Weighing in on Whole Grains: A Review of Evidence Linking Whole Grains to Body Weight[1]

Nicola M. McKeown,[2,3] Adela Hruby,[2] Edward Saltzman,[4] Silvina Furlong Choumenkovitch,[5] and Paul F. Jacques[2]

Currently, an estimated 32.9% of American adults are overweight, 34.3% are obese, and 5.9% are extremely obese (38). In fact, adults defined as being normal weight, i.e., those whose body mass index (BMI) falls in the range of 18.5 to 24.9 kg/m^2, are a minority within the U.S. population. Coupled with declines in physical activity, overconsumption of calorie-rich, nutrient-poor foods is contributing to this obesity epidemic. Recent estimates indicate that 90% of the U.S. population is exceeding its discretionary calorie allowance and not meeting recommendations for most dietary nutrients (25). One group of problematic foods that is high in sugar and fat and contributes to excess consumption of discretionary calories is refined grain-based foods, including many desserts and snack foods.

A modest weight loss of roughly 5–10% of body weight can translate into substantial health improvements in metabolically at-risk individuals (2,49,50,56). For instance, in a study of overweight and obese adults with impaired glucose tolerance, a 6% weight loss achieved through lifestyle modification translated into a 58% reduction in the incidence of type 2 diabetes (23). Although many lifestyle and dietary modifications have been shown to prevent weight gain or promote successful weight loss, another effective strategy may be the substitution of whole-grain equivalents for refined-grain foods (38).

On January 31, 2011, the *Dietary Guidelines for Americans 2010* (DGA) was released. With respect to grains, the 2010 DGA recommends that individuals “consume at least half of all grains as whole grains” and “increase whole-grain intake by replacing refined grains with whole grains.” For an adult consuming 2,000 kcal daily, this translates into consumption of at least three ounce-equivalent servings per day of whole grains (51). Based on a systematic review of the evidence, the DGA advisory committee concluded that “moderate evidence shows that intake of whole grains and grain fiber is associated with lower body weight.”

In this review of the literature, scientific evidence on the relationships between whole grains and body weight, weight loss, and measures of adiposity, from both observational and human intervention studies, is examined, and some gaps in the current knowledge base are identified.

What Are Whole Grains?

The U.S. Food and Drug Administration (FDA) defines whole grains as those grains consisting of the “intact, ground, cracked or flaked fruit of the grains whose principal components—the starchy endosperm, germ and bran—are present in the same relative proportions as they exist in the intact grain” (53), which is consistent with the definition approved by AACC International. The outer bran layer is composed of nondigestible, mainly insoluble, poorly fermentable carbohydrates (such as cellulose, hemicellulose, and arabinoxylan), while the inner germ and starchy endosperm contain viscous soluble fibers and fermentable oligosaccharides. During the refinement of whole wheat into white flour, the outer bran and inner germ layers are removed, and the remaining endosperm is processed into flour. As a consequence of this refining process, there is substantial loss of dietary fiber, as well as minerals, vitamins, and other nutrients (Fig. 1). Whole-grain foods that undergo processing and reconstitution must deliver the same proportion of bran, germ, and endosperm as the original grain to be classified as containing whole grains. Whole-grain foods that display the FDA health claim, “Diets rich in whole grain foods and other plant foods, and low in saturated fat and cholesterol, may help reduce the risk of heart disease,” (52) must contain ≥51% (total weight) whole-grain ingredient(s) that contain ≥11% dietary fiber. Major sources of whole grains in the U.S. diet include whole-grain breads and ready-to-eat (RTE) breakfast cereals. Although enrichment of refined flour with thiamine, riboflavin, niacin, and iron and fortification with folic acid improve its nutritional value, many refined-grain products, such as desserts

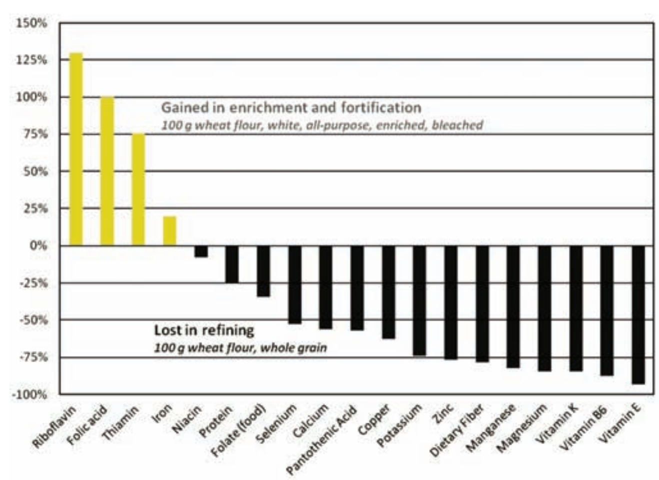

Fig. 1. Percentage of nutrients lost or gained in the refining process. (Source: USDA National Nutrient Database for Standard Reference)

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[2] Nutritional Epidemiology Program, U.S. Department of Agriculture, Jean Mayer Human Nutrition Research Center on Aging, Tufts University, Boston, MA, U.S.A.
[3] Corresponding author. Nicola M. McKeown, USDA, Jean Mayer Human Nutrition Research Center on Aging, Tufts University, 711 Washington St., Boston, MA 02111, U.S.A. E-mail: nicola.mckeown@tufts.edu; Tel: +1.617.556.3008; Fax: +1.617.556.3008.
[4] Energy Metabolism Laboratory, U.S. Department of Agriculture, Jean Mayer Human Nutrition Research Center on Aging, Tufts University, Boston, MA, U.S.A.
[5] John Hancock Research Center on Physical Activity, Nutrition, and Obesity Prevention, Tufts University, Friedman School of Nutrition Science and Policy, Boston, MA, U.S.A.

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and baked goods, are calorie-dense and micronutrient- and fiber-poor (13).

Current Estimates of Dietary Intake of Whole Grains

Most grain products consumed in the United States are refined. Prior to 2000, the average American consumed <1 serving of whole grains per day (8). According to data collected in 2000 for a nationally representative sample of women, 30% consumed no whole grains, while only 6% consumed the recommended 3 servings/day (12). More recent estimates suggest that U.S. adults on average are consuming 0.7 servings of whole grains per day (42); when compared to reported whole-grain intake in 2005, it appears consumption had increased by 20% by 2008 (55). In some segments of the population, consumption of whole-grain foods remains negligible. For example, Asian and Hispanic adults in the United States, whose traditional diets contain large amounts of refined white rice (41), generally do not consume whole grains (30). In children and adolescents, whole-grain intake remains low (16). Based on data collected between 1999 and 2004, only 4% of children and 4.3% of adolescents consumed at least 3 servings of whole grains per day (59).

While some estimates of whole-grain intake in the United States have been obtained using methods such as 24 hr recalls and multiple-day food intake records, the most frequently utilized method in observational studies has been food frequency questionnaires (FFQs). FFQs are designed to measure average long-term diet and usually reflect intake over the prior year. Estimates of whole-grain intake using FFQs have been reported in many studies. However, estimating whole-grain intake using an FFQ may lead to misclassification; for example, the food group "dark bread" may misclassify some people who are consuming refined wheat or pumpernickel breads, leading to an overestimation of whole-grain intake. Comparisons between epidemiologic studies of the relationship between whole grains and health have been further complicated by the fact that definitions of whole grains vary from study to study. In early studies, for example, whole grains were classified based on the definition of Jacobs et al. (17), a definition that includes whole-grain breakfast cereals (≥25% whole-grain content), dark breads, brown rice, oatmeal, and other FFQ-specific foods such as wild rice, bran muffins, and whole-wheat crackers. This broader definition of whole grains also includes added bran and added germ (components of whole grains) and, thus, does not conform to the FDA definition of whole grains. In many epidemiological studies, estimates of whole grains are expressed in servings per day and fail to consider that the amount of whole grain in each serving can vary substantially. Thus, associations observed between whole grains estimated as servings and various outcomes would be expected to be stronger with a more precise estimate of whole-grain intake. Some recent observational studies (18,19) have applied a more quantitative estimate of whole grains, expressed in grams per day. This classification of whole grains allows for separate analysis of the bran and germ contents of whole grains, which may vary both in nutrient composition and health benefits, and limits analyses to only those foods that meet the FDA's requirements for whole-grain health claims: products containing ≥51% whole grains by weight (53). For the purpose of this review, we will refer to both the Jacobs et al. (17) classification and FDA requirements for whole-grain health claims (52) as described in epidemiological studies.

Observational Evidence Relating Whole-Grain Intake to Weight

BMI is most often used to define overall adiposity, while waist circumference is used as a measure of abdominal or central obesity. Waist circumference, which has replaced measures such as waist-to-hip ratio in many investigations, is becoming increasingly important in observational studies as a measure of abdominal adiposity due to its strong association with cardiometabolic risk factors (22). To date, several cross-sectional studies have observed an inverse association between whole-grain intake and BMI and abdominal adiposity in adults (20). In a recent meta-analysis of 15 observational studies, Harland and Garton (15) calculated that the weighted mean difference in BMI was 0.63 kg/m^2 less in those consuming high levels of whole grains compared with those consuming no or low levels of whole grains. To put these differences in perspective, a mean difference in BMI of ≈0.5 kg/m^2 on the population level translates into a 5% increase in the rate of coronary events (1), 2% increase in risk of ischemic stroke, and 3% increase in risk of hemorrhagic stroke (26). Furthermore, Harland and Garton (15), in a pooled analysis of six studies, found that waist circumference was 2.7 cm smaller in consumers with high whole-grain intake versus low intake, indicating improved central adiposity, as well as overall adiposity, with greater whole-grain intake. In a systematic review, Williams et al. (57) also concluded there was strong evidence that a diet high in whole grains was associated with lower BMI, smaller waist circumference, and reduced risk of being overweight. However, much of the evidence is based on cross-sectional studies, which do not allow the inference of causality. Furthermore, in most of the cross-sectional studies mentioned above (20), the Jacobs et al. (17) classification was used to define whole-grain intake.

Only two prospective studies have specifically examined the relationship between whole-grain intake and weight gain in adults (24,29). Of these, only one study applied the FDA definition, including only those products containing ≥51% whole grains by weight (24). In this prospective study, Koh-Banerjee et al. (24) examined changes in whole-grain intake and 8 year weight gain in 27,082 healthy middle-aged men enrolled in the Health Professional's Follow-up Study. Based on estimates of products that contained ≥25% whole grain or bran by weight, men who increased their intake of whole-grain foods by ≥1.5 servings/day gained significantly less weight over 8 years than did men with smaller changes in intake of whole grains (0.73 kg compared to 1.25 kg in highest versus lowest quintiles of change in whole-grain intake; $P < 0.0001$). After applying the stricter FDA whole-grain health claim requirements (i.e., whole-grain foods containing ≥51% whole grain by weight), the dose-response relationship was slightly weaker but consistent, with a significant inverse relationship observed between whole-grain intake and weight gain (0.69 kg compared to 0.96 kg in highest versus lowest quintiles of change in whole-grain intake; $P = 0.002$). Based on the data, it appears that greater consumption of whole-grain or bran foods slows weight gain and that the whole-grain content of food sources exerts a beneficial effect.

Liu et al. (29) examined the relationship between whole grain (defined as ≥25% whole-grain content by weight) intake and the development of obesity and weight gain in 74,091 healthy nurses in the Nurse's Health Study. In this cohort, dietary habits were assessed every two years from 1984 until 1996 using the Harvard FFQ. Over every 2–4 year period, women who increased their intake of whole-grain foods by 1.62 servings/1,000 kcal/day gained significantly less weight compared with women whose whole-grain intake remained low (1.23 kg compared to 1.52 kg; $P < 0.0001$). These differences in weight gain were independent of both changes in intake of different types of fats as well as caloric intake. Furthermore, women who increased their whole-grain intake were ≈20% less likely to become obese and 33% less likely to gain more than 25 kg over the entire 12 year period. In contrast, refined-grain intake was associated with significantly greater weight gain and greater risk of becoming obese over the same period.

Other prospective studies have linked whole-grain foods, such as breakfast cereals or fiber from cereal sources (largely derived from whole-grain foods and added bran), to lower weight gain (Table I). In 2005, Bazzano et al. (3) reported that men who consumed 1 or more servings per day of breakfast cereal gained less weight over 13 years of follow-up compared with those who never or rarely (less than once a month) consumed breakfast cereals (1.81 versus 2.27 kg; $P = 0.007$). This benefit was largely attributed to higher intakes of whole-grain, rather than refined-grain, breakfast cereals. In a large cohort of European participants ($N = 89{,}432$), Du et al. (9) examined the relationship between dietary fiber from different sources and changes in weight and waist circumference over 6.5 years of follow-up. In a meta-analysis of the data, they found that higher intake (10 g/day) of cereal fiber was associated with an annual waist circumference and weight decrease of 0.10 cm and 77 g, respectively. Koh-Banerjee et al. (24) also examined changes in dietary fiber intake and 8 year weight gain in the Health Professional's Follow-up Study and observed that changes in cereal and fruit fiber intake were independently inversely related to weight gain. It is likely that the physiologic effects of dietary fiber depend on its source, but the estimation of cereal fiber is constrained by the same problems encountered when defining whole grains, i.e., accurately quantifying grams of grain fiber in foods.

A related question is whether there is any prospective evidence linking a greater intake of refined-grain foods to gains in overall or central adiposity. The evidence again is limited to a handful of prospective studies (14,24,29,39). In their paper based on the Nurse's Health Study, Liu et al. (29) observed that increases in the intake of refined grains were associated with greater weight gain in women (mean weight gain of 0.99 kg compared to 1.65 kg in lowest versus highest quintiles of change in refined-grain intake; for trend, $P < 0.0001$). In contrast, changes in consumption of refined grains did not protect against 8 year weight gain in men (24). In Dutch women, but not men, intake of refined bread was associated with greater increases in waist circumference over a 6 year period independent of concurrent changes in overall adiposity (14), suggesting an independent effect on abdominal fat accumulation. Other studies have characterized grain consumption using dietary pattern approaches either derived from cluster or factor analyses—often defining "white bread" or "refined grain and sweets" patterns, for example (28,40). In a prospective study of 459 healthy adults, researchers observed that the mean annual change in waist circumference was more than three times greater for subjects in a "white bread" cluster (1.32 ± 0.29 cm) than for those in a "healthy" cluster that included more fruit, high-fiber cereal, and reduced-fat dairy and fewer traditional fast foods, sodas, and salty snacks (0.43 ± 0.27 cm) ($P < 0.05$) (39). Cross-sectional studies have also linked high refined-grain intake and dietary patterns rich in refined grains to greater abdominal adiposity (5,28,33) and visceral adipose tissue (VAT) (34).

Little is known about whole-grain intake and its impact on body weight in other ethnic groups or segments of the population, such as children, adolescents, and the elderly. In one cross-sectional study of U.S. adolescents (47), higher intake of whole grains was linked with lower BMI (7% lower) and smaller waist circumference (5.6% smaller), with the observed difference corresponding to an ≈5 kg difference between the highest and lowest intakes of whole grains; most of the difference in BMI was attributed to fat mass, not lean mass. In contrast, another study showed no relationship between changes in whole-grain intake during puberty and changes in percent body fat or BMI (7). Using combined data from 1999 and 2004 for children and adolescents in the National Health and Nutrition Examination Survey, Zanovec et al. (59) found no relationship between whole-grain consumption and any measures of body weight in 6–12 year old children and, in fact, found some indications that higher intakes of whole grains may be related to greater adiposity. However, in adolescents, higher intakes were inversely related to BMI and central adiposity.

In elderly Americans, an estimated 62.5% of men and 74.9% of women 60–69 years of age are abdominally obese (27). Given a longer life expectancy, research on the health benefits of whole grains in older adults is becoming increasingly important. In a

Table I. Prospective studies on whole-grain or cereal-fiber intake and changes in body weight and abdominal adiposity

			Subject Characteristics[a]				Effects of Higher WG Intake[b]	
Study	Region	Sample (N)	Baseline Age Range (years)	Dietary Assessment Method	Exposure Examined	Length of Follow-up (years)	Less Weight Gain	Less Gain in Abdominal Adiposity[c]
Adults								
Liu et al. (29)	USA	74,091	38–63	FFQ	WG	12	+	…
Koh-Banerjee et al. (24)	USA	27,082	40–75	FFQ	WG	8	+	…
Bazzano et al. (3)	USA	17,881	40–84	FFQ	WG RTEBC	13	+	…
Du et al. (9)	Europe	89,432	20–78	FFQ	Cereal fiber[d]	6.5	+	+
Adolescents and children								
Cheng et al. (7)	Germany	215	8–15	3 day FR	WG	4	–	…

[a] FFQ = Food frequency questionnaire; FR = food record; WG = whole grain; and RTEBC = ready-to-eat breakfast cereal.
[b] Typically includes age, sex, physical activity, smoking, and total energy intake in multivariate models adjusted for lifestyle factors. + = Statistically significant association found ($P < 0.05$); – = no statistically significant association found ($P \geq 0.05$); and … = not determined.
[c] Abdominal adiposity may include measures of waist circumference, waist-to-hip ratio, trunk body fat, etc.
[d] Total fiber intake examined, not explicitly whole grain intake.

cohort of 535 healthy older adults, Sahyoun et al. (45) observed that BMI decreased across increasing quartile categories of whole-grain intake. However, because of the redistribution of body fat with aging (48), in older adults BMI is considered a poorer indicator of overall obesity than abdominal adiposity, which is better reflected by waist circumference. Unfortunately, there is limited observational data on the relationship between whole grains and abdominal adiposity in this segment of the population. As far as we are aware, just one study of 434 adults over 60 years of age reported that higher consumption of whole-grain foods was associated, in a dose-dependent manner, with a significantly lower percentage of abdominal fat, as determined by dual-energy X-ray absorptiometry (DXA) (35). In the same study, the relationship between whole-grain intake and BMI was marginally significant (for trend, $P = 0.08$). DXA provides estimates of body composition (fat-free mass, fat mass, and bone mineral density) for specific regions of interest, such as the trunk. Unlike computed tomography or magnetic resonance imaging, DXA cannot accurately distinguish visceral adipose tissue (VAT) from subcutaneous adipose tissue (SAT).

More recently, due to advancements in and the availability of imaging technology, different aspects of diet have been linked to VAT, which is a stronger predictor of cardiovascular disease risk than total body fat (11). McKeown et al. (34) examined the cross-sectional associations between whole- and refined-grain intakes and abdominal SAT and VAT in 2,834 Framingham Heart Study participants. In this cohort of middle-aged adults, VAT volume was ≈10% lower in individuals consuming ≈3 or more servings of whole grains per day compared with those who essentially consumed no whole grains (<0.2 servings/day), even after accounting for other lifestyle and dietary factors. In contrast, higher refined-grain intake (≥4 servings/day) was associated with increased VAT. With respect to SAT, an inverse relationship was also observed. McKeown et al. (34) also examined whether the observed benefits of whole grains would remain if individuals were also consuming high amounts of refined grains, independent of total energy intake. Joint classification analysis showed that those who consumed more whole grains had lower VAT volumes, but that this association was not present among those with the highest refined-grain intake, suggesting that in the presence of high refined-grain intake, the observed benefits of whole grains are lost.

As has often been highlighted in reviews of epidemiologic evidence, observational studies have limitations that need to be considered in tandem with study findings. It is possible that the observed beneficial associations between higher whole-grain intake and body weight are a reflection of healthier lifestyles and dietary patterns. For instance, diets high in whole grains are usually more nutrient-dense. Statistical approaches can be applied to separate the independent effects of whole grains on body weight from known lifestyle and dietary behaviors, but residual confounding by unknown or poorly measured factors remains a problem. One limitation of observational studies is that physical activity, which contributes not only to energy balance but also to insulin sensitivity and disease risk, is not always controlled for in statistical analyses, or if it is controlled, it is inadequately measured (often based on self-reported levels). Another potential limitation is that estimates of BMI or weight are sometimes based on self-reported measures by study participants, which may lead to misclassification.

Intervention Evidence Relating Whole-Grain Intake to Weight

A summary of the findings from dietary intervention studies that examined the impact of diets rich in whole grains on changes in anthropometric measures is provided in Table II. Many of these studies have employed hypocaloric interventions designed to investigate the impact of whole-grain diets on metabolic risk factors. Based on these studies, the impact of whole-grain diets on changes in body weight beyond the changes expected from calorie restriction can be considered as a secondary outcome.

Katcher et al. (21) examined the effect of whole-grain foods in a hypocaloric diet on weight loss and cardiometabolic risk factors in 50 obese adults with metabolic syndrome. In this randomized, open-label, parallel-arm study, participants were assigned to either a whole-grain intervention or a refined-grain control. At baseline, the average intake of whole grains in each arm of the study was ≈1 serving of whole grains per day. To ease the transition, the study participants in the whole-grain group were advised to consume 3 servings of whole-grain foods daily for the first 2 weeks and then increase their intake to the target of 4–7 servings/day (depending on their initial energy needs). At the end of the study, participants in the whole-grain group had increased their whole-grain intake to ≈5 servings/day, while those in the refined-grain group consumed fewer than 0.2 servings of whole grains per day. The primary sources of whole-grain foods in this study were bread and rolls (2–2.5 servings/day); other sources included RTE cereals, brown rice, oatmeal, pasta, salty snacks, and snack bars (0.5–1.0 servings/day). Poor compliance with the study protocol may have contributed to the lack of a significant difference between groups in many of the study outcomes, including body weight and waist circumference; the initial nine study participants in the whole-grain group averaged only a 7 kcal/day deficit from baseline, leading to a mere 1.0 kg of weight loss. When investigators emphasized to the subsequent 15 whole-grain group participants that they should avoid refined grains and include only whole grains in their diet, participants averaged a 430 kcal/day deficit from baseline, resulting in 5.3 kg of weight loss. Interestingly, despite the similar degree of weight loss observed in both groups, there was a significantly greater decrease in percent body fat in the abdominal region in the whole-grain group compared with the refined-grain group.

Three intervention studies (31,36,46) have examined the effects of whole-grain RTE cereals as part of a dietary program for weight loss on body weight (36) and cardiovascular disease risk factors (31,46). In one study (46), 43 overweight and normal-weight adults were randomized for 6 weeks to one of two hypocaloric diets, one of which supplied 45 g of oats per 1,000 kcal. Both diets provided an energy deficit of 1,000 kcal/day below weight-maintenance needs. Similar weight loss and changes in percent fat mass (determined by hydrodensitometry) were observed in both groups (46). A second randomized pilot intervention study also found that the inclusion of a whole-grain cereal as part of a hypocaloric diet did not independently contribute to greater weight loss (36). Weight loss in overweight and obese adults did not differ between those individuals assigned to exercise and a hypocaloric diet with whole-grain cereals or exercise and a hypocaloric diet without whole-grain cereals. After 24 weeks, the average weight loss from baseline to week 24 of the diets was 5.7 ± 0.7 kg and 6.2 ± 0.7 kg, respectively, while the exercise-only control group lost 1.75 ± 0.62 kg.

In contrast, consumption of a whole-grain, RTE oat cereal as part of a dietary program for weight loss had a favorable effect on abdominal adiposity independent of overall weight loss (31). Maki et al. (31) randomized 204 overweight and obese adults to one of two treatment groups: a hypocaloric diet with two daily portions of whole-grain oat cereal or a hypocaloric diet with low-fiber foods. Both diets provided an energy deficit of 500 kcal/day, and although weight loss was similar in both arms of the study, a significantly greater decrease in waist circumference, albeit small, was observed in the whole-grain arm compared with the low-fiber control (–3.3 versus –1.9 cm).

One randomized control study (54) of overweight and obese adults, designed to compare a weight-loss diet that included specific dietary advice regarding carbohydrate-containing

Table II. Intervention studies examining the impact of whole-grain intake on changes in body weight and abdominal adiposity[a]

Study	Study Design	Sample (*N*)	Subject Characteristics[b] BMI (kg/m^2)	Age (years)	Intervention: Treatment	Control	Duration	Result
Katcher et al. (21)	Randomized, parallel-arm, open-label study (hypocaloric)	50 U.S. males and females with metabolic syndrome	35.7	46	WG diet counseling	RG diet counseling	12 wk	Diets effective for weight loss; significantly greater decrease in abdominal fat for treatment compared with control (−2.2 vs. −0.9%)
Saltzman et al. (46)	Randomized, parallel-arm, feeding study (hypocaloric)	41 U.S. healthy males and females	26.4	44.5	Rolled oats (45 g/1,000 kcal)	Low soluble fiber	2 wk run-in 6 wk	Diets effective for weight loss; no significant differnce in % fat mass for treatment compared with control (−2.7 vs. −2.5 kg)
Maki et al. (31)	Randomized, parallel-arm, feeding study (hypocaloric)	144 U.S. overweight and obese males and females	≈32	≈48.5	2 servings of energy-matched low-fiber foods	2 servings of WG RTE oat cereal	12 wk	Weight loss not different between groups; WC decreased more with treatment compared with control (−3.3 vs. −1.9 cm)
Melanson et al. (36)	Randomized, parallel-arm, pilot trial (hypocaloric)	134 U.S. overweight and obese males and females	30.9	42.3	Diet + exercise, or diet with WG cereals + exercise	Exercise only	24 wk	Greater weight loss with both diets (−4.7 to −5 kg) compared with exercise group (−1.6 kg); no difference between hypocaloric arms
Venn et al. (54)	Randomized, parallel-arm study	113 New Zealand males and females	≈35	42	DR,[c] except 2 servings of bread or cereal were replaced with 2 servings of pulses per day and all cereals were WG	DR[c]	18 months	Both control and treatment groups weight; greater loss in WC observed with treatment compared with control (2.8 cm difference between groups)
Brownlee et al. (6)	Randomized, parallel-arm study	316 U.K. males and females	30	46	Group 1: 60 g of WG/day for 16 weeks Group 2: 60 g of WG/day for 8 weeks, followed by 120 g of WG/day for 8 weeks	No dietary change (<30 g of WG/day)	16 wk	No change in body weight or % body fat with higher WG intake compared with control

[a] WG = Whole grains; RG = refined grains; and WC = waist circumference.
[b] Mean values. BMI = body mass index.
[c] National Health Foundation of New Zealand dietary recommendations (DR) followed: 3 servings of vegetables, 2 servings of fruits, 6 servings of breads and cereals, 2 servings of reduced fat milk and milk products, 1–2 small servings of protein-rich foods selected from lean meats, poultry, fish, seafood, and legumes, 1–2 tablespoons of monounsaturated or polyunsaturated fat and oil products, and small amounts of nuts and seeds.

foods, reported greater decreases in waist circumference in the intervention compared with the control group. In this study, 53 participants assigned to the intervention diet received rolled oats and rye, canned pulses (chickpeas, lentils, and beans), and wheat and rye breads made with whole-meal flour, while 55 participants assigned to the control group received corn flakes, cans of fruits and vegetables, and refined breads. Adherence to the intervention diet was better at 2 and 6 months compared with 12 months, with consumption of pulses averaging 1.5–2 servings/day more in the intervention group compared with the control group; differences in whole-grain intake were much lower, on average 0.3–0.6 servings/day more in the intervention group than in the control group. Despite similar weight loss, ≈5 kg at 18 months, the intervention group had a significantly greater decrease in waist circumference compared with the control group: the mean between-group difference was 2.8 cm.

More recently, Brownlee et al. (6) conducted a large intervention study (WHOLEheart Study) designed to examine the effects of incorporating whole-grain foods into the diets of 316 free-living, overweight adults in the United Kingdom who did not routinely consume whole grains. In this study, participants were randomized to three different diet arms: control with no dietary change; intervention with 60 g of whole grains daily for 16 weeks; or intervention with 60 g of whole grains daily for 8 weeks, followed by 120 g of whole grains daily for 8 weeks. Despite a substantial study duration (16 weeks), no significant differences were observed in BMI, percent body fat, waist circumference, or any of the measured cardiometabolic risk factors. One potential concern in the study was compliance with the intended study protocol. It appears that participants included whole-grain foods as additions rather than substitutions to their regular diets, a problem encountered in other intervention studies (21). In this study, self-reported energy intake was lower, on average, at 16 weeks compared with the baseline of participants on the control diet, while participants on either whole-grain intervention appeared to have higher energy intakes. As noted elsewhere (32), despite reporting higher energy intakes in the whole-grain intervention groups, no differences in body weight were observed, even though anticipated weight gain based on the reported energy intake in the whole-grain groups would have been in the range of 2 to 3 kg over the 16 weeks. Thus, addition of whole-grain foods while failing to compensate by omitting other foods, including refined-grain foods, may have affected the findings. Further, the mechanism underlying the lack of weight gain, despite higher reported energy intakes in the whole-grain groups, merits further exploration.

A randomized, controlled, cross-over study designed to examine the effects of three sources of whole grains on blood pressure reported some interesting findings with respect to body weight (4). After following a Step 1 diet for 2 weeks, overweight and obese adults were randomized to a diet that replaced 20% of energy with either whole wheat or brown rice, barley, or half wheat and rice and half barley for 5 weeks. Over the course of the study, participants lost 1 kg, but interestingly, it was observed that by replacing refined with whole grains they maintained or lowered body weight while increasing energy intakes.

Whole grains are rich in dietary fiber, and inclusion of whole grains in weight-loss regimens substantially increases the dietary fiber content of a diet (21,36,54). Several reviews have highlighted the mechanistic roles of dietary fiber in weight management (44). One proposed mechanism is that prolonged chewing and the slower rate of absorption and digestion of whole grains may promote a greater feeling of fullness for longer periods of time. Although there is little information available on the effects of whole grains on satiety (i.e., the feeling of being satisfied after eating), some study participants have reported feeling less hungry between meals while on whole-grain diets compared with refined-grain diets (21,43). Alternatively, the slower digestion and absorption of whole grains may result in a reduction in postprandial glucose and insulin concentrations and such hormonal effects, in turn, may favor the oxidation and lipolysis of fat rather than its storage. Another mechanism by which dietary fiber may limit weight gain or gain in adiposity is the fermentation of fiber to short-chain fatty acids (SCFAs)—acetic, propionic, and butyric acids—in the colon. These bacterial SCFAs can be utilized for de novo lipid or glucose synthesis (58) and, thus, provide an additional source of energy for the body. SCFAs may also affect satiety via the production and release of gastrointestinal satiety hormones such as the peripheral peptide tyrosine-tyrosine (PYY) and glucagon-like peptide-1 (GLP-1) (37). PYY and GLP-1 are important modulators of food intake that affect gastric emptying (37); in addition, GLP-1 acts as an incretin hormone (10).

Based on intervention studies, including whole grains in weight-loss regimens involving caloric restriction does not appear to lead to greater weight loss, although it does improve the overall quality of the diet (36) and has added beneficial effects on metabolic risk factors, such as markers of inflammation (e.g., C-reactive protein) and lipid profiles (21,31,46). There is some evidence to suggest that incorporating whole grains into the diet may play a role in altering body composition or metabolism irrespective of loss of body weight, but this evidence is limited (21,31,54).

Current Gaps in the Knowledge Base

With respect to our estimates of whole-grain intake using traditional dietary assessment methods, as the field moves forward we need to give greater consideration to how we define whole grains and consider including biomarkers of whole-grain intake to confirm observed associations in epidemiological studies. Further research on the effects of whole-grain intake in the presence of desserts and other refined-grain products on health outcomes needs to be more closely examined in observational studies.

So, where do we stand today in terms of research on the role of whole grains in weight gain and loss? Evidence from epidemiological studies suggests that people who consume more whole grains have lower body weight and less weight gain; however, the vast majority of the evidence is from cross-sectional studies. Thus, there is a gap in the knowledge base that researchers need to fill—evidence from prospective studies using the strict FDA whole-grains health claim requirements (≥51% whole grain by weight) to characterize whole-grain intake and its relationship not only to weight gain but also to changes in body fat distribution. As the field moves forward, evidence from prospective studies applying the FDA whole-grains health claim requirements will help elucidate the role of whole grains in body weight. Furthermore, future efforts should focus on designing studies that consider the influence of different types of grains on body fat depots, improve dietary assessments for whole grains, and further examine the health benefits of whole grains in children, adolescents, the elderly, and different ethnic groups.

Differing intervention study designs and the underlying metabolic status of study participants hamper our ability to fully understand the role of whole grains in body composition and weight loss. For example, some trials have focused on inclusion of oat-based whole grains, while others have incorporated different sources of grains into the diet. Differences in the sources of whole grains administered in studies, challenges concerning compliance with dietary regimens under free-living conditions versus compliance in studies in which all food is provided, and baseline whole-grain intake of participants are all factors that may further explain the inconsistent results observed in intervention studies. In the design of future randomized, controlled trials, the limitations encountered by other weight-loss interventions should be taken into consideration. Another gap in the knowledge base that should be considered is whether replacing refined grains with whole-grain equivalents changes body fat distribution, as determined using magnetic resonance imaging to distinguish VAT from SAT, under both isocaloric and hypocaloric settings.

There is a moderate body of evidence to suggest that whole grains are linked with lower body weight, but clearly, there is a need for more prospective and intervention studies to consider the impact of grains on body fat distribution and weight gain. In line with current dietary recommendations, adults should be encouraged to replace refined-grain ingredients and foods with whole-grain alternatives and practice other healthy lifestyle changes to maintain a healthy weight and prevent undesired weight gain.

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