A Low-Carbohydrate, Whole-Foods Approach to Managing Diabetes and Prediabetes

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Diabetes is a systemic disease that has reached epidemic proportions worldwide during the past 30 years,[1] and this trend shows no sign of slowing down. In the United States alone, it is estimated that almost 26 million people have diabetes, including 7 million not yet diagnosed.[2] The statistics are even worse for prediabetes (impaired fasting glucose or impaired glucose tolerance), which is believed to affect 79 million Americans > 20 years of age.[2]

Risk factors for type 2 diabetes include, but are not limited to, family history, ethnicity, and obesity, whereas people with certain autoimmune conditions, pancreatic disease, and genetic predisposition are at increased risk for type 1 diabetes.[3] Regardless of the type, individuals with diabetes experience abnormal carbohydrate metabolism because of a variety of factors, including impaired insulin secretion and insulin resistance.

After carbohydrates were recognized as the macronutrient primarily responsible for increasing blood glucose, severe restriction was used to manage hyperglycemia before the discovery of insulin in 1922.[4] Until the early 1970s, a lower-carbohydrate, higher-fat diet was considered appropriate for nutritional management of diabetes.[5] In 1980, the first set of Dietary Guidelines for Americans included recommendations to adopt an eating pattern lower in fat to prevent chronic health conditions such as diabetes, cardiovascular disease (CVD), and hypertension.[6] Although these guidelines state that they "do not apply to people who need special diets because of diseases or conditions," many clinicians began recommending lower-fat eating patterns, and people with diabetes began adopting them.

Although the American Diabetes Association (ADA) has recommended for more than 15 years that macronutrient composition and meal plans be based on individual preferences and needs, many clinicians continue to prescribe a low-fat meal plan for diabetes management. In terms of teaching carbohydrate consistency, a popular nutrition intervention used in clinical practice is known as the "Diabetes Plate." This meal-planning approach contains three to five carbohydrate choices per meal—one to three starch choices, one milk serving, and one piece of fruit—for a total of 45–75 g of carbohydrates, with additional carbohydrates from several cups of nonstarchy vegetables.[7] Recommended snacks typically contain 15–30 g of carbohydrate each.

This approach provides a balanced eating plan and a method of meal planning that works well for some people, but its carbohydrate content may be too high for some people with diabetes who are trying to optimize their blood glucose control or for patients who prefer to eat fewer carbohydrates. Nutritional management of diabetes is often challenging, especially for individuals who are motivated to achieve the recommended blood glucose targets through nutrition and exercise alone or to minimize the amount of medication needed to reach these goals.

Recent and older studies have provided evidence that carbohydrate restriction improves blood glucose control, insulin resistance, and

obesity.[8–11] Since 2008, ADA has recognized that low-carbohydrate diets may be effective for weight loss and glycemic control in people with diabetes.[3] However, of all the eating strategies employed in the management of diabetes and prediabetes, eating patterns dubbed as "low-carbohydrate" are arguably the most controversial among clinicians because of concerns about their safety, effectiveness, and sustainability, along with their impact on the kidneys, bones, lipids, and thyroid.

This article provides a brief review of the research on carbohydrate restriction, discusses its role in diabetes management, and offers practical guidance for clinicians to assist patients interested in following a low-carbohydrate eating pattern.

Defining a Low-Carbohydrate Diet

The Recommended Dietary Allowance (RDA) for nutrient intake is determined by the Institute of Medicine's Food and Nutrition Board. This value is used to establish the Daily Values (DVs) seen on food labels. Although the RDA for carbohydrate is 130 g, the DV is set at 300 g for individuals consuming 2,000 calories per day (or 60% of calories). The Acceptable Macronutrient Distribution Range, which is the range of intakes considered to be healthful by the Food and Nutrition Board, is 45–65% of total calories or 225–325 g based on a total intake of 2,000 calories per day.[12]

The minimum amount of carbohydrate recommended is 130 g per day. This recommendation is based on the amount of glucose required to maintain the needs of the central nervous system (CNS).[12] However, if carbohydrate intake falls below this level, glucose requirements for the CNS, red blood cells, retina, lens, and renal medulla can be met via gluconeogenesis from amino acids, glycerol, and lactic acid. It has been established that all other systems, including portions of the brain, can safely use ketones as their energy source in times of glucose scarcity.[13]

A very-low-carbohydrate ketogenic diet (VLCKD) generally contains < 50 g and often as few as 20 g of total carbohydrate per day. At this point, ketosis occurs, wherein ketones can be measured in the urine or blood and may also be smelled on the breath. Nutritional ketosis should not be confused with diabetic ketoacidosis, an extremely dangerous condition characterized by severe hyperglycemia and excessive production of ketone bodies caused by inadequate insulin and resulting in electrolyte imbalances, profound dehydration, and a markedly acidic pH.

Many "consistent-carbohydrate" or "diabetic" meal plans contain < 300 g of carbohydrate but considerably more than the 130-g RDA. On average, it has been observed that people with diabetes eat ~ 45% of their calories from carbohydrate.[14–17] Defining low-carbohydrate diets is difficult because there is no consistent definition. In a recently published systematic review of macronutrients published by the ADA,[18] definitions for very-low-carbohydrate diet (21–70 g/day) and moderately low-carbohydrate (30 to < 40% of calories) were suggested. These definitions were proposed to evaluate the research to date on carbohydrate intake and glycemic control and are not considered all-inclusive, but rather are representative of definitions used by authors conducting research in this area.

Common Concerns About Low-Carbohydrate Diets

A common criticism of low-carbohydrate diets is the effect of excessive protein intake on bone health and renal function. Reddy et al.[19] reported that protein intake of 164–170 g on a 6-week VLCKD increased net acid load, urinary calcium losses, and risk of kidney stones. An earlier review[20] of several studies of high-protein diets demonstrated that increasing consumption of alkaline foods (i.e., fruits and vegetables) resulted in a significant decrease in net acid excretion and calciuria along with increased bone deposition. Carter et al.[21] found no difference in bone turnover between subjects following a VLCKD and those on a control diet after 3 months. Recent research[22] suggests that protein intake of 120 g/day does not adversely affect kidney health in people with normal renal function. There is some evidence that carbohydrate restriction coupled with moderate protein intake may even benefit people with kidney disease and diabetes.[23]

Because cardiovascular events and stroke are the primary causes of death in people with diabetes, it is important to consider the effect of carbohydrate restriction on lipid profiles and markers of inflammation. Although several studies have demonstrated that low-carbohydrate, high-fat eating patterns tend to raise LDL cholesterol,[24–27] whether this increases the risk for vascular events remains controversial. Oxidized LDL has been implicated in coronary artery disease,[25,28,29] and inflammatory conditions such as obesity and elevated blood glucose play a significant role in lipid oxidation.[25] It has been established that LDL particle size and pattern, triglyceride levels, and the ratio of total cholesterol to HDL cholesterol are important factors in cardiac risk, and there is evidence that low-carbohydrate diets may result in less atherogenic lipid profiles than higher-carbohydrate intakes.[8,9,30,31]

High saturated fat intake has been linked to increases in serum cholesterol levels. Although low-carbohydrate diets are not inherently higher in protein than low-fat diets, they contain significantly more fat and typically fall outside of ADA recommendations to restrict saturated fat to < 7% of calories.[3] However, the role of saturated fat in heart disease is unclear. A recent meta-analysis[32] of 21 prospective epidemiological studies found that saturated fat intake was not associated with an increased risk for coronary heart or vascular disease or stroke. However, nutritional epidemiological studies provide only one category of evidence for evaluating the relationship between saturated fat intake and risk for CVD and stroke. Results from clinical trials are needed to clarify whether cardiovascular risks are likely to be influenced by the specific nutrients used to replace saturated fat. Certain saturated fats such as coconut oil may have health benefits, including antitumor and antimicrobial activity.[33]

In addition to the cardiovascular implications of saturated fat, the effect of saturated fat on glycemic control should also be considered. In a recent systematic review,[18] one randomized, controlled trial was identified that included individuals with type 2 diabetes to compare glycemic control outcomes for saturated fatty acids versus monounsaturated fatty acids with the total fat remaining equal. In this study, there were no significant differences between diets in postprandial glucose levels or insulin responses. However, the impact of low-carbohydrate diets higher in saturated fat on insulin sensitivity and insulin resistance requires further study.

A less studied area that clinicians should consider is the impact low-carbohydrate diets have on thyroid function. Carbohydrate may influence the conversion of thyroxine to triiodothyronine (T3), the hormone responsible for the regulation of growth, metabolism, and body temperature. It has been known since the 1970s that carbohydrate restriction typically lowers T3 levels, with the effect more pronounced at very low carbohydrate intakes.[34,35] More recently, Bisschop et al.[36] found that a VLCKD providing only 12 g of carbohydrate per day resulted in a significant decline in plasma T3 levels in subjects consuming a 2,500-calorie diet. Another study[37] looking at the physiological response to a VLCKD showed a reduction in serum T3 levels but no change in resting metabolic rate. Volek et al.[38] reported that consuming a 2,500-calorie ketogenic diet containing 50 g of carbohydrate did not affect T3 uptake. Although free T3 was not measured, during the 6-week study, subjects achieved a weight loss of 7 lb and increased their muscle mass. However, these studies used carbohydrate levels (e.g., 12 g per day) that are very low and not probably replicable in the real world, had small samples sizes, were of short duration, and found that changes in the T3 levels were not universal among subjects. Therefore, further research in this area is recommended to understand the impact of low-carbohydrate diets on thyroid function.

Potential Benefits of Low-Carbohydrate Diets for People With Diabetes

Results from several short- and long-term studies demonstrate that people often experience improvement in glycemic control with carbohydrate restriction.[39–43] In a recent systematic review,[18] reducing total carbohydrate intake was found to improve markers of glycemic control and insulin sensitivity. However, the included studies were small, of short duration, and had higher dropout rates, and the quality of the study design varied (e.g., many were not randomized, controlled trials).

The amount of carbohydrate used in studies varies, and the optimal level of carbohydrate intake has not been established and will presumably vary based on factors such as a person's size, activity level, and postprandial blood glucose response. For example, in a study by Westman et al.[42] using VLCKDs, greater glycemic improvements were observed by restricting carbohydrates to < 20 g/day compared to a low–glycemic index diet. However, improved diabetes control has also been shown with a macronutrient distribution of 20% carbohydrate, 50% fat, and 30% protein.[40,41] Additional research is needed to help define the optimal intake of carbohydrates.

Preventing hypoglycemia is an ongoing struggle for individuals taking insulin or insulin-stimulating oral medications. Although the majority of recent studies have involved subjects with type 2 diabetes, there is evidence that low-carbohydrate eating patterns can also improve glycemic control in people with type 1 diabetes. Nielsen et al.[44] found that subjects with type 1 diabetes consuming a meal plan containing 70–90 g/day of carbohydrate not only achieved lower A1C and postprandial blood glucose levels, but also experienced fewer episodes of hypoglycemia because of fewer errors in matching their carbohydrate intake to their insulin dosage.

Yancy et al.[10] reported that 17 of 21 patients with type 2 diabetes were able to discontinue (n = 7) or reduce (n = 10) their dosage of insulin or oral diabetes medications after consuming a VLCKD for 16 weeks. Importantly, people whose diabetes is diet-controlled are no longer at risk for hypoglycemia. However, it is presumed that the participants whose blood glucose control improved sufficiently to render diabetes medication unnecessary were in the early stages of diabetes, given the progressive nature of the disease.

Weight control often becomes increasingly difficult in type 2 diabetes, particularly for people who require large doses of insulin or insulin secretagogues known to promote weight gain. Several studies have demonstrated that low-carbohydrate diets are at least as effective as low-fat diets in achieving weight loss.[9,11,31,45] A meta-regression by Krieger et al.[46] demonstrated that limiting carbohydrates to < 30% of total energy resulted in a significantly greater weight loss than higher carbohydrate intake and a better retention of fat-free mass.

Claims that VLCKDs promote weight loss as a result of a metabolic advantage are controversial and have never been proven.[47,48] It appears more likely that successful weight loss is related to a spontaneous reduction in caloric intake during carbohydrate restriction stemming from increased satiety.[43,45,48,49]

Practical Applications for Clinicians

In light of the evidence supporting the benefits of carbohydrate restriction, this eating pattern should be considered as a legitimate option to discuss with patients who have diabetes or prediabetes. A low-carbohydrate eating pattern based on whole foods can meet nutritional needs, promote satiety, and provide a varied, highly palatable meal plan that can be followed indefinitely. However, certain guidelines should be followed to ensure that the eating pattern is nutritious, well-balanced, and sustainable.

Although several studies have demonstrated impressive glycemic control and weight loss results with VLCKDs, this degree of carbohydrate restriction can be difficult to adhere to over the long term. Because more moderate carbohydrate restriction has also been shown to be modestly effective for diabetes

and weight management, this is a reasonable approach with which to begin. A more moderately restricted, nutrient-dense carbohydrate meal plan contains 20–25% of energy as total carbohydrate (100–125 g in a 2,000-calorie meal plan), 20–30% as protein, and 45–60% as total fat and may be easier for patients to follow than a VLCKD. The important role of physical activity for people with prediabetes and diabetes should also be emphasized.[3]

Consuming plant foods that are high in fiber should be a major objective because this is the one component of carbohydrate that has a negligible effect on blood glucose. When counting carbohydrates, it is often recommended that half of the grams of fiber be subtracted from a food if the total amount of fiber is > 5 g. However, with a whole-foods approach, the amount of fiber consumed at a meal may be substantial, even if most of the individual items contain < 5 g per serving. For this reason, the amount of total versus digestible carbohydrate is reported in Table 1, which provides a low-carbohydrate sample menu and nutritional analysis.

Low-carbohydrate diets are often disparaged for providing inadequate calcium, folate, vitamin C, and fiber. The sample menu in Table 1 demonstrates that this criticism is unwarranted because these nutrients can exceed the RDA or adequate intake (AI) amounts without reliance on fortified foods or supplementation. Although the saturated fat content of 13% of total calories is higher than the ADA recommendation of < 7%, this may be a

Table 1. Sample 2,000-Calorie Low-Carbohydrate Menu and Nutrient Analysis

Breakfast

- 2 eggs cooked with 1 tsp coconut oil or olive oil
- 2 cups cooked kale with 2 tsp coconut oil or olive oil and a dash of salt
- 1 cup raspberries with 2 Tbsp chopped pecans
- Water, tea, or coffee

Lunch

- Southwestern salad: 1 large chopped red bell pepper, 2 oz cooked chicken, 1 cup Greek yogurt, 4 Tbsp guacamole, 4 Tbsp sliced black olives, and 2 Tbsp salsa
- 1 cup honeydew melon cubes
- Water, tea, or coffee

Snack

- 6 celery stalks with 2 Tbsp natural peanut butter

Dinner

- 6 oz salmon grilled with 1 Tbsp olive oil and rosemary
- 3 cups mixed green salad, ½ cup pickled beets, 2 Tbsp olive oil,. and 2 tsp balsamic vinegar
- 2 zucchini cut into thin slices and grilled with 1 Tbsp olive oil
- 1 small orange
- Water, tea, or coffee

Percentage of RDA/AI

- Calcium: 126
- Folate: 152
- Vitamin C: 230
- Fiber: 144

	Grams	Kcal	% of Kcal
		2,031	
Total fat	124	1,117	55
• Saturated fat	29		13
• Polyunsaturated fat	36		
• Monounsaturated fat	59		
Protein	110	447	22
Total carbohydrate	116	467	23
• Fiber	36		
• Effective carbohydrate	80		

NOTE: Those who wish to stay within ADA guidelines may choose to use monounsaturated fats in place of foods higher in saturated fats, such as coconut oil and cheese.

reasonable amount for many people. Those who wish to stay within ADA guidelines may choose to use monounsaturated fats in place of foods higher in saturated fats such as coconut oil and cheese.

Carbohydrate, protein, and fat recommendations should be tailored to individual preferences and needs, but providing guidelines can be helpful. Advise patients to aim for 30–35 g of total carbohydrates per meal in the form of several cups of vegetables and a piece of fruit. It may be prudent to recommend a moderate portion of protein such as 4–6 oz per meal. Fat content on a low-carbohydrate diet will vary based on caloric intake and the amount of protein and carbohydrate consumed but will typically fall between 90 and 150 g/day. Moderate intake of monounsaturated fat from avocados, olive oil, olives, and nuts should be encouraged. Other plant and animal foods will provide additional monounsaturated fats, as well as essential fatty acids, polyunsaturated fats, and saturated fats, all of which may have a role in good health.[8,33]

Individuals taking mealtime insulin or hypoglycemic agents who switch to a low-carbohydrate diet may require dosage decreases to prevent hypoglycemia and should initially be followed closely by their health care provider, certified diabetes educator, or other diabetes professional. This is particularly important for patients using premixed insulin with fixed premeal doses rather than those self-adjusting mealtime insulin doses using carbohydrate-to-insulin ratios.

Although many people experience positive changes in biomarkers, lipid levels, and blood pressure, patients should continue to be monitored frequently to assess whether pharmacological changes are indicated. Finally, it is important to help patients understand that diabetes is a progressive disease and that, over time, β-cell function may decline to levels at which meal planning and physical activity may no longer effectively control blood glucose, and diabetes medication may be required.[50]

Summary and Conclusions

Some patients want to try a low-carbohydrate eating pattern for various reasons, and, as clinicians, we should find ways to help patients safely and effectively achieve glycemic control. Although a low-carbohydrate diet may not be the best method for everyone, for some, it may be the key to finally achieving recommended blood glucose targets.

Clinicians are recognizing that an "optimal" diet is one that is highly individualized; in the future, personalized nutrition may take individualization to a new level. Diabetes health care professionals must be open-minded and consider multiple options for diabetes management. The primary aim should be to collaborate with patients to assist them in meeting their goals in a way that works best for them.

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