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A place for dietary fibre in the management of the metabolic syndrome

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Purpose of review

To control the global increase of obesity and associated-metabolic syndrome, nutritional advice remains an important objective. This review discusses factors that may explain how dietary fibre would be helpful in the management of food intake, body weight and metabolic syndrome.

Recent findings

Dietary fibre could play a role in the management of the metabolic syndrome through its ability to control body weight evolution through its effect on satiety; to modulate glucose homeostasis/insulin sensitivity and to positively affect factors implicated in cardiovascular diseases. The relevance and the relative importance of these effects in control of metabolic syndrome remain unknown. Recent experimental data suggest that the modification of gut peptides – involved in appetite and glucose homeostasis – could constitute a 'metabolic relay' allowing specific (fermentable) dietary fibre to act on appetite and other components of the metabolic syndrome.

Summary

Dietary fibre intake may modulate parameters associated with the control of the metabolic syndrome, namely food intake (and body weight), glycemia and insulinemia, blood lipids and blood pressure. The efficacy of dietary fibre differs according to their dietary sources (fruits, legumes or cereals), but also to their specific chemical structure, responsible for their physical properties (i.e. gel forming capacity) or for their fermentation capacity in the lower part of the gut. The fermentability of dietary fibre seems important to generate specific effects on satiety and glycemia through the release of gut peptides such as glucagon-like peptide-1.

Keywords

body weight, dietary fibre, food intake, metabolic syndrome

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Abbreviations

CVD	cardiovascular disease
GLP-1	glucagon-like peptide-1 (7–36) amide
HOMA-IR	homeostasis model assessment of insulin resistance

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Introduction

There is at present an intense debate among nutritionists and scientists regarding the best way to prevent or manage the metabolic syndrome. This syndrome refers to a cluster of abnormalities together with insulin resistance. The constellation of metabolic abnormalities include glucose intolerance, insulin resistance, central adiposity, mild dyslipidemia and hypertension [1,2••]. The cause of this syndrome is largely unknown, but involves complex interactions between genetic, metabolic, and environmental factors, including diet [3,4]. Persons with the metabolic syndrome should adhere, among the set of dietary principles, to an increased dietary intake of fruits, vegetables and whole grains, which are considered as an important source of dietary fibre [5]. Dietary fibres would appear to be of particular interest with regard to their putative role in the management of the metabolic syndrome, by modulating food intake, body weight, glucose homeostasis, plasma lipid profile and associated risk factors for cardiovascular disease [6••]. Nevertheless, traditional diets, which are known to be high in fibre, are also low in fat content, thus making difficult the interpretation of the relative contribution of high dietary fibre and low dietary fat intake in their documented protective effect [7]. The aim of this review is to highlight the different ways by which dietary fibre might be implicated in the complex management of the metabolic syndrome, specifically in body weight, food intake, diabetes and cardiovascular disease.

Dietary fibre and body weight management: epidemiological data

At the outset, it is crucial to bear in mind that the definition of dietary fiber is rather complex and in constant evolution [8]. Dietary fibres are the edible constituents of plants foods (or analogous carbohydrates) that escape digestion in the upper intestine and which undergo complete or partial fermentation in the large intestine; it has been suggested that dietary fibre components include non-starch polysaccharides, lignin, non-digestible oligosaccharides, resistant starch and associated plant substances [9]. Epidemiological or cross-sectional observational studies claim that fibre intake is inversely correlated with body weight. In a recent prospective cohort study, the association between changes in whole-grain intake and weight gain over a period of 8 years was shown in 27 082 men aged 40–75 years [10•]. In multivariate analyses, an increase in whole-grain consumption was inversely associated with long-term weight gain. Interestingly, the authors examined the relationship between cereal, fruit, and vegetable fibre and weight change and, after simultaneous adjustment for each three sources of fibre, found significant inverse associations for cereal and fruit fibre, but not for vegetable fibre. In addition, the dose response relation was greater for fruit fibre. For every 20 g/day increment in fruit fibre; weight gain was reduced by 2.51 kg as compared with a body weight reduction of only 0.81 kg for a similar increment in cereal fibre intake [10•]. These findings are in line with those of another prospective cohort study of 74 091 US women (Nurses' Health Study) aged 38–63 years and followed over 12 years, which documented that women who consumed more whole grains consistently weighed less than those who consumed less whole grains or refined grains [11]. Over the 12-year follow-up period, the body weight gain was an average of 1.52 kg in women with the greatest increase in dietary fibre intake (median intake 42.4 g/day). Moreover, compared with women who were in the lowest quintile of fibre intake (median intake 3.5 g/day), women who increased their intake in dietary fibre to the highest quintile reduced their risk of major weight gain by 49%, thus underscoring the potential importance of increasing the intake of dietary fibre to control body weight.

The independent effect of bran, germ and different types of fibre, such as non-digestible oligosaccharides, on body weight is not known and should be further investigated.

Dietary fibre and food intake

Three decades ago, it was proposed that fibre acts as a physiological modulator of energy intake by different mechanisms, which include displacement of available energy and nutrients from the diet; increase in chewing, which limits food intake by promoting saliva and gastric juice secretion resulting in increased satiety and decrease in the absorption efficiency of the intestine [12]. More recent evidence indicates that dietary fibre may also have an effect on satiation (sensation of fullness during an eating period, leading to the cessation of eating) or satiety (sensation of fullness between eating episodes that tends to inhibit the resumption of eating) [13]. An increase in satiety after the consumption of meals rich in dietary fibre, is followed by a decrease in subsequent hunger. In ad-libitum studies on energy intake, a mean loss of weight of approximately 1.9 kg was observed, which may be due to the 10% lower energy intake induced by 14 g/day of additional fibre intake in the diet [14]. This effect of dietary fibre was more pronounced in obese participants [14]. Pereira and Ludwig [15] reviewed 27 studies performed between 1984 and 2000 and found that, in 17 studies, dietary fibre intake was associated with a beneficial effect on energy intake reduction, with seven studies having reported mixed effects and three reporting no effect of dietary fibre on satiety [15]. The type of fibre, the dose, the time of administration, the participant characteristics (healthy or obese), as well as the method of satiety assessment, are important confounding parameters which make the interpretation of the data on the modulation of food intake by dietary fibre intake difficult.

The mechanisms by which dietary fibre intake modulates food intake and body weight are multiple and interesting [16••]. Satiation may be mediated through the intrinsic properties of dietary fibre-containing foods, such as a decrease in energy density, a prolonged chewing and mastication period, or through its gelling properties in the stomach. Comparative studies on the influence of alginate and guar gum on stomach content in human volunteers have shown that dietary fibre forming gels, when they come in contact with acids, increase the sensation of fullness, a phenomenon merely due to the distension of the gastric antrum and may occur without any effect on gastric emptying [17•]. A delayed gastric emptying is proposed, however, as a mechanism explaining the satiating effect of several dietary fibres [16••].

Satiation and satiety are under neuronal and hormonal control [18•]. Recent evidence has improved our understanding of the relationship between events occurring in the gut and the central effect of gastrointestinal peptides involved in the control of food intake [19•]. In this regard, scanty but promising experimental evidence is available on the release of anorexigenic and orexigenic peptides in the lower part of the gut by fermentable dietary fibre. For instance, the reduction of food/energy intake by dietary fibre has been observed in several rat models (lean rats or mice, Obese Zucker fa/fa rats, high-fat diet-induced obese mice) in which inulin-type fructans fibre, an extensively fermented fibre in the caeco-colon, were added in the diet. This decrease in food/energy intake was not observed when fructans were substituted by non-fermentable dietary fibre (microcrystalline cellulose) [20]. The 'satietogenic' effect of fructans was associated with a significant increase in plasma anorexigenic gut-derived peptides, PYY and glucagon-like peptide-1 (7–36) amide (GLP-1) as well as to a reduction in serum ghrelin levels [21]. GLP-1 is not only involved in the control of appetite, food intake, and body weight gain, but it also improves glucose homeostasis, and it is therefore considered as an interesting target in the treatment of the metabolic syndrome [22]. A recent study [23] showed that dietary fructans (3 x 6.6 g oligofructose/day for 7 days) was able to increase serum GLP-1 level in patients with gastric reflux. Another study [24] reported that the addition of inulin as a fat replacer in a breakfast meal was able to increase satiety and to lower energy intake the following day. In humans, the influence of dietary fibre on GLP-1 release has, however, not been extensively studied. An increase in post-prandial response of GLP-1 was observed after ingestion of β-glucan-rich rye bread by healthy subjects [25]. The administration of guar gum (together with galactose) promoted the increase in GLP-1 in women (not in men), and this was related to a significant increase in satiety [26•]. Concerning the type of fibres, the available experimental evidence is generally supportive of fermentable fibres enhancing satiety to a larger extent than non-fermentable dietary fibres with attendant greater reductions in energy intake. In a pilot study, however, which compared both fermentable (pectin, β-glucan) and non-fermentable (methylcellulose) dietary fibre added as a supplement (about 27 g/day) in the diet of human volunteers for a 3-week period, methylcellulose was shown to be more satiating than the fermentable fibres [27].

Dietary fibres, insulin resistance, and diabetes

The glycemic index of foods is now considered to be an important feature in the development of insulin resistance as determined by the homeostasis model assessment of insulin resistance (HOMA-IR). After adjustment for potential confounding variables, total but also fruit and cereal dietary fibre intakes were inversely associated with HOMA-IR in the Framingham Offspring Study [28•].

A recent review [6••] highlighted the complexity of the influence of dietary fibre on glycemia and diabetes control. Epidemiological studies support the concept that a high intake of whole grains (three servings per day) protects against the development of type 2 diabetes mellitus. An improvement of glycemic control has been shown for grain foods, legumes, vegetables and fruit, but this effect may not be attributed conclusively to the presence of one specific type of dietary fibre (soluble dietary fibre) only. The maintenance of the intact structure of dietary fibre in food products, which is known to be modified by processing or food preparation methods has been proposed as an important factor allowing the control of glycemia. Future studies therefore on GLP-1 synthesis in relation to dietary fibre would be of great interest in glucose homeostasis and risk for diabetes [29].

Dietary fibres and cardiovascular diseases

The role of dietary fibre in the prevention of cardiovascular diseases (CVDs) has received renewed and increasing attention in recent years. Pereira *et al.* [30] performed a pooled analysis of cohort studies investigating the link between dietary fibre and the risk of CVD. They analysed the original data from 10 prospective cohort studies from the United States and Europe and estimated the association between dietary fibre intake and the risk of CVD. After adjustment for demographics, body mass index, and lifestyle factors, each 10 g/day increment of energy-adjusted and measurement error-corrected total dietary fibre was associated with a 14% decrease in the risk of all coronary events and a 27% decrease in the risk of coronary death. Other evidence indicates that eating whole grain cereals, fruits and vegetables, significantly lowers the prevalence of important risk factors for CVD, including hypertension and obesity [31,32].

Although several causative factors for CVD have been considered, the mechanisms by which dietary fibre may exert beneficial cardiovascular protection are not fully elucidated. Recent evidence indicates that inflammation may be an important mediator in the association of CVD and dietary fibre intake [33••]. King *et al.* [34] reported that C-reactive protein (CRP) a clinical indicator of inflammation, is associated with CRP intake. The likelihood of having elevated CRP in the highest dietary fibre intake group was significantly lower than that in the lowest dietary fibre intake group, which suggests that dietary fibre may help control the inflammatory process associated with CVD.

Dietary fibre intake from a variety of sources has been associated with a significantly decreased risk of CVD. For example, in the Nurses Health Study, women in the highest quintile of dietary fibre intake (median 22.9 g/day) had an adjusted 47% lower relative risk for major coronary events than in the lowest quintile (median 11.5 g/day) [35]. Furthermore, hypertension is a criterion in the diagnosis of the metabolic syndrome. Different trials have examined the effect of dietary fibre supplementation on blood pressure. Two meta-analyses on the published randomized placebo-controlled trials of the last decades were recently published [36•,37•]. In summary, a significant change in both systolic and diastolic blood pressure has been documented mainly in hypertensive and older (>40 years) populations with fibre supplementation of about 10 g per day [36•]. The duration of intervention was also an important criterion for a beneficial effect (more than 8 weeks of dietary fibre supplementation was required) [37•]. Other recent data have also confirmed a dietary fibre induced decrease in blood pressure, and support the concept that a dietary fibre-enriched diet (about 10 g dietary fibre as oat bran in supplement for 12 weeks) led to a significant change in systolic (−1.8 mmHg; −4.3 to 0.8) and diastolic blood pressure (−1.2 mmHg; −3.0 to 0.5) [38•].

The influence of dietary fibre on blood lipids, an important risk factor for CVD, has been extensively documented and will not be referred to in this review. Suffice to mention that a recent intervention study [39•] documented that a modest increase in dietary fibre consumption in healthy participants (from 1.97 g/day to 4.11 g/day) for 3 months was sufficient to decrease LDL cholesterol (and blood glucose): effects which may be mediated independently of body weight regulation [39•].

Conclusion

Past and recent epidemiological and prospective studies corroborate the putative role of dietary fibre in the management of the metabolic syndrome. Only few studies, however, have considered the combined effect of all the components of the metabolic syndrome. The Framingham Offspring Study reported that the prevalence of the metabolic syndrome – as defined by the National Cholesterol Education Program criteria – was improved by high cereal fibre intake (contributing to the beneficial effect of whole grain), but not by fruit or vegetable dietary fibre [28•]. Specific types of dietary fibre [40•] in the diet may have significant beneficial effects on weight loss, due to a reduction of food intake, improved cholesterol level, glucose and insulin response, and blood pressure. At present, there is no clear answer to the question on the effect of the type of dietary fibre (soluble versus insoluble, with or without gelling properties, from cereals, fruit or vegetables) may have on food intake, or metabolism. The better understanding of the biochemical mechanisms by which dietary fibre may modulate satiety, glucose or lipid metabolism and hypertension is essential for rational nutritional advice regarding the cluster of disorders which characterize the metabolic syndrome. In this context, the modulation of gastrointestinal peptides by (perhaps fermentable) dietary fibre would undoubtedly be an interesting and promising area of further research, which would elucidate how events occurring in the gut regulate food intake, obesity and associated disorders.

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