Carbohydrate and diabetes: Is the source or the amount of more importance?

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High- or Low-Carbohydrate Diets

The Continuing Controversy

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The optimal amount of carbohydrate in the diet for persons with diabetes or at risk for the disease is an ongoing topic of debate. After all the research and discussion over the years, one might think that the issue would have been resolved. Instead, you can find research to support whatever side of the debate you happen to agree with, and this suggests that there is no clear answer to the question.

A major goal of nutrition-therapy interventions in diabetes is to help achieve and maintain glycemic control. Because food carbohydrates are the major determinant of postprandial blood glucose levels, low-carbohydrate diets might seem to be the logical approach for achieving this goal (1). However, the important factor is the balance between carbohydrate and available insulin. When the pancreas produces the required amount of insulin, individuals remain euglycemic regardless of the amount of carbohydrate they consume. In addition, foods that contain carbohydrate are important sources of energy, fiber, vitamins, and minerals and are a mainstay of healthful eating. According to the Dietary Reference Intakes, the Recommended Dietary Allowance for carbohydrate is 130 g/day as an average minimum requirement (2). This minimum is based on the need for glucose as an energy source in the brain and central nervous system.

Managing carbohydrate intake is, however, a primary strategy for controlling blood glucose and lipid levels. How best to do this has been, and continues to be, controversial. This article addresses the following questions:

- Does a high intake of carbohydrate-containing foods cause insulin resistance?
- Does a low-carbohydrate diet improve glycemic control?
- Do carbohydrates increase triglyceride levels?
- Is a low- or high-carbohydrate diet better for weight loss?

In each section, the "bottom line" gives my conclusions after reviewing the evidence. As stated earlier, it is likely that some readers will agree and others will disagree.

Carbohydrates and Insulin Resistance

The evidence. One of the difficulties in examining the effect of carbohydrate on insulin action is that any change in one component of the diet is accompanied by changes in other components of the diet. As carbohydrate in the diet is increased, fat is generally decreased, and vice versa. Given that chronic consumption of foods high in fat, especially saturated fatty acids, is reported to increase insulin resistance (3), it is difficult to discern which macronutrient change may contribute to the improvement in insulin resistance.

A review compared short-term intervention studies with high- versus low-carbohydrate intake in subjects without and with diabetes (4). Of 11 studies in subjects without diabetes, 7 reported an increase in insulin sensitivity from the high-carbohydrate diet and 5 reported no difference. Of 8 studies in subjects with diabetes, 5 reported improvement in insulin sensitivity from the high-carbohydrate diet and 3 reported no difference. The author concluded that high-carbohydrate diets do not adversely affect insulin sensitivity and may offer some benefits.

Longer-term clinical trials have also reported no harmful effects on insulin sensitivity from a high-carbohydrate diet. In a study of Pima Indians, a high-carbohydrate diet improved fasting insulin and blood glucose levels despite no change in insulin action as compared with a low-carbohydrate diet (5). Another study examined the effect of the Dietary Approaches to Stop Hypertension (DASH) diet. Implementing the DASH dietary pattern (which is high in carbohydrates) in individuals with hypertension enhanced insulin sensitivity compared with control subjects with a usual lifestyle intervention (i.e. weight

loss if overweight, reduced sodium intake, and increased physical activity) (6). The Women's Health Initiative also showed that increasing carbohydrate and lowering fat intake over 6 years had no adverse effects on blood glucose, insulin, or lipid levels (7).

Epidemiologic studies have also examined the relationship between macronutrient composition and the onset of Type 2 diabetes. The San Luis Valley Study, the Health Professionals Follow-Up Study, the Nurses Health Study, and the Iowa Women's Health Study all failed to show a relationship between total carbohydrate intake and hyperinsulinemia or the onset of diabetes (8).

The bottom line. Excessive energy intake causing persons to become overweight or obese—not carbohydrate intake—contributes to the development of insulin resistance (8). Therefore, prevention of weight gain by appropriate energy intake, independent of the macronutrient composition, is the best approach for preventing insulin resistance. To improve insulin sensitivity, a negative energy balance is reported to be more important than weight loss. Energy restriction alone improved insulin resistance almost immediately and long before obese individuals lost a substantial amount of weight. When a weight-maintaining diet was implemented, most of the improvements in insulin sensitivity were lost even if weight was not regained (9). The benefits of physical activity, also independent of weight loss, on insulin sensitivity are also well known (10).

Carbohydrates and Glycemia

The evidence. Another debated issue is the ideal intake of carbohydrate to facilitate glycemic control in persons with diabetes. Two recent studies have examined the association between carbohydrate intake and levels of glycosylated hemoglobin (HbA_{1c}) in persons with Type 2 and Type 1 diabetes (11, 12). The first, a cross-sectional study in American Indians with diabetes, assessed dietary intake in 1,284 participants from the Strong Heart Study (11). Higher intakes of total fat (more than 25% to 30% of energy), saturated fatty acids (more than10% of energy), and monounsaturated fatty acids (more than10% of energy) and lower intake of carbohydrate (less than 35% to 40% of energy) were associated with poorer glycemic control ($P<0.01$ for all). Similar results were reported in the Diabetes Control and Complications Trial in intensively treated participants with Type 1 diabetes who had complete dietary data through 5 years of follow-up (12). Among the 532 subjects, those who consumed diets higher in total fat and saturated fatty acids and lower in carbohydrate had worse glycemic control, independent of exercise and body mass index. The authors concluded that contrary to common advice to restrict carbohydrate intake, individuals with Type 1 diabetes should be advised to limit their intake of saturated fatty acids and to consume nutrient-dense carbohydrates such as fruits, whole grains, and vegetables, while taking appropriate insulin doses as needed.

A meta-analysis of 19 short-term studies (interventions ranged from 10 days to 6 weeks) investigated the effects of a low-fat, high-carbohydrate (LFHC) diet and a high-fat, low-carbohydrate (HFLC) diet in 306 patients with Type 2 diabetes (13). Median carbohydrate/fat ratios in the LFHC and HFLC diets were 58%/24% and 40%/40%, respectively. No significant differences were found between the diets in the reduction in HbA_{1c}, total cholesterol, and low-density lipoprotein cholesterol (LDL-C), but the LFHC diet increased fasting insulin and triglyceride levels and decreased high-density lipoprotein cholesterol (HDL-C). However, the LFHC diet did not elevate triglycerides when energy restriction was prescribed. Studies that included an increase in fiber and whole grains were excluded from the meta-analysis.

Also of interest are two other short-term studies (14, 15). The first was a crossover trial (4 weeks on each diet) that compared a diet rich in carbohydrate (52% of energy) and fiber (28 g/1,000 kcal), essentially based on legumes, vegetables, fruits, and whole cereals, with a diet low in carbohydrate (45%) and high in monounsaturated fatty acids (MUFAs) (23%) in 18 subjects with Type 2 diabetes (14). The higher-carbohydrate diet significantly reduced total cholesterol, LDL-C, postprandial blood glucose, and insulin; increased HDL-C; and had effects similar to those of the comparison diet on triglycerides. The authors concluded that the quality of carbohydrate is important, not just the amount. Similarly, a low-fat vegan diet (75% carbohydrate) improved HbA_{1c} levels by 1% and

lowered total cholesterol, LDL-C, and triglycerides (15).

Since publication of the meta-analysis (13), three 1-year studies comparing high- and low-carbohydrate diets have been published (16–18). In the Canadian Trial of Carbohydrate in Diabetes, two high-carbohydrate/low-fat diets (47%/31% and 52%/27% of energy, respectively) and one low-carbohydrate/high-MUFA diet (39%/40% of energy) were compared (16). At 1 year, HbA_{1c}, body weight, and lipids did not differ significantly between diets. Changes were detected at 3 months with a decrease in triglycerides and an increase in HDL-C in the low-carbohydrate group, but these changes had disappeared by 6 months. The authors suggested that the potentially deleterious effect of high-carbohydrate diets on blood lipids is a temporary phenomenon lasting less than 6 months.

In another 1-year study, a high-carbohydrate diet (60% carbohydrate/25% fat) was compared with a high-MUFA diet (45% carbohydrate/40% fat [20% MUFA]) in 124 overweight or obese subjects with Type 2 diabetes (17). Weight loss was similar at 12 months (~3.9 kg), and comparable improvements in HbA_{1c}, HDL-C, insulin, and diastolic blood pressure were observed with both diets. In the third study, a low-carbohydrate diet modeled after the Atkins diet was compared with a low-fat diet modeled after that used in the Diabetes Prevention Program in 105 overweight adults with Type 2 diabetes (18). Weight loss was again similar at 1 year (3.4%) and there were no significant changes in HbA_{1c} or blood pressure, but a greater increase in HDL-C was reported in the low-carbohydrate diet group.

The bottom line. Most individuals with diabetes in the United States do not eat a low- or high-carbohydrate diet, but rather report a moderate intake of carbohydrate; studies indicate that this is approximately 44% of total energy in individuals with Type 2 diabetes (19) and about 46% in individuals with Type 1 diabetes (12). Furthermore, it appears difficult for persons with Type 2 diabetes to eat a high-carbohydrate diet. In the United Kingdom Prospective Diabetes Study, despite receiving individual education from dietitians on the recommended carbohydrate intake of 50% to 55%, patients reported an energy intake from carbohydrate of 43%, which was similar to that in the general public (20). Perhaps the best advice we can give to patients is to make healthful carbohydrate choices and to be vigilant about portion sizes.

Carbohydrates and Triglycerides

The evidence. It is often recommended that carbohydrates be avoided because they raise triglyceride levels. Carbohydrates do increase triglyceride levels when the energy consumed is weight-maintaining and 55% or more of the energy is from carbohydrate (21). However, in the meta-analysis cited earlier (13), reduced-energy diets with high-carbohydrate content did not significantly increase triglycerides compared with low-carbohydrate content. In another analysis of low-carbohydrate versus low-fat weight-loss diets, the low-carbohydrate diet had a more favorable effect on triglycerides, but the low-fat and therefore higher-carbohydrate diet did not raise triglycerides (22).

In an analysis of data from the third National Health and Nutrition Examination Survey, carbohydrate intakes amounting to greater than 55% of energy did increase triglycerides and lower HDL-C. Carbohydrate intakes of 50% to 55% of energy had the most favorable effect on lipids, including triglycerides (23).

The bottom line. Controlling energy intake is more important than the carbohydrate and fat composition of the diet in improving triglyceride levels. Furthermore, it is unlikely that persons with Type 2 diabetes, even those on weight-maintaining diets, will consume the amount of carbohydrate that raises triglyceride levels (more than 55% of energy intake). In my experience in clinical practice, if individuals consume more than 55% of energy from carbohydrate, they are either drinking large amounts of regular soft drinks or are on a vegetarian diet. It is interesting to note, however, that a low-fat, vegan diet in subjects with Type 2 diabetes actually had a favorable effect on triglycerides (15).

Carbohydrates and Weight Management

The evidence. The rationale for use of a low-carbohydrate diet for weight loss is that with carbohydrate restriction, fuel sources shift from glucose and fatty acids to fatty acids and ketones, leading to appetite restriction, weight loss, and improvements in risk mark-

ers of cardiovascular disease (24). A meta-analysis of randomized controlled trials (5 trials including 447 subjects) examined the effects of low-carbohydrate versus low-fat diets on weight loss and cardiovascular risk factors in overweight and obese adults (22). After 6 months, individuals in the low-carbohydrate diet group had lost more weight (–3.3 kg) than those in the low-fat diet group. However, at 12 months, weight loss was similar. Changes in blood pressure were not different between groups. Whereas total cholesterol and LDL-C decreased more in the low-fat diet group, HDL-C and triglyceride values changed more favorably in the low-carbohydrate diet group. Thus, neither diet showed a clear benefit on cardiovascular risk factors.

A 6-month study in subjects with Type 2 diabetes compared a low-carbohydrate, ketogenic diet (LCKD) with a low-glycemic-index, reduced-calorie diet (25). Both interventions resulted in weight loss; improvements in HbA_{1C}, fasting insulin, and HDL-C; and reductions in medications, but the improvements were greater in the LCKD group. Two issues of concern, however, are the short duration of the study and the high dropout rate in the LCKD group; only 44% of those randomly assigned to LCKD completed the 6-month trial, compared with 59% in the control group. Further, the improvements observed in the study may be temporary. A 48-week trial of an LCKD diet versus a low-fat diet plus orlistat by the same investigators reported similar improvements in weight, HbA_{1C}, insulin, and lipids at study end (26).

Perhaps the "gold standard" of how to conduct weight-loss studies is that by Sacks and colleagues (27), which compared weight-loss diets with different compositions of carbohydrate (35% versus 65%), protein (15% versus 25%), and fat (20% versus 40%). The study randomly assigned 811 overweight adults at two sites, and 80% of the participants completed the study at 2 years. At 6 months, subjects in each diet group had lost an average of 6 kg (7%), but they began to regain weight after 12 months. At 2 years, all completers had lost an average of 4 kg. Satiety, hunger, satisfaction with diet, and attendance at group sessions were similar for all diets, and all diets improved lipid-related risks, fasting insulin, and blood pressure. The authors concluded that "any type of diet, when taught for the purpose of weight loss with enthusiasm and persistence, can be effective."

The bottom line. The key to weight loss is primarily energy intake and not macronutrient composition. A 1-year trial compared four popular weight-loss diets and concluded that all reduced-energy diets modestly reduce body weight; the amount of weight loss depends on adherence to the diet and not the diet type (28). During the first 6 months of dieting, participants in weight-loss trials lose 5% to 9% of their starting weight. At about 6 months, regardless of the intervention, weight plateaus. With continued support, 3% to 6% of weight loss can be maintained (29). Although this may seem discouraging, it is important to remember that this is the amount of weight loss that has important health benefits, including prevention of Type 2 diabetes, decreases in blood pressure, decreases in circulating inflammatory markers (C-reactive protein and cytokines), and potential improvements in triglycerides, total cholesterol, and LDL-C (30). Health-care professionals should continue to stress the benefits of modest weight loss as an important public-health message.

Summary

Calories count! Although the public and health-care professionals would like an easier and more "interesting" answer, this conclusion is supported by clinical studies. Excess total energy intake causes overweight and obesity and thus insulin resistance, poor glycemic control, and elevated triglyceride levels; when energy intake is reduced, the result is modest weight loss. Even a 5% weight loss has major health benefits. Telling patients to eat less is easy advice to give, but it is very difficult for individuals to implement. Education, counseling, and support are needed (although these would be topics of another article). With regard to carbohydrates, perhaps the best advice we can give to patients and to the public is to choose healthful carbohydrate foods (fruits, vegetables, whole grains, low-fat milk, and legumes) in appropriate amounts and portion sizes.

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