Dietary Approaches to Prevent the Metabolic Syndrome

Quality versus quantity of carbohydrates

The metabolic syndrome refers to a cluster of specific abnormalities with insulin resistance as the underlying pathophysiological defect. Its clinical identification is based on measures of abdominal obesity, atherogenic dyslipidemia, raised blood pressure, and glucose intolerance (1). About one-fourth of U.S. adults have the metabolic syndrome, according to the criteria defined by the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (NCEP ATP III) (2). Given the continuing epidemic of overweight and obesity, it is likely that the prevalence of the metabolic syndrome will continue to grow. The metabolic syndrome is a precursor to type 2 diabetes and a strong risk factor for coronary heart disease (CHD) and stroke (1).

The metabolic syndrome has been identified as a target for dietary therapies to reduce cardiovascular disease risk other than LDL cholesterol lowering by the NCEP ATP III (1). Although clear evidence from metabolic studies, epidemiological studies, and clinical trials supports the consumption of unsaturated fats from natural liquid vegetable oils and nuts at the expense of saturated and *trans* fats (rather than simply lowering total fat) in the treatment of various components of the metabolic syndrome (e.g., dyslipidemia, insulin resistance, and glucose intolerance) and in the prevention of CHD (3), the optimal types and amounts of carbohydrates in the diet remain controversial. It is now well established that low-fat, high-carbohydrate diets not only lower HDL and raise triglycerides but also generally produce higher postprandial glucose and insulin responses. However, metabolic consequences of carbohydrates depend not only on their quantity but also on their quality. The glycemic response of a given carbohydrate load depends on the food source, which has led to the development of the glycemic index, ranking foods by their ability to raise postprandial blood glucose levels. In addition, effects on blood glucose and lipid metabolism by carbohydrate-rich foods depend on fiber content and type. Controlled feeding studies have found benefits of whole grains on insulin sensitivity and glucose (4) and lipid metabolism (5) compared with refined grains. In addition, several epidemiological studies found that diets rich in whole grains may protect against cardiovascular disease, stroke, and type 2 diabetes (5).

In this issue of *Diabetes Care*, McKeown et al. (6) add epidemiological data linking high-fiber, whole grain foods and low–glycemic index diets to lower insulin resistance and a lower risk of the metabolic syndrome. In a cross-sectional study among 2,834 participants of the Framingham Offspring Study, total fiber, cereal fiber, fruit fiber, and whole grain intakes were associated with lower insulin resistance (as measured with the homeostasis model assessment for insulin resistance [HOMA-IR]), while glycemic index and load were positively associated with insulin resistance. Furthermore, whole grain and cereal fiber intakes were associated with a reduced risk of the metabolic syndrome, with cereal fiber accounting for most of the whole grain effect. A higher glycemic index was associated with a higher risk of the metabolic syndrome, while no associations were observed for glycemic load, total carbohydrate intake, refined grain intake, or other sources of dietary fiber. The validated food frequency questionnaire applied in this study to assess dietary exposure was designed to capture not only absolute quantity of carbohydrates, but also quality aspects of carbohydrate-containing foods, particularly cereals. While associations between dietary variables and HOMA-IR were independent of obesity, it remains unclear whether the associations with the metabolic syndrome were largely mediated by effects on obesity or by effects on insulin resistance and blood lipids as well because whole grain intake was not significantly related to blood pressure, HDL cholesterol, triglycerides, or fasting glucose after controlling for BMI in an earlier report from this study population (7). In a recent report from the Insulin Resistance Atherosclerosis Study (8), the inverse association between whole grain intake and insulin resistance remained significant but was attenuated after adjustment for BMI and waist circumference, suggesting that benefits of whole grain intake on the metabolic syndrome are in part mediated through obesity.

Despite compelling evidence supporting a role of whole grain consumption in chronic disease prevention, different types of fibers from whole grain foods appear to have different metabolic effects. Whole grain products from oat, barley, rye, and psyllium are high in soluble fiber, while wheat and corn typically contain insoluble fiber. Lipid-lowering properties were generally observed for grain products rich in soluble fiber, but not for those rich in insoluble fiber (9). In epidemiological studies, however, insoluble fiber—but not soluble fiber—was found to be inversely associated with diabetes risk (10,11), and cereal fiber was found to have stronger effects on diabetes and cardiovascular disease risk (3) compared with fiber sources particularly rich in soluble fiber. Other characteristics of whole grain foods, besides their high fiber content, might also be important in glucose and lipid metabolism, for example, the physical form and degree of processing of whole grains and the presence of organic acids, enzyme inhibitors, and other bioactive compounds (12). Epidemiological studies are unlikely to yield detailed evaluations of these pathways, and basic and experimental research is clearly warranted.

The concept of glycemic index remains controversial. At extremes, it is either dismissed as an irrelevant indicator (13) or embraced as the sole yardstick

with which to classify "good" or "bad" foods, especially in popular diets. Major health organizations in the U.S., including the American Diabetes Association, discourage the use of the glycemic index in nutritional therapy, despite the fact that the concept has now been widely adopted by many international organizations. The weight of current evidence, including data from the present study, indicates that the glycemic index is useful in characterizing the quality of carbohydrates beyond dietary fiber. However, the glycemic index database needs to be further developed and standardized, particularly in different populations and in the context of mixed meals. The concept of glycemic load is appealing because it captures both the quality and quantity of carbohydrates as well as potential interactions between them. In practice, glycemic load can be lowered by reducing the total amount of carbohydrates in the diet, the overall dietary glycemic index, or both, although reducing the amount of carbohydrates (especially refined carbohydrates) is more effective in lowering glycemic load than reducing the overall dietary glycemic index alone.

Prevailing dietary guidelines continue to recommend very high intakes of grain products without a clear distinction between whole and refined grains (14). Many popular diets that focus on weight loss, on the other hand, have jumped on the low-carbohydrate bandwagon, prohibiting virtually all carbohydrates, especially in the initial phase of the diet. Both approaches are incompatible with current scientific evidence and can have long-term adverse health implications. With the growing epidemic of obesity and the metabolic syndrome, reduction in the consumption of refined carbohydrates and sugar, replaced by either minimally processed whole grain products and healthy sources of fats and protein, should become a major public health priority, together with regular physical activity and weight maintenance.

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References

1. Executive Summary of The Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III). *JAMA* 285:2486–2497, 2001
2. Ford ES, Giles WH, Dietz WH: Prevalence of the metabolic syndrome among US adults: findings from the Third National Health and Nutrition Examination Survey. *JAMA* 287:356–359, 2002
3. Hu FB, Willett WC: Optimal diets for prevention of coronary heart disease. *JAMA* 288:2569–2578, 2002
4. Pereira MA, Jacobs DR Jr, Pins JJ, Raatz SK, Gross MD, Slavin JL, Seaquist ER: Effect of whole grains on insulin sensitivity in overweight hyperinsulinemic adults. *Am J Clin Nutr* 75:848–855, 2002
5. Liu S: Intake of refined carbohydrates and whole grain foods in relation to risk of type 2 diabetes mellitus and coronary heart disease. *J Am Coll Nutr* 21:298–306, 2002
6. McKeown NM, Meigs JB, Liu S, Saltzmann E, Wilson PWF, Jacques P: Carbohydrate nutrition, insulin resistance, and the prevalence of the metabolic syndrome in the Framingham Offspring Cohort. *Diabetes Care* 27:538–546, 2004
7. McKeown NM, Meigs JB, Liu S, Wilson PW, Jacques PF: Whole-grain intake is favorably associated with metabolic risk factors for type 2 diabetes and cardiovascular disease in the Framingham Offspring Study. *Am J Clin Nutr* 76:390–398, 2002
8. Liese AD, Roach AK, Sparks KC, Marquart L, D'Agostino RB Jr, Mayer-Davis EJ: Whole-grain intake and insulin sensitivity: the Insulin Resistance Atherosclerosis Study. *Am J Clin Nutr* 78:965–971, 2003
9. Jenkins DJ, Kendall CW, Augustin LS, Vuksan V: High-complex carbohydrate or lente carbohydrate foods? *Am J Med* 113 (Suppl. 9B):30S–37S, 2002
10. Meyer KA, Kushi LH, Jacobs DR Jr, Slavin J, Sellers TA, Folsom AR: Carbohydrates, dietary fiber, and incident type 2 diabetes in older women. *Am J Clin Nutr* 71:921–930, 2000
11. Montonen J, Knekt P, Järvinen R, Aromaa A, Reunanen A: Whole-grain and fiber intake and the incidence of type 2 diabetes. *Am J Clin Nutr* 77:622–629, 2003
12. Liu S: Whole-grain foods, dietary fiber, and type 2 diabetes: searching for a kernel of truth. *Am J Clin Nutr* 77:527–529, 2003
13. Pi-Sunyer FX: Glycemic index and disease. *Am J Clin Nutr* 76:290S–298S, 2002
14. U.S. Department of Agriculture, U.S. Department of Health and Human Services: *Nutrition and Your Health: Dietary Guidelines for Americans.* Washington, DC, U.S. Government Printing Office, 2000