Shortened title: Can dietary fibre intakes of 30g be achieved?

Key words/phrases: fibre, dietary guidelines, eatwell guide, carbohydrates and health

Abstract

Background: UK Government recommendations for dietary fibre intakes have recently increased to 30 g/day, well below current population intakes. This study aimed to explore whether this target could be achieved and the effects on markers of cardiometabolic health.

Methods: In this four-week, high fibre intervention study 15 participants were instructed to achieve dietary fibre intakes of 30 g/day.

Results: Dietary fibre intakes significantly increased post intervention (16.0 ± 8.1 g/day; p<0.001). No significant changes in glucose and triglyceride concentrations were observed and there was a significant increase in average body weight (0.7 ± 1.2 kg p = 0.025). **Conclusion:** This study shows that achieving the new dietary fibre recommendations of 30g/day is achievable, in the short-term, in a sample of British adults without any observed effect on health markers.

Introduction

Chronic disease is the leading cause of death and disability across the globe. The role of different dietary factors, such as dietary fibre, in the development of chronic disease including cardiovascular disease (CVD) and type two diabetes has received much scientific scrutiny in decades past [(1-3)].

Prospective cohort studies demonstrate an inverse relationship between dietary fibre intake and CVD incidence. In a systematic review and meta-analysis, Threapleton *et al.*[(4)] conducted an analysis of twenty-two prospective cohort studies and reported reduced incidence of CVD (risk ratio 0.91 per 7 g/day (95% confidence intervals 0.88 to 0.94)) and coronary heart disease risk (0.91 (0.87 to 0.94)) with increasing dietary fibre intakes, thus supporting current dietary fibre recommendations. Prospective cohort studies also indicate there is strong evidence diets rich in fibre are inversely associated with incidence of type 2 diabetes. A meta-analysis of prospective cohort studies (n = 19) included in the European Prospective Investigation into Cancer and Nutrition (EPIC)-InterAct study found higher intakes of dietary fibre were associated with a reduced risk of developing diabetes (HR Q4 vs Q1 0.82; 95% CI 0.69, 0.97) [(5)]. Results from randomised controlled trials (RCTs) that investigated an effect of dietary fibre intake on CVD and type two diabetes risk factors, such as cholesterol and LDL-cholesterol, have shown reductions but effects on fasting triglyceride and glucose concentrations are mixed [(6-9)]. The health effects of dietary fibre have recently been considered by the Scientific Advisory Committee on Nutrition

(SACN) and published in its report *Carbohydrates and Health* [10]. It showed that the evidence base has strengthened, in a number of areas, since last considered in reports published in the 1980s and 1990s.

SACN made two key recommendations with respect to dietary fibre; to adopt a new definition of dietary fibre and increase the UK population's dietary fibre intake to 30 g/day. The new definition is a wider definition of dietary fibre using the Association of Official Analytical Chemists' (AOAC) method. The new recommendations are a considerable increase on previous recommendations – approx. 5g increase - over the previous dietary reference value (DRV) for dietary fibre. The latest National Diet and Nutrition Survey (NDNS) shows UK population intakes of dietary fibre are still well below recommendations [11] with mean intakes of dietary fibre being 20.1 g and 17.2 g per day in males and females respectively, as measured by the AOAC method*. Based on the extent of the disparity between current intakes and the new recommendations, achieving this much higher target will be a considerable challenge [12] . Therefore the aim of our study was to explore whether a group of healthy free living British adults could achieve the newly specified population fibre intake recommendation of 30 g/day and the effects this had on risk factors of CVD and diabetes.

Material and Methods

Participants

A total of 21 normal weight (BMI < 25 kg/m^2) male and females were recruited. Exclusion criteria for the study were: 1) diagnosis with irritable bowel syndrome (IBS) or coeliac disease; 2) a body mass index (BMI) >30kg/m^2; 3) habitual consumption of >30 gram/day of dietary fibre. The study was conducted, at St. Mary's University, Twickenham, according to the guidelines laid down in the Declaration of the Helsinki and all procedures were approved by the St Marys' University Ethics Sub-Committee.

Study design and intervention

After baseline assessment and screening, eligible participants attended an education day led by a qualified Nutritionist and were instructed to achieve dietary fibre intakes of 30 g/day for a four-week intervention period. Participants learnt about high fibre foods and received a seven-day menu plan (validated against a menu produced by SACN [10]), which included wholegrain bread and pasta, brown rice, baked potatoes and pulses. The menu was based on home cooked foods, as this was the

* AOAC fibre intake calculated using a conversion factor of 1.33 x NSP

best route to achieving 30g fibre/day. Portion size was not included in the menu as the study was intended to reflect the choices of a free-living population. Participants were advised to use the menu for ideas to increase fibre intakes and modify it based on food preferences, substituting lower fibre foods typically eaten for high fibre foods, including more vegetables, fruit and high fibre snacks, such as dried fruit and nuts. Recipes and starter packs containing high fibre products were also provided to improve compliance.

Metabolic measurements

Weight and height were assessed and BMI was calculated at week zero (baseline) and week four (endpoint). Height was measured using a Seca free-standing height measure stadiometer and recorded to the nearest 0.1cm with the head positioned in the Frankfort plane [13]. Body weight was measured in duplicate using a portable Marsden MS-4203 digital scales (Marsden Weighing group, Oxfordshire, UK) and recorded to the nearest 0.1 kg. Following a 12 hour overnight fast, blood samples were collected pre and post intervention. Triglyceride and glucose levels were measured using a validated CardioChek PA blood analyser (CardioChek, Indianapolis, IN, USA) via finger or earlobe-prick test by trained researcher [14].

Dietary measurement

Dietary fibre intake was assessed by the use of a four-day estimated food record completed before baseline (week zero) and endpoint (week four). Participants were instructed by researchers on how to assess portion sizes using household measurements (e.g. grams, tablespoon, glass, bowl) and complete records. Data were entered into Nutritics professional diet analysis software, Version 3.5, (Nutritics Limited, Ireland) to obtain grams of fibre per day. Validity of dietary intake data was assessed using the Goldberg cut-offs [15].

Statistical methods

Based on a sample size calculation with an alpha of 0.05, a power of 0.80, a standard deviation of 6.6 g/day and a clinical effect of 7 g/day, 15 participants were needed for this study. To allow for a predicted attrition of 25%, 21 participants were recruited. Results are presented as means ± standard deviations. A paired t-test was used to analyse differences in energy and fibre intakes over time and differences in glucose levels, as a result of the intervention. A Wilcoxon signed rank test was used to determine changes in triglycerides concentrations. Differences were considered statistically significant at $p < 0.05$. Statistical analysis was carried out using IBM SPSS Statistics software, Version 21 (IBM, Armonk, New York, USA).

Results

Participants

Of the 21 participants recruited, two were excluded from the intervention due to habitually high intake of fibre and failure to submit a food diary at baseline, a third participant was excluded due to a missing food diary at end point. Three participants were identified as under-reporters and were removed from further analysis. The final sample for analysis consisted of 15 participants, 5 males and 10 females, with an average age of 40.3 ± 9.9 years (Table 1). Most participants were close to meeting the recommended intake of fibre and participants showed compliance in increased fibre intakes on baseline values. Reported baseline mean fibre intakes were 19.3 ± 4.1 g/day and baseline mean energy intake was 8.9 ± 1.6 MJ/day.

Changes in dietary fibre and energy intake

Dietary fibre intakes significantly increased from 19.3 ± 4.1 g/day to 35.3 ± 7.8 g/day (average reported increase of 16.0 ± 8.1 g/day) post intervention ($p<0.001$). Adherence to the high fibre diet was high with 80% of participants exceeding the target of 30 g/day. Those that did not reach the target (n=3, 2 Female, 1 male) reported consuming significantly less energy at endpoint (7.1 ± 1.9 MJ) than those who did reach the 30g/day target (9.2 ± 1.3 MJ) p=0.023. Reported fibre intakes at endpoint were similar for females 35.6g ± 8.8 g compared to males 34.6 ± 6.1 g (Figure 1). However, a comparison of fibre density showed f emales were reporting a higher density of 18.2 ± 3.6 g/4.19 MJ compared to males 14.5 ± 2.2 g/4.19 MJ although this was not found to be significantly different ($p = 0.134$). Average reported energy intakes decreased slightly from 8.9 ± 1.6 MJ/day to 8.8 ± 1.6 MJ/day but were not changed significantly as a result of the intervention ($p = 0.891$).

Changes in metabolic variables and body weight

As shown in Table 1, the four-week high fibre intervention did not alter concentrations of glucose ($p = 0.209$) or triglycerides ($p = 0.448$). However, the intervention appeared to cause a significant (a difference of 0.7 ± 1.2 kg; p = 0..025) increase in body weight gain.

Discussion

This is the first study to our knowledge to demonstrate a sample of UK adults can meet dietary fibre recommendations of 30 g/day. All participants increased their dietary fibre intake on baseline values. Those that did not reach the target (n = 3) were predominately female and consuming significantly less energy. In the present study male and female participants had similar daily intakes of fibre (35.6 ± 8.8 g for females and 34.6 ± 6.1 g for males) post intervention. Females have a lower average energy consumption and it may be more difficult for females in the population to achieve the new dietary fibre recommendations as reflected in current habitual intakes[12]. Recommendations for dietary fibre differ by gender for example in Australia and the United States of America. An adequate intake of 30 g and 25 g/day in males and females is proposed in Australia[16] and 38 g and 25 g/day in males and females respectively in America[17]. However, gender differences were not recommended by SACN as they were based on the observation that the greatest reduction in disease risk is at 30 g of fibre (AOAC) or more per day [10].

A further objective of this study was to examine effects of the fibre intervention on risk factors of cardiovascular disease and diabetes. Results indicate that the 4-week high fibre intervention had no effect on fasting glucose and triglyceride levels. Previous RCTs have found contradictory results for the effect of a high fibre diet on blood glucose in healthy and diseased groups [6,7,9]. Aller *et al.*[6] observed a 12% decrease, on baseline values, in fasting blood glucose concentrations of healthy volunteers following a high fibre diet (30 g/day) for three months. Moderate levels of dietary fibre (7.5 g/day) have been shown to lower fasting blood glucose levels of obese, mildly hyperglycaemic males [9]. More recently, a meta-analysis by SACN[10] of four RCTs that examined the effects of a dietary fibre on fasting blood glucose concentration found no effect.

Similar to results reported here, a number of RCTs have also observed no effect of the high fibre diets on triglyceride levels[6,7,18]. SACN[10] carried out a pooled meta-analysis of RCTs that investigated consumption of dietary fibre on fasting triglycerides, and found no association between fibre intake and triglyceride levels.

Consideration should be given to the health status of the participants and the effect this might have had on findings. With an average BMI of 23.0 kg/m^2 and triglycerides and glucose levels at baseline already within the healthy range, it is possible that a high fibre diet could have limited impact, as it would be hard to reduce levels of these biomarkers of disease further.

Surprisingly, the present study resulted in significant increase (0.7 kg) in body weight, which in itself is a strong marker of cardiometabolic health and could have affected triglyceride levels. Miller *et al.*[19] identified that a 5 to 10% reduction in body weight can reduce triglyceride levels by 20%. Therefore, the fact participants gained weight could have reduced the impact of the high fibre diet on triglyceride levels. Other studies have reported that high fibre diets lead to a reduction in body weight. An intervention in healthy volunteers (n = 20) on a high fibre diet of 40g/day caused a statistically significant average weight loss of 0.45 kg (p=0.05) and a reduction in BMI of 0.14 kg/m^2 (p = 0.05)[20]. However, SACN[10] reported no evidence of an association between dietary fibre (g/day or fibre density) and body weight change based on moderate evidence from cohort studies.

There are a number of limitations in our study worth noting. Primarily the menu plan did not account for differences in individual energy requirements and may have resulted in some participants inadvertently increasing their energy intake. Also as with the use of any dietary assessment methods under-reporting and portion sizes estimates are a potential source of error. The increase in body weight may, in part, have been attributed to the fact that data collection occurred during the summer months and resulted in reduced physical activity of participants albeit this was not assessed at endpoint. The duration of the study could have been a limiting factor in observing changes in biochemical markers and due to its small size the sample included in the present cohort may not be representative of the UK population. Future work may benefit from targeting less healthy and less motivated populations to understand how sustainable changes can be implemented and also to determine if less healthy populations can benefit more in terms of reductions in risk factors.

In conclusion, this study shows that achieving the new dietary fibre recommendations of 30 g/day is achievable, in the short-term, in a sample of British adults without any observed effect on measured markers of cardiometabolic health. Further, to achieve this recommendation many people in the UK will need to increase their dietary fibre intakes substantially, with an emphasis on substitution with higher fibre varieties rather than supplementation to avoid unintended increases in energy intake, which will require a concerted effort from food manufactures and other stakeholders (e.g. health care professionals).

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None of the authors had a conflict of interest.

Figures and tables submitted with manuscript

Fig. 1 Reported fibre intake and fibre density of male and female participants at endpoint (error bars show one standard deviation)

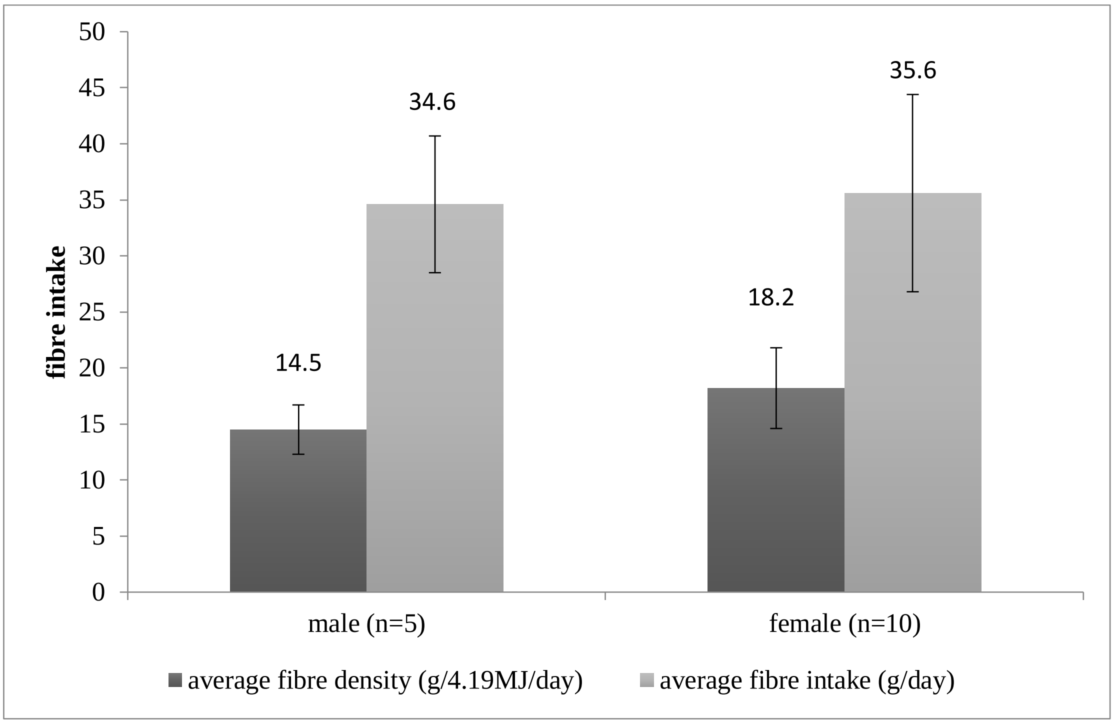

Table 1. Anthropometric, dietary and biochemical variables measured at baseline and endpoint during a four week high fibre intervention.
(values are means with standard deviations)

	Baseline (n=15)	Endpoint (n=15)	Difference	P value
Age (y)	40.3 ± 9.9			
Weight (kg)	67.1 ± 13.1	67.8 ± 13.2	0.7 ± 1.2	0.025
BMI (kg/m^2)	23.0 ± 2.4	23.3 ± 2.4	0.3 ± 0.4	0.022
Fibre (g/day)	19.3 ± 4.1	35.3 ± 7.8	16.0 ± 8.1	0.000
Fibre Density (g/4.19MJ)	9.2 ± 2.0	17.0 ± 3.6	7.7 ± 3.6	0.000
Energy (MJ/day)	8.9 ± 1.6	8.8 ± 1.6	-0.05 ± 1.4	0.891
Glucose (mmol/l)	4.8 ± 0.6	4.6 ± 0.6	-0.2 ± 0.5	0.209
Triglycerides (mmol/l)	1.0 ± 0.5	1.0 ± 0.4	-0.1 ± 0.4	0.448[a]

[a] Wilcoxon matched pairs test (paired t-test used for all other variables)

References

1. Anderson JW, Randles KM, Kendall CW *et al*. (2004) Carbohydrate and fiber recommendations for individuals with diabetes: a quantitative assessment and meta-analysis of the evidence. J Am Coll Nutr **23**, 5-17.
2. Cho S, Qi L, Fahey G, Klurfeld D (2013) Consumption of cereal fiber, mixtures of whole grains and bran, and whole grains and risk reduction in type 2 diabetes, obesity, and cardiovascular disease. *Am J Clin Nutr* **98**, 594-619.
3. Satija A & Hu F (2012) Cardiovascular Benefits of Dietary Fiber. *Curr Atheroscler Rep* **14**,505-514.
4. Threapleton D, Greenwood D, Evans C *et al.* (2013) Dietary fibre intake and risk of cardiovascular disease: systematic review and meta-analysis. *BMJ* **347**, 6879-6879
5. The InterAct Consortium (2015) Dietary fibre and incidence of type 2 diabetes in eight European countries: the EPIC-InterAct Study and a meta-analysis of prospective studies *Diabetologia* Published online May 29. doi: 10.1007/s00125-015-3585-9 Chandalia M, Garg A, Lutjohann D *et al*. (2000) Beneficial Effects of High Dietary Fiber Intake in Patients with Type 2 Diabetes Mellitus. *N Engl J Med* **342**, 1392-1398.
6. Aller R, De Luis DA, Izaola O *et al.* (2004). Effect of soluble fiber intake in lipid and glucose levels in healthy subjects: a randomized clinical trial. *Diabetes Res Clin Pract* **65**, 7-11.
7. Andersson A, Tengblad S, Karlstrom B *et al.* (2007) Whole-grain foods do not affect insulin sensitivity or markers of lipid peroxidation and inflammation in healthy, moderately overweight subjects. *J Nutr* **137,** 1401-1407.
8. Ulmius M, Johansson A, Önning G (2009) The influence of dietary fibre source and gender on the postprandial glucose and lipid response in healthy subjects. *Eur J Nutr*. **48**, 395-402.
9. Kobayakawa A, Suzuki T, Ikami T *et al.* (2013) Improvement of fasting plasma glucose level after ingesting moderate amount of dietary fiber in Japanese men with mild hyperglycemia and visceral fat obesity. *J diet suppl* **10**, 129-141.
10. SACN (2015) Carbohydrates and Health. London. The Stationary Office
11. Bates B, Cox L, Nicholson S *et al.* (2016) National Diet and Nutrition Survey: Results from Years 5-6 (combined) of the Rolling Programme (2012/13 – 2013/14): report. Public Health England, Department of Health, London.
12. Hooper B, Spiro A and Stanner S (2015) 30 g of fibre a day: An achievable recommendation? *Nutri Bull*, **40**, 118-129.

13. Cameron N (1984) The measurement of human growth. Instrumentation, surface landmarks, and anthropometric measurements. Croom Helm, Kent.

14. Noor Ani A, Ummi Nadiah Y, Noor Azah D *et al.* (2012) Sensitivity and specificity of CardioChek®PA in detecting individuals with abnormal cholesterol and glucose level. *Int J Biomed* **2,** 132-135.

15. Goldberg GR, Black AE, Jebb SA *et al.* (1991). Critical evaluation of energy intake data using fundamental principles of energy physiology: 1 Derivation of cut-off limits to identify under-recording. *Eur J Clin Nutr*, **45**, 569-581

16. National Health and Medical Research Council (2013) Australian Dietary Guidelines. Canberra: National Health and Medical Research Council.

17. Institute of Medicine, 2002 https://www.nap.edu/read/10490/chapter/1 (accessed 5 October 2016)

18. Brownlee I, Moore, C, Chatfield *et al.* (2010) Markers of cardiovascular risk are not changed by increased whole-grain intake: the WHOLEheart study, a randomised, controlled dietary intervention. *Br J Nutr* **104**, 125-134.

19. Miller M, Stone N, Ballantyne C *et al*. (2011) Triglycerides and Cardiovascular Disease: A Scientific Statement From the American Heart Association. *Circulation*, **123**, 2292-2333

20. Foerster J, Maskarinec G, Reichardt N *et al.* (2014) The Influence of Whole Grain Products and Red Meat on Intestinal Microbiota Composition in Normal Weight Adults: A Randomized Crossover Intervention Trial. *PLoS ONE* **9**(10), e109606.