Carbohydrates, Grains, and Whole Grains and Disease Prevention Part II. Blood Pressure, Metabolic Syndrome, and Diabetes[1,2]

Julie M. Jones, Roberto J. Peña, Renee Korczak, and Hans J. Braun[3]
Global Wheat Program, CIMMYT

The prominence of carbohydrates (CHOs) and grains in dietary guidance as the base of the diet and as core components for promoting health and preventing disease has recently been called into question. Grain-based foods, and the CHOs they contain, have been accused of promoting obesity, which can be a factor in increased risk of developing certain chronic diseases, such as hypertension, metabolic syndrome (MetS), and diabetes. Increased consumption of CHOs and grains is alleged to initiate changes in the microbiome and metabolic pathways that create conditions that negatively impact health. Specifically, some have charged that wheat- and grain-based foods, especially those with added sugars and highly refined CHOs, add calories to the diet and contribute to increases in obesity, hypertension, MetS, diabetes, and other chronic diseases (1,2). Some even claim that these foods "constitute a greater threat to health than the added effects of smoking and alcohol abuse" (3).

In contrast, a review of the literature discussing the findings from numerous epidemiological and intervention studies shows that grains and grain-based foods, when consumed as part of a healthy and balanced dietary pattern, may actually reduce the risk of weight gain, obesity, hypertension, MetS, and related chronic diseases. In short, studies show that these foods are not part of the problem, but rather can be part of the solution when included in the right amounts as part of a balanced dietary pattern.

The current review is the fifth in a series of papers looking at the role of CHOs, grains, and whole grains in health and will build on the earlier reviews, which addressed their roles in body weight, inflammation, and glycemic response (4–7), to assess their roles in blood pressure, stroke, glucose tolerance, MetS, and diabetes. Although it is known that different grains may have different effects on health, this review focuses on grains as a group, contrasts the roles of refined and whole grains, and discusses in more detail where specific grains or grain-based foods stand out.

Relationship of CHOs, Grains, Whole Grains, and Dietary Fiber to Blood Pressure

CHOs and Blood Pressure

High blood pressure, also called hypertension, occurs when there is too much pressure exerted against the walls of the blood vessels. Chronic hypertension causes the heart to work too hard, can damage the arteries and kidneys, and can put the individual at risk for cardiovascular disease and MetS. In the United States and the United Kingdom, 33–40% of the population has hypertension, with the percentage nearly doubling for people over the age of 65. In the United States, 10% of children have hypertension. Although there is no identifiable cause for most cases of primary hypertension, there are many contributing factors—genetics, ethnicity, obesity, lack of exercise, smoking, stress, age, and diabetes are all factors. In terms of diet, the types of fat and balance of fatty acids, amount of salt, and amounts of potassium and other minerals consumed and dietary patterns have all been implicated, as have the amounts and types of CHOs consumed, with some suggesting that grains and refined CHO-rich foods are part of the problem. However, the percentage of CHO in the diet does not seem to be associated with adverse changes in blood pressure. If anything, it may be associated with lower blood pressure (8).

Until the advent of effective blood pressure medications in the 1940s, a diet consisting only of rice and fruit was used to successfully treat "malignant hypertension" (9). Although the blood pressure-lowering effect of the rice and fruit diet was similar to that of many drugs, the diet fell out of favor due to difficulties with compliance. Nonetheless, the effects of this diet suggest that high-CHO diets are not a cause of elevated blood pressure and may help with blood pressure management.

Most epidemiological or interventional studies show that following diets or dietary patterns containing the recommended amount of CHO as well as other nutrients either has no impact on blood pressure or is associated with lower blood pressure. For example, in the OmniCarb randomized control trial (RCT) of 63 overweight adults following a Dietary Approaches to Stop Hypertension (DASH) diet, neither high (58%) nor low (40%) CHO diets had any impact on blood pressure (10). The glycemic index (GI) of the

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[3] Corresponding author. CIMMYT, Global Wheat Program, Km 45 Carretera México-Veracruz, El Batán, Texcoco, C.P. 56130, Estado de México, México. E-mail: h.j.braun@cgiar.org

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CHO ingested also was not shown to impact blood pressure.

Epidemiological evidence is similar to that from intervention studies. For example, in the Korean National Health and Nutrition Examination Survey (NHANES), 2007–2010, neither the percentage of calories from CHO nor the actual amount of CHO consumed had an impact on blood pressure (11). Further, Chinese adolescent males consuming diets high in CHO (>55%) were shown to have lower systolic blood pressure than males consuming diets lower in CHO (12). Similar trends were observed in elderly Chinese adults, for whom a moderate CHO intake was associated with lower blood pressure (13). Those eating >400 g of rice/day versus those eating <200 g/day had a 40% lower risk of hypertension (14).

CHOs consumed as part of a balanced dietary pattern have been shown to play an important role in hypertension. For example, analysis of Korean NHANES IV data (15,16) showed that the traditional Korean dietary pattern, which is high in rice (and kimchi), was associated with a 40% lower risk of hypertension than a pattern rich in meat, alcohol, fast foods, and fried noodles. Unbalanced Korean dietary patterns, characterized by high intake of CHOs and sodium and little food variety, were associated with a higher risk of elevated blood pressure only in women (17). These studies suggest that it is not the CHO itself, but rather the overall dietary balance that impacts blood pressure. The Mediterranean diet, which is balanced for all dietary constituents, including grains, was associated with lower blood pressure in an RCT (18). Although studies from India show that diets containing 67% CHO and 440 g of refined grains/day were associated with higher blood pressure (19), it should be pointed out that those in the quartile eating the most refined grains followed diets that were far from the recommended pattern.

Dietary Fiber and Grains and Blood Pressure

Dietary Fiber. Dietary fiber intakes in prospective cohort studies are inversely associated with high blood pressure. This was true for the segment of more than 17,000 NHANES III participants living in the southeastern United States who had the lowest intake of dietary fiber (20). Similarly, for a French cohort of 6,000 men and women, those with the highest total and insoluble dietary fiber intakes had the lowest blood pressure (21). In a Spanish cohort of nearly 6,000 university graduates, those with the highest intakes of cereal fiber decreased their risk of elevated blood pressure by up to 40% compared with those with the lowest intakes of cereal fiber. A meta-analysis of 25 RCTs shows that dietary fiber added to the diet of hypertensive subjects for 8 weeks lowered diastolic blood pressure (22). In the International Study of Macro/Micronutrients and Blood Pressure (INTERMAP) (23) of older men and women at risk for cardiovascular disease (CVD), higher dietary fiber intake was associated with lower systolic blood pressure. Insoluble fibers, like those found in most grains, appeared to have a much greater impact on blood pressure than soluble fibers.

Although dietary fiber intake appears to be important, overall diet quality matters as well. In a cohort of black Americans (24), those with higher blood pressure not only followed a diet low in dietary fiber, the diet was high in other dietary components with negative health impacts. Thus, the authors of the study concluded that poor diet quality and low dietary fiber intake, rather than CHO or grain intakes, contributed to higher blood pressure (24).

Whole Grains. An association between whole grain intakes and lower blood pressure has been shown in some, but not all, studies. For example, a large French cross-sectional study showed whole grain intakes were inversely associated with blood pressure (25). Further, subjects who substituted 48 g of whole grains/day for refined grains for a short time showed a decrease in systolic blood pressure (26). Both nonmalted and malted whole grain cereals consumed in a crossover design lowered the blood pressure of obese subjects (27). Replacing 3 servings of refined grains with 3 servings of a mix of whole grain wheat and oats caused a decrease in systolic blood pressure in just 3 weeks (28). After 12 weeks, systolic blood pressure decreased with consumption of either all whole wheat or a mix of grains. On the other hand, intervention studies in Europe and the United States failed to show that consumption of whole grain cereals resulted in lower blood pressure in consumers with low whole grain intakes (29,30).

Refined Grains and Grain-Based Foods. A number of studies show an association between dietary patterns high in refined grains and elevated blood pressure. For example Qatari women of childbearing age who followed a "traditional, sedentary pattern" consisting of refined grains, dairy products, and meat in addition to low physical activity had a twofold risk of elevated blood pressure (31). In India a dietary pattern of refined grain intake also was associated with higher blood pressure (19). In the latter study, those with the highest intakes of refined grains consumed more calories and less protein (including dairy and fish), >400 g of refined grains/day, and >65% of calories as CHO and had significantly lower intakes of potassium and fiber-containing fruits, vegetables, and legumes.

Breads and Cereals. The role of breads and cereals in the diet with respect to blood pressure is often difficult to discern because of their close association with other components in the diet that affect blood pressure. One intervention trial compared the breakfasts of adults 18–35 years of age. It showed that a breakfast composed of a refined flour bagel resulted in the same blood pressure as a breakfast composed of an egg; however, insulin sensitivity was improved with the bagel breakfast (32). In terms of dietary patterns, Japanese individuals who followed a "bread and dairy products" pattern had a lower risk of elevated systolic blood pressure compared with those following a "seafood" or "high-fat/Western" pattern, which were associated with slightly elevated risk (33). Further, the bread and dairy products pattern lowered blood pressure nearly as much as the "prudent" diet (i.e., containing lower levels of fat, cholesterol, and protein).

In addition, bread has been used as a vehicle to add functional ingredients such as resistant starch, soy, or other components known to impact blood pressure to the diet (34). If bread itself had a significant impact on blood pressure, it would be a poor vehicle for addition of these functional components.

Dietary guidance often recommends the replacement of refined grain breads and cereals with whole grain versions. However, the impact of such substitutions has not been consistent across studies. When 6 servings of refined grain (5 of 6 were breads or breakfast cereals) were replaced by whole grain counterparts in a crossover design, dietary fiber intake went up, but there was no effect on blood pressure (35). Similar findings were observed when whole grain bread, biscuits, and pasta were substituted for refined grain versions (36). In contrast, one study comparing the impact of refined grain cereals with nonmalted and malted whole grain cereals found that the whole grain foods decreased blood pressure (27). Whole grain oats and its β-glucan content has also been shown in a number of studies to lower blood pressure (37).

Rice. A number of studies show an association between inclusion of rice in a balanced dietary pattern and lower blood pressure (13). For example, in a 5 year study of more than 1,200 adults in Jaingsu, China, a 10% increase in the percentage of rice included in staple food patterns was associated with a 9% decrease in the risk of high blood pressure (38).

Intervention studies do not provide a clear picture concerning the impact of brown rice versus white rice intake on blood pressure. In a crossover design intervention study with overweight and obese females of childbearing age, brown rice intake decreased blood pressure compared with white rice (39). However, in a 6 week study of middle-aged Chinese men and women at risk for diabetes, substituting brown rice for white rice offered no advantage for many endpoint measures, including blood pressure (40).

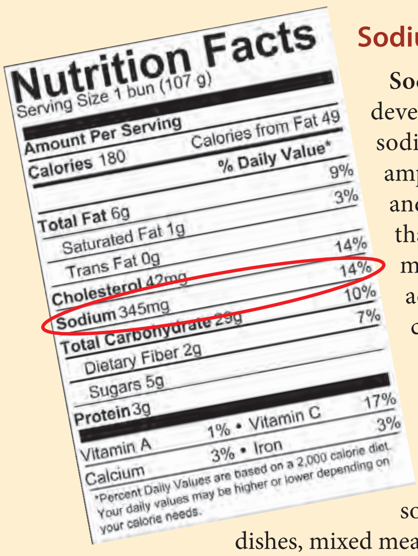
Grain-Based Foods and Sodium. Many grain-based foods are major contributors of sodium to the diet (discussed in the text box). Salt consumption has been linked to elevated blood pressure, which is a leading cause of premature mortality worldwide. Salt consumption generally is 5–10 times greater than physiological requirements, leading the World Health Organization to suggest modest salt reduction in diets as a public health measure to reduce the risk of chronic disease (41). There appears to be a strong association between high sodium intake (>6 g/day) and both blood pressure and CVD events in hypertensive and some elderly individuals. However, there may be a U-shaped risk curve because there seems to be no association between sodium and clinical events at intake levels of 3–6 g/day, while there are higher rates of clinical events at intakes under 3 g/day (42).

CHOs and Grains and Blood Pressure—A Summary

CHOs and grain-based foods consumed as part of a balanced diet do not appear to elevate blood pressure and, in some instances, may lower it. The latter appears to be true even though grain-based foods are major contributors of dietary sodium. The results from studies in which whole grain products are substituted for refined grain products are mixed. However, the DASH diet, which emphasizes whole grain breads and cereals as part of its healthy dietary pattern, has documented success in lowering blood pressure. Further, products with viscous fibers, like those found in whole grain oats, have been shown to lower blood pressure, and studies on rice show that it may be associated with lower blood pressure.

Because grain and whole grain products provide dietary fiber, including soluble dietary fiber, and whole grains contain phenolics, these foods are likely to have marked effects on the microbiota, which may lower blood pressure. From a mechanistic view, whole grains and the dietary fibers they contain, can impact blood pressure through compounds generated or formed during their digestion, hydrolysis, or fermentation. For instance, short-chain fatty acids formed during fermentation can impact receptors that control blood pressure (52). In addition, compounds associated with the blood pressure-lowering, angiotensin-converting enzyme (ACE inhibitory) are produced (53–55). However, more needs to be known about the quantity of the compounds formed, their half-life, the concentration needed for impact, and how they are transported to target tissues in humans. Nevertheless, it is highly likely that both dietary fiber and whole grains can change the microbiome and that this could impact blood pressure (56).

Both whole grains and dietary fiber are recommended as part of blood pressure management regimens by health promotion organizations such as the American Heart Association, the American College of Cardiology, and the Canadian Hypertension Education Program (57). These recommendations emphasize the inclusion of both as part of a balanced dietary pattern.



Sodium, Bread, and Grain-Based Foods

Sodium Intakes—Many populations in both developed and developing countries consume sodium in excess of daily guidelines. For example, the U.S. Centers for Disease Control and Prevention (CDC) (43) determined that, excluding salt added at the table, the mean daily sodium consumption for U.S. adults (2007–2008) was 3,266 mg and for children was 3,279 mg.

Of the sodium in the diet of U.S. adults, 44% came from 10 food categories. Five grain-based food categories were among the top ten contributors: bread and rolls, cold cuts/cured meats, pizza, poultry, soups, sandwiches, cheese, mixed pasta dishes, mixed meat dishes, and savory snacks. For children, 43% of sodium was contributed by the same five grain-based food categories as for adults, with the addition of a sixth category, mixed Mexican dishes, and soups. Very similar data exist for special populations of children, such as diabetics, in other parts of the world (44–48).

Sodium in Breads and Cereal Foods—According to a CDC survey of U.S. packaged foods (49), the sodium content of 72 breads and buns sampled varied from 320 to 857 mg/100 g, with a mean of 512 mg/100 g. Sodium content of cereals ranged from 407 to 670 mg/100 g, with a mean of 421 mg/100 g. Thus, depending on the food products chosen, breads and cereals may account for between 20 and 67% of the recommended daily intake of sodium for healthy adults. A study of hypertensive individuals in Europe showed that bread accounted for about one-fourth of all daily salt intake and was one of six foods shown to be associated with urinary sodium (50).

The discussion concerning salt in grain-based foods may help explain the variability seen in studies linking grains and blood pressure. Although one might deduce that with this food group contributing so much sodium in the diet, there would be a consistent blood pressure-elevating effect, this is not the case. These data highlight the ongoing debate about the role of dietary salt overall and the role of salt in grain-based foods in particular in modulating blood pressure (51).

Relationship of CHOs, Grains, and Whole Grains to MetS

MetS

MetS is described by a constellation of conditions that includes elevated blood pressure, visceral obesity, elevated blood lipids, and impaired glucose tolerance. MetS generally stems from the combination of an atherogenic diet, sedentary lifestyle, and overweight or obesity. The constellation of symptoms represents a significant risk for developing diabetes and CVD and increases mortality rates from 20 to 80% (58). It has been estimated that 30–40% of the adult population over the age of 65 worldwide has MetS (59), although incidence varies by ethnicity, country, age, etc. No single diet is currently recommended for individuals with MetS; however, epidemiological studies have shown the Mediterranean, DASH, and New Nordic (60) diets to be beneficial. Whole grains and dietary fiber are some of the many dietary components common to these dietary patterns, which also include fruits, vegetables, dairy, calcium, vitamin D, monounsaturated fatty acids, and omega-3 fatty acids (61).

The discussion on MetS will build on the previous review on obesity (4), especially visceral obesity, and on the earlier discussion of blood pressure and will look at these in concert with impaired glucose tolerance and elevated blood lipids and the evidence from dietary patterns.

CHOs and MetS

As with obesity, the amount of CHO in the diet required to prevent or treat MetS is the subject of much debate. High CHO intake has been shown to increase the risk of MetS in some studies, but not in others. For example, in a cohort from northern China, the quartile ingesting the highest amount of total CHO, compared with the lowest, had triple the risk of hyperlipidemia and more than double the risk of MetS (62). Starchy CHO foods were strongly linked to MetS, while other CHO-rich foods were not. Similarly, high CHO intake also was associated with a nearly threefold increase in risk of MetS in low-income men over the age of 60 in Malaysia (63). A Thai national survey documented an association between high CHO intake (especially high consumption of glutinous rice) and increased risk of MetS (64). The authors postulate that the consumption of high-GI glutinous rice elevated triglycerides and lowered HDL cholesterol. However, the same study showed that those with a high intake of meat products were more likely to have symptoms associated with MetS, including elevated blood pressure, elevated fasting blood glucose, and abdominal obesity. Intakes of CHO much higher than recommended (only 5% of energy from fat) for subjects in the Korean NHANES survey ($N \approx 34{,}000$) also increased the risk of MetS (65).

Gender, physical activity, body mass index (BMI), and dietary fiber content all appeared to modify the effect of high CHO intake on MetS risk. For example, in Korean adolescents, high CHO and rice intake and glycemic load (GL) were associated with increased blood lipids in girls, but with reduced HDL cholesterol levels in boys (11). In boys high GL also was significantly associated with increased fasting glucose levels.

In a national Thai survey (66), the adverse effect of high dietary CHO intakes on MetS was lower among those who were physically active and higher among those who were sedentary. Among participants in the Korean NHANES survey, high CHO intake increased risk of MetS, but only

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among those who had BMIs > 25 kg/m^2 (67). Another review observed a detrimental effect of a high CHO diet on MetS, but only when the CHO foods were low in fiber and had a high GI (68).

No effect of CHO intake on MetS was shown in some cohorts. For example, in the Whitehall II study of more than 5,000 British men and women, no dietary component was related to MetS (69). Similar findings were observed in adult Iranian women and older Brazilian women, in that CHO intake was unrelated to risk of MetS (70,71). Neither CHO nor GI was related to MetS in obese subjects in the DiOGenes study (72).

Low-CHO diets have been shown in some studies to elevate MetS risk because of their complement of high-fat, energy-dense foods (73). For example, Japanese diabetics choosing a low-CHO diet were at higher risk of having more MetS risk factors (74). Although some support the argument that diets that somewhat or severely limit CHO may be useful in treating diabetes and MetS (75), there seems to be no clear answer regarding an optimal macronutrient mix (76).

Dietary Fiber and Whole Grains and MetS

Diets low in dietary fiber are associated with increased risk of MetS (77). The role of dietary fiber often not only involves the fiber itself, but also involves the dietary fiber complex of the bran and its attached phytonutrients.

Dietary fibers, specifically some viscous fibers such as β-glucan, are associated with lower risk of MetS. A recent review showed how variables linked to MetS, including appetite control, glucose control, hypertension, and gut microbiota composition, are impacted by β-glucan (78,79). The data supporting adequate dietary fiber in the diet to prevent and treat MetS are so convincing that dietary fiber recommendations are included in published guidelines (80).

Whole grains and minimally processed cereals appear to be associated with decreased risk of MetS, while highly processed cereal-based foods, especially grain-based desserts with high GI or added fat, are associated with higher risk (81). A number of studies have shown an association between higher whole grain intake and decreased risk of MetS and between low intake of these types of foods and increased risk (82,83). For example, in an Iranian sample population (84), the risk of having hypertension, hypertriglyceridemia, and MetS decreased dose dependently as whole grain intake increased. In like manner, the risk of having hypertension, hypercholesterolemia, hypertriglyceridemia, and MetS increased as refined grain intake increased.

Higher refined grain intake was significantly associated with increased risk of all symptoms associated with MetS in a population of Asian Indians who habitually consumed high-CHO, often marginal, diets (19,85). In fact, those in this population with very high rates of insulin resistance and type 2 diabetes mellitus (86) were in the quartile with the highest intake of refined grains and were nearly eight times more likely to have MetS than those in the lowest quartile. In the Framingham Offspring cohort, which had a lower risk of diabetes than South Asian individuals (87), the "refined grains and sweets" dietary pattern was associated with increased risk of insulin resistance (85). In this pattern, refined grains and cereals contributed 13.3% of calories, whole grains contributed 5.3% of calories, and sweet baked foods and other sweets contributed 13.8% of calories. In the dietary pattern described as "fruit, reduced fat dairy and whole grains," refined grains contributed 11.3% of calories, whole grains contributed 8.8% of calories, and sweet baked foods and other sweets contributed 4.8% of calories. It is important to note that the largest difference in food intake was not between refined and whole grains but between consumption of sweet baked foods and other sweets. In fact, diets in the refined grains and sweets pattern contained the highest percentage of energy from sugar and total fat, including cholesterol and saturated fat, and more sugar than all categories other than the soda category. The GI of the two dietary patterns was not significantly different, but the refined grains and sweets pattern had significantly lower adherence to a healthy pattern as evidenced by lower potassium levels, which is a marker of fruit and vegetable intake. Such studies attribute the increase in risk of elevated blood pressure to dietary patterns high in refined grains and sweets. However, the grouping of refined grains as breads and cereals with indulgent grain-based foods and lack of fruits and vegetables may lead to the erroneous deduction that refined grains are the cause of elevated blood pressure, when the cause may be overconsumption of grain-based desserts and underconsumption of fruits and vegetables. As a result, attribution of cause is challenging due to the confounding that results from bundling staple grain-based foods with grain-based desserts and to the lack of other important components in the diet.

The effect of refined grains on MetS risk is inconsistent among epidemiological studies. Refined grain intake in the multiethnic U.S. Atherosclerosis in Communities cohort was not related to MetS risk, and whole grain intake resulted in reduced risk (83). However, in a cohort from northern China, wheat and rice intakes were found to be risk factors in MetS. In this study both cereals were part of the grouping called "starchy CHOs," and these were associated with increased risk of MetS (62).

Intervention studies that replaced some whole grains with refined grains produced more consistent findings. For example, in a study of 50 overweight and obese subjects with increased waist circumference, substitution of whole grains for refined grains had a modest effect on markers of inflammation, lipid levels, and other measures associated with MetS (88). Especially in individuals with prediabetes, replacement of refined grains with whole grains helped to normalize blood glucose. Similarly, in an Italian cohort substitution of refined grains with whole grains reduced postprandial insulin and triglyceride responses (89). In overweight, postmenopausal Mexican women, elimination of high-energy refined grain-based foods increased the probability of having normal fasting glucose (90).

Specific Grains and Grain-Based Foods and MetS

Bread and Pasta. Bread and pasta are major sources of CHO and wheat in most Western diets. Therefore, studies showing the benefits or risks of CHO and grain-based foods in these cohorts would show primarily the effect of wheat. Further, for many adults bread and pasta would make up a significant dietary contribution. Therefore, studies showing the benefits of whole grains in many Western cohorts would show the benefits of wheat-based foods (91).

With regard to MetS, however, the role of these foods is unclear. It is known that bread as part of a balanced dietary pattern is associated with lower risk of MetS (92). So, if a food is associated with higher risk, it is hard to determine whether the effect is due to the specific food, such as bread, or to the overall dietary pattern. What has been documented is that in more than 5,000 French adults, bread, as well as dairy, intake was inversely related to the frequency of MetS in men, but not in women (93). Men who ate more than 50 g of bread/day had at least a 40% lower prevalence of MetS (93). However, when patterns were assessed, as occurred in the Malmo Diet and Cancer Cohort study, the "white bread" food pattern (8% of energy from white bread) was associated with a higher risk of several components of MetS, including higher risk of hyperinsulinemia in women and higher risk of dyslipidemia in both men and women. In contrast, there was a lower risk of central obesity and dyslipidemia with the "fiber bread" food pattern (2% of energy from fiber bread) for men (94). In the CASPIAN study (95), consumption of bread made with white (refined) flour increased the risk of MetS in both boys and girls 8–14 years of age.

Thus, in some studies high intakes of bread were associated with decreased risk or increased risk in some genders, but the overall dietary pattern appears to be important. The cause is probably not bread per se, because some interventions use it as a vehicle for addition of functional foods, enhancing absorption of phenolics to reduce inflammation, and addressing problems associated with MetS (96–99).

Pasta and bread, although both are often made from wheat, frequently cause different blood glucose and insulin responses and, therefore, may have different impacts on MetS risk. In a Finnish study (100), pasta together with rye bread lowered risk of MetS more than a combination of oats, wheat, and potatoes. In a British crossover study with more than 800 subjects aged 40–65 years, those with a lower risk of abnormal glucose tolerance followed a healthy balanced diet with frequent intake of raw and salad vegetables, fruits, fish, pasta, and rice and low intake of fried foods, sausage, fried fish, and potatoes (101). A Korean study showed that the addition of instant noodles to either the "Korean traditional pattern" or the "meat and fast-food pattern" changed the patterns from having no increased risk of MetS to increasing the risk of MetS, but only for women (15). Further analysis of the patterns showed that those who added noodles and bread for breakfast also ingested more fat throughout the day (102). Hence, the role of bread and certain pasta or noodle dishes may impact the risk of MetS, but the impact appears to be modulated by gender and total diet.

Barley, Oats, and Rye. Barley (103), oats (104), and rye (34,98) are all associated with reduced risk of symptoms associated with MetS, not only because of their dietary fiber contributions, such as β-glucan, but also because of their phytochemical contributions, such as avenanthramides and secoresorcinols. A Finnish intervention study compared a diet with about one-third of the calories delivered by rye bread and pasta to one delivering the same number of calories from a combination of oats, wheat, and potatoes. The results showed that the rye combinations improved insulin and blood glucose more than the other combination in subjects with risk factors for MetS.

Rice. Analysis of data showing the effects of white rice on MetS produced mixed results. In the Iranian Tehran Lipid and Glucose Study of 1,476 adults aged

19–70 years, the relative risk of MetS was higher (RR = 1.66) for those in the highest quartile of white rice consumption compared with the lowest (105). The risk increased for participants who had central obesity, were sedentary, who consumed a low-fiber diet, and for whom white rice constituted >25.6% of total energy intake. Other studies (106–108) also showed that consumption of rice and glutinous rice were associated with increasing risk factors for MetS. In Korean adolescents, high white rice intake was significantly associated with an increased risk of insulin resistance and MetS in girls, but not in boys (11). However, the effect of rice appeared to be related to the balance of other foods in the diet. Findings from the Korean NHANES survey show that the risk of MetS increased among those eating white rice but only if they were not eating rice with beans or multigrains (109).

In more than 200 adults in Jaingsu, China, who were followed for 5 years, rice intake was associated with only one risk factor for MetS—hyperglycemia (38). Furthermore, in this study although rice increased fasting blood glucose, it also had some beneficial effects. A 10% increase of rice in staple foods was associated with reduced blood pressure and slightly less weight gain. The authors conclude that rice intake was not associated with the risk of MetS and that risk was associated with food patterns.

Dietary Patterns that Include CHOs and Grains and MetS

Balanced dietary patterns that include CHOs, grains, and cereals are associated with lower risk of MetS (64). Western-type dietary patterns, which are characterized by high intakes of meat or meat products, snacks, baked desserts, and sugar-sweetened beverages and which provide high amounts of saturated fatty acids and simple CHOs as added sugars, are associated with higher risk of MetS. n contrast, dietary patterns such as the Mediterranean, DASH, and New Nordic diets, which are characterized by high intakes of whole grain foods, vegetables, fruits, whole cereals, and fish, are associated with reduced risk of MetS (92). The greater the adherence to such diet plans, the more various symptoms of MetS return to normal and the lower the risk for MetS (110). Principal components analysis by Panagiotakos et al. (111) showed that in the Attica region of Greece a dietary pattern that included cereals, fish, legumes, vegetables, and fruits was independently associated with reduced levels of clinical and biological markers linked to MetS, whereas the opposite association was found for meat and alcohol intakes. In subjects with MetS, those who followed the New Nordic diet, which included whole grains and a balance of berries, fruits, vegetables, fish, nuts, and low-fat dairy products, for 2 weeks had reduced blood pressure compared with those following the control diet, which included wheat products, dairy fat-based spread, and lower intake of fruits, vegetables, and fish (112).

The results are similar for other non–Western-type dietary patterns. For older Chinese adults two dietary patterns—the "traditional food pattern," consisting of vegetables, fruits, rice, pork, and fish, and the "soybean, grain, and flour food pattern"—were associated with end points that would reduce risk of MetS. The other two patterns, the "fast and processed food pattern" and the "dairy and animal food pattern," were associated with increases in factors contributing to MetS (13). The mixing of beans and rice was important in reducing the risk factors for MetS in a study of Korean adults (113).

Similarly, the "balanced Korean diet," a typical Korean diet of rice and kimchi (a spicy, pickled cabbage dish) supplemented by a variety of foods, not only lowered the risk of elevated blood pressure in men and women by >40%, it lowered the risk of hypertriglyceridemia in men and MetS in women by >30% (17). On the other hand, analysis of the Korean NHANES survey data for the "unbalanced Korean diet," a diet characterized by high intakes of CHO and sodium and little food variety, showed it was associated with a higher risk of elevated blood pressure and MetS in South Korean women.

Grains and Whole Grains and MetS—A Summary

Refined grains and CHOs may be associated with increased risk of MetS, but not all studies show this association. In fact, some studies show that consumption of wheat breads and foods prepared with other grains reduce the risk of MetS, whereas low-CHO diets increase the risk of MetS. What is clear is that adequate dietary fiber intake and healthy dietary patterns that include the right mix of CHOs, grains, whole grains, and other dietary components decrease risk of MetS and its components. Certain whole grains, such as rye, may be especially beneficial for those with MetS.

In short, it is difficult to attribute MetS to high CHO or grain intake, high saturated fat intake, or inadequate intakes of other nutrients. Dietary patterns that are high in fat and low in dietary fiber and whole grains can be problematic in terms of preventing and managing MetS. Inclusion of dietary CHOs, balanced with respect to type and amount, as part of diets containing other recommended components is fundamental to reducing the risk and management of MetS. The key appears to be dietary patterns, such as the DASH, New Nordic, or Mediterranean diets, which provide all the food groups in an optimal balance and deliver adequate levels of nutrients.

Relationship of CHOs, Grains, and Whole Grains to Diabetes and Its Treatment

The role of dietary CHOs in preventing and treating diabetes was discussed well before the discovery of insulin nearly 100 years ago. Reviews by diabetes associations and professionals from around the world suggest that consumption of CHOs be managed rather than eliminated (114–116). However, there is much discussion about the amount and type of CHOs recommended for preventing type 2 diabetes mellitus (T2DM) and treating both type 1 diabetes mellitus (T1DM) and T2DM.

CHOs and Diabetes

Data from prospective cohort studies suggest that the percentage of CHO in the diet does not appreciably influence diabetes risk (117,118). In the U.S. Nurses' Health Study, with more than 70,000 participants, higher CHO intake was not related to increased risk of diabetes (119). However, higher starch intake was associated with increased risk in the Nurses Health Study, but not in postmenopausal women in Iowa or in the Women's Health Study (120–122). Also, in a subcohort of the European Prospective Investigation into Cancer and Nutrition (EPIC), digestible CHO intake, which would include starch, was not associated with incident diabetes in either men or women (123). In fact, in the EPIC cohort (124) CHO intake was associated with lower risk of T2DM, but the association was attenuated by controlling for lifestyle and dietary confounders, including waist circumference and dietary fiber intake. It appears that CHO by itself is not associated with increased risk.

The combined amounts of CHO, fat, and fiber consumed appear to be important. An early study of the effects of high-fat, low-CHO diets showed that they were associated with increased risk of T2DM (125). More recent studies have reported similar findings. For example, for the 20,000 participants in the Chinese NHANES survey, high-fat, low-CHO diets were associated with higher incidence of T2DM than were traditional high-CHO Chinese diets (126). In the U.S. Male Health Professionals' Follow-Up Study ($N \approx 40{,}000$), those following low-CHO diets high in animal fat and protein were almost 75% more likely to develop T2DM than those who followed a more moderate diet (127).

Dietary Fiber and Diabetes

Dietary fiber content is one aspect of CHO quality that modifies T2DM risk. Diets rich in dietary fiber, especially cereal fiber, appear to reduce the risk of T2DM. Data from prospective cohort studies demonstrate an inverse association between dietary fiber from cereal products and T2DM risk (128). Compared to fruit fiber, cereal fiber showed a stronger inverse association with diabetes risk (119). Data on black U.S. women ($N = 59{,}000$) show that cereal fiber was associated with reduced risk of T2DM; this inverse asso-ciation was much stronger for those with BMIs < 25 (129). Data from the Nurses' Health Study show that cereal fiber and starch/cereal fiber ratio were critical for favorable levels of the T2DM risk factors adiponectin and C-reactive protein (CRP) (118,119,128). In a meta-analysis, 13 of 16 observational studies showed an inverse relationship between dietary fiber intake and these markers of inflammation (130).

Glycemic response, usually measured as GI or GL, is another aspect of CHO quality that may modify T2DM risk. A meta-analysis of prospective studies shows that low-GI and -GL diets, compared with diets with higher GI and GL, were associated with lower risk of T2DM (118,131, 132). However, the effect of GL alone was small, with those subjects following diets in the highest quintile of energy-adjusted GL showing a 10% higher risk of T2DM. Those who consumed a diet that was both high in GI or GL and low in cereal fiber had an ≈50% higher risk of T2DM (132).

The effect of GI and GL on diabetes is modified not only by dietary fiber intake, but also by gender, obesity, and other dietary components. In the Japan Public Health Center-based Prospective Study, in which diets were high in CHO, particularly from white rice, the relationship between GI and GL and diabetes was affected by body weight and gender, as well as diet composition (133). Both GI and GL were positively associated with the risk of T2DM among women, and the relationship was stronger for women with BMIs < 25, as was observed in black U.S. women (129,131). The fat content of the diet pattern mattered, but its impact varied by gender. In women, diets low in GI and high in fat were associated with lower risk than for those women following a diet with low-GI and lower total fat intakes. In men, high dietary GI together with high fat intake was positively associated with risk of diabetes (133). In the Nurses' Health Study, consumption of moderate amounts of alcohol attenuated the effect of GL on diabetes risk (134). In a cohort of black U.S. women, GI was positively associated with risk of diabetes, with an incident relative risk for the highest versus the lowest quintile of 1.23. The impact of a high-GI diet was greater in women with a BMI < 25 (129).

Some studies show no relationship between either dietary GI or GL and incident T2DM. In the eight country subset of the EPIC cohort (123) and the more than 7,000 white Britons in the Whitehall II study, neither high dietary GI nor GL was associated with increased risk of incident diabetes (135). The lack of consistency among findings from various cohorts may be due to the high variability of the GI measure and the very difficult problem of assigning GI and GL to foods in a food frequency survey. Further, diet quality can vary markedly with differences in GI and GL, and all of these variables can impact T2DM risk (136,137).

Grains and Whole Grains and Diabetes

Epidemiological studies suggest an inverse association between the intake of whole grains (including bran) and risk of T2DM (138). For example, a recent systematic review and meta-analysis of 16 prospective cohort studies shows that the consumption of 3 servings of whole grain/day was associated with a 32% reduced risk of T2DM (118). Further analyses showed the same protective association for whole grain bread, whole grain cereals, wheat bran, and brown rice (139). Similarly, analyses by de Munter et al. (140) showed the same relative protection for whole grains and bran in the diets of women in the Nurses' Health Studies I and II. In a large systematic review and meta-analysis, Aune et al. (141) found an inverse dose-response relationship between whole grain consumption and incidence of T2DM in postmenopausal women. However, in the Women's Health Initiative Observational Study ($N = 72{,}215$), the inverse association observed between high whole grain intake and reduced risk of incident T2DM was attenuated after adjustment for dietary fiber (142). This finding emphasizes the importance of dietary fiber intake in preventing T2DM.

Studies assessing associations between refined grain intakes and risk of T2DM report mixed results. In their meta-analysis Aune et al. (141) showed that refined grains had an RR = 0.97, indicating that risk of T2DM was neither increased nor decreased. In the Atherosclerosis Risk in Communities (ARIC) cohort (880 middle-aged adults), analyses of dietary patterns showed that the intake of low-fiber breads and cereals was one factor associated with increased risk of insulin resistance and T2DM (143). It may be that dietary fiber and resistant starch intakes are key factors because replacing refined grains with whole grain appeared to help protect against T2DM (144).

Specific Grain-Based Foods and Diabetes

Breads and Cereals. Whole grain breads, whole grain cereals, wheat bran, and brown rice all were associated with lower risk of diabetes in a systematic review and meta-analysis of cohort studies of postmenopausal women (136). Breakfast cereal intake also was associated with a 37% reduced risk of T2DM in the Physicians' Health Study cohort of more than 20,000 men (145). The inverse association between cereal intake and T2DM became stronger when only whole grain breakfast cereal was considered. Studies of more than 4,000 9–10 year old children in the United Kingdom showed that those eating a high-fiber breakfast cereal had lower insulin resistance than those eating other breakfast product types. Further, the children had more favorable T2DM risk profiles (146). A recent evidence-based review gave a B grade (graded on a scale of A [can be trusted] to D [weak, apply with caution]) to evidence linking consumption of whole grain or high-fiber breakfast cereals to a lower risk of diabetes (147).

Six dietary factors, two of which were oatmeal and rye bread consumption, were used to measure adherence to the New Nordic Diet as assessed in 57,053 Danish men and women. Those with a high rate of adherence had a 25% lower risk of T2DM than those with poor adherence (148).

Rice. A few studies have shown that consumption of white rice was associated with increased risk of T2DM (149,150). One study only showed that increased risk occurred, but only in women (151). Further, modeling studies predict that the replacement of white rice with brown rice would be associated with a 16% decreased risk of T2DM (149).

In terms of risk of mortality due to diabetes, consumption of dietary fiber and ready-to-eat breakfast cereals was associated with lower mortality from all causes and specific causes, including diabetes (152). Whole grain and cereal fiber intakes were associated with lower risk of death from diabetes in the more than 360,000 subjects in the NIH-AARP cohort (153).

CHOs, Grains, and Whole Grains and Treatment of Diabetes

CHOs. The causes of T2DM and T1DM are very different, but the recommendations regarding dietary treatment are closely aligned. Because CHOs impact postprandial blood sugar, counting CHOs is critical to keep blood glucose levels consistent. Counting is based on the principle that 15 g of CHO equals 1 serving (or choice) of CHO. Counting enables the amount of CHOs ingested to stay the same while allowing consumption of a wide variety of CHO-based foods without wide swings in blood glucose and, thus, ideally keeping glycated hemoglobin A1c (HbA1c)—a major marker of the degree of blood glucose control over time—at levels that are as low as possible. Advanced CHO counting is useful for determining insulin dose and is used by those with an insulin pump or who regularly inject insulin. In a recent review, this latter method was shown to result in a trend toward slightly lower HbA1c on average (154).

For those with diabetes, some recommend following diets that minimize dietary CHO to manage fasting blood glucose and other measures. However, in a meta-analysis of 19 RCTs of overweight subjects (3,209 participants), low-CHO diets compared to those with recommended CHO levels showed no differences in mean fasting blood sugars at any point measured during the 24 months of the study (155). Similarly, studies, including a meta-analysis of 53 studies of diets for those with diabetes lasting at least 4 weeks, found no significant differences between diets deemed to be low CHO (<45 g/day) and those that included more CHO with respect to metabolic markers and glycemic control (156,157). In the year-long Canadian Trial of Carbohydrates in Diabetes—a controlled trial looking at 62 individuals with T2DM whose dietary control was deemed to be good—the percentage of energy from CHO (39–55%) did not affect most markers of T2DM, including HbA1c (158).

Despite these findings, however, some continue to recommend a lower percentage of energy from CHO as part of a diabetic diet, especially if weight loss is desired. For example, Diabetes UK suggests that low-CHO diets can lead to improvements in HbA1c and reductions in body weight in the short term (<1 year) (159). However, they note that weight loss may be due to reduced calorie intake and not specifically result from CHO restriction. Further, they note a lack of evidence related to long-term effects of low-CHO diets (159). Thus, this organization and others such as the American Diabetes Association recommend CHO counting (160).

GI and GL. Data both for and against the use of GI and GL as part of dietary management of diabetes exist. The largest of the RCTs is the year-long Canadian Trial of Carbohydrates in Diabetes (155). In diabetics with good control through diet, changing the GI or GL of their diets did not impact HbA1c. In other words, after subjects consumed a high-GI diet with 47% of energy from CHO, a low-GI diet (GI = 55) with 52% of energy from CHO, or a low-CHO diet (GI = 59) with 39% of energy from CHO, no significant difference was observed in their HbA1c. While following the low-GI diet, fasting glucose was significantly higher, but 2 hr postload glucose was significantly lower. The only documented advantage of the low-GI diet over the diet with total CHO controlled or the high-CHO diet was 30% lower CRP (158). In a review of the effects of GI and GL in the diet on management of diabetes, there were no significant differences in HbA1c and fasting glucose, but there were significantly greater drops in CRP and fasting insulin with low-GI/GL diets (161).

Although a number of studies show little difference, others show low-GI/GL diets have advantages. In a systematic review and meta-analysis, low-GI and high-GI food groups were compared (162). The low-GI food group resulted in more beneficial effects on HbA1c and fructosamine than did the high-GI food group. Similarly, in a cross-sectional study with 640 T2DM patients 28–75 years of age a high-GL diet was associated with a 2.5-fold increase in the risk of hyperglycemia and a 3-fold increase in HbA1c (163). In overweight men, insulin sensitivity increased with a diet low in GI and moderate in CHO content (i.e., low GL) (164). Thus, it appears that the findings are too variable to make a recommendation for one diet over another.

Dietary Fiber, Resistant Starch, Whole Grains, and Treatment of Diabetes

Dietary Fiber. Consumption of dietary fiber, especially certain viscous fibers, has been associated with lowering of postprandial blood glucose levels, improving blood lipid profiles, lowering markers of inflammation, increasing insulin sensitivity, and changing the gut microbiome. Therefore, adequate dietary fiber intake is recommended (GI = 63) for the treatment of diabetes (165–167). In a cross-sectional study of 640 diabetics, higher intake of dietary fiber was associated with lower risk of elevated fasting serum glucose, but not with lower risk of elevated HbA1c (160). An analysis of RCTs showed that high-fiber diets (up to 42.5 g/day), including foods rich in dietary fiber and dietary fiber supplements containing soluble fiber (up to 15.0 g/day), reduced glycated hemoglobin and fasting plasma glucose (168).

There is no agreement concerning an optimal amount of dietary fiber intake for improvement of blood glucose control. Although some recommendations suggest at least 25 g/day, studies have shown that as much as 50 g/day may be needed to improve blood glucose control (169,170). In response, some argue that such dietary fiber intakes are so far above levels regularly ingested as to be unrealistic. Supporting this position, two systematic reviews found little evidence that dietary fiber significantly improves glycemic control at levels usually ingested (116,171). However, other studies have shown some lowering of preprandial glucose and HbA1c with dietary fiber intakes under 50 g/day, especially if the diets were plant based (172,173). Despite the ongoing controversy, various health professional organizations recommend that people with diabetes consume at least the amount of dietary fiber and whole grain recommended for the general public, especially because dietary fiber intakes are associated with lower all-cause mortality in people with diabetes (174,175).

There is general agreement that various cereal fibers in the diets of those with T2DM are beneficial and that consumption of a mix of fiber types appears to be advantageous (176). In an intervention study using cereal fibers, the insulin sensitivity of those assigned to follow a diet with 52% of energy from CHO and 43 g of cereal fiber/day was 25% better than the insulin sensitivity of those assigned to follow diets with lower fiber (14 g/day) or more protein intake (177).

Whole Grains. Results of a meta-analysis of 45 epidemiological studies and 21 RCTs show that fasting glucose was lower in subjects consuming between 48 and 80 g of whole grain/day compared with consumers who rarely if ever ate whole grains (178). T2DM subjects with a gene polymorphism putting them at high risk showed a decrease in fasting glucose, insulin resistance, and triglyceride with the substitution of whole grains and legumes for refined rice in a high-CHO diet (≈65% of energy) (179).

Several whole grain components, likely acting simultaneously, promote beneficial effects in the diets of diabetics. Lowered blood glucose is attributed to several mechanisms, which include the following:

1) Formation of a barrier that prohibits amylases from accessing the starch
2) Formation of a gel that reduces the rate of amylase penetration into the starch granules, causing a decreased rate of glucose entry into the bloodstream
3) Changes in the rate of gastrointestinal transit
4) Acting as a substrate for gut microbiota that produce fermentation products and that impact blood lipids, glucose swings, and inflammation, which helps reduce complications of diabetes

CHOs, Grains, Whole Grains, and T1DM. Diets recommended for treating T1DM are often the same as those recommended for treating T2DM. Recent data from continuous glucose monitoring highlight the complexity of postprandial glucose patterns in individuals with T1DM, showing that fat slows gastric emptying and reduces glucose in the first 2–3 hr after eating (180). Such monitoring shows that meals that are high in fat and protein require more insulin than meals that are lower in fat and protein but that have identical CHO contents. Such studies indicate that meal composition rather than total CHO content or GI must be considered. In many cases the mechanisms of food effects are the same despite the very different etiologies of T1DM and T2DM.

Specific Grain-Based Foods and Treatment of Diabetes

Breads. A number of small studies have shown that substitution of breads that have a lower GIs and more cereal fiber improve one or more factors associated with diabetes, such as insulin economy (181). Some, but not all, studies show improvements in fasting glucose and other measures of glucose response (182). For example, low-GI chapatti prepared with bran had a lower postprandial glucose and insulin response compared with chapatti prepared with refined flour (183). The response was more pronounced in diabetic subjects than in normal subjects. In several studies whole grain rye breads or breads with added fibers resulted in various improvements in markers associated with diabetes risk, including significantly lower blood glucose levels and improved glycemic parameters compared with those observed with other whole grain or refined grain breads (183).

When compared with regular white (refined) bread, breads with added guar (184) or 3 g of β-glucan (185) improved lipid profiles and insulin resistance in patients with T2DM. The type of fiber in whole grains impacts diabetes factors, and oat β-glucan helps to modulate blood glucose. The degree of impact of β-glucan depends on properties in oat-based foods that affect the viscosity and molecular weight of the glucan when eaten (186).

Dietary Patterns. Dietary patterns have been linked not only to the prevention of T2DM, they have been studied for management of T1DM and T2DM in a variety of populations. A study of the subset of individuals with diabetes in the Korean NHANES survey revealed the importance of dietary patterns (187). The "Korean healthy pattern," including whole grains, legumes, vegetables, and fruits, improved lipid profiles over other diets. Total CHO intake was lower in the Korean healthy pattern (69%) than in the "rice pattern," but not as low as the 61.2% in the higher fat "bread and meat and alcohol pattern."

A comparison of diets with low-GI, low-CHO, and Mediterranean patterns in a meta-analysis of 20 RCTs (n = 3,073) showed that all diets led to greater improvement in glycated hemoglobin compared with control diets (188). However, the Mediterranean diet resulted not only in slightly greater weight loss than the other diets, but also better HbA1c than the other two diets studied. A recent review suggested that patterns with overall diet quality should be emphasized to lower risk of complications and improve management of diabetes (189). Diets that promote weight loss are particularly advantageous. A 2016 meta-analysis (190) showed that the Mediterranean diet reduced the risk of MetS and diabetes and was beneficial for those with diabetes.

Two recent reviews showed that a few studies suggest intermittent fasting and ketosis are advantageous both in preventing and treating diabetes and abnormal glucose tolerance, especially for those who need to lose weight (191,192). However, many more robust clinical trials testing this hypothesis are needed before this controversial approach is adopted.

Healthy, nutrient-dense foods that provide the correct balance of nutrients, dietary fiber, and bioactive components in dietary patterns similar to the Mediterranean diet are needed. Such diets positively impact the microbiome and various metabolic pathways and reduce inflammation, elevated blood pressure, impaired glucose tolerance, symptoms of diabetes and cardiometabolic disease (193). Further, balanced diets have been shown to be effective in multiethnic cohorts, such as those in the Women's Health Initiative, for both the prevention and management of these disorders (194). These findings emphasize that it is a healthy pattern and not one nutrient versus another that provides the most benefit.

Conclusions

Body weight, elevated blood pressure, MetS, and diabetes appear to be best addressed and prevented by diets that enable weight maintenance and loss when necessary, that focus not on the elimination of CHOs and grains, but rather on the ingestion of foods and nutrients within tested, balanced dietary patterns. These diets would contain from 45 to 65% CHO, including high levels of the dietary fiber and phytochemicals present in whole grains. Both are associated with a lower risk of elevated body weight (4) and lower risk of hypertension, MetS, and diabetes.

Consumption of an optimal number of grains and optimal balance of whole and refined grains—and the fibers and phytochemicals they contain—as part of a balanced diet can help reduce markers of inflammation; modulate blood glucose; and positively impact factors associated with insulin resistance, risk of hypertension, MetS, diabetes, and inflammation. Although there is no universal agreement concerning a dietary strategy to prevent or delay the onset of these conditions, the data do align to suggest there are preferred dietary patterns that reduce the risk and others that increase the risk for developing these conditions. All of the preferred dietary patterns include an optimal balance of CHO, dietary fiber, whole grains, and refined grains. They are characterized by a higher intake of food groups that are generally recommended for health promotion, including protein in appropriate quantities and varieties (e.g., meat, fish, poultry, and legumes); recommended servings of fruits and vegetables; optimal sources of calcium or amounts of dairy products; an optimal mix of fats, including beneficial fats from nuts and seeds; and, finally, the enjoyment of small amounts of indulgent foods.

Patterns such as the DASH, Mediterranean, and New Nordic diets and the USDA MyPlate recommendations, as well as many others, that include balanced amounts of all macronutrients, vitamins, minerals, and phytonutrients do not eschew any food groups, including grains and breads, meet this balance (195). Sadly, only 3–8% of Americans eat according to such patterns. Less than 4% of Americans meet the dietary fiber intake requirement, and less than 1% meet the whole grain intake requirement. Data from many other countries also show a large gap between recommended patterns and actual intakes. For many, servings are too large, and grain-based desserts and other high-calorie, low-nutrient foods provide too many calories at the expense of nutrient-rich fruits and vegetables and whole and refined grain staple foods. General diets do need improvement, but elimination of CHOs and grain-based foods will not provide the improvements needed for most individuals.

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