

Low-Carbohydrate Diets

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Americans spend \$33 billion annually on weight loss products and services, and a large portion of this money is spent on low-carbohydrate diets. Because of their higher protein and fat content and lower fiber and carbohydrate content, concerns have been raised about the potential health consequences of low-carbohydrate diets. Published long-term data are lacking. Short-term studies comparing traditional low-fat diets with low-carbohydrate diets found lower triglyceride levels, higher high-density lipoprotein cholesterol levels, similar low-density lipoprotein cholesterol levels, and lower A1C levels in persons on low-carbohydrate diets. These diets induce greater weight loss at three and six months than traditional low-fat diets; however, by one year there is no significant difference in maintained weight loss. Weight loss is directly related to calorie content and the ability to maintain caloric restriction; the proportions of nutrients in the diet are irrelevant. Low-carbohydrate diets had lower dropout rates than low-fat diets in several studies, possibly because of the high protein content and low glycemic index, which can be appetite suppressing. Data indicate that low-carbohydrate diets are a safe, reasonable alternative to low-fat diets for weight loss. Additional studies are needed to investigate the long-term safety and effectiveness of these and other approaches to weight loss. (*Am Fam Physician* 2006;73:1942-8, 1951. Copyright © 2006 American Academy of Family Physicians.)



ILLUSTRATION BY MARK SCHULER

► **Patient information:** A handout on low-carbohydrate diets, written by the authors of this article, is available on page 1951.

► **See related editorial** on page 1896.

Obesity is a major public health risk in the United States, where 65 percent of adults are overweight (i.e., they have a body mass index [BMI] of 25 kg per m² or greater).¹ The prevalence of obesity in the United States was 14.5 percent from 1976 to 1980² and has since risen to 30.5 percent.¹ The percentage of children who are overweight (i.e., BMI in the 95th percentile or greater for age and sex) is at an all-time high: 10.4 percent of two- to five-year-olds, 15.3 percent of six- to 11-year-olds, and 15.5 percent of 12- to 19-year-olds,³ based on growth charts from 1979.⁴ Black and Hispanic children are more likely to be overweight than white children (21.5, 21.8, and 12.3 percent, respectively).⁵

Approximately 365,000 U.S. deaths in 2000 were attributed to poor diet and physical inactivity (15.2 percent of total deaths), the second leading cause of death for that year.⁶ Obesity-related medical expendi-

tures were estimated to be \$75 billion in 2003, approximately one half of which was financed by Medicare and Medicaid.⁷

At any given time, 45 percent of women and 30 percent of men in the United States are trying to lose weight.⁸ However, less than 25 percent of these persons actually reduce their caloric intake and increase their activity level.⁸ Consumers spend \$33 billion annually on weight loss products, diets, and services,⁸ and a significant proportion of this money is spent on low-carbohydrate diets.

Definition of Low-Carbohydrate Diet

Low-carbohydrate diets restrict caloric intake by reducing the consumption of carbohydrates to 20 to 60 g per day (typically less than 20 percent of the daily caloric intake). The consumption of protein and fat is increased to compensate for part of the calories that formerly came from carbohydrates (*Table 1*).⁹ The Atkins Diet¹⁰ is the prototypical low-

SORT: KEY RECOMMENDATIONS FOR PRACTICE

| <i>Clinical recommendation</i> | <i>Evidence rating</i> | <i>References</i> |
|---|------------------------|-------------------|
| Low-carbohydrate diets are slightly more effective than low-fat diets for initial, short-term weight loss (three to six months), but they are no more effective after one year. | C | 22-24, 26-29 |
| Low-carbohydrate diets do not adversely affect lipid profiles, but evidence of their effect on long-term cardiovascular health is lacking. | C | 22-24, 26-28 |
| Supplementation with a multivitamin should be considered in persons on a low-carbohydrate diet. | C | 9 |
| Because long-term data on patient-oriented outcomes are lacking for many diets, it is not possible to clearly endorse one diet over another. | C | 26, 29, 30 |

A = consistent, good-quality patient-oriented evidence; B = inconsistent or limited-quality patient-oriented evidence; C = consensus, disease-oriented evidence, usual practice, expert opinion, or case series. For information about the SORT evidence rating system, see page 1874 or <http://www.aafp.org/afpsort.xml>.

carbohydrate diet. This type of diet differs from ketogenic diets used for seizure prevention, which substitute fat for protein and carbohydrates.

Diets such as the Zone Diet,¹¹ Carbohydrate Addict's Diet,¹² and later phases of the South Beach Diet¹³ restrict carbohydrates to 40 percent of calories or less, and they focus more on the glycemic index of foods than the Atkins Diet.

Glycemic Index

The glycemic index is a rating system for foods based on the extent to which they raise blood sugar levels in the two hours after they are eaten (Table 2^{14,15}). The reference point is pure glucose or white bread, which is arbitrarily scored as 100. The higher the glycemic index, the more rapidly that carbohydrate is released into the bloodstream as glucose.¹⁴

Foods with a high glycemic index induce a

**TABLE 1
Nutritional and Caloric Assessment of Various Diets**

| <i>Diet</i> | <i>Total calories per day</i> | <i>Carbohydrate grams per day (% of calories)</i> | <i>Protein grams per day (% of calories)</i> | <i>Fat grams per day (% of calories)</i> |
|----------------------------|-------------------------------|---|--|--|
| Typical American diet | 2,200 | 275 (50) | 82.5 (15) | 85 (35) |
| Low-carbohydrate diet | | | | |
| Atkins Diet | | | | |
| Induction phase | 1,152 | 13 (5) | 102 (35) | 75 (59) |
| Ongoing phase | 1,627 | 35 (9) | 134 (33) | 105 (58) |
| Maintenance phase | 1,990 | 95 (19) | 125 (25) | 114 (52) |
| Moderate-carbohydrate diet | | | | |
| Carbohydrate Addict's Diet | 1,476 | 87 (24) | 84 (23) | 89 (54) |
| Low-glycemic-index diet | | | | |
| Sugar Busters! | 1,521 | 176 (46) | 89 (23) | 44 (26) |
| Low-fat diet | | | | |
| Weight Watchers | 1,462 | 207 (57) | 73 (20) | 42 (26) |
| Very low-fat diet | | | | |
| Ornish Diet | 1,273 | 258 (81) | 48 (15) | 13 (9) |

NOTE: Nutrient breakdowns are based on approximate average daily intake and therefore may not total 100 percent of daily calories.

*Adapted with permission from Freedman MR, King J, Kennedy E. Popular diets: a scientific review. *Obes Res* 2001; 9(suppl 1):3S,11S,12S.*

more rapid insulin response. When coupled with a meal that is rapidly converted to glucose, this insulin response can cause a relative hypoglycemic period within the postprandial period (Figure 1). It has been suggested that this reactive hypoglycemia can stimulate the appetite and lead to increased caloric intake.^{14,16} This theory has been proposed as a partial explanation for the increase in obesity rates in recent

decades despite the emphasis on diets with lower fat and higher carbohydrate content. Between 1989 and 1996, total daily caloric intake increased, primarily from carbohydrates, but to a lesser extent from fats.¹⁷

Eating foods with a high glycemic index also can lead to higher levels of circulating insulin. Persons with this metabolic syndrome have high insulin levels, and hyperinsulinemia has been implicated as a mediator for heart disease.¹⁴ For each standard deviation increase in fasting insulin levels, the odds ratio of developing ischemic heart disease increases 60 percent in men 45 to 76 years of age.^{14,18} One case-control study¹⁹ showed that consumption of a high-glycemic-index diet was associated with a higher risk of diabetes. It is important to note, however, that the benefits of a lower-glycemic-index diet, such as the South Beach Diet, Sugar Busters!,²⁰ and others, have not been tested in randomized controlled trials (RCTs) measuring patient-oriented outcomes.

Overview of Low-Carbohydrate and Low-Glycemic-Index Diets

Most diets take a phased approach. In general, dieters initially are limited to less than 20 g of carbohydrates per day. During this initiation, ketosis is established, demonstrating that the body's glycogen supplies have been consumed and that protein and fat are being used as fuel. Carbohydrates are then slowly added back into the diet until weight loss stops and weight is maintained. The amount of carbohydrates needed for weight maintenance is individualized. The final stages focus on development of lifelong eating habits that allow a moderate amount of calories.

Low-carbohydrate and low-glycemic-index diets are variations on the theme of initiation and maintenance. The Atkins Diet tends to remain higher in fat and lower in carbohydrates, whereas the South Beach Diet recommends a more balanced diet that limits fat and processed or refined carbohydrates. Participants in the Zone Diet, on the other hand, must consume the proper ratio of carbohydrates to protein to fats (i.e., 40:30:30) from initiation to maintenance.

TABLE 2

Glycemic Index of Selected Foods

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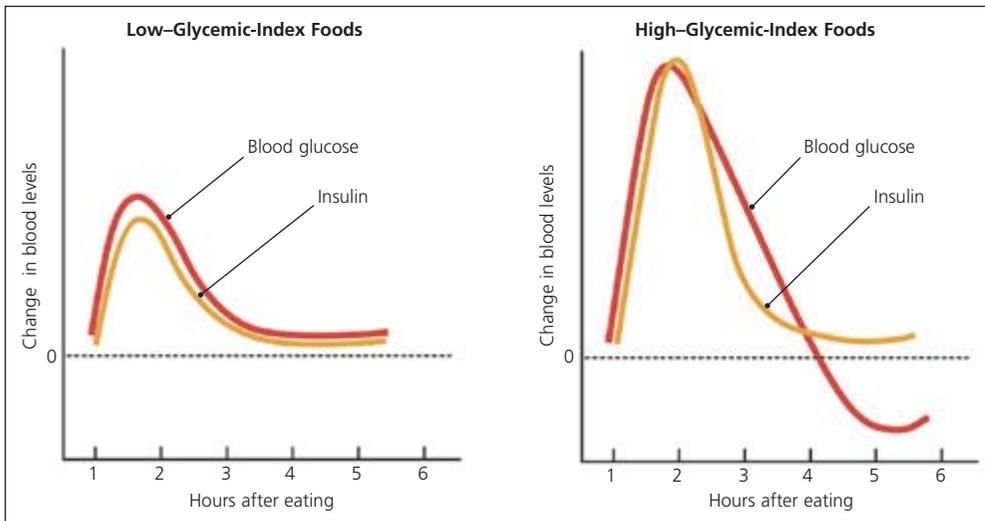


Figure 1. Comparison of blood sugar responses to low- and high-glycemic-index foods.

Weight is maintained when the number of calories consumed equals the number burned. When this ratio is out of balance, persons gain or lose weight. Proponents of low-carbohydrate diets often claim that it is the composition of the diet rather than the caloric content that induces weight loss. However, low-carbohydrate diets generally are low-calorie diets with a high protein content. Protein has been shown to be more hunger satisfying than carbohydrates or fats,²¹ which may explain the lower dropout rates for low-carbohydrate diets compared with traditional low-fat diets.²²⁻²⁴ Successful low-carbohydrate dieters simply eat fewer calories than they burn.

In addition to being low-calorie diets, low-carbohydrate diets also initially induce significant water diuresis. The majority of this diuresis is likely the result of glycogenolysis from increased protein consumption. Glycogen binds water at a rate of 2 to 4 g of water per gram of glycogen.²⁵ As glycogen stores are consumed for energy, two to four times that weight in water is shed through urine. Thus, a portion of the early weight loss in these diets is water weight. An insignificant number of additional calories may be lost through ketosis or ketones in the urine; however, this theory has not been established convincingly.

A significant shortcoming of low-carbo-

hydrate diet plans is that the importance of physical activity is only minimally addressed. Presumably, any beneficial effects that these diets may have on weight could be augmented by exercise. Physicians should reinforce this potential benefit during office visits with patients on low-carbohydrate diets.

Effectiveness

A systematic review²⁶ of primarily short-term observational studies found that low-carbohydrate diets were no more effective for weight loss than higher-carbohydrate diets, and that weight loss was directly related to the degree of caloric restriction and duration of the diet.

Four RCTs^{22-24,27} published since that systematic review reported that greater short-term weight loss (i.e., up to six months) occurred with low-carbohydrate diets than with low-fat diets. However, at one year the amount of weight lost did not differ significantly between the two groups.^{24,28} In one study²⁸ of 132 obese patients, those on a low-carbohydrate diet lost 5.1 kg (11 lb, 4 oz) at one year whereas those on a low-calorie, low-fat diet lost 3.1 kg (6 lb, 13 oz). This difference was not statistically significant.

A recent RCT²⁹ compared the Atkins,

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Ornish, Weight Watchers, and Zone diets for one year. Each diet significantly reduced the weight of participants by 2.1 to 3.3 kg (4 lb, 10 oz to 7 lb, 4 oz). All of the diets were equally effective.

A small RCT³⁰ with overweight adolescents demonstrated similar results. Adolescents on a low-carbohydrate diet lost more weight at three months than those eating a low-fat diet. No long-term RCTs in this age group have been published.

Safety

Low-carbohydrate diets have been controversial, largely because of concerns about the possible negative effects that high fat intake (particularly saturated fat) may have on overall health. However, these diets do not adversely affect lipid levels.^{22-24,26-28} In fact, in 24-week,²² six-month,²⁷ and one-year²⁸ comparisons with patients on traditional low-fat diets, patients on low-carbohydrate diets had lower triglyceride levels, higher high-density lipoprotein (HDL) cholesterol levels, similar low-density lipoprotein cholesterol levels, and lower A1C levels.

Two studies^{30,31} of adolescent patients on low-carbohydrate diets also found no detrimental effects on cholesterol profiles at three and five months; the five-month cohort study³¹ actually found a decrease in total cholesterol levels.

The relatively low fiber intake of patients on low-carbohydrate diets raises concerns about constipation and long-term risks of cancer and diverticular disease. Theoretic concerns exist about osteoporosis resulting from increased calciuria and lower intake of magnesium, potassium, and vitamin C.⁹ Low-carbohydrate diets also raise uric acid levels and may exacerbate gout. Constipation, diarrhea, dizziness, halitosis, headaches, insomnia, kidney stones, and nausea have been reported in persons on low-carbohydrate diets.^{9,32} There have been reports that these diets may impair cognitive ability; however, the evidence for this risk is limited.³³

The higher fat content of low-carbohydrate diets raises concerns about their long-

term safety. Although information about the effect on lipid profiles is somewhat reassuring, lipid levels are not a patient-oriented outcome, and diets high in fat have been associated with serious medical problems, including breast cancer and heart disease.^{34,35} Long-term studies are needed to determine if these associations exist when patients consume a low-calorie diet.

Low-carbohydrate diets have been criticized for being nutritionally inadequate. Analyses of these diets have found that vitamins A, B₆, C, and E; thiamine; folate; calcium; magnesium; iron; potassium; and fiber are deficient.⁹ Although the reported deficiencies in calcium and magnesium seem contrary to the high dairy and nut intake allowed by these diets, supplementation with fiber and a multivitamin may be warranted,⁹ with additional calcium supplementation in women.

Low-Carbohydrate Diets in Clinical Practice

Traditional low-fat diets are only now being studied rigorously, and as such, mortality and morbidity data to support their use are sparse. In recent direct short-term comparisons, low-carbohydrate diets were found to be no more or less effective than low-fat diets at safely maintaining weight loss, although low-carbohydrate diets may be more effective in the very short term (i.e., up to six months).

Obesity results from the interplay between genes and environment; their contributions vary with each person. It is therefore reasonable to suspect that different types of diets (e.g., low-carbohydrate, low-fat, very low-fat) may be of varying benefit in different persons. Part of the solution may be to pair the most appropriate diet with each patient based on eating habits, patterns, and desires.

Part of the genetic component of obesity is insulin resistance, the probable common pathway for metabolic syndrome (*Table 3*³⁶). Low-carbohydrate diets may be particularly helpful in patients with metabolic syndrome.

The physiologic effects of consuming low-glycemic-index foods (e.g., lower insulin levels, less hunger)¹⁴ may explain why persons who successfully lose weight with

Adherence is the key to long-term success for safe, effective, lasting weight loss.

TABLE 3

World Health Organization Criteria for Metabolic Syndrome

Insulin resistance or glucose intolerance and at least two of the following conditions:

Atherogenic dyslipidemia (mainly increased triglyceride levels and low high-density lipoprotein cholesterol levels)

Central obesity

Elevated blood pressure

Microalbuminuria

Information from reference 36.

low-carbohydrate diets take in fewer calories.²³ Scant evidence exists that low-carbohydrate diets result in weight loss because of increased calorie use via ketogenesis. However, if low-carbohydrate diets safely modify insulin response and glucose metabolism and decrease caloric consumption,¹⁴ they are a reasonable alternative for persons who are willing to adhere to these diets.

Adherence is the key to long-term success for safe, effective, lasting weight loss. There is no way to predict which patients will benefit most from certain types of diets, and attempts to create an optimal patient-diet dyad can be only hypothesized based on each patient's medical and diet histories and laboratory findings. An individualized approach probably is the best solution. Caloric intake must be less than caloric expenditure to achieve weight loss. A low-carbohydrate diet combined with an exercise program can help selected patients safely achieve weight loss and improve their biochemical profiles.

Cautions

None of the diets discussed in this article have been studied in a controlled clinical trial for longer than one year, and no study has measured clinical outcomes such as disease-specific mortality, cardiovascular events, and all-cause mortality. A low-carbohydrate diet that limits the intake of fruits, vegetables, and legumes cannot be endorsed, and physicians should counsel patients to exercise regularly as part of any health maintenance program.

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