Cereal grains, legumes, and weight management: a comprehensive review of the scientific evidence

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There is strong evidence that a diet high in whole grains is associated with lower body mass index, smaller waist circumference, and reduced risk of being overweight; that a diet high in whole grains and legumes can help reduce weight gain; and that significant weight loss is achievable with energy-controlled diets that are high in cereals and legumes. There is weak evidence that high intakes of refined grains may cause small increases in waist circumference in women. There is no evidence that low-carbohydrate diets that restrict cereal intakes offer long-term advantages for sustained weight loss. There is insufficient evidence to make clear conclusions about the protective effect of legumes on weight.

INTRODUCTION

Overweight and obesity are key features of the metabolic syndrome and prevention of excessive weight gain is a health priority internationally. Increased consumption of whole-grain foods, like cereals and legumes, may protect against obesity, but concern has been expressed that refined-grain intake may directly contribute to increases in obesity. It has been noted that high levels of carbohydrate consumption, especially from high-glycemic-index cereals, is a relatively recent phenomenon in evolutionary terms and attention has been drawn to the correlation between consumption of refined carbohydrate and the increasing prevalence of obesity.

Cereal grains are generally an excellent source of carbohydrate, dietary fiber, and protein and are a good source of many B-group vitamins, vitamin E, and a number of minerals, especially iron, zinc, magnesium, and phosphorus. In many countries national dietary guidelines recommend plentiful consumption of grain foods as the basis of a healthy diet and emphasis has increasingly been placed on increasing consumption of whole grains. One of the key recommendations of the 2005 US Dietary Guidelines is "consume three or more ounce-equivalents of whole-grain products per day, with the rest of the recommended grains coming from enriched or whole-grain products. In general, at least half the grains should come from whole grains".

From a consumer point of view, one of the most commonly held popular beliefs about diet is that grains, and the carbohydrates they contain, provide excess energy to the body and are therefore "fattening". At the same time, one of the key benefits that consumers recognize from eating a plant-based diet is the ability to help control body weight. Therefore, there is a need to assess the evidence about the role of grains in the prevention and management of overweight and obesity, to ensure health messages are evidence-based and consistent with the best research available.

EVIDENCE BASE

While there is strong epidemiological evidence for a beneficial effect of whole grain and legume consumption on the risk for many chronic diseases, especially cardiovascular disease and diabetes, such evidence does not usually explain the mechanisms of action or necessarily give sufficient guidance to base quantitative or qualitative recommendations. In the case of grain foods it is unclear to what extent the fiber content, glycemic index, nutrient density, or other features (such as impact on gut flora) of the foods are the main causes of these health effects.
Studies that have directly examined the relationship of grain intake to obesity are quite sparse. They fall into the following three main categories: 1) cross-sectional epidemiological studies noting associations between measures of overweight and obesity with either dietary patterns that are higher in grain foods, or actual measures of particular foods; 2) prospective studies that have measured changes in weight over time and examined associations among rates of weight change and diet patterns; and 3) experimental clinical studies in which the intake of grain foods is manipulated.

From an experimental approach, clinical trials are the gold standard for establishing cause and effect relationships that have been potentially identified in epidemiological studies. However, studies that aim to change one of the major components of a diet, like grains, can rarely be conducted in a blind fashion and are always confounded by the inevitable consequent changes to the nutritional profile of the diet as a result: the choice of foods that are replaced can be as important as those that are added. Increasingly, nutrition research is moving toward examination of dietary patterns as a whole, rather than specific foods. The Dietary Approaches to Stop Hypertension (DASH) study\(^8\) and the Lyon Diet Heart Study\(^9\) are examples of this approach. However, even these studies are relatively rare, and very often the best data on which dietary recommendations can be based is still largely epidemiological in nature, i.e., either descriptive cross-sectional studies, or prospective studies examining changes in risk factors over time and correlations with dietary patterns or changes.

Defining the term “whole grain” presents difficulties in terms of analyzing and interpreting all these types of research studies and making dietary recommendations. Several epidemiological studies have defined whole-grain foods as those products that contain \(\geq 25\%\) whole-grain content or bran by weight.\(^{10-12}\) The US Food and Drug Administration (FDA) requires that foods contain \(>51\%\) by weight of whole-grain ingredients in order for health claims to be made.\(^{13}\) However, neither of these definitions takes into account the structure of the grain, and the glycemic index (GI) of whole-grain foods can vary significantly depending on the degree of intactness. The fact that grain structure and GI are rarely considered in epidemiological studies makes interpretation of the scientific literature imprecise.\(^7\)

**LITERATURE SEARCH**

This paper reviews existing research regarding the role of cereal grains and legumes in the prevention or management of overweight and obesity and considers how existing dietary recommendations might be modified to take new information into account. To do this, we carried out a search for original studies and reviews in the following databases: PubMed, Medline, Scopus, Cinhal, and ScienceDirect, for the period 1980–2005. The following search terms were used: cereal, grain, wholegrain, legume, pulse, bread, pasta, rice, wheat, barley, oat, rye, soy, bean, and pea, in conjunction with obesity, overweight, satiety, BMI, and waist. Studies were limited to those that were published in English, conducted in humans, and reported anthropometric outcome measures. The references in identified papers were also examined individually to supplement the electronic search.

A total of 556 abstracts were identified for review. Of these, only 121 were directly relevant to the topic; most of the others were excluded because they did not report original data or because they only examined intermediate markers such as energy intake or satiety hormones, rather than direct measures of overweight and obesity. Relevant studies were assessed for scientific quality using the methods and criteria described by the European Heart Network,\(^{14}\) and studies with a low quality rating were excluded (generally because they lacked control groups or the methods were inadequately described or validated). This left a total of 53 eligible studies included in the final review.

**EPIDEMIOLOGICAL STUDIES**

**Studies of dietary patterns**

Principal component analysis and cluster analysis are two statistical techniques that have become increasingly popular in the examination and description of complex dietary patterns. Eleven published studies were found that reported analysis of dietary intakes that identified patterns with higher consumption of cereals and/or legumes. Only one of these, in a sub-sample of 466 men in the Health Professionals Follow-up Study, found no association between BMI and quintiles of conformance with a prudent diet including higher intakes of whole grains and legumes.\(^{15}\) All the others found such patterns to be associated with lower measures of obesity. The studies include both male and female subjects from a wide range of age groups (8–87 years) and in 12 different countries.

Analysis of the diets of 4999 adults in the Malmo Diet and Cancer Cohort study identified six diet patterns and found that central obesity (waist circumference above reference values of 94 cm in men and 80 cm in women) was least likely to occur in those consuming patterns dominated by fiber-rich bread (OR 0.79 for women and 0.58 men). There was no evidence of increased risk of obesity with diets in which 15–18% of energy was provided by white bread.\(^{16}\) In the UK Women’s Cohort Study with 33,971 adults, seven clusters...
of food consumption were identified, three of which had high cereal levels: health conscious (high bran, wholemeal, and pulses), low diversity vegetarians (high wholemeal bread and pulses), and high diversity vegetarians (high wholemeal bread, cereals, pasta and rice, and pulses). Women with these patterns had significantly lower average BMI values as well as the lowest proportion of obese subjects (5–9% vs. 10–12% in the other four clusters). Another prospective study performed in the United Kingdom (the Isle of Ely study, with 802 adults) identified four diet patterns and found the one with high intakes of rice, pasta, and pulses was negatively correlated with waist-to-hip (WHR) ratio.

In the United States, factor analysis of dietary data from the Baltimore Longitudinal Study of Aging (BLSA) identified six food patterns among 449 adults aged 30–80 years. Subjects consuming a fiber-rich pattern, high in non-white bread, whole grains, beans, and legumes, had the lowest BMI, smallest waist circumference (WC), and the smallest mean annual increase in BMI. In older adults, the same pattern was also found. Cluster analysis of the diets of subjects aged 70–77 years in the cross-sectional SENECA baseline study in Europe and the Framingham Heart Study cohort identified five dietary patterns; the two that were significantly associated with the lowest BMI and WC were those highest in grains and legumes, nuts, and seeds.

The same relationship was found in a longitudinal survey of 8-year-old Australian children; a food pattern with high consumption of cereals and bread was an independent negative predictor of BMI in multivariate models. Another study that has reported a relationship with a prudent diet pattern is from the Danish MONICA surveys, showing that diets with more whole-grain cereals are associated with lower BMI. In Brazil, factor analysis of the diets of 2489 adults identified three patterns, including the traditional diet relying mainly on rice and beans. This pattern was associated with a lower risk of overweight or obesity in logistic models adjusted for dieting, age, physical activity, and energy expenditure (OR 0.87).

A few studies are more difficult to interpret because of the food-group patterns that were identified. One cluster analysis of the diets of 189 US adults aged 66–87 years found a high nutrient-density pattern (with higher intakes of cereal, rice, pasta, and beans) was associated with a lower risk of overweight and excessive WC; but this same pattern also had a lower intake of bread. A study of two other US data sets – from the Geisinger Rural Aging Study (GRAS) and the Boston Area study – also provide some contradictory results. A two-cluster analysis of the GRAS data found individuals in a cluster with more breakfast cereal, but less bread, had a lower mean WC (93.5 cm vs. 97.2 cm; p < 0.05), and participants in the Boston study with a pattern high in breakfast cereals, milk, and fruit had significantly lower BMI (25.9) than those consuming a pattern high in grains, bread and poultry (27.1). The types of breads were not distinguished in these studies.

Because of the different food clusters identified in these studies, and the fact that many do not report details of the amounts of individual foods consumed in each, it is difficult to reach firm conclusions from the results. The great majority of these studies found an association between a prudent dietary pattern with higher levels of cereals and legumes with lower measures of overweight; they therefore support current recommendations to include these foods in a healthy diet. However, these studies do not provide a clear consensus on the role of bread specifically, nor the differing effects of whole-grain versus refined cereals. They also provide no dose-response data about the relationship. Information from cross-sectional studies, with more quantitative estimates of intakes, is needed to address these issues.

**Cross-sectional studies**

Sixteen studies were identified that examined weight status in relation to consumption of particular grain foods. The largest of these was the Iowa Women’s Health Study of 34,942 post-menopausal women, which used the 127-item food frequency questionnaire (FFQ) from the Nurses Health Study and defined whole-grain foods as those with at least 25% whole grain or bran by weight. At baseline and in follow-up surveys, higher grain intake was associated with lower BMI and WC. Higher refined-grain intake (median 30 servings per week) was associated with a slightly higher WHR (0.836 vs. 0.842 in quintiles 1 and 5, respectively), but there was no significant association with BMI.

From diet recalls collected from 9323 participants in the USDA’s 1994–1996 Continuing Survey of Food Intakes by Individuals, it was reported that those consuming whole-grain food were less likely to be overweight: only 7% of people consuming at least three servings per day of whole-grain foods had a BMI above 25, compared to 69% of non-consumers. The same result was found in a survey of 285 13-year-olds in the US state of Minnesota. Analysis of tertiles of whole-grain intake found significant inverse associations with BMI (Q3: 21.9 vs. Q1: 23.8; p = 0.05) and WC (76.8 vs. 81.4; p = 0.02) after adjustment for age, sex, and race.

Some studies have reported no adverse relationship with refined-grain intake. A cross-sectional study with data from the Framingham Offspring Study found subjects in the upper quintile of whole-grain intake (20.5 servings per week) had lower BMI and WHR, whereas no association was found with refined-grain intake, up to a
median of 38.9 servings per week in the highest quintile.\textsuperscript{12} In results from the 1998–1999 Portuguese National Health Survey, with over 39,000 individual dietary interviews, logistic regression analysis showed bread consumption (which is traditionally mostly refined) was not related to the risk of BMI > 30, while consumption of starchy foods (rice/pasta/potatoes) was protective ($p < 0.001$).\textsuperscript{29}

A cross-sectional study of 827 adults in Tehran, Iran, examined quartiles of intake of whole- and refined-grain foods and reported multivariate adjusted odds ratios for obesity and abdominal adiposity.\textsuperscript{30} There was no relationship between consumption of either grain type and obesity, but the odds ratio of WC above the recommended limits was 0.90 in the highest quartile of whole-grain intake ($p$ for trend < 0.04). The relationship with refined-grain intake was not significant. In a larger sample from the same study, there was also no relationship between energy intake from carbohydrate and BMI.\textsuperscript{31}

Baseline data from 13,064 adults in the prospective ARIC study of cardiovascular disease, found that white Americans in the highest quintile for cereal fiber intake (5.1 g/d) had a slightly but significantly lower BMI of 26.4 compared with 26.8 for those in the lowest quintile of cereal fiber intake (2.7 g/d).\textsuperscript{32} However, in the African American cohort, those in the highest quintile for cereal fiber intake had a higher BMI than those in the lowest quintile 29.3 vs. 28.7. Similar trends were found for legume fiber. Only one other study has provided data on legume intake. In a study of 9984 adults in Tehran, Iran, the risk of being centrally obese was significantly lower in men in the fourth quartile of legume intake (30 g/d) than in other quartiles, but this relationship was not found in women.\textsuperscript{33}

Most of these studies have examined intakes of cereal or legume foods in general rather than specific types. Six studies have examined the relationship between breakfast cereal consumption and obesity. The largest of these is based on data from 17,881 men in the Physicians Health Study.\textsuperscript{34} At baseline, men in the lowest category for breakfast cereal consumption were significantly heavier than those in the highest category (BMI 24.8 vs. 24.1; $p < 0.0001$). At the 8-year follow-up, men with higher intake of cereals, regardless of grain type, had a significantly lower weight gain, and at 13 years, those who consumed at least one serving of whole-grain cereal daily had a significantly lower weight gain than those who rarely or never ate whole-grain cereals (2.28 kg compared with 1.87 kg; $p < 0.05$).

NHANES survey data from 4218 adults in 1999–2000 also shows that consumers of ready-to-eat breakfast cereal (RTEC) ate significantly less fat and more fiber ($p < 0.001$) than non-RTEC consumers for both men and women.\textsuperscript{35} There was a significantly lower prevalence of BMI > 25 among the female RTEC breakfast eaters (OR = 0.7) and linear regression analyses indicated an inverse association between RTEC consumption and BMI in women, but not in men.

In the National Heart, Lung and Blood Institute Growth and Health Study of 2379 girls aged between 9 and 19 years, after adjusting for energy intake, mean days of eating breakfast cereal (of any kind) was negatively correlated with BMI and risk of being overweight.\textsuperscript{36} Younger children show the same relationship. A cross-sectional survey of 603 American children aged 6–12 years also found a statistically significant inverse relationship between BMI and frequency of eating RTEC.\textsuperscript{37} Only 16% of 7–9-year-old children who ate > 8 servings for 14 days were overweight, compared to 50% of those who ate ≤ 3 servings ($p < 0.01$).

Similar relationships have been found in European populations. In Cretan adolescents frequency of RTEC intake was associated with significantly lower BMI and WC.\textsuperscript{38} In Spanish schoolchildren, it was found that overweight subjects, particularly females, omitted breakfast more frequently and took smaller quantities of cereals than did normal-weight subjects.\textsuperscript{39}

Many of these cross-sectional studies have limitations based on the use of food-frequency questionnaires that sometimes make it difficult to clearly separate whole- and refined-grain foods. For example, the standard 127-item FFQ from the Nurses Health Study includes amongst whole-grain foods some lower-fiber foods such as popcorn, couscous, and breakfast cereals with 25% whole-grain content. This may underestimate the protective effects of whole-grain foods that meet the FDA definition of more than 50% by weight. Despite this limitation, these cross-sectional studies are quite consistent in demonstrating that higher intakes of whole-grain cereals and legumes are associated with lower BMI, WC, and risk of overweight. While one major study showed a slightly higher WHR (but not BMI) with higher consumption of refined grains, three other studies did not support that finding.

**Longitudinal studies of weight change**

Examining how food intakes are associated with changes in body weight may provide even better information on which to base recommendations. It is recognized that, for many people, returning from overweight to normal weight is difficult to achieve, and in some countries dietary recommendations now put priority on minimizing further weight gain rather than losing weight.\textsuperscript{40} Table 1 summarizes the eight studies of this kind that were identified.
Table 1  Prospective observational studies investigating the effect of cereals or legumes on changes in weight or waist circumference.

<table>
<thead>
<tr>
<th>Author</th>
<th>Subjects</th>
<th>Study design</th>
<th>Outcomes measured</th>
<th>Key results</th>
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</thead>
<tbody>
<tr>
<td>Stamler and Dolecek (1997)²⁴</td>
<td>12,569 males in the Multiple Risk Factor Intervention Trial (baseline mean BMI 27.7)</td>
<td>Weight and BMI measured annually for 6 years comparing a special intervention (SI) group with usual care (UC). The SI group was initially counseled in 10 weekly group sessions to modify diets to reduce total and saturated fat, cholesterol, and alcohol and to increase polyunsaturated fats. Regression analyses assessed relations between food group intakes and weight change.</td>
<td>BMI; weight loss</td>
<td>In both groups weight loss was associated with increased or higher percentages of energy from total carbohydrate and fiber intake and, for SI men, higher percentages of energy from starch. Subjects who achieved the greatest weight loss (&gt;6.8 kg) had the highest energy intakes from breads and cereals and the highest 6-year increases in bread and cereals intake (3.5% Δ); those who gained weight had the lowest overall intakes and the smallest increases (p &lt; 0.001).</td>
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<td>Schultz et al (2002)³⁴</td>
<td>11,005 women and 6,646 men in the EPIC-Potsdam cohort (all non-smokers)</td>
<td>Large multicenter European cohort study. Two-year changes in measured weight and diet assessed by FFQ. Differences in mean food group intake across weight changes were tested using ANOVA</td>
<td>Weight change</td>
<td>Among women, large weight loss (&gt;2 kg/y) was significantly predicted by higher intakes of cereals (pasta, rice, breakfast cereals) with an OR of 1.43 (p &lt; 0.05) but was unrelated to bread or legume intake. Among men, there were no significant associations</td>
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<td>Li et al (2003)⁵⁶</td>
<td>74,091 females in the Nurses' Health Study</td>
<td>The US cohort has been followed every two years since 1976 using a validated FFQ and self-reported weight. Data is presented from 1984–1996. Multiple regression analysis examined relationships with whole grain and refined grain intake</td>
<td>Weight; BMI; OR of developing BMI ≥ 30</td>
<td>At baseline, the mean weight of women in the highest quintile of whole-grain intake was 0.9 kg less than those in the lowest quintile (p &lt; 0.0001). The OR for developing obesity over 12 years was 0.81 in the highest quintile of whole grains (p = 0.0002) and 1.18 for refined grains (p &lt; 0.0001)</td>
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<td>Koh-Banerjee et al (2004)⁴⁶</td>
<td>27,082 men aged 40–75 years at baseline in the Health Professionals Follow-up Study</td>
<td>Longitudinal prospective study over 8 years (1986–1994). Self-reported weights and validated FFQ administered in 1986, 1990, and 1994. Multivariate linear regression used to examine changes in grain intake and weight</td>
<td>Weight</td>
<td>An increase in WG intake was inversely associated with long-term weight gain (p &lt; 0.001). For every 40 g/d increment in WG, weight gain was reduced by 0.49 kg. Association with WG persisted after accounting for changes in bran and fiber intakes</td>
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<tr>
<td>Newby et al (2003a)⁶⁵</td>
<td>1379 healthy children in North Dakota aged 2–5 years</td>
<td>One-year prospective study with dietary and anthropometric data collected at two visits 6–12 months apart. Linear regression used to examine associations between weight change and food-group intake</td>
<td>Weight; food-group servings</td>
<td>A 0.19 kg lower weight gain per year was observed with each additional serving of breads and grains, including rice, pasta, and breakfast cereals (p &lt; 0.001). Total fat and fiber was not related to weight change</td>
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<td>Newby et al (2003b)³⁶</td>
<td>449 healthy subjects aged 30–80 years in the Baltimore Longitudinal Study of Aging</td>
<td>7-year follow-up from 1984 to 1991. Heights and weights measured bi-annually. Dietary intakes measured with 7-day records at entry. Cluster analysis used to define five dietary patterns</td>
<td>BMI; WC</td>
<td>Mean annual change in WC was more than 3 times as great for subjects in the “white bread” cluster (1.32 cm) as for those in the “healthy” cluster, which included the highest levels of WG cereals and legumes (0.43 cm) (p &lt; 0.05)</td>
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<td>Halkjaer et al (2004)⁶⁵</td>
<td>1,200 women and 1,236 men aged 30–60 years in the MONICA I study in Denmark</td>
<td>Height and weight measured and a 26-item FFQ administered in 1982, 1987, and 1993. Multiple regression analysis examined associations of weight change and intakes of 10 food groups</td>
<td>BMI; WC</td>
<td>A high intake of refined bread was associated with 6-year increase in WC for women, even after adjustment of BMI (r = 0.29; p &lt; 0.05). WG intake was associated (but not significantly) with decreased WC</td>
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<td>Borget al (2004)⁶³</td>
<td>36 obese men 35–50 y in a RCT to reduce weight with a very-low-calorie diet and exercise.</td>
<td>3-month follow-up with dietary assessment by a 4-day food diary and classification of 15 food groups used in counseling, including high-fiber breads (to be increased) and other grain products (to be used moderately)</td>
<td>Weight; Three Factor Eating Questionnaire</td>
<td>Increased consumption of high-fiber bread was one of the best-maintained behavior changes and was correlated with food restraint scores (r = 36; p = 0.03)</td>
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</table>

Abbreviations: BMI, body mass index; FFQ, food frequency questionnaire; OR, odds ratio; RCT, randomized controlled trial; WC, waist circumference; WG, whole grain.
The US Health Professionals Follow-up Study has data on 27,082 males, and multivariate linear regression has examined mean weight changes over 8 years against quintiles of whole-grain intake and various fiber types. A strong dose-response relationship was observed, and for every 40 g/d increment in whole-grain intake from all foods, weight gain was reduced by 0.49 kg. Cereal fiber intake was also inversely associated with weight gain, independent of whole grain (p for trend <0.001). For every 20 g/d increment in cereal fiber, weight gain was reduced by 0.81 kg.

The same relationship was seen in the 6-year follow-up of 12,569 males in the Multiple Factor Risk Intervention Trial. Those subjects who achieved the greatest weight loss (≥15 lb) were those who had the highest intakes of cereals and breads (p = 0.002) and those who made the largest increases in percentage energy contribution from breads and cereals (p < 0.001). There was no relationship with legume intake, but overall intakes were generally very low. These results were supported in a small study of food selection habits by 36 subjects over 2 years following weight loss. Consumption of high-fiber bread was one of the key sustainable changes in food intake amongst those who were successful in maintaining weight loss.

In large studies including women the same pattern has been reported. In a two-year follow-up in the longitudinal EPIC study with 11,005 women, consumption of higher levels of cereals (pasta, breakfast cereals, rice) predicted large weight loss of 2 kg or more (OR 1.43), but neither bread nor legume consumption was related to weight change. A one-year prospective study in 1379 children aged 2–5 years found that bread and cereal consumption, but not fiber, significantly predicted weight loss. There was a 0.16 kg lower weight change per year with each additional daily serving of breads and grains.

While these studies have considered cereals and grains in general, three have separately compared the effects of whole-grain and refined cereals, and in each case refined grains were positively associated with weight increases. In the Nurses Health Study, with 74,091 healthy women, the relationship between changes in grain consumption and development of obesity over 12 years was examined. At baseline, women in the highest quintile of whole-grain consumption weighed approximately 0.9 kg less than those in the lowest quintile. Higher intake of whole grains over the 10 years studied was associated with lower average weight gain in the 2–4-year interval between assessments (mean increase of 1.58 kg in the lowest quintile vs. 1.07 kg in the highest; p < 0.0001). In contrast, higher intakes of refined grains were related to weight gain (0.99 kg vs. 1.65 kg, p < 0.0001).

Two other studies have used food-pattern analysis to provide some evidence on the different effects of whole grains versus refined grains. The BLSA Study followed 449 subjects over seven years and related five dietary patterns to annual changes in BMI and WC. There was a significantly greater annual increase in WC (but not BMI) among subjects on the white bread pattern (with the highest grain intake and 15.8% total energy from white bread), compared with the healthy pattern (with only 3.2% energy from white bread) (1.32 cm vs. 0.43 cm; p < 0.05). An analysis of Danish data from the MONICA study examined associations between baseline food intake and subsequent changes in BMI-adjusted WC over six years. A higher intake of refined bread (white and rye) was associated with WC gain in women (0.29 cm per quintile), but not in men (where there was a non-significant inverse association). There was no association with whole-grain intake.

Even with these prospective studies, their observational nature hampers straightforward interpretation. Because changes are time dependent, we cannot be certain that changes in diet preceded changes in weight. For example, those who had recently gained weight might increase their intake of grain products when following a lower-fat/high-fiber diet to lose weight.

The overall results are therefore somewhat inconsistent. Most studies have found an inverse relationship between whole-grain intake and weight gain, but there is still very limited evidence in relation to legume intake. In a few studies, higher intakes of refined grains appeared to be associated with increases in WC and BMI in women, but the weight changes, though statistically significant, seemed to be relatively minor in absolute terms (<0.7 kg over a 12-year period). Furthermore, no studies were found that examined the association of high and low GI grain consumption with body weight.

**INTERVENTION STUDIES**

While such observational studies are useful, they can only indicate associations between diets and health outcomes, rather than provide evidence of causal relationships. Consumption of cereals or legumes may be a marker for other healthy lifestyle practices such as physical activity, smoking avoidance, and lower fat and alcohol intakes. While good-quality studies attempt to control for some of these factors, they cannot reliably be used to predict outcomes when diet patterns are changed.

A total of 17 intervention studies were found that examined the impact of increased intakes of grains and legumes. Six of these only measured the effects on intermediate measures such as satiety or energy intake; the other 11 directly reported changes in weight or WC and these are summarized in Table 2.

Only a few of these studies reported a better rate of weight loss when the grain intake of the diet was
### Table 2  Intervention studies that have investigated the effect of cereals or legumes on weight or waist circumference.

<table>
<thead>
<tr>
<th>Author et al. (year)</th>
<th>Subjects</th>
<th>Study design</th>
<th>Diet</th>
<th>Outcomes measured</th>
<th>Key results</th>
</tr>
</thead>
</table>
| Melanson et al. (2006) | 54 overweight and obese adults | RCT with two 12-week phases (counseling and monitoring) | 1) 500 kcal hypocaloric plus exercise (avoiding cereals)  
2) Hypocaloric fiber-rich diet with WG plus exercise  
3) Exercise only | Weight and BMI | Hypocaloric diet with cereals resulted in higher fiber intake (27.5 vs. 17.5 g; p < 0.001) than low-cereal diet. Weight loss on WG diet (4.7 kg; p < 0.001) was not different from the diet with less cereal |
| Azadbakht et al. (2005) | 116 overweight men and women | 6-month RCT with 2 intervention diets and one "eat as usual" control | 1) 500 kcal restriction (3 servings WG/d)  
2) 500 kcal restricted DASH diet (4 servings WG)  
3) Exercise only | Weight and WC | Reduced weight (13–16 kg) and WC (5–7 cm) (p < 0.04) in the two intervention diets compared to control |
| McAuley et al. (2005) | 96 overweight insulin-resistant women | RCT with 8-week weight loss and 16-week maintenance phases | High-fat (Atkins) diet; high-protein (Zone) diet; high CHO (at least 6 servings of WG) | BMI and WC | Subjects on the HP and HF diet lost significantly more weight and WC by 24 weeks (6.9 kg/8.8 cm and 7.1 kg/9.8 cm, respectively) compared to those on the HC diet (4.7 kg/6.9 cm); p < 0.01 |
| Waller et al. (2004) | 62 healthy men and women | 4-week RCT | 1 cup of breakfast cereal with milk consumed 90 min after dinner meal | Weight | No significant difference between groups overall, but high-compliance subjects lost more weight (–1.85 kg) than non-compliers (–0.39 kg); p = 0.06 |
| Jimenez-Cruz et al. (2003) | 14 overweight subjects with type 2 diabetes | Randomized 6-week crossover trial | Low- and high-GI diets – low-GI diet was high in WG bread and beans | Weight and BMI | Reduction of BMI by 0.6 and weight (1.5 kg) (p = 0.04) in low-GI period. No change during high-GI period |
| Bylund et al. (2003) | 18 men with prostate cancer | 12-week RCT pilot study with added bread | 700 kcal rye or wheat soft bread and crisp-breads as part of a 35% E fat diet | Weight | Weight decreased significantly in both groups: rye (1.1 kg) and wheat (1.5 kg) |
| Pereira et al. (2002) | 11 diabetic overweight men and women | Randomized controlled crossover trial with food provided for two 6-week periods | WG diet (28 g/d dietary fiber) vs. refined-grain diet (18 g/d fiber); both 54% E CHO | Body weight | No difference in weight between diets; fasting insulin lower on WG and safety higher |
| Matts (2002) | 109 overweight men and women | RCT with 2-week RTEC supplementation phase and 4-week volumetric diet phase, compared to 2 control groups | 1 serving RTEC (either Special K or a variety) with skim milk and one serving of fruit replacing either lunch or dinner | Weight fat mass | Losses of 1.91 kg and 1.37 kg in the two RTEC groups was mostly in fat mass and significantly greater than in control groups (p < 0.05). No change in control groups |
| Saltzman et al. (2001) | 52 healthy men and women, both normal and overweight | 8-month RCT | 2 energy-restricted diets, one with 45 g oats/100 kcal | Weight | Both groups lost weight, but no difference with higher oat content |
| Kirk et al. (2000) | 22 overweight adults | 2 weeks replacing one meal with breakfast cereal, followed by 4 weeks ad lib high-CHO regime | Stage 1: 45 kcal RTEC with skim milk; stage 2: encouraged to use RTEC as snack | Weight | Weight loss of 2 kg (p < 0.001) in intervention phase maintained over 4 weeks of high CHO diet |
| Lean et al. (1997) | 110 overweight women | 6-month RCT outpatients with 12-month follow-up | 1200 kcal high-CHO diet (58% E; 7 servings of bread/d) vs. low-CHO (35% E; 4 servings of bread/d) | BMI and WC | 6-month reductions in BMI (–2.2) and WC (–5.7 cm) on high-CHO diet (p < 0.001); not significantly different to low CHO diet |

**Abbreviations:** BMI, body mass index; CHO, carbohydrate; DASH, Dietary Approaches to Stop Hypertension; HC, high carbohydrate; HF, high fat; HP, high protein; GI, glycemic index; RCT, randomized controlled trial; RTEC, ready-to-eat cereal; WC, waist circumference; WG, whole grain.
increased. One small trial performed in Mexico compared a low- and a high-GI diet, providing 63 g vs. 55 g, respectively, of carbohydrate from cereals and legumes.49 The low-GI diet (high in whole-grain bread and beans, and with less white bread and rice), resulted in improved glycemic control and greater weight loss. Three other studies examined the effect of increasing the RTEC content of the diet, either by replacing one evening meal with a cereal-based meal, or by using RTEC as additional snacks.50–52 All three reported modest but favorable reductions in weight in the RTEC-supplemented diets, but all were relatively short-term studies and long-term outcomes were uncertain. Nonetheless, these findings support those from the National Weight Control Registry that showed regular breakfast consumption and eating a low-fat high-carbohydrate diet are some of the behaviors of successful weight-loss maintainers.53

All of the other studies demonstrated that a diet with high cereal content can support weight control, although most did not find a superior rate of weight loss when compared to diets with lower cereal intake levels. The largest and most recent of these trials compared exercise combined with two 500 kcal hypocaloric diets, where subjects were instructed to either avoid cereals or to eat at least two meals per day containing fiber-rich whole-grain cereals.54 Both diet groups lost more weight than subjects instructed only to exercise, but weight loss between the two diet groups did not differ.

Another RCT, with 116 overweight subjects who were prescribed two 500 kcal-restricted diets, found a significant decrease in both weight and WC in subjects following diets with 7–8 grain servings/day (including 3–4 servings of whole grains), compared to a control diet with only one serving of whole grain per day.55 However, this study did not have an energy-restricted control diet; so, while it can be concluded that weight loss is possible following a diet including a total of 7–8 servings of grains, no conclusions can be drawn about the relative efficacy of this dietary pattern.

One study, comparing high-protein (HP), high-fat (HF), and high-carbohydrate (HC) diets, found that subjects lost significantly more weight on the HP and HF diets, but that the subjects ingesting at least six servings of whole grains per day on the HC diet still achieved significant reductions in weight and waist circumference.56 Another comparison of high and low CHO 1200-kcal diets (including 7 vs. 4 servings of bread per day, respectively) found both led to significant weight loss, and there was no difference in BMI reduction between the two approaches.57

Other studies investigating increases in particular cereals have also been carried out. Supplements of 700 kcal of both rye and wheat bread resulted in similar weight loss in one study,58 but this was a study with cancer patients that was primarily examining outcomes of cell proliferation and plasma lignans, so the relevance to healthy subjects is unclear. An eight-month trial adding oats to energy-restricted diets for overweight healthy men and women found a trend toward reduced hunger in the high-oat-intake group, but no difference in the effects on weight loss.59

A few intervention studies have directly compared the effects of whole grains and refined grains. One examined the different effects of a high whole-grain versus high refined-grain intake (in diets with the same percentage of energy from carbohydrate) on insulin sensitivity in overweight and obese adults.50 The authors found lower fasting insulin levels and higher satiety ratings with the whole-grain-rich diets, but no difference in weight after a six-week period. This finding of increased satiety (and sometimes reduced energy intake) with higher cereal intake has been confirmed in several other studies,61–65 although one study with 10% lupin flour added to bread reported that, although this reduced the GI, it did not affect satiety ratings of the bread or subsequent food intake after consumption at breakfast.56

In summary, there are few well-controlled studies that have specifically examined the effect of higher intakes of cereals and legumes on weight reduction or maintenance in the long term, or compared the effects of refined- and whole-grain cereals specifically. It may be that in short-term studies, low-carbohydrate diets result in greater weight loss, but those that are summarized here provide consistent evidence that weight loss is still achievable in diets that are high in cereals, especially the whole-grain variety.

**MECHANISMS OF ACTION OF GRAIN FOODS**

Several of the studies reported here have noted that higher grain intakes are associated with lower total energy intakes.61 The main postulated mechanism is through the higher fiber content of diets high in whole grains and legumes. Diets higher in fiber can affect energy balance through intrinsic effects (energy density and palatability), hormonal effects (such as gastric emptying and post-prandial glycemia and insulinemia), and colonic effects (such as the influence of short-chain fatty acids on satiety).57,68

While dietary fiber appears strongly inversely associated with body weight and weight gain in epidemiological studies, the effects of different sources of fiber and resistant starch are not well established and not all of the effect of whole grains may be explained by their fiber content. In the Health Professionals Study, associations between whole-grain intake and reduced weight gain was attenuated after adjustments were made for micronutrients like magnesium, and they persisted after changes in
bran and fiber intakes were accounted for, thus suggesting additional metabolic effects beyond the effect of the fiber content.41

The lower GI values of diets high in whole grains and legumes may be another important factor.69 Low GI foods, and whole grains in particular, are likely to be beneficial through promoting satiety.70 The intake of whole grains may also slow starch digestion or absorption, which leads to relatively lower insulin and glucose responses that favor the oxidation and lipolysis of fat rather than its storage. But it should be noted that not all whole-grain foods necessarily have a low GI (e.g., some wholemeal breads) and some refined-grain breakfast cereals with added protein have a low GI value; thus, the effects of whole grain and GI are not necessarily the same.

Nonetheless, the higher GI of most refined grains may be the possible mechanism whereby refined grains have been associated with small increases in waist circumference in some studies. Experimental data from animal feeding trials indicate that refined-grain products, unlike whole-grain products, can induce an increase in fat synthesis even when the total energy intake is unchanged and body weight remains constant,71 so advising people they can eat a diet with an unlimited amount of highly refined carbohydrates is probably not appropriate.

Along with whole grains, legumes constitute another food group that has been relatively understudied in the epidemiological context. The current evidence for recommendations about their inclusion in a healthy diet relate to their nutrient content (i.e., low in fat and a good source of soluble fiber and protein), rather than strong evidence for their role in chronic disease prevention. In relation to weight control, it may be that their generally low GI value is the main benefit in weight control, since it may enhance satiety,72 although there have been suggestions that alpha-amylase inhibitors in legumes may play a role as well.73

LOW-CARBOHYDRATE DIETS

With the rising rates of overweight and obesity in most of the Western world, there has been a recent growth in diet books promoting low-carbohydrate diets, such as the Atkins Diet and the South Beach Diet, which include advice to avoid grain products and which promote diets that provide less than 30% of energy from carbohydrates.74

Since the year 2003 six studies ranging from three to twelve months’ duration have compared conventional and low-carbohydrate diets.75–80 They all reported slightly better results with the low-carbohydrate diets, with weight loss differences ranging from 3.8 to 5.8 kg over six months. However, studies that followed participants for longer periods found the difference lost significance after twelve months.81 The mechanism of action of low-carbohydrate diets still seems to be solely via decreased energy intake. This probably results from the greater satiety or monotony of the food choices and not from any special metabolic effect, such as ketosis. When energy and protein intake is kept the same, there is no difference in weight loss when very-low-carbohydrate and low-fat diets are compared.82

There are data suggesting that diets high in carbohydrate are more satiating than diets high in fat and that voluntary energy intake is likely to be lower with high-carbohydrate than high-fat diets.83 Furthermore, surveys of people who are successful at long-term maintenance of substantial weight loss show that they follow high-carbohydrate, low-fat diets.84 In recent evidence-based practice guidelines, the Australian National Health and Medical Research Council cautioned against the use of low-carbohydrate diets and concluded that a low-fat diet with increased physical activity is still the best approach for obesity management.85

CONCLUSION

The findings reported here are generally consistent with other studies concluding that grains and legumes are protective against heart disease and diabetes and are consistent with public health dietary recommendations to make bread and cereals the foundation of a healthy diet and to emphasize whole grain in this context. The risk of obesity may be reduced by replacing refined cereal sources with more whole-grain, high-fiber, and low-GI-grain foods, but further randomized trials are necessary to determine the absolute effect of such interventions and to guide new product development. Moreover, the causes of obesity are multifactorial and the outcomes from manipulations of diet alone are likely to be influenced not only by patterns of activity but also by genetic factors that may determine how a person responds.86

In the published observational studies, the highest quintiles of whole-grain intakes that are associated with the lowest risk of obesity are at levels equal to three servings per day. In the United States, the average intake of whole grains is less than one serving a day and less than 10% of Americans consume the recommended three servings per day,87 so there is substantial opportunity to improve the grain and legume intake of most people. Unfortunately, there are also substantial barriers to increasing the consumption of whole-grain and legume foods,88 including traditional preferences for refined products, limited availability in supermarkets and food service settings, lack of familiarity with cooking techniques, and confusion in product labeling.

Our knowledge of the relationship between grains and obesity is still incomplete and at the recent Whole Grain and Health summit at the University of Minnesota...
it was recommended that further research is needed in the following areas: 1) the link between whole grains and health, 2) development of innovative products, and 3) effective communication with consumers about whole-grain foods. Nonetheless, the totality of evidence available from research to date shows there is little evidence that a high level of grain consumption increases the risk of obesity and it does provide strong support for continuing messages to the public that a diet high in whole-grain cereals and legumes will support good overall health and is likely to help maintain a healthy body weight.

Summary points

There is good evidence from both epidemiological and intervention studies for the following assertions: 1) a diet high in whole grains is associated with lower BMI, WC, and risk of being overweight; 2) a diet high in whole grains and legumes can help reduce weight gain; and 3) significant weight loss is achievable with energy-controlled diets that are high in cereals and legumes.

There is weak evidence that high intakes of refined grains may cause small increases in WC in women. There is no evidence that low-carbohydrate diets that restrict cereal intake offer long-term advantages for sustained weight loss. There is insufficient evidence to make clear conclusions about the protective effect of legumes on weight. The levels reported in most epidemiological studies are too low to demonstrate clear effects and there have been no clinical trials examining the effect of increased legume intake on longer term weight status.

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REFERENCES


