age (quartiles) and ethnic group (white European, black African origin, South Asian and mixed/other) (all fitted as fixed effects) was also examined. The same approach was used for secondary outcomes (cereal fiber intake, total energy intake, carbohydrate, protein and fat intakes, body weight, fat mass and fat mass percentage).

The primary analysis was a complete case analysis based on all children randomized with data on the primary outcome (fasting plasma AR) both at baseline and follow-up. A sensitivity analysis (effectively an intention to treat analysis) was carried out for the primary outcome by examining the impact of missing fasting plasma AR data at baseline (n=8) or

follow-up (n=59), using multiple imputation methods with chained equations (*mi impute*) using 40 simulations; 12 subjects with AR missing at both baseline and follow-up were excluded. Predictors included in the multiple imputation were AR at baseline or follow-up as well as sex, age quartiles, ethnic group and cereal fiber intervention group because they were potential predictors of missingness; 260 of 272 children randomised were included in this imputation analysis. Finally, an exploratory per protocol analysis was conducted which included only children who reported eating the cereal on most or all days.

***Results***

Figure 1 summarizes numbers of children recruited and randomized into the study. Between September 2017 and June 2018, a total of 782 children took part in initial eligibility assessments (response rate of 63%). Of these 782 children, 377 (48%) children were eligible to take part in the trial (all reported that they were currently eating a low fiber breakfast cereal and all of whom scored at least one high fiber and one low fiber cereal in the top two palatability categories). In total, consent was received for 299 participants, of whom 272 children (72% of eligible) attended the baseline assessment and were randomized (see figure 1), 135 children were allocated to receive the high fiber breakfast cereal and 137 children the low fiber breakfast cereal. Complete fasting plasma total AR data at baseline and one month were available for 193 children who were included in the complete case analysis (87 in the high fiber group and 106 in the low fiber group); the sensitivity analysis for missing AR data was carried out in 260 children with at least one AR value.

Table 1 presents the baseline characteristics of the participants. There were more girls than boys; white European origin was the largest ethnic group, with smaller proportions of black Africans, South Asians and other/mixed ethnicities. Total plasma AR and reported cereal

fiber intakes were slightly higher at baseline in the group allocated to high fiber, while protein and fat intakes were higher at baseline in the low fiber group. Total energy intakes and the anthropometric measures did not differ markedly between the intervention groups.

Most children (87%) reported eating the allocated cereal on most or all days through the intervention period, although this proportion was higher in the low fiber group (94%) than the high fiber group (80%) (mean difference: 13.8%; 95% CI: 9.8, 18.7%). Table 2 presents differences in changes in the primary and secondary outcomes during the one-month trial period between the high fiber group and the low fiber group in the complete case analysis; all analyses included a term for school (random effect) whilst model 2 also included adjustments for sex, age quartiles, ethnic group (fixed effects). At follow-up, the high fiber cereal intervention group was associated with a significantly greater adjusted increase in fasting AR compared to changes in the low fiber cereal group and a greater adjusted increase in self-reported cereal fiber intakes. There were no changes in any of the other secondary outcomes measured, including dietary intakes (total energy, carbohydrate, fat and protein) and indices of adiposity (body mass index or fat mass index). Multiple imputation was used to impute fasting AR values which were missing either at baseline (n=8) or at follow-up (n=59) and included in the analysis; 12 children with missing AR data at both time points were excluded from this analysis. In this analysis, very similar increases in fasting AR were observed in the high fiber cereal group compared to the low fiber group to that observed in the complete case analysis. Differences in changes in the blood-based risk markers over the study period between the two groups were examined (Table 3), no significant differences were observed.

At follow-up, most children (60%) reported that they had “really enjoyed taking part”, and 25% reported that they had “enjoyed taking part”, with the remaining children reporting that “it was alright” (12%) or “did not really enjoy it” (3%). Similar proportions of acceptability were recorded for both high fiber and low fiber groups.

## *Discussion*

An intervention which provided free supplies of palatable high fiber breakfast cereals to 9-10 year-old children, and free supplies of palatable low fiber cereals for the control group, with support and encouragement provided to both groups to eat breakfast based on recognised BCTs, successfully increased cereal fiber intakes in the intervention group over a one-month period. This was documented both by a difference in change in plasma AR (appreciably higher in the high fiber group compared to the low fiber group following the one-month trial period) and by data from a 24-hour recall taken at the end of the one-month period, showing that nearly 3 grams more cereal fiber was consumed in the high fiber group compared to the low fiber group, with no other changes observed in dietary intakes or adiposity measures between the two groups. Adherence (children who recalled eating the breakfast cereal every day or most days) was good, although slightly lower in the high fiber group compared to the low fiber group.

This intervention in children was unique in its design; the main aim was to change cereal fiber intake without altering other components of the diet, through the provision of replacement foods rather than nutritional supplements. This appears to have been successfully achieved, with changes in cereal fiber in the high fiber group (documented both by changes in AR and dietary recall) achieved without changes in energy intake, in macronutrient or micronutrient intakes or in weight and other anthropometric measures. Previous intervention trials in children have tended to be multi-component and have changed numerous aspects of the diet, including fiber intakes, to achieve an improvement in health outcomes (25-27). Often these approaches led to changes in total energy intakes and weight status (26). Some previous interventions which aimed to increase fiber intakes were

unsuccessful (26, 27), even when substitute foods were provided (28), emphasising the importance of the behavioral support to encourage consumption of the breakfast cereal. The behavior change techniques (BCTs) used were based on the key constructs of the Social Cognitive Theory of behavior change (22). They aimed to increase self-efficacy, self-regulation and create environmental triggers to help to remind and motivate the participants to eat the breakfast cereal daily throughout the study period. The BCTs were applied in both groups to maximise the achieved difference in cereal fiber intake we might achieve, this also meant that both researcher and participant could remain blind to allocated cereal group. Although the participants may have been able to identify the cereal they were eating (a common issue for dietary interventions), they were unaware of the trial aim to increase fiber intakes in the high fiber group.

*Strengths and Limitations:* A particular strength of this trial was the use of an objective marker of whole-wheat cereal fiber intakes (AR), used in conjunction with subjective self-reported measures to compare the change in intakes in the different breakfast cereal groups; both measures consistently showed higher cereal fiber intakes in the high fiber intervention group. Reassuringly, these differences in the primary outcomes suggest that any contamination which took place between the intervention and control groups was limited (in the light of the marked differences in cereal fiber intake observed). Participants were individually randomized (rather than using a cluster randomized design) for greater statistical efficiency. The consistency of the AR differences between the high and low fiber groups in the complete case analysis and the imputation (intention to treat) analysis is reassuring. However, we acknowledge that even the MAR analyses cannot guard against data that are not missing at random conditional on the covariates. ARs are phenolic lipids which are present in the bran fraction of wheat and rye, once consumed they are absorbed and

detectable in plasma. They have therefore been suggested as potential biomarkers of wholegrain wheat and rye intakes (29). There are clear advantages of using objective markers of dietary intakes and although not a precise measure of cereal fiber intake at an individual level, plasma AR provides both a degree of ranking in individuals (28,29) and an objective marker of recent cereal fiber intake from whole wheat and rye at a group level (30). In the current trial, participants were asked to consume whole-wheat breakfast cereals therefore consuming all parts of the grain, the measure of plasma AR was used solely as a measure of adherence to the intervention and not to examine any potential relationship between AR and metabolic outcomes. In relation to previous studies, it is difficult to compare AR concentrations across different age groups as absorption, distribution and/or elimination appears to be highly influenced by age (higher AR values in younger children). Plasma AR concentrations in the present study were of a similar magnitude, though slightly lower than, 8-10-year-old Danish children with higher wholegrain intakes (31).

This feasibility study was not powered to detect moderate intervention effects on insulin resistance, glycaemic control or other markers of cardio-metabolic risk, which showed no statistically significant differences. However, potentially meaningful favourable population-wide changes in these markers (for example, a reduction in mean fasting insulin of 1.0 mU/L) could not be confidently excluded. Thus, a substantially larger trial (estimated sample size of ~1500 participants based on data from this study) would be needed to investigate the efficacy of this intervention on fasting markers of insulin resistance, of a magnitude consistent with our earlier observational study (19). Although the current investigation suggested that large numbers would need to be screened to identify eligible children, over 70% of participants completed the trial which could potentially be increased with a strong focus on the importance of fasting and successful blood sampling. It is also

possible that the use of much larger doses of fiber (through supplements) and the use of maximally stimulated measures of insulin resistance (assessed with euglycaemic hyperinsulinaemic clamps) could reduce the size of trial needed, though these would increase its invasiveness and would probably limit its practical feasibility.

In summary, we have developed an acceptable intervention which appreciably increases markers of daily cereal fiber intakes in children. Given the current low population intakes of cereal fiber in this age group, an intervention which increases cereal fiber by up to 3 grams/day could have widespread public health relevance and applicability. Future research is needed to see if this change in diet leads to an improvement in markers of type 2 diabetes and can be sustained in the longer term.

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authors read and approved the final version. None of the authors have any conflicts of interest.

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Table 1: Baseline characteristics of all participants by intervention group[1]

| | Intervention group, median (IQR) | | |
|---|---|---|---|
| | Low fiber n=137 | High fiber n=135 | All n=272 |
| Age, y | 9.9 (9.6, 10.3) | 9.9 (9.6, 10.2) | 9.9 (9.6, 10.2) |
| Sex, % female | 56 | 62 | 59 |
| Ethnicity, n (%) | | | |
| White European | 60 (43.8) | 53 (39.3) | 113 (41.5) |
| Black African | 19 (13.9) | 26 (19.3) | 45 (16.5) |
| South Asian | 34 (24.8) | 33 (24.4) | 67 (24.6) |
| Other | 24 (17.5) | 23 (17.0) | 47 (17.3) |
| Total energy intake[2], kcal/d | 1,322 (1,095, 1,651) | 1,345 (1,067, 1,676) | 1,344 (1,081, 1,654) |
| Cereal Fiber intake[2], g/d | 4.2 (2.6, 6.5) | 4.7 (2.7, 6.3) | 4.5 (2.7, 6.4) |
| Carbohydrate[2], g/d | 194 (156, 239) | 196 (153, 237) | 194 (155, 237) |
| Protein[2], g/d | 53.3 (40.6, 63.1) | 50.5 (38.4, 65.2) | 51.1 (39.0, 63.9) |
| Fat[2], g/d | 47.0 (34.9, 59.4) | 43.2 (29.4, 61.7) | 44.8 (32.0, 61.0) |
| Weight, kg | 34.5 (29.8, 41.5) | 34.7 (30.7, 40.9) | 34.6 (30.3, 41.1) |
| Fat mass[3], kg | 7.7 (6.1, 11.2) | 8.1 (6.1, 11.1) | 7.9 (6.1, 11.2) |
| Fat mass[3], % | 23.0 (20.1, 28.9) | 23.1 (20.0, 27.6) | 23.0 (20.0, 27.9) |
| Baseline fasting plasma analytes | n=128 | n=124 | n=252 |
| Total AR, nmol/L | 42.1 (22.2, 85.7) | 43.8 (26.4, 82.5) | 43.1 (24.6, 85.5) |
| Insulin, mU/L | 6.8 (4.6, 10.3) | 7.1 (4.9, 9.0) | 7.0 (4.8, 10.0) |
| Glucose[4], mmol/L | 4.5 (4.2, 4.7) | 4.5 (4.3, 4.7) | 4.5 (4.2, 4.7) |
| LDL cholesterol, mmol/L | 2.0 (1.7, 2.4) | 2.0 (1.5, 2.5) | 2.0 (1.6, 2.4) |
| HDL cholesterol, mmol/L | 1.4 (1.2, 1.7) | 1.4 (1.2, 1.7) | 1.4 (1.2, 1.7) |
| TGs, mmol/L | 0.6 (0.5, 0.8) | 0.6 (0.5, 0.8) | 0.6 (0.5, 0.8) |
| Vitamin C[5], µmol/L | 67.4 (52.6, 83.0) | 69.4 (56.2, 81.0) | 68.4 (54.6, 81.4) |
| Baseline fasting HbA1c[6], mmol/mol | 33.1 (31.4, 35.1) | 33.2 (31.7, 34.7) | 33.1 (31.6, 34.7) |

[1]Values represented are median (IQR) or frequency (%)
Missing data: [2] low fiber: n=6, high fiber: n=1; [3] high fiber: n=1; [4] low fiber: n=3, high fiber: n=3; [5] low fiber: n=6, high fiber: n=6; [6] low fiber: n=3, high fiber: n=1;

Table 2: Effect of high fiber cereal intervention compared to low fiber cereal on total plasma alkyresorcinol, dietary intake, weight and adiposity in participants who provided baseline and follow up data: complete case analysis[1]

| Outcome | N | Model | Effect of high fiber intervention Difference (95% CI) | p |
|---|---|---|---|---|
| Plasma total AR, nmol/L | 193 | Model 1 | 41.6 (21.7, 61.5) | <0.0001 |
| | | Model 2 | 40.7 (21.7, 59.8) | <0.0001 |
| Cereal fiber, g/d | 252 | Model 1 | 2.9 (2.0, 3.8) | <0.0001 |
| | | Model 2 | 2.9 (2.0, 3.7) | <0.0001 |
| Energy intake, kcals/d | 252 | Model 1 | 44.6 (-80.6, 169.8) | 0.49 |
| | | Model 2 | 47.3 (-79.6, 174.1) | 0.47 |
| Carbohydrate, g/d | 252 | Model 1 | 2.0 (-16.3, 20.3) | 0.83 |
| | | Model 2 | 1.6 (-16.9, 20.1) | 0.86 |
| Protein, g/d | 252 | Model 1 | -0.1 (-5.6, 5.3) | 0.96 |
| | | Model 2 | 0.1 (-5.5, 5.7) | 0.97 |
| Fat, g/d | 252 | Model 1 | 4.0 (-2.4, 10.4) | 0.22 |
| | | Model 2 | 4.4 (-2.0, 10.8) | 0.18 |
| Weight, kg | 261 | Model 1 | 0.0 (-0.1, 0.2) | 0.67 |
| | | Model 2 | 0.0 (-0.1, 0.2) | 0.63 |
| Fat mass, kg | 261 | Model 1 | 0.0 (-0.2, 0.2) | 0.87 |
| | | Model 2 | 0.0 (-0.2, 0.2) | 0.88 |
| Fat mass, % | 261 | Model 1 | 0.0 (-0.3, 0.4) | 0.87 |
| | | Model 2 | 0.0 (-0.4, 0.4) | 0.92 |

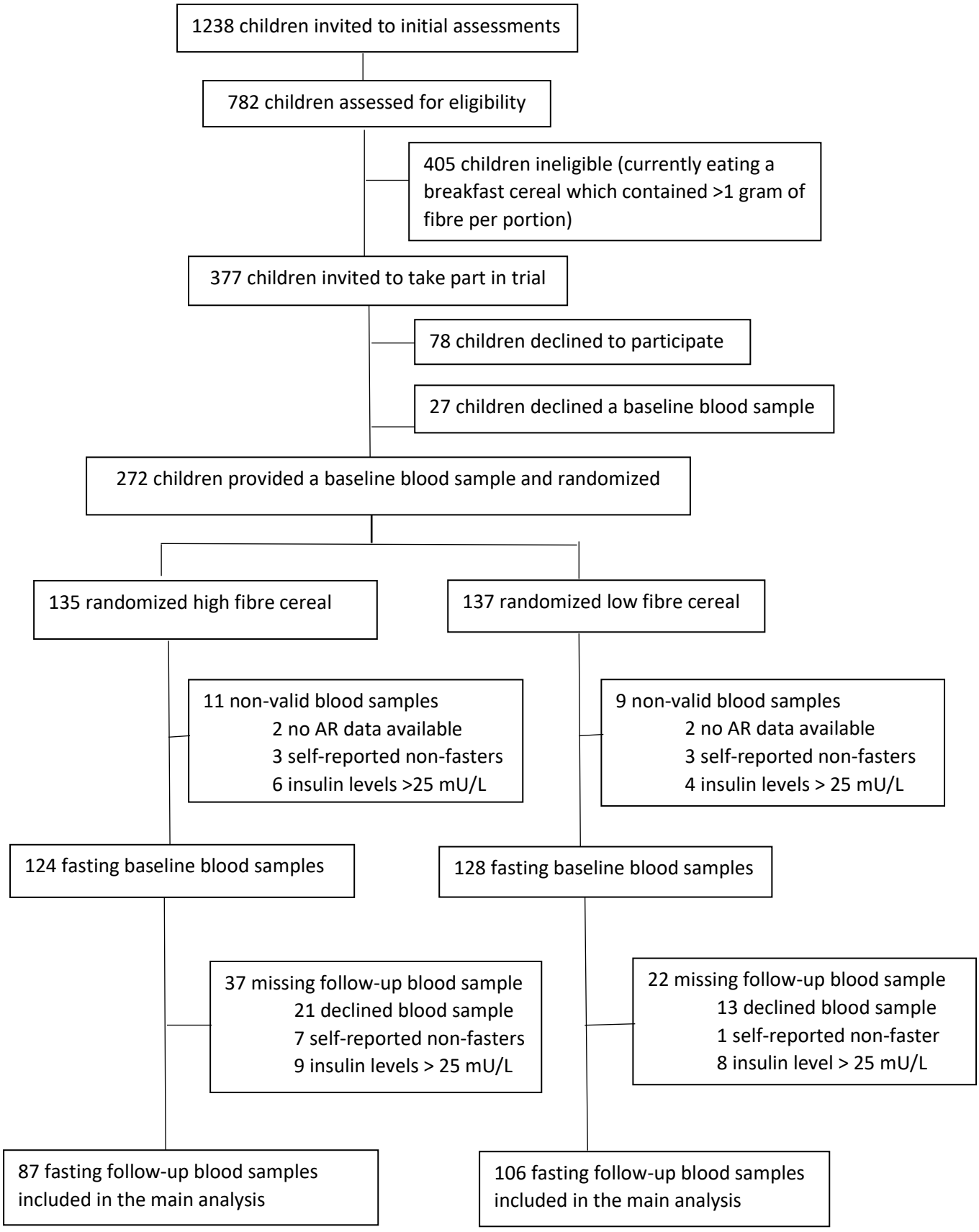
[1] Values represented are mean (95% confidence intervals)
Model 1: Outcome at follow-up was regressed on outcome at baseline and intervention group with adjustment for school (random effect)
Model 2: Outcome at follow-up was regressed on outcome at baseline and intervention group with adjustment for school (random effect), age (quartiles), sex, ethnic group (fixed effects)
p-values are based on a Wald test for statistical significance

Table 3: Effect of high fiber cereal intervention compared to low fiber cereal on blood markers in participants who provided baseline and follow up data: complete case analysis

| Outcome | N | Model | Effect of high fiber intervention Difference (95% CI) | p |
|---|---|---|---|---|
| Plasma Insulin, mU/L | 193 | Model 1 | -0.1 (-1.0, 0.8) | 0.85 |
| | | Model 2 | -0.1 (-1.0, 0.8) | 0.81 |
| Whole blood HbA1c, mmol/mol | 189 | Model 1 | -0.3 (-0.8, 0.3) | 0.37 |
| | | Model 2 | -0.3 (-0.9, 0.3) | 0.32 |
| Plasma Glucose, mmol/L | 188 | Model 1 | 0.0 (-0.1, 0.1) | 0.84 |
| | | Model 2 | 0.0 (-0.1, 0.1) | 0.74 |
| Plasma LDL-chol, mmol/L | 193 | Model 1 | -0.1 (-0.2, 0.0) | 0.18 |
| | | Model 2 | -0.1 (-0.1, 0.0) | 0.27 |
| Plasma HDL-chol, mmol/L | 193 | Model 1 | 0.0 (-0.1, 0.1) | 0.74 |
| | | Model 2 | 0.0 (0.0, 0.1) | 0.53 |
| Plasma Triglyceride, mmol/L | 193 | Model 1 | 0.0 (0.0, 0.1) | 0.47 |
| | | Model 2 | 0.0 (0.0, 0.1) | 0.33 |
| Plasma vitamin C, µmol/L | 186 | Model 1 | 0.4 (-4.4, 5.2) | 0.87 |
| | | Model 2 | 0.8 (-3.9, 5.6) | 0.73 |

Model 1: Outcome at follow-up was regressed on outcome at baseline and intervention group with adjustment for school (random effect)
Model 2: Outcome at follow-up was regressed on outcome at baseline and intervention group with adjustment for school (random effect), age (quartiles), sex, ethnic group (fixed effects)
p-values are based on a Wald test for statistical significance

Figure 1: Trial participant recruitment, randomization and follow-up


1238 children invited to initial assessments
782 children assessed for eligibility
405 children ineligible (currently eating a breakfast cereal which contained >1 gram of fibre per portion)
377 children invited to take part in trial
78 children declined to participate
27 children declined a baseline blood sample
272 children provided a baseline blood sample and randomized
135 randomized high fibre cereal
137 randomized low fibre cereal
11 non-valid blood samples
2 no AR data available
3 self-reported non-fasters
6 insulin levels >25 mU/L
9 non-valid blood samples
2 no AR data available
3 self-reported non-fasters
4 insulin levels > 25 mU/L
124 fasting baseline blood samples
128 fasting baseline blood samples
37 missing follow-up blood sample
21 declined blood sample
7 self-reported non-fasters
9 insulin levels > 25 mU/L
22 missing follow-up blood sample
13 declined blood sample
1 self-reported non-faster
8 insulin level > 25 mU/L
87 fasting follow-up blood samples included in the main analysis
106 fasting follow-up blood samples included in the main analysis