Article:
Evans, CEL orcid.org/0000-0002-4065-4397 (2020) Dietary fibre and cardiovascular health: a review of current evidence and policy. Proceedings of the Nutrition Society, 79 (1). pp. 61-67. ISSN 0029-6651

https://doi.org/10.1017/S0029665119000673

Dietary fibre and cardiovascular health: a review of current evidence and policy

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Presented at Nutrition Society winter meeting, London, 4th December 2018

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Contributions

CE wrote the first and subsequent drafts.

Key words:

Dietary fibre, wholegrain, nutritional epidemiology, behaviour change, nutrition policy

Abstract

Dietary fibre is comprised of many different, mainly plant based, compounds that are not fully digested in the human gut. Insoluble fibres include cellulose, hemi-celluloses and lignin and soluble fibres include pectins, beta-glucan and hydro-colloids. In the UK the daily recommended amount has increased to 30g but only 13% of men and 4% of women meet this recommendation. Currently the mean intake for adults is 21g for men and 17g for women. There is a wealth of epidemiological evidence based on systematic reviews of trials and cohorts to support the higher fibre recommendation. This includes evidence of reductions in risk for cardiovascular disease (both heart disease and stroke) and lower risk of type 2 diabetes, lower blood pressure, lower LDL cholesterol, as well as some cancers. Beneficial effects of fibre operate via a diverse range of mechanisms throughout the digestive system including the mouth, stomach and small and large intestine; some of which are still not completely understood. The updated recommendation for fibre is a long way from a typical British diet and requires several daily portions of fruit and vegetables and wholegrain foods. Improving dietary fibre intakes will require a variety of actions and policies from stakeholders; however, there is currently more of a focus on reducing sugar than increasing fibre. In order to increase the number of adults meeting the fibre recommendation, social marketing and labelling of high fibre foods are warranted as well as reformulation and wider availability of wholegrain versions of popular foods.

Definition and sources of dietary fibre

Dietary fibre is complex and includes a wide range of plant based compounds that are not fully digested in the human gut. A universally agreed definition was only recently approved in 2009 by the CODEX Alimentarius after nearly 20 years of deliberation[1]. The CODEX Alimentarius was founded in 1963 as part of the World Health Organisation Food and Agriculture Organisation (WHO/FAO) and is the international body that sets guidelines for national regulatory authorities. Dietary fibre is defined as "Carbohydrate polymers with 10 or more monomeric units, which are not hydrolysed by the endogenous enzymes in the small intestine of humans". These polymers are usually naturally occurring in food but also include carbohydrate polymers which have been obtained from food by physical, enzymatic or chemical processes or are synthetic and have been shown to be beneficial to health. One of the main reasons that an agreed definition is needed is to enable international harmonisation for food labelling and food composition tables. In the UK the primary definition of dietary fibre was traditionally the Englyst method which did not include lignin or resistant starch. These components are now included in the approved definition which closely agrees with the AOAC method traditionally used in most countries around the world.

Dietary fibre can be classified into different categories with each category having different attributes. The most common method, although not necessarily the most appropriate, is categorisation into four groups based on solubility. These include high molecular weight soluble and insoluble fibres, resistant starches and prebiotics. Details on only the first 2 categories are provided here. Insoluble fibres include cellulose, lignin and hemi-celluloses such as Arabinoxylan and Glucomannan. Soluble fibres include pectins, cereal beta-Glucan and hydro-colloids such as gums (e.g.guar or mannan) and mucilages (including Psyllium). These are found in varying amounts in different foods.

Fibre sources are generally plant based foods namely cereals and potatoes, beans and pulses and fruits and vegetables; all foods that are encouraged as depicted on the UK Eat Well Guide[2]. Approximately half of all dietary fibre comes from cereals and about a third from fruits and vegetables[3]. Grains provide mainly cellulose and hemi-cellulose, fruits and vegetables cellulose, hemi-cellulose and pectin, and legumes, hemi-cellulose, pectin and resistant starches. Sources of fibre have changed over the last few decades in the UK. According to data from 1940 to 2000 published by DEFRA, consumption of fruit, pasta and rice has increased but intakes of bread, potatoes and vegetables have decreased[4] inevitably

leading to changes in the mix of different types of fibre in the diet. Historically in hunter-gatherer times the main sources were fruits and vegetables but not cereals resulting in a dramatic shift from soluble to insoluble fibre. Common types of dietary fibre currently consumed in the UK and their main sources are provided in table 1.

Table 1: Food sources of common types of dietary fibre in the UK

Fibre type	Definition	Food sources
Cellulose	Polysaccharides of glucose	Main component of cell walls of most plants
Hemi-cellulose	Polysaccharides of other sugars	Cereal grains are main source
Lignin	Woody fibre	In outer layers of cell grains
gums, mucilages	hydrocolloids	In endosperm of grain, legumes, nuts and seeds
Pectins	Polysaccharides containing galacturonic acid	In cell walls and intracellular tissue of fruits, veg and legumes
Beta-glucans	Branched structure of glucose polymers	Cell walls in oats and barley
Resistant starch	Starch not digested in small intestine	Legumes, unripe bananas, potatoes (stored)

Actual and recommended intakes of dietary fibre

Intakes of dietary fibre have varied over time in the UK and also vary greatly around the world. Many countries have high intakes of fibre but in general high income countries tend to have lower than optimal intakes[5]. Recommendations from WHO state that a healthy diet should contain more than 25g of dietary fibre[1] and most European countries recommend between 25 and 30 of fibre daily[5]. Some countries have different recommendations for men and women, e.g. Australia and New Zealand recommend 25g or more for women and 30g or more for men[5]. Many countries base recommendations at a level that equates to 3-4g per MJ which is the reason why men, who generally have higher energy intakes, sometimes have

a higher fibre recommendation than women[5]. In the UK the reference nutrient intake (RNI) for adults is 30g daily based on the AOAC method (which replaced the non-starch polysaccharides method in 2002). The new recommendations released in 2015 were based on the large review of carbohydrates and health commissioned by the Scientific Advisory Committee on Nutrition (SACN) in the UK and increased the fibre recommendation by approximately 25% from 24g (18g of NSP) to 30g. Based on the latest available data from the British National Diet and Nutrition Survey (NDNS) years 7-8, very few adults in the UK meet this recommendation and actual intakes are about two thirds of recommended levels. Mean daily intakes for men and women are 21g and 17g respectively with only 13% of men and 4% of women consuming 30g or more dietary fibre daily[6]. In order to meet the recommended intake it is necessary to eat several portions of fruit, veg, cereals and legumes daily. Some countries such as the US have even less success, with actual intakes at half the recommended intakes. Fibre sources as well as recommendations vary by country. Northern European countries including Germany, Sweden and Denmark (but not the UK) typically have high intakes of cereals such as wholemeal bread while Southern European countries typically consume more fruit[7]. In the UK, vegetable consumption is generally higher than fruit. From the same analysis legume intake was low in all the European countries included except for Spain. Table 2 provides information on fibre content per 100g and by portion of common foods that are major contributors to fibre intake in the UK.

In the UK there is currently no recommended intake for wholegrain foods. Median intake of wholegrain foods such as wholemeal bread is 20g per day but 20% don't consume any wholegrain foods. Given the health benefits there is evidence that this would be beneficial in the UK and it could be based on recommendations that currently exist in other countries. For example, the US Dietary guidelines for Americans recommend a minimum of 3 daily servings of wholegrain foods. One serving is the equivalent to 1 slice of bread or 1 small bowl of cereal or half a cup of brown rice[8].

Table 2: contribution by weight and portion of foods commonly contributing to fibre intake[9]

Food	**AOAC fibre per 100g**	**Portion (g)**	**AOAC fibre per portion (g)**
White bread	2	35	0.7
Brown bread	4.5	35	1.6

Wholemeal bread	7.4	35	2.6
Jacket potato	2.4	200	4.8
Apple	2.0	100	2
Porridge oats	8.2	40	3
Banana	1.9	150	3
Baked beans	4.2	175	7.0
carrots	3.1	80	2.5
cabbage	2.0	80	1.6

112

113 **Mechanisms of fibre in the gut**

114 Fibre has an impact on health via many different mechanisms due to its interaction in many
115 parts of the digestive system including the mouth, stomach, small intestine and large intestine
116 (colon). The three most commonly documented health benefits include 1) colonic function
117 with reductions in transit time, increase in stool bulk and colonic fermentation (production of
118 short chain fatty acids; 2) reductions in blood cholesterol and 3) reductions in blood
119 glucose[(5)]. Additional published research has reported other mechanisms including improved
120 gut microbiota[(10)] and reduced blood pressure[(11)]. Brief descriptions of these are given with
121 references that provide further details if required. Reduced transit time and increased stool
122 bulk is mainly effected by insoluble fibres such as cellulose and hemicellulose as well as
123 psyllium. Diets high in legumes and wholegrain are particularly effective in reducing gut
124 transit time. The beneficial effects of fibre on cholesterol are well documented. Research into
125 the effect of beta-glucans is the most extensive and a minimum of 3g dose is recommended
126 for a health benefit [(12)]. In the small intestine the beta-glucans increase viscosity and reduce
127 the reabsorption of bile acids which in turn reduce the levels of circulating cholesterol.
128 Pectin, psyllium and guar gum have also been reported to reduce LDL cholesterol albeit with
129 smaller reductions in cholesterol [(12)]. Glucose and insulin responses are also influenced
130 mainly by soluble fibres such as beta-glucans in a similar way. In the small intestine, soluble
131 fibre entraps sugars. The increased viscosity of soluble fibre forms a barrier and leads to
132 slower glucose absorption and inhibits amylase leading to reduced starch digestion and
133 improved insulin sensitivity. Some fibres increase satiety which may lead to weight loss. For
134 example, soluble fibres mix with partially digested food in the stomach which slows down
135 stomach emptying. Beta-Glucans may also release appetite suppressants such as CCK that
136 could play a role in increased satiety. There is evidence that some types of soluble fibre lower

blood pressure. This may occur through the same pathway as the reduction in absorption of sugars; as insulinaemia can lead to endothelial dysfunction and hypertension [11; 13]. It may also be related to satiety and weight loss which are highly correlated to blood pressure. Higher fibre consumption may reduce inflammatory markers such as C Reactive protein (and increase in anti-inflammatory factors)[14] although the evidence reports that quite large increases are needed to reduce CRP to a useful degree. Although the focus of this paper is cardiovalcular disease, it is important to mention that fermentation by faecal flora to short chain fatty acids (SCFA) in turn dilutes carcinogens, the mechanism most likely to be involved in reducing the risk of cancer of the colon[15] and some fibres may affect oestrogen metabolism inhibiting reabsorption and synthesis that could explain the link between dietary fibre and reductions in breast cancer risk[16]. Less is known about the role of different types of fibre on the gut microbiota, of which bacteria are the main component. Suggested hypotheses include increasing favourable bacteria and modulating gene expression[12; 17].

Epidemiological evidence on dietary fibre and health

Approximately a third of all deaths in the UK are due to cardiovascular disease (CVD)[18] in addition to considerable levels of morbidity. Potentially modifiable markers of higher risk for CVD include type 2 diabetes mellitus (type 2 DM) and its precursors (high blood sugars and low insulin sensitivity), obesity and high blood pressure. This review focuses on the links between fibres and the risk of CVD as well as risk factors. The highest quality study design that minimises potential bias is a randomised controlled trial, although this isn't always possible to conduct. Systematic reviews of trials and prospective cohorts are included here as evidence wherever possible.

The evidence available reports on different types of fibre including total fibre, wholegrain and beta-glucans. The evidence from total fibre is reported first for each risk factor if available, followed by any evidence available on specific fibre types. A systematic review of prospective cohorts investigating the risk of CVD with fibre consumption reported a reduction in CVD risk of 9% (95% CI 6-12%) with 7g higher intake of total fibre[19]. The risk ratio for all of the 10 individual studies was consistently lower than 1 indicating a strong and consistent association. Further analysis of the data using cubic splines indicated that the relative risk was over 1 when total fibre was lower than 18g per day. Increasing fibre well above 30g further reduced the risk ratio but the 95%CI widened due to the data being scarce at this level of fibre intake. The pooled estimates for different types and sources of fibre in

the same review were all consistently below 1 for soluble fibre, insoluble fibre, fibre from cereals, fibre from fruit and fibre from vegetables but the risk ratio reductions were not all statistically significant. The number of studies was greatly reduced to 3-5 studies for each fibre type which may mean that power was substantially reduced or it may indicate that not all types of fibre are protective to the same extent. Results for coronary heart disease (CHD are similar[19]. A separate review on associations between fibre consumption and first stroke[20] also indicate that total fibre is protective although it is not clear whether certain types of fibre are driving this relationship.

There is also evidence that total fibre reduces the risk of type 2 diabetes by 6% per 7g of fibre[21]. Wholegrain foods may be particularly protective for type 2 diabetes. The pooled estimate indicates that risk of type 2 diabetes is reduced by 32% (95% CI 19-42%) per three servings of wholegrain. If one serving of wholegrain reduces risk by 1/3 of this amount, each slice of wholemeal bread (equivalent to one serving) reduces risk by 10%[22]. Certain types of fibre may also have an effect on blood pressure in healthy individuals that are not hypertensive. A systematic review of trials investigating the effects of seven different fibre types found that diets rich in beta-glucans, with a median difference of 4g of beta-glucan between control and intervention groups, reduced blood pressure by 2.9mmol Hg (95% CI 0.9 to 4.9) for SBP and by 1.5mm Hg (95% CI 0.2 to 2.7) for DBP. The effects may be stronger for individuals who are already hypertensive [13]. Beta-glucans also appear to play a role in reducing LDL cholesterol in healthy and hypercholesteraemic individuals. A review of trials reported a reduction of 0.15mmol (95%CI 0.09-0.21) in unclassified participants and a reduction of 0.20mmol (95% CI 0.13 – 0.26) in participants with hypercholesterolaemia. These trials reported a similar median difference of 3.5g of beta glucans. This is the equivalent to a bowl of oat based cereal such as porridge combined with an oat containing snack such as a cereal bar.

Increasing consumption of fibre

There is a general consensus that a healthy diet is high in plant foods such as fruits and vegetables and wholegrain foods with moderate amounts of protein and dairy foods and a small amount of foods and drinks high in fats and sugars but few populations are anywhere close to an optimal diet. A large review of the global effect of diet reported that non-optimal intakes of whole grains, fruits and sodium accounted for half of deaths and two thirds of disability adjusted life years (DALYs) related to diet[23]. A focus on policies related to fibre

and whole grains is therefore highly recommended. The UK, compared to many European countries, has low intakes of fibre from cereals although fibre intake from vegetables is higher than average.

Changing dietary behaviour is difficult and complex. Despite many people being aware of what constitutes a healthy diet, diet quality is generally poor in the UK[24]. This is particularly true of young people and British adolescents are reported to have some of the worst diets in Europe[25]. The British Nutrition Foundation (BNF) has designed a week's menu of meals and snacks that meet the SACN recommendations of 5% free sugars and 30g of fibre. It is a long way from what most people normally eat consisting of mainly high fibre cereal foods with few puddings, cakes, biscuits, confectionery or sugary drinks. Public Health England has initiated a range of strategies to reduce free sugars, particularly sugary drinks since the recommendations were updated in 2015. The sugar reduction plan incorporates the existing childhood obesity plan and the calorie reduction plan[26], both of which are in the process of being evaluated with the first year progress report for sugar reduction published in 2018[27] and the second year progress report due in 2019. However, less attention has been paid to increasing fibre since the recommendations were introduced in 2015. It is not clear whether the priority areas identified by PHE for reducing free sugars[28] will have any impact on fibre consumption. One reason for less focus on fibre could be the lack of any food based guidelines. Some countries, for example the US have a wholegrain recommendation of 3 portions of wholegrain foods per day. According to the dietary guidelines for Americans, at least half of grains should come from whole grains[29]. One portion is one slice of wholemeal bread, 1 tablespoon oats or 3 tablespoons of wholegrain cereal. The definition of what can be included as a wholegrain food is not easily defined and has been formally discussed by a roundtable of European and American experts in 2012[30]. The expert panel recommended that a food providing at least 8 g of whole grains/30-g serving be defined as a whole-grain food. This is a lower proportion (around 27% wholegrain) than previously put forward in the UK where at least 51% (equivalent to about 16g per portion) was recommended[31]. Seal et al strongly encourage a unified global approach[32] to enable manufacturers and health promoters to provide clear and consistent advice. For now there is no immediate plan to introduce a recommendation for daily consumption of whole grain foods in the UK.

Rather than focussing on fibre alone it may be the case that fibre, or certain types of fibre, are contributing to an overall healthy dietary pattern that is more strongly associated with health benefits than fibre alone. Assessing the glycaemic index and glycaemic load are ways of

measuring the burden on the glycaemic response after eating and are affected by soluble fibre in particular. However, the associations with metabolic disease do not appear to be stronger with measures of glycaemic index/load than with fibre. For example, the association of beta-glucans and blood pressure were broadly similar to the association of glycaemic index with blood pressure[33] and heart disease risk[34] when comparing pooled estimates of meta-analyses. Perhaps this is the case because sources of fibre are also sources of carbohydrates which by definition increase the glycaemic response. It is beneficial to ensure that important sources of fibre have as low a glycaemic response as possible and this may be influenced by different factors. It may be possible to improve the glycaemic response for different cereals. For example, oat flakes give a much lower secretion of glucose dependent insulinotropic peptide (GIP) than oat flour[35] providing a rationale for processing and milling oats and other cereals to give as large a surface area as possible. Other measures of diet quality are the Mediterranean diet and the Nordic diet. These are both high in fibre and both associated with positive health outcomes including blood lipids, blood pressure and insulin sensitivity[36; 37; 38].

Currently in the UK the recommendation to increase fibre is based on total fibre (in addition to the 5 a day fruit and vegetable policy). Policy areas that could improve fibre intake include improved labelling and education, social marketing based on fibre, increased marketing of wholegrain foods and fruits and vegetables and increased availability of wholegrain foods and fruits and vegetables.

The agreement to use AOAC for food labelling in the UK helped to provide clarity and consistency and enable comparisons with food packaging produced in other countries. European Commission rules state that foods containing at least 3g of fibre/100g can be labelled as a source of fibre and foods containing at least 6g of fibre/100g can be labelled as high in fibre[39]. However, information on the fibre content of foods is not as accessible as information on other nutrients such as saturated fat and sugar. There is usually nothing on the front of pack food label to indicate how much fibre is in the food. The front of pack traffic light label includes details on energy, total fat, saturated fat, total sugar and salt. Given the wealth of evidence on the health benefits of fibre, wholegrain and fruits and vegetables updates of the traffic light system could consider the inclusion of fibre. This would necessitate losing one of the existing nutrients. On balance, the existing evidence on associations with health is weakest for total fat as high intakes of poly-unsaturated fat such as olive oil as part of the Mediterranean diet are associated with positive health outcomes[40].

Social marketing as part of the Change 4 Life Campaign also has a role to play in raising awareness of the benefits of high fibre diets. To date, there is little information on fibre on the website or in the advertising campaign[41]. Providing consistent information in different formats to raise awareness and change attitudes is known to be effective in improving public health behaviours[42]. Evaluations should always be carried out to ensure that interventions do not widen inequalities, a common problem with interventions relying on interest in health, levels of education and ability to pay[43].

Reformulation of foods has successfully improved the quality of food sold in the UK in terms of salt[44] and trans fats[45]. A particular marker of success is the reduction in inequalities in trans fats consumption in the UK[45]. The new recommendations for fibre have motivated and challenged the food industry to improve foods in terms of fibre content in an attempt to reduce the 12g gap between current and recommended intakes. The Institute of Grocery Distribution (IGD) have produced a free guide for nutritionists and food scientists working in industry to help increase fibre content in a range of foods[46]. Their fibre working group recommends holistic reformulation so that the whole food is taken into account not just specific nutrients to ensure that improvement of one nutrient does not come at the detriment of another – e.g. free sugars or energy. Inevitably some foods are high in both types of nutrients. Flapjack is an obvious example as it is high in both fibre and saturated fats and sugars. Are we able to say that the positive health benefits of the fibre outweigh the negative effects of the saturated fats and sugars? This is very difficult to achieve at the individual food level. IGD encourages reformulation to increase fibre for a number of reasons not solely due to the recommendations. As a result of public consultation they recommend higher fibre for health benefits, to enable health claims to be made, to respond to consumer demand and to be more in line with the values of certain customer groups. The growth in avocados and chia seeds are cited as examples of high growth areas in the interactive guide. Currently, availability of wholegrain versions of popular flour based foods such as pastries and cakes, either in supermarkets or outside the home in cafes is very low and they are rarely available. This may be because despite recipes using wholemeal flour improving texture and taste in baked products, wholegrain foods have a reputation for being dry and boring[47]. More positive marketing is needed to encourage a cultural shift in attitudes. A comprehensive range of strategies are needed to encourage people to consume healthier diets not just a focus on negative aspects of diets such as fats and sugars[23] Introducing a wide range of different policies and actions also has the added benefit of reducing the risk of widening inequalities in

diet and health[48]. The shift in focus by public health nutritionists to reduce sugary foods and drinks as well as fats rather than encouraging healthier foods may have come at the expense of policies promoting higher intakes of healthy foods including those rich in fibre.

Conclusions

In summary, high intakes of fibre are associated with a wide range of health outcomes including type 2 diabetes and cardio-vascular health. However, despite increases in the recommended values for fibre released in 2015 most of the UK population consume considerably less than the 30g of fibre recommended daily. Action is needed from a range of stakeholders including the food industry, supermarkets, restaurants, public health nutritionists and government to ensure improvements in information and labelling, availability and popularity of high fibre diets. Furthermore, evaluation of interventions and programmes at regional or national level are needed to ensure the needs of different groups are met but particularly to ensure that interventions do not widen inequalities in diet and health. New food based policies such as recommended daily portions of wholegrain foods could be considered in the future and are likely to improve population health.

Acknowledgements

I would like to mention my colleagues at the University of Leeds who have provided information and inspiration. These are Professor Janet Cade, Dr Darren Greenwood, Dr Victoria Burley and Professor Alan Mackie.

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