Evidence-Based Nutrition Principles and Recommendations for the Treatment and Prevention of Diabetes and Related Complications

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Historically, nutrition principles and recommendations for diabetes and related complications have been based on scientific evidence and diabetes knowledge when available and, when evidence was not available, on clinical experience and expert consensus. Often it has been difficult to discern the level of evidence used to construct the nutrition principles and recommendations. Furthermore, in clinical practice, many nutrition recommendations that have no scientific supporting evidence have been and are still being given to individuals with diabetes. To address these problems and to incorporate the research done in the past 8 years, this 2002 technical review provides principles and recommendations classified according to the level of evidence available. It reviews the evidence from randomized, controlled trials; cohort and case-controlled studies; and observational studies, which can also provide valuable evidence (1,2), and takes into account the number of studies that have provided consistent outcomes of support. In this review, nutrition principles are graded into four categories based on the available evidence: those with strong supporting evidence, those with some supporting evidence, those with limited supporting evidence and those based on expert consensus.

Evidence-based nutrition recommendations attempt to translate research data and clinically applicable evidence into nutrition care. However, the best available evidence must still be moderated by individual circumstances and preferences. The goal of evidence-based recommendations is to improve the quality of clinical judgments and facilitate cost-effective care by increasing the awareness of clinicians and patients with diabetes of the evidence supporting nutrition services and the strength of that evidence, both in quality and quantity.

Before 1994, the American Diabetes Association's (ADA's) nutrition principles and recommendations attempted to define an "ideal" nutrition prescription that would apply to everyone with diabetes (3–5). Although individualization was a major principle of all recommendations, it was usually done within defined limits for recommended energy intake and macronutrient composition. The 1994 nutrition recommendations shifted this focus to one that emphasized effects of nutrition therapy on metabolic control (6,7). The nutrition prescription is determined considering treatment goals and lifestyle changes the diabetic patient is willing and able to make, rather than predetermined energy levels and percentages of carbohydrate, protein, and fat. The goal of nutrition intervention is to assist and facilitate individual lifestyle and behavior changes that will lead to improved metabolic control. This focus continues with the 2002 nutrition principles and recommendations.

Medical nutrition therapy (MNT) is an integral component of diabetes management (8,9) and diabetes self-management education (10). (Medical nutrition therapy is the preferred term and should replace other terms, such as diet, diet therapy, and dietary management.) MNT for diabetes includes the process and the system by which nutrition care is provided for diabetic individuals and the specific lifestyle recommendations for that care. However, recommendations should not only be based on scientific evidence but should also take into consideration lifestyle changes the

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Abbreviations: ADA, American Diabetes Association; ADI, acceptable daily intake; DASH, Dietary Approaches to Stop Hypertension; DCCT, Diabetes Control and Complications Trial; DPP, Diabetes Prevention Program; DRI, Dietary Reference Intake; FDA, U.S. Food and Drug Administration; FPG, fasting plasma glucose; GFR, glomerular filtration rate; GRAS, Generally Recognized as Safe; MNT, medical nutrition therapy; NCEP, National Cholesterol Education Program; NHANES, National Health and Nutrition Examination Survey; RD, registered dietitian; RDA, recommended dietary allowance; UKPDS, U.K. Prospective Diabetes Study; VLCD, very-low-calorie diet.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

individual can make and maintain. Cultural and ethnic preferences should be taken into account, and the person with diabetes should be involved in the decision-making process.

Results from the Diabetes Control and Complications Trial (DCCT) and the U.K. Prospective Diabetes Study (UKPDS) convincingly demonstrated the importance of glycemic control in preventing the microvascular complications of diabetes (11,12). In both trials, MNT was important in achieving treatment goals (13,14). MNT in diabetes addresses not only glycemic control but other aspects of metabolic status as well, including dyslipidemia and hypertension—major risk factors for cardiovascular disease. This is important, as macrovascular complications are the major contributors to the morbidity and mortality associated with diabetes (15).

The current nutrition principles and recommendations for diabetes focus on lifestyle goals and strategies for the treatment of diabetes. Now, for the first time, the 2002 recommendations specifically address lifestyle approaches to diabetes prevention; they distinguish MNT for treating and managing diabetes from MNT for preventing or delaying the onset of diabetes, as the two may not necessarily be the same.

Whether for management or prevention of diabetes and its complications, basic to the nutrition recommendations is the underlying concern for optimal nutrition through healthy food choices and an active lifestyle. The ADA supports and incorporates the nutrition recommendations from major organizations, such as the U.S. Department of Agriculture (*Dietary Guidelines for Americans*) (16), American Heart Association (17), National Cholesterol Education Program (18), American Institute for Cancer Research (19), and Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (20).

Although many studies have focused on the role of single nutrients, food, or food groups in disease prevention or promotion, emerging research suggests there are health benefits from food patterns that include mixtures of food containing multiple nutrients and nonnutrients (21–27). Although this approach makes it difficult to elucidate mechanisms through which the diet composition affects a particular health outcome, it does represent a practical approach to making realistic nutrition recommendations for improving health.

The health professional with the greatest expertise in providing MNT for diabetes is the registered dietitian (RD) knowledgeable and skilled in diabetes management (8–10,28). Outcome studies (13,29–34) have demonstrated that MNT provided by RDs results in a 1.0% decrease in HbA_{1c} in patients with newly diagnosed type 1 diabetes (29), a 2.0% decrease in HbA_{1c} in patients with newly diagnosed type 2 diabetes (14), and a 1.0% decrease in HbA_{1c} in patients with an average 4-year duration of type 2 diabetes (30). The effectiveness of dietitian-delivered MNT in improving dyslipidemia has also been demonstrated (35–41). However, it is essential that all team members involved in diabetes treatment and management be knowledgeable about MNT and supportive of the patient's need to make lifestyle changes (42–45).

GOALS OF MEDICAL NUTRITION THERAPY FOR DIABETES

— Goals of MNT that apply to all persons with diabetes are as follows:

1. To attain and maintain optimal metabolic outcomes, including
   a. blood glucose levels in the normal range or as close to normal as is safely possible to prevent or reduce the risk for complications of diabetes
   b. a lipid and lipoprotein profile that reduces the risk for macrovascular disease
   c. blood pressure levels that reduce the risk for vascular disease
2. To prevent and treat the chronic complications of diabetes; modify nutrient intake and lifestyle as appropriate for prevention and treatment of obesity, dyslipidemia, cardiovascular disease, hypertension, and nephropathy
3. To improve health through healthy food choices and physical activity
4. To address individual nutritional needs, taking into consideration personal and cultural preferences and lifestyle while respecting the individual's wishes and willingness to change

The goals of MNT that apply to specific situations include the following:

1. For youth with type 1 diabetes, to provide adequate energy to ensure normal growth and development, and to integrate insulin regimens into usual eating and physical activity habits
2. For youth with type 2 diabetes, to facilitate changes in eating and physical activity habits that reduce insulin resistance and improve metabolic status
3. For pregnant or lactating women, to provide adequate energy and nutrients needed for optimal outcomes
4. For older adults, to provide for the nutritional and psychosocial needs of an aging individual
5. For individuals being treated with insulin or insulin secretagogues, to provide self-management education for treatment (and prevention) of hypoglycemia, acute illnesses, and exercise-related blood glucose problems
6. For individuals at risk for diabetes, to decrease the risk by encouraging physical activity and promoting food choices that facilitate moderate weight loss or at least prevent weight gain

The next sections of this technical review paper focus on MNT for the management of diabetes. The first section includes nutrition recommendations for type 1 and type 2 diabetes—intake of carbohydrate, sweeteners, protein, fat, micronutrients, and alcohol; energy balance and obesity; and special considerations. The second section reviews MNT for special populations—children and adolescents, pregnant and lactating women, and older adults. The third section reviews MNT for acute complications—hypoglycemia and acute illness—and comorbid conditions—hypertension, dyslipidemia, nephropathy, and catabolic illness. The last section reviews lifestyle recommendations for the prevention or delay of diabetes.

MEDICAL NUTRITION THERAPY FOR TYPE 1 AND TYPE 2 DIABETES

Carbohydrate and diabetes

When referring to common food carbohydrates, the following terms are preferred: sugars, starch, and fiber (Table 1). This classification is based on the recommendations of the Food and Agriculture

Table 1 —*Carbohydrate classification and terminology*

Major dietary carbohydrate classes based on degree of polymerization and subgroups	Components	U.S. food labeling designation
Sugars* (1–2 molecules)		
Monosaccharides	Glucose, galactose, fructose	Sugars
Disaccharides	Sucrose, lactose	Sugars
Polyols (sugar alcohols)	Sorbitol, mannitol, xylitol, isomalt, malitol, lactitol, hydrogenated starch hydrolysates	Sugar alcohol
Oligosaccharides (3–9 molecules)		
Malto-oligosaccharides	Maltodextrins	Other carbohydrate
Other oligosaccharides	Raffinose, stachyose, fructo-oligosaccharides	Other carbohydrate
Polysaccharides (>9 molecules)		
Starch*	Amylose, amylopectin, modified starches	Other carbohydrate
Fiber* (non-starch polysaccharides)	Cellulose, hemicellulose, pectins, hydrocolloids	Dietary fiber

All U.S. food labeling designations are in total grams of carbohydrate. *Preferred terminology. Adapted from World Health Organization and Food and Agriculture Organization of the United Nations: *Carbohydrates in Human Nutrition.* Food and Agriculture Organization of the United Nations, Rome, 1998.

Organization of the United Nations and the World Health Organization in which carbohydrates are classified according to their degree of polymerization and are initially divided into three principal groups—sugars, oligosaccharides, and polysaccharides (46). Terms such as simple sugars, complex carbohydrates, and fast-acting carbohydrates are not well defined; use of these terms should be abandoned.

A number of factors influence glycemic response to food, including the amount of carbohydrate (47), type of sugar (glucose, fructose, sucrose, lactose) (48), nature of the starch (amylose, amylopectin, resistant starch) (49), cooking and food processing (degree of starch gelatinization, particle size, cellular form) (50), and food structure (51), as well as other food components (fat and natural substances that slow digestion—lectins, phytates, tannins, and starch-protein and starch-lipid combinations) (52). Fasting and preprandial glucose concentrations (53–56), the severity of glucose intolerance (57), and the second meal or lente effect (58) are other factors affecting the glycemic response to food.

Carbohydrate and type 1 diabetes

In trying to establish nutrition recommendations for the prescription of carbohydrate for patients with type 1 diabetes, there are several problems: the paucity of studies, the small number of subjects studied, and the lack of long-term studies. Although several studies in subjects with type 1 diabetes have been done comparing differing amounts or percentages of calories from carbohydrate (59–61), there is no body of evidence to suggest changing the 1994 recommendation that 60–70% of total energy be distributed between carbohydrate and monounsaturated fat based on nutrition assessment and treatment goals (6). A basis for choosing between carbohydrate and monounsaturated fat, other than ethnic or cultural preferences, is not readily available. In some studies (59,60), a high-carbohydrate diet compared to a high−monounsaturated fat diet resulted in a higher glycemic profile, with no differences in the lipid profile; however, insulin may not have been adjusted appropriately to cover the amount of carbohydrate ingested. In another study (61) comparing a high-carbohydrate diet to a high−monounsaturated fat diet, there were no differences in glycemia, but there was an increase in postprandial triglycerides with the high−monounsaturated fat diet.

More information is available regarding the effects of different types of carbohydrate on postprandial glycemia. In type 1 patients with diabetes, the ingestion of a variety of starches or sucrose, both acutely (62–68) and for up to 6 weeks (69–72), was shown to produce no significant differences in glycemic response if the total amount of carbohydrate is similar. Studies in controlled settings (62–69) and in free-living subjects (70–72) have demonstrated similar results.

Studies show a strong relationship between the premeal insulin dosage and the postprandial response to the carbohydrate content of the meal (73–76). In individuals receiving intensive insulin therapy, the total amount of carbohydrate in the meal did not influence glycemic response if the premeal insulin was adjusted for the carbohydrate content of the meal (73). The premeal insulin dosage required was not affected by the glycemic index, fiber, fat, or caloric content of the meal. Furthermore, wide variations in meal carbohydrate content did not modify the basal (long-acting) insulin requirement. The concept of total meal carbohydrate determining the premeal insulin dosage is further supported by the DCCT, in which it was shown that individuals who adjusted their premeal insulin dosages based on the carbohydrate content of meals had 0.5% ($P < 0.03$) lower HbA_{1c} levels than those who did not adjust premeal insulin (13).

For individuals receiving fixed dosages of short- and intermediate-acting insulin, day-to-day consistency in the amount and source of carbohydrate has been associated with lower HbA_{1c} levels (77). Day-to-day variations in energy and protein or fat intakes were not significantly related to HbA_{1c}.

Glycemic index. The usefulness of low−glycemic index diets in individuals with type 1 diabetes is controversial. Five studies ($n = 48$; range 12 days to 6 weeks) (78–82) have compared low−glycemic index diets to high−glycemic index diets for longer than 1 day. The results from these studies did not provide convincing evidence of benefit. Four studies (78,80–82) measured HbA_{1c}, and none reported differences in HbA_{1c} between low− and high−glycemic index diets. Four studies (78–81) measured glycated albumin or

fructosamine; three of those (78–80) reported decreases in glycated albumin or serum fructosamine after the incorporation of low–glycemic index food in the diet, and one reported no differences in serum fructosamine (81). Three studies (78–80) measured fasting plasma glucose (FPG) concentrations, and none reported differences in FPG between low– and high–glycemic index diets. Insulin requirements were measured in four studies (79–82); one (79) reported lower insulin requirements from low– compared to high–glycemic index diets, whereas three (80–82) reported no differences in insulin dosages. Therefore, although the use of low–glycemic index food may reduce postprandial glucose levels, there is not sufficient evidence of long-term benefit to recommend general use of low–glycemic index diets in individuals with type 1 diabetes.

In a cross-sectional study of 2,810 people with type 1 diabetes from the EURODIAB IDDM Complications Study (83), the glycemic index calculated from 3-day food records was examined for its relation to HbA_{1c} and serum lipid concentrations. HbA_{1c} levels were lower in the lowest glycemic index quartile compared with the highest quartile. Of the serum lipids, only HDL cholesterol was independently related to the glycemic index. Interestingly, the consumption of bread and pasta had the biggest effect on the overall glycemic index.

The effects on lipids after low– compared to high–glycemic index diets appear to be minimal. Two studies (79,80) measured cholesterol concentrations and three studies (78–80) measured HDL cholesterol concentrations, but none reported differences in the low– compared to the high–glycemic index diets. One study (80) reported lower triglyceride levels, but one (78) did not.

Although it is clear that carbohydrates do have differing glycemic responses, the data reveal no clear trend in outcome benefits. If there are long-term effects on glycemia and lipids, these effects appear to be modest. Moreover, the number of studies is limited, and the design and implementation of several of these studies is subject to criticism.

Fiber. Early short-term studies using large amounts of fiber (>30 g/day) in small numbers of suboptimally controlled type 1 subjects (84–87) suggested a positive effect of fiber on glycemia. However, in a study of type 1 diabetes subjects on intensive insulin therapy, 56 g of fiber had no beneficial effect on glycemic control (81). A recent study (88) randomized subjects being treated with two or more injections of insulin per day and HbA_{1c} levels of 7–10% to either a high-fiber (50 g/day), low–glycemic index diet or a low-fiber (15 g/day), high–glycemic index diet for 24 weeks. The high-fiber diet significantly reduced mean daily blood glucose concentration ($P < 0.05$), the number of hypoglycemic events ($P < 0.01$), and, in the subgroup of patients compliant to diet, HbA_{1c} ($P < 0.05$), but had no beneficial effect on cholesterol, HDL cholesterol, or triglyceride concentrations. Conversely, a cross-sectional analysis of dietary fiber in type 1 diabetes patients enrolled in the EURODIAB IDDM Complications Study revealed that a higher intake of total fiber (grams per day) was independently associated with higher levels of HDL cholesterol in both men and women, and lower LDL cholesterol levels in men but not women (89). No substantial differences were observed between soluble and insoluble fiber intakes. Mean total fiber intake was 18.5 g/day in men and 16.2 g/day in women.

The *Dietary Guidelines for Americans* (16) recommends that all Americans choose a variety of fiber-containing food, such as whole grains, fruits, and vegetables, because they provide vitamins, minerals, fiber, and other substances important for good health. This is an appropriate recommendation for people with type 1 diabetes as well.

There is strong evidence for the following statements:

- Studies in healthy subjects support the importance of including food containing carbohydrate from whole grains, fruits, vegetables, and low-fat milk in the diet.
- With regard to the glycemic effects of carbohydrates, the total amount of carbohydrate in meals and snacks is more important than the source or type.
- Individuals receiving intensive insulin therapy should adjust their premeal insulin dosages based on the carbohydrate content of meals.

There is some evidence for the following statements:

- Individuals receiving fixed daily insulin dosages should try to be consistent in day-to-day carbohydrate intake.
- Although the use of low–glycemic index food may reduce postprandial hyperglycemia, there is not sufficient evidence of long-term benefit to recommend use of low–glycemic index diets as a primary strategy in food/meal planning for individuals with type 1 diabetes.
- As for the general public, consumption of fiber is to be encouraged; however, there is no reason to recommend that people with type 1 diabetes consume a greater amount of fiber than other Americans.
- Percentages of carbohydrate should be based on individual nutrition assessment.

The following statement is based on expert consensus:

- Carbohydrate and monounsaturated fat together should provide 60–70% of energy intake.

Carbohydrate and type 2 diabetes

As is the case for type 1 diabetes, there is no body of evidence relating to people with type 2 diabetes to suggest changing the 1994 recommendation that 60–70% of total energy be divided between carbohydrate and monounsaturated fat. In weight-maintaining diets for type 2 patients with diabetes, replacing carbohydrate with monounsaturated fat reduces postprandial glycemia and triglyceridemia (90,91), but there is concern that increased fat intake in ad libitum diets may promote weight gain and potentially contribute to insulin resistance (92–100). Thus the contributions of carbohydrate and monounsaturated fat to energy intake should be individualized based on nutrition assessment, metabolic profiles, and weight and treatment goals.

In individuals with type 2 diabetes, postprandial glucose levels and insulin responses to a variety of starches and sucrose are similar if the amount of carbohydrate is constant (69,71,101–106). This has been demonstrated in both controlled (69,101–104) and in free-living subjects (71,105,106). When studied, the effects of starches and sucrose on plasma lipids were similar and no adverse effects were observed (103–106).

Glycemic index. There have been nine studies (80,82,107–113) involving type 2 diabetes subjects (n = 129) that have compared low−glycemic index and high−glycemic index diets for longer than 1 day. One study (107) reported lower HbA_{1c} levels in low− compared to high−glycemic index diets, whereas four studies (80,82,108,109) reported no differences in HbA_{1c} levels. Three studies (110–112) reported significantly lower fructosamine levels in low− compared to high−glycemic index diets, whereas three other studies (108,109,113) reported no significant differences in fructosamine. No differences in fasting plasma glucose concentrations were reported in eight studies (80,107–113), and no differences in insulin levels were found in two studies (107,109).

In studies that also assessed the effects of low− and high−glycemic index diets on plasma lipids, there were no consistent results. One study (112) reported positive differences on cholesterol levels, whereas four (80,107,108,113) reported no differences. One study reported positive differences in HDL cholesterol levels (109), whereas five (80,108,110,112,113) reported no differences. Four studies (108–110,112) reported no differences in LDL cholesterol levels. One study (80) reported positive differences in triglyceride levels; five studies (107,108,110–112) reported no differences.

Although studies in type 2 diabetes subjects have not consistently reported a relation between glycemic index and insulin and lipid levels, studies in other populations have reported an association between either lower glycemic index diets or lower glycemic loads with lipids, in particular HDL cholesterol, and insulin levels. In a cross-sectional study of middle-aged adults, the glycemic index of the diet was the only dietary variable significantly related to serum HDL cholesterol concentration (114), and a recent analysis (115) of the Third National Health and Nutrition Examination Survey (NHANES III) reported a change in HDL concentration of –2.3 mg/dl per 15-unit increase in glycemic index. In a study of 32 patients with advanced coronary heart disease, 4 weeks of a low−glycemic index diet improved glucose tolerance and insulin sensitivity compared to a high−glycemic index diet over the same period (116). The same group reported that a low− compared to a high−glycemic index diet improved adipocyte insulin sensitivity in women at risk for coronary heart disease (117).

The glycemic load, defined as the product of the glycemic index value of a food and its carbohydrate content, has been reported to be positively associated with the risk of developing type 2 diabetes in men and women (118,119) and coronary heart disease in women (120). In a cross-sectional study of healthy postmenopausal women, dietary glycemic load was inversely related to plasma HDL cholesterol and positively related to fasting triglycerides (121). In the analysis of the NHANES III results, a high glycemic load was associated with a lower concentration of plasma HDL cholesterol (115).

Fiber. Early studies of the effects of fiber on glycemia showed promising results, but may have suffered from methodological errors (i.e., poor control of confounding variables such as weight loss, differences in energy consumed, different food sources with potential differences in starch digestibility, and differences in dietary fat content) (122). In a study in which dietary variables were controlled for, increasing the fiber content of the diet from 11 to 27 g/1,000 kcal did not lead to improvements in glycemia, insulinemia, or lipemia (123).

In contrast, a diet supplemented with large amounts of water-soluble, gel-forming fiber, such as guar gum, reduced postprandial glycemia (124). In support of this finding, another study comparing a diet containing 24 g fiber per day (high usual intake) to a diet containing 50 g fiber per day found that the intake of food high in dietary fiber improved glycemic control, reduced hyperinsulinemia, and decreased plasma lipids (125). It thus appears that ingestion of large amounts of fiber is necessary to confer metabolic benefit. It is not clear whether the palatability and gastrointestinal side effects of fiber in this amount would be acceptable to most people.

A meta-analysis of 67 controlled clinical trials indicated that diets high in soluble fiber decrease total and LDL cholesterol, but had a small HDL-lowering effect and did not affect triglyceride concentrations (126). Patients with hypercholesterolemia were not more responsive to dietary fiber than healthy individuals. However, the authors concluded that the effect of soluble fiber within practical ranges on cholesterol was modest (daily intake of 3 g soluble fiber, e.g., 3 apples or 3 bowls [29-g servings] oatmeal can decrease total cholesterol by ~5 mg/dl, an ~2% reduction), and on risk of heart disease may be only small.

Newer fiber supplements such as psyllium (127) and β-glucan (128,129) have mixed short-term effects on glycemia and lipemia and require further study.

There is strong evidence for the following statements:

- Studies in healthy subjects and those at risk for type 2 diabetes support the importance of including food containing carbohydrate from whole grains, fruits, vegetables, and low-fat milk in the diet.
- With regard to the glycemic effect of carbohydrates, the total amount of carbohydrate in meals or snacks is more important than the source or type.

There is some evidence for the following statements:

- Although the use of low−glycemic index food may reduce postprandial hyperglycemia, there is not sufficient evidence of long-term benefit to recommend general use of low−glycemic index diets in type 2 diabetes patients.
- As for the general population, consumption of fiber is to be encouraged. Although large amounts of dietary fiber (~50 g per day) may have beneficial effects on glycemia, insulinemia, and lipemia, it is not known if such high levels of fiber intake can be maintained long-term.

The following statement is based on expert consensus:

- Carbohydrate and monounsaturated fat should together provide 60–70% of energy intake. However, the individual's metabolic profile and need for weight loss should be considered when determining the monounsaturated fat content of the diet. Increasing fat intake may result in increased energy intake.

Nutritive sweeteners

Sucrose. Sucrose is a common, naturally occurring disaccharide composed of a glucose and a fructose molecule. Average per capita consumption of sucrose and other sugars in the U.S. is estimated to be 94 g/day, accounting for 22% of energy

intake (130). Historically, the most widely held belief about nutrition and diabetes was that added sugars should be avoided and naturally occurring sugars restricted. This belief was based on the assumption that sucrose and other sugars were more rapidly digested and absorbed then starch-containing food and thereby aggravated hyperglycemia. However, scientific evidence does not support this assumption.

The available evidence from clinical studies demonstrates that dietary sucrose does not increase glycemia more than isocaloric amounts of starch (67,69,101,103, 104,106,131,132). Thus the intake of sucrose and sucrose-containing food in diabetic individuals need not be restricted because of a concern about aggravating hyperglycemia. If sucrose is part of the food/meal plan, it should be substituted for other carbohydrate sources or, if added, should be adequately covered with insulin or other glucose-lowering medication. In addition, the intake of other nutrients (such as fat) often ingested with sucrose-containing food should be taken into account. In one study, when individuals with type 2 diabetes included sucrose in their daily meal plan, no negative impact on dietary habits or metabolic control was observed (133).

Fructose. Fructose is a common, naturally occurring monosaccharide that accounts for ~9% of average energy intake in the U.S. (134). Fructose is somewhat sweeter than sucrose. It has been reported that ~33% of dietary fructose comes from fruits, vegetables, and other natural sources in the diet and ~67% comes from food and beverages to which fructose has been added (135).

In several studies in diabetic subjects, fructose produced a reduction in postprandial glycemia when it replaced sucrose or starch as a carbohydrate source (69,106,136,137). Thus fructose might be a good sweetening agent in the diabetic diet. However, this potential benefit is tempered by the concern that fructose may have adverse effects on plasma lipids. Consumption of large amounts of fructose (15–20% of daily energy intake [90th percentile of usual intake]) has been shown to increase fasting total and LDL cholesterol in subjects with diabetes (137) and fasting total and LDL cholesterol and triglycerides in nondiabetic subjects (138–141).

Table 2 —*Sugar alcohols: caloric content and regulatory status*

Sugar alcohol	Caloric content (kcal/g)	FDA designation
Erythritol	0.2	GRAS affirmation petition accepted for filing
Hydrogenated starch hydrolysates	3.0	GRAS affirmation petitions accepted for filing
Isomalt	2.0	GRAS affirmation petition accepted for filing
Lactitol	2.0	GRAS affirmation petition accepted for filing
Maltitol	3.0	GRAS affirmation petition accepted for filing
Mannitol*	1.6	Food additive permitted in food or in contact with food on an interim basis pending additional study
Sorbitol*	2.6	Affirmed as GRAS
Xylitol	2.4	Food additive permitted for direct addition to food for human consumption

Caloric content based on Federation of American Societies for Experimental Biology, "The evaluation of the energy of certain polyols used as food ingredients," June 1994, (unpublished), and Life Sciences Research Office: "Evaluation of the net energy value of maltitol," April 1999 (unpublished). *"Excess consumption may have a laxative effect" must be on label for foods whose reasonably foreseeable consumption may result in the daily ingestion of 20 g mannitol or 50 g sorbitol.

Sugar alcohols (polyols). Sugar alcohols are classified as hydrogenated monosaccharides (e.g., sorbitol, mannitol, xylitol), hydrogenated disaccharides (e.g., isomalt, maltitol, lactitol), and mixtures of hydrogenated mono- (sorbitol), di- (maltitol), and oligosaccharides (e.g., hydrogenated starch hydrolysates) (46). They are used in food as sweeteners and bulking agents. Sugar alcohols have been designated by the U.S. Food and Drug Administration (FDA) as safe for use as food additives or as Generally Recognized as Safe (GRAS) by affirmation petitions accepted for filing by the FDA (Table 2). The FDA has not indicated a need to designate an acceptable daily intake. Food prepared with sugar alcohols may claim on the label that there is an association between sugar alcohols and reduced risk of dental caries. Because sugar alcohols are only partially absorbed from the small intestine, the claim of reduced energy values per gram is allowed. However, if certain polyols are used in food, a warning concerning excess consumption and laxative effects of polyols is required on the food label (Table 2).

In some studies, ingestion of sugar alcohols (~50 g) by healthy and diabetic individuals has produced lower postprandial glucose responses than after ingestion of fructose, sucrose, or glucose (142–147). Because of the reduced available energy of sugar alcohols, the possibility exists that they could be used to reduce energy intake (as with fat replacers and nonnutritive sweeteners). However, no studies have been published showing this to be the case, and the small energy savings do not appear to result in a significant reduction in total daily energy intake. Intake of food containing sugar alcohols such as sorbitol has been reported to cause diarrhea in children with diabetes (148) and adults (149).

There is strong evidence for the following statements:

- Sucrose does not increase glycemia to a greater extent than isocaloric amounts of starch.
- Sucrose and sucrose-containing food do not need to be restricted by people with diabetes based on a concern about aggravating hyperglycemia. However, if sucrose is included in the food/meal plan, it should be substituted for other carbohydrate sources or, if added, be adequately covered with insulin or other glucose-lowering medication.

There is some evidence for the following statements:

- Fructose reduces postprandial glycemia when it replaces sucrose or starch in the diabetic diet.
- Consumption of fructose in large amounts may have adverse effects on plasma lipids.
- The use of sugar alcohols as sweetening agents appears to be safe.
- Sugar alcohols may cause diarrhea, especially in children.

There is limited evidence for the following statement:

- The use of added fructose as a sweetening agent is not recommended.

The following statements are based on expert consensus:

- Sucrose and sucrose-containing food should be eaten in the context of a healthy diet, and the intake of other nutrients ingested with sucrose, such as fat, should be taken into account.
- There is no reason to recommend that diabetic individuals avoid naturally occurring fructose in fruits, vegetables, and other food.
- It is unlikely that sugar alcohols in the amounts likely to be ingested in individual food servings or meals will contribute to a significant reduction in total energy or carbohydrate intake, although no studies have been conducted to support this.

Resistant starch. Resistant starch (nondigestible oligosaccharides and the starch amylose) (Table 1) is not digested and therefore not absorbed as glucose in the small intestine. It is, however, almost completely fermented in the colon and produces about 2 kcal/g of energy (46). It is estimated that resistant starch and unabsorbed starch represent ~2–5% (usually <10 g/day) of the total starch ingested in the average Western diet (150). Legumes are the major food source of resistant starch in the diet, containing 2–3 g resistant starch per 100 g cooked legumes. Uncooked cornstarch contains about 6 g resistant starch per 100 g dry weight (151). It has been suggested that ingestion of resistant starch produces a lesser increase in postprandial glucose than digestible starch and correspondingly lower insulin levels. As a result, it has been proposed that food containing naturally occurring resistant starch (cornstarch) or food modified to contain more resistant starch (high amylose cornstarch) may modify postprandial glycemic response, prevent hypoglycemia, and reduce hyperglycemia; these effects may explain differences in the glycemic indexes of some food.

There have been several one-meal (152–154) and second-meal studies (155–157) in nondiabetic subjects, comparing subjects' physical response to food high in resistant starch and their response to food with an equivalent amount of digestible starch. All studies found some reduction in postprandial glucose and insulin responses to the first meal, but observed mixed results after the second meal. Long-term studies have not consistently confirmed these results (155,158–161).

Published studies involving people with diabetes have focused on uncooked cornstarch and its potential to prevent nighttime hypoglycemia (162–165). In uncontrolled studies, evening cornstarch in specific dosages or dosages based on g/kg body weight resulted in less hypoglycemia around 0200 h in all groups (166, 167). Longer term studies of evening cornstarch snacks in adults with type 1 diabetes reported less hypoglycemia at 0300 h (168). In subjects with type 2 diabetes, evening cornstarch snacks increased nocturnal glucose and insulin (165). It has not been established that bedtime cornstarch snacks are more effective in preventing nocturnal hypoglycemia than other types of carbohydrate.

The is limited evidence for the following statement:

- Resistant starches have no established benefit for people with diabetes.

Nonnutritive sweeteners. There are presently four nonnutritive sweeteners (also referred to as high-intensity sugar alternatives, low calorie, or alternative sweeteners) approved for use in the U.S.: saccharin, aspartame, acesulfame potassium (acesulfame K), and sucralose. Saccharin, originally linked to human cancer based on a study in rats more than two decades ago, has now been dropped from the FDA list of cancer-causing chemicals (169).

The newest product approved by the FDA is sucralose (made from sucrose through a multistep process in which three hydrogen-oxygen groups are replaced with three chlorine atoms). Sucralose has been shown to have no effect on glucose homeostasis in diabetic subjects (170,171). FDA approval is being sought for three other nonnutritive sweeteners: alitame (formed from the amino acids aspartic acid and alanine), cyclamates (removed from the market in 1970), and neotame (similar to aspartame but 30–60 times sweeter and will not require special labeling for phenylketonuria) (172). A recent trend in the food industry is to blend high-intensity sweeteners. This decreases the total amount of individual sweeteners used and may improve taste.

Nonnutritive sweeteners approved by the FDA must undergo rigorous scrutiny and are not allowed on the market unless they are demonstrated to be safe for the public, including people with diabetes, to consume. For all food additives, including nonnutritive sweeteners, the FDA determines an acceptable daily intake (ADI), defined as the amount of a food additive that can be safely consumed on a daily basis over a person's lifetime without risk. Actual intake is much less than the ADI. Although the daily ADI for aspartame is 50 mg/kg body wt, the range of actual daily aspartame intake at the 90th percentile is 2–3 mg/kg body wt (173). Table 3 lists ADIs of nonnutritive sweeteners (174).

Studies to determine the effects of nonnutritive sweeteners during preg-

Table 3—*ADI of nonnutritive sweeteners*

	ADI (mg/kg body wt)	Average amount in 12-oz can of soda* (mg)	Cans of soda to reach ADI for 60-kg (132-lb) person (*n*)	Amount in packet of sweetener (mg)	Packets to reach ADI for 60-kg (132-lb) person (*n*)
Acesulfame K	15	40†	25†	50	18
Aspartame	50	200	15	35	86
Saccharin	5‡	140	2	40	7.5
Sucralose	5	70	4.5	5	60

*Fountain drinks may have different amounts and may contain a sweetener blend. †based on most typical blend with 90 mg aspartame. ADIs are independent. With this sweetener blend, it takes 35 cans to reach the ADI of aspartame. ‡set by Joint Expert Committee of Food Additives of World Health Organization (175). Adapted from Powers M: Sugar alternatives and fat replacers. In *American Diabetes Association Guide to Medical Nutrition Therapy for Diabetes*. Franz MJ, Bantle JP, Eds. Alexandria, VA, American Diabetes Association, 1999.

nancy and lactation have been conducted in animals. No adverse effects have been reported (175).

There is strong evidence for the following statement:

- Nonnutritive sweeteners are safe for people with diabetes when consumed within the ADI levels established by the FDA.

The following statement is based on expert consensus:

- It is unknown if use of nonnutritive sweeteners improves long-term glycemic control or assists in weight loss.

Protein and diabetes

In the U.S., protein intake accounts for 15–20% of average adult energy intake, a statistic that has varied little from 1909 to the present. Protein intake is also fairly consistent across all ages, from infancy to older age (176, 177), and appears to be similar in individuals with diabetes. Protein intake in subjects with type 2 diabetes in the U.K. Prospective Diabetes Study was 21% of daily energy (32); protein intake in children with type 1 diabetes has been reported to be 17% of daily energy (178).

Protein needs. It has been assumed that in people with diabetes, abnormalities of protein metabolism are less affected by insulin deficiency and insulin resistance than abnormalities of glucose metabolism (179). However, moderate hyperglycemia may contribute to increased turnover of protein in type 2 diabetic subjects. During moderate hyperglycemia, obese subjects with type 2 diabetes, compared to nondiabetic obese subjects, had an increase in whole-body nitrogen flux and a higher rate of protein synthesis and breakdown (180,181).

A high-quality protein (95 g protein/day), very-low-energy diet capable of maintaining nitrogen balance in obese subjects without diabetes did not prevent negative nitrogen balance in diabetic subjects, despite weight loss and improved glycemic control (181). This increased protein turnover was restored to normal only with oral glucose-lowering agents or exogenous insulin sufficient to achieve euglycemia and with increased protein intake (182,183). These study results suggest that people with type 2 diabetes have an increased need for protein during moderate hyperglycemia and an altered adaptive mechanism for protein sparing during weight loss. Thus with energy restriction, the protein requirements of people with diabetes may be greater than the recommended dietary allowance (RDA) of 0.8 g protein/kg body wt, although not greater than usual intake, which is ~1.0 g protein/kg body wt or ~100 g protein/day (32). However, individuals consuming very low energy intakes may have a deficiency in protein intake and require an assessment of protein adequacy.

Protein degradation and conversion of endogenous and exogenous protein to glucose in type 1 diabetes depends on the state of insulinization and corresponding glycemic control. Insulin deficiency increases whole-body protein synthesis, protein breakdown, oxidation of essential amino acids (184), and gluconeogenesis (185). Conversion of excess dietary protein or endogenous protein to glucose may occur and, in turn, adversely influence glycemia.

Short-term kinetic studies have demonstrated increased protein catabolism in type 1 diabetic subjects treated with conventional insulin therapy (186–188). In one study, to protect against increased protein catabolism, type 1 subjects required near-normal glycemia and an adequate protein intake (188). Because most adults eat at least 50% more protein than required, people with diabetes appear to be protected against protein malnutrition when consuming a usual diet.

Protein and development of nephropathy. An association between dietary protein intake and the development of renal disease has been suggested. In seven studies, dietary protein intake was reported to be similar in patients with diabetes with and without nephropathy (189–195). In all studies, protein intake was in the range of usual intake and rarely exceeded 20% of the energy intake. In a cross-sectional study of 2,500 type 1 diabetic subjects, those who reported protein consumption <20% of total energy had average albumin excretion rates <20 mcg/min (196). Those in whom protein intake was ≥20% of daily energy (22% of patients) had average albumin excretion rates >20 mcg/min (in the range of microalbuminuria). In individuals with macroalbuminuria, 32% consumed >20% of total energy from protein versus 23% for those with microalbuminuria and 20% for those with normal albumin excretion. This suggests that a high-protein intake may have a detrimental effect on renal function.

The long-term effects of consuming >20% of energy as protein on the development of nephropathy has not been determined. However, intake of protein in the usual range does not appear to be associated with the development of diabetic nephropathy.

Glucose responses to protein. A number of studies in healthy, normal-weight subjects (197) and subjects with controlled type 2 diabetes (blood glucose <200 mg/dl) (198–200) have demonstrated that ingested protein does not increase plasma glucose concentration. Gannon et al. (200) reported that during the 8-h period after subjects with type 2 diabetes ingested 50 g protein in the form of very lean beef, ~20–23 g of protein were deaminated, which in theory could yield ~11–13 g glucose. However, the amount of glucose appearing in the circulation was only ~2 g, confirming that ingested protein does not result in a significant increase in glucose concentration. This raises the question that if gluconeogenesis from protein is occurring, why does the glucose produced not appear in the general circulation after the ingestion of protein?

In type 2 diabetic subjects, the peak plasma glucose response to carbohydrate is similar to the response to carbohydrate plus protein (197–199), suggesting that protein does not slow the postprandial absorption of carbohydrate.

In individuals capable of secreting insulin, protein ingestion is just as potent as glucose ingestion in stimulating insulin secretion (197–200). The net effect on glucose output by the liver depends on the ratio of insulin to glucagon. In type 1 or type 2 diabetic subjects, the glucagon response to protein is considerably greater than in nondiabetic subjects (201).

In one study of subjects with well-controlled type 1 diabetes, the addition of protein to a meal did not slow the absorption of carbohydrate or change either the postprandial peak glucose response to the meal or glucose levels at 5 h (202). Furthermore, in type 1 diabetic subjects, the rate of restoration to euglycemia after hypoglycemia did not differ when treatment was given with carbohydrate or carbohydrate plus protein (203). Glucose levels, the time to peak plasma glucose levels,

and subsequent rate of glucose fall were similar after both treatments.

Protein's effect on satiety and/or energy balance. It has been claimed that high-protein, low-carbohydrate diets produce weight loss and improvements in glycemia. It should be noted that most of these diets tend to be high in fat. In one study of high-protein diets, there was a significant decrease in weight and plasma triglycerides at 12 weeks (204). However, plasma LDL cholesterol levels were increased. There is no research available to document that high-protein diets maintain long-term weight reduction any better than traditional weight-loss diets and that they are safe for long-term use.

The Continuing Survey of Food Intake by Individuals 1994–1996 (177) was used to examine the relationship among prototype popular diets (205). In a comparison of low-carbohydrate diets (≤30% of energy from carbohydrate [high protein diets]) and high-carbohydrate diets (>55% of energy from carbohydrate), diet quality was lower and total and saturated fat intake was higher on the lower carbohydrate diet, whereas energy intake and BMI were approximately similar between the two.

The effects of dietary protein on the regulation of energy intake and satiety have not been adequately studied (206,207). Short-term meal studies suggest that protein does exert a positive effect on satiety (208–211). However, results from one study demonstrated that although hunger was suppressed to a greater extent after a high-protein than a high-fat or high-carbohydrate breakfast, the changes in hunger were not of sufficient magnitude to change ad libitum lunchtime energy intake 5 h later or energy intake for the rest of the day, which were similar after all three breakfast types (210).

There is strong evidence for the following statement:

- In individuals with controlled type 2 diabetes, ingested protein does not increase plasma glucose concentrations, although ingested protein is just as potent a stimulant of insulin secretion as carbohydrate.

There is some evidence for the following statements:

- For diabetic individuals, there is no evidence to suggest that usual protein intake (15–20% of total daily energy) should be modified if renal function is normal.
- For diabetic individuals, especially those with less-than-optimal glycemic control, the protein requirement may be greater than the RDA, but not greater than usual intake.
- Contrary to advice often given to patients with diabetes, the available evidence suggests the following: *1*) dietary protein does not slow the absorption of carbohydrate and *2*) dietary protein and carbohydrate do not raise plasma glucose later than carbohydrate alone and thus do not prevent late-onset hypoglycemia.

There is limited evidence for the following statement:

- It may be prudent to avoid protein intake >20% of total daily energy.

The following statement is based on expert consensus:

- The long-term effects of diets high in protein and low in carbohydrate are unknown. Although such diets may produce short-term weight loss and improved glycemia, it has not been established that weight loss is maintained. The long-term effect of such diets on plasma LDL cholesterol is also a concern.

Dietary fat and diabetes

Saturated fats and dietary cholesterol. The primary goal regarding dietary fat in patients with diabetes is to decrease intake of saturated fat and cholesterol (212–214). Saturated fat is the principal dietary determinant of LDL cholesterol (213). Compared to nondiabetic subjects, diabetic subjects have an increased risk of coronary heart disease with higher intakes of dietary cholesterol (215). The ADA (8,212) and the National Cholesterol Education Program's Adult Treatment Panel III (18) have recommended that the serum LDL cholesterol goal be <100 mg/dl. To assist in achieving this goal, it is recommended that food with a high content of saturated fatty acids and cholesterol be limited (17,18).

In a meta-analysis (216) of 37 dietary intervention studies in free-living subjects, plasma total cholesterol decreased from baseline by 24 mg/dl (10%), LDL cholesterol by 19 mg/dl (12%), and triglycerides by 15 mg/dl (8%) in Step I (10% saturated fat and 300 mg cholesterol) interventions ($P < 0.01$ for all). In Step II interventions (7% saturated fat and 200 mg cholesterol), total cholesterol decreased by from baseline by 32 mg/dl (13%), LDL cholesterol by 25 mg/dl (16%), and triglycerides by 17 mg/dl (8%) ($P < 0.01$ for all). HDL cholesterol decreased by 7% ($P = 0.05$) in response to Step II but not Step I dietary interventions. Positive correlations between changes in dietary total and saturated fatty acids and changes in total, LDL, and HDL cholesterol were observed. Adding exercise resulted in greater decreases in total and LDL cholesterol and triglycerides and prevented the decrease in HDL cholesterol associated with low-fat diets. However, studies in diabetic subjects demonstrating the effects of specific percentages of saturated fatty acids (e.g., 10 vs. 7% of energy) and specific amounts of dietary cholesterol (e.g., 300 vs. 200 mg) are not available. Therefore, the goal for patients with diabetes remains the same as for the general population: to reduce saturated fat intake to <10% of energy intake. Some individuals (i.e., those with LDL cholesterol ≥100 mg/dl) may benefit by reducing saturated fat to <7% of energy intake. The goal for dietary cholesterol intake is <300 mg/day and for individuals with LDL cholesterol ≥100 mg/dl, <200 mg/day.

For patients with diabetes, the debate has focused not on the extent to which saturated fatty acids and cholesterol intake should be limited, but rather on what is the best alternative energy source. Plasma cholesterol reductions of 9–29% have been reported in four studies in which saturated fat was replaced with carbohydrate in diabetic diets (217–220). Two of these studies also measured plasma LDL and HDL cholesterol and reported that substituting a low-fat (<30% of total daily calories), high-carbohydrate diet for a high−saturated fat diet resulted in reductions in LDL, but not HDL, cholesterol. (217,218) Glycemic control was improved or unchanged as a result of restricting dietary saturated fat and replacing it with carbohydrate (217,219,221–224). See Table 4 for classification of fatty acids (225).

Table 4 —*Composition of some common dietary fatty acids and typical food sources*

Fatty acid (common name)	Chemical notation	Amount found in U.S. diet (g/day)		Food sources
		Men	Women	
Polyunsaturated fatty acids				
Linoleic acids	18:2, n-6	14.7	10.4	Vegetable oil, nuts, seeds
α-linolenic acid	18:3, n-3	1.6	1.1	Flaxseed oil (linseed oil), canola oil, soybean oil, walnuts
Eicosapentaenoic acid (EPA)*	20:5, n-3	0.1 (based on EPA and DHA together)		Fish and fish oil, plankton
Docosahexaenoic acid (DHA)*	22:6, n-3			Fish and fish oil, oceanic algae, plankton
Monounsaturated fatty acids				
Oleic acid	18:1, n-9 (*cis* form)	31.0	20.8	Olive oil, soybean oil, canola oil, safflower oil, peanut oil, almonds, cashews, pecans, avocado, peanuts, peanut butter
Elaidic acid	18:1 n-9 (*trans* form)	4.2	1.8	Solid margarines, shortenings, salad dressing, processed food containing partially hydrogenated oil
Saturated fatty acids				
Lauric acid	12:0	0.9	0.7	Meats, poultry, butterfat in butter, nonskim milk or yogurt, cheese, ice cream, egg yolks
Myristic acid	14:0	2.7	1.9	Dairy products, food made with coconut oil
Palmitic acid	16:0	1.7	11.6	Dairy products, meat, processed grain products
Stearic acid	18:0	8.1	5.4	Dairy products, meat, processed grain products, chocolate

*Both DHA and EPA can be synthesized from α-linolenic acid. Adapted from Sega-Isaacson CJ, Carello E, Wylie-Rosett J: Dietary fats and diabetes mellitus. Is there a food fat? *Current Diabetes Reports* 1:161–169, 2001

Monounsaturated fats. Diets high in *cis*-monounsaturated fatty acids (hereafter referred to simply as monounsaturated fat) (90,226–229) or low in fat and high in carbohydrate (216–223) result in improvements in glucose tolerance and lipids compared with diets high in saturated fat. Diets enriched with monounsaturated fat may also reduce insulin resistance (227); however, some studies have reported total dietary fat to be associated with insulin resistance (96–100). Metabolic study diets in which energy intake is maintained and that are high in either carbohydrate or monounsaturated fat lower plasma LDL cholesterol equivalently (90). Low−saturated fat (i.e., 10% of energy), high-carbohydrate diets increase postprandial levels of plasma glucose and insulin, increase plasma triglycerides (90), and, in some studies, were shown to decrease plasma HDL cholesterol when compared in metabolic studies to isocaloric high−monounsaturated fat diets (91,230). However, high−monounsaturated fat diets have not been shown to improve fasting plasma glucose or HbA_{1c} values. Therefore, if saturated fat calories need to be replaced, they can be replaced with carbohydrate or monounsaturated fat, either of which can contribute to a reduction in plasma LDL cholesterol. There is, however, concern that when high−monounsaturated fat diets are eaten ad libitum outside of a controlled setting, they may result in increased energy intake and weight gain (216). Studies comparing diets high in monounsaturated fat with diets high in carbohydrate with ad libitum energy intake are needed to evaluate the efficacy of these diets and determine which dietary intervention is superior for reducing cardiovascular risk. Each individual's metabolic profile and need to lose weight will determine the MNT recommendations. For example, a diet in which 60–70% of energy is to be derived from carbohydrate and monounsaturated fat may emphasize carbohydrate intake for the patient to achieve weight loss and monounsaturated fat for the patient to improve plasma triglyceride levels or postprandial glycemia. Furthermore, an Asian patient may be more comfortable with a high-carbohydrate diet, whereas a patient of Mediterranean descent may prefer a monounsaturated fat−containing diet. Monounsaturated fats can also be considered for food preparation and substituted for saturated fats in fat spreads and snacks.

Polyunsaturated fats. Only a few studies have evaluated the effects of polyunsaturated fat on plasma lipid levels and glycemic control in subjects with diabetes. In one study of type 2 subjects with diabetes, a diet high in total and polyunsaturated fat resulted in lower plasma total and LDL cholesterol than a diet high in

total and saturated fat, but produced no difference in other plasma lipid levels (231). Another study in type 2 diabetic subjects compared a diet high in polyunsaturated fat with one high in monounsaturated fat and reported higher plasma total and LDL cholesterol, fasting glucose, and insulin levels with the polyunsaturated fat diet (232).

N-3 polyunsaturated fat (omega-3 fatty acids). Food sources of n-3 polyunsaturated fatty acids include fish, especially fatty fish, as well as plant sources such as flaxseed and flaxseed oil, canola oil, soybean oil, and nuts. N-3 fatty acid supplements have been shown to reduce plasma triglyceride levels, especially in hypertriglyceridemic individuals (233), and to have beneficial effects on platelet aggregation and thrombogenicity (234). Increasing the intake of n-3 polyunsaturated fatty acids has been shown to be beneficial in subjects with diabetes (235–237). Although fish oil supplementation may be beneficial in lowering plasma triglyceride levels in type 2 diabetic subjects, the accompanying rise in plasma LDL cholesterol is of concern (238,239). Therefore, if n-3 fatty acid supplements are used, the effects on plasma LDL cholesterol should be monitored. Glucose metabolism is not likely to be adversely affected with the use of n-3 supplements (236,237,240). N-3 supplements may be most beneficial in the treatment of severe hypertriglyceridemia (236,241). Although studies of the effects of n-3 fatty acids in patients with diabetes have primarily used supplements, there is evidence from the general population that food containing n-3 fatty acids, specifically eicosapentaenoic acid and docosahexaenoic acid, has cardioprotective benefits (242–246).

Transunsaturated fatty acids. Trans fats—unsaturated fatty acids formed when vegetable oils are processed and made more solid (hydrogenation)—are found in some margarines and in food prepared or fried in hydrogenated vegetable oils. Trans fats also occur naturally in small amounts in meats and dairy products. The mean intake of trans fatty acids in the U.S. has been estimated at 2.6% of total caloric intake and 7.4% of total fat intake (247). When studied independently of other fatty acids, the effect of trans fatty acids is similar to that of saturated fats in raising plasma LDL cholesterol. Trans fatty acids also lower plasma HDL cholesterol (248–250). Studies in nondiabetic subjects support limiting the intake of trans fatty acids.

Stanols/sterols. Plant stanols are found in very small amounts in food from plants such as corn and soy and in other vegetable or plant oils. Within plant tissue they are derived from plant phytosterols. They differ from plant sterols in that their ring structure is saturated. Plant stanols are esterified to other vegetable oil fatty acids to enhance their lipid solubility and make them easier to use as an ingredient in food. Plant sterol and stanol esters block the intestinal absorption of dietary and biliary cholesterol (251) by competing with cholesterol for entry into the mixed micelles that must form during digestion for dietary fatty acids, cholesterol, and fat-soluble vitamins to be absorbed. Plant stanols/sterols in the amount of ~2 g/day have been shown to lower serum total cholesterol by up to 10% and LDL cholesterol by up to 14% (251–255).

Low-fat diets. There are potential benefits from low-fat diets. Low-fat diets are usually associated with modest loss of weight, which can be maintained as long as the diet is continued (230,256) and if combined with aerobic exercise (216,257,258). In studies evaluating the effect of ad libitum energy intake as a function of dietary fat content, low-fat, high-carbohydrate intake is associated with a transient decrease in caloric intake and modest weight loss, leading to a new equilibrium body weight (221,259–268). With this modest weight loss, a decrease in total cholesterol and plasma triglycerides and an increase in HDL cholesterol occur. Consistent with this, low-fat, high-carbohydrate diets over long periods of time have been shown to not increase plasma triglycerides and, when reported, have led to modest weight loss (230,269, 270). Although the significance of the effects of reduced dietary fat intake are controversial (256,271–279), reduced-fat diets have been shown to maintain weight loss better than other types of reduced energy diets (216,257,280–283).

In type 2 diabetic subjects, restrained eating behaviors combined with dietary fat restriction have been shown to have beneficial effects on glycemia, plasma lipids, and/or weight (284–286). A higher intake of total dietary fat is associated with higher levels of plasma LDL cholesterol, and the adverse effect of a higher carbohydrate intake on triglycerides has been found in individuals who have undiagnosed diabetes or have gained weight during the previous year (287).

Fat replacers/substitutes. Dietary fat intake can be decreased by reducing the amount of high-fat food in the diet. Another option is to provide lower fat or fat-free versions of food and beverages. This can be accomplished by removing some fat or by using fat replacers (ingredients that mimic the properties of fat with significantly fewer calories than fat) in food formulations. The FDA has approved the majority of the fat replacers as GRAS because the substances' ingredients have a long history of safe use in food. A few replacers (notably olestra) have been approved as food additives; approval of these requires both demonstration of safety and premarket approval (288–290). Although olestra has no effect on water-soluble nutrients, it can lead to a loss of fat-soluble vitamins.

Two recent studies involving diabetic subjects and food made with fat replacers have been reported (291,292). One of these, a short-term study (292), provided correctly labeled regular or fat-free food to free-living subjects with and without diabetes. Use of fat substitutes/replacers in reasonable amounts (five low-fat or no-fat products per day) produced a small decrease in dietary fat, saturated fat, and cholesterol intake with little or no decrease in total energy intake or weight. When fat replacers are used in larger amounts (293,294), there can be a significant decrease in energy intake. Long-term studies are needed to assess the effect of food containing fat replacers/substitutes on the macronutrient content of the diets patients with diabetes and their utility in achieving treatment goals.

Studies in nondiabetic subjects provide strong evidence for the following statements:

- In all, <10% of energy intake should be derived from saturated fats. Some individuals (i.e., those with LDL cholesterol ≥100 mg/dl) may benefit from lowering saturated fat intake to <7% of energy intake.
- Dietary cholesterol intake should be <300 mg/day. Some individuals (i.e., those with LDL cholesterol ≥100 mg/dl) may benefit from lowering dietary cholesterol to <200 mg/day.
- Intake of transunsaturated fatty acids should be minimized.
- Current fat replacers/substitutes ap-

proved by the FDA are safe for use in food.

Studies in diabetic subjects provide strong evidence for the following statement:

- To lower plasma LDL cholesterol, energy derived from saturated fat can be reduced if concurrent weight loss is desirable or replaced with carbohydrate or monounsaturated fat if weight loss is not a goal.

There is some evidence for the following statements:

- Polyunsaturated fat intake should be ~10% of energy intake.
- In weight-maintaining diets, when monounsaturated fat replaces carbohydrate, it may beneficially affect postprandial glycemia and plasma triglycerides but not necessarily fasting plasma glucose or HbA_{1c}.
- Incorporation of two to three servings of plant stanols/sterols (~2 g) food per day, substituted for similar food, will lower total and LDL cholesterol.
- Reduced-fat diets when maintained long term contribute to modest loss of weight and improvement in dyslipidemia.

There is limited evidence for the following statement:

- Two or more servings of fish per week provide dietary n-3 polyunsaturated fat and can be recommended.

The following statements are based on expert consensus:

- Monounsaturated fat and carbohydrate together should provide ~60–70% of energy intake. However, increasing fat intake may result in increased energy intake.
- Fat intake should be individualized and designed to fit ethnic and cultural backgrounds.
- Use of low fat food and fat replacers/substitutes by patients with diabetes may reduce total fat and energy intake and thereby facilitate weight loss.

Energy balance and obesity

Many individuals with type 2 diabetes are overweight, with ~36% having a BMI ≥ 30 kg/m^2, which would classify them as obese (295). The prevalence of obesity is higher in women and members of minority populations with type 2 diabetes (295). As body adiposity increases, so does insulin resistance (296–298). Obesity may also aggravate hyperlipidemia and hypertension in type 2 patients with diabetes (299).

Because of the effects of obesity on insulin resistance, weight loss is an important therapeutic objective for obese individuals with type 2 diabetes. Short-term studies lasting 6 months or less have demonstrated that weight loss in type 2 diabetic subjects is associated with decreased insulin resistance, improved measures of glycemia, reduced serum lipids, and reduced blood pressure (300–302). Long-term data assessing the extent to which these improvements can be maintained in people with type 2 diabetes are not available.

Data from the general public suggest that long-term maintenance of weight loss is challenging. In two observational studies on weight maintenance after weight loss in nondiabetic subjects, one study (303) reported that only 6% in the final study group maintained a 5% weight loss over 9–15 years, while in a random telephone survey (304), 21% of 228 overweight subjects reported that they had intentionally lost weight and maintained a weight loss of 10% for at least ≥ 5 years. However, long-term data assessing the extent to which weight loss is maintained in patients with diabetes are not available. In studies of weight loss in type 2 diabetic subjects (305–307), the most successful long-term weight loss from diet was reported in the Diabetes Treatment Study (307), with weight loss of 9 kg maintained over the 6-year study period. To accomplish this required long-term access to therapeutic contact.

The reason that long-term weight loss is difficult for most people to accomplish is probably because energy intake and energy expenditure, and thereby body weight, are controlled and regulated by the central nervous system (308–310). Although our understanding of central nervous system regulation of energy balance is incomplete, it is thought that the hypothalamus may be the center of control. Neuropeptide Y, leptin, insulin, and a variety of other neural, endocrine, and gastrointestinal signals also appear to be involved. Individual characteristics of central nervous system control of energy balance may be genetically determined. For example, in a study of Danish adoptees, there was a strong relation between BMI of the adoptees and their biological parents, and no relation whatsoever between the BMI of the adoptees and their adoptive parents (311). These study results suggest that genetic factors have an important role in determining body weight. Other data support this conclusion (312,313). Furthermore, environmental factors often make losing weight difficult for those genetically predisposed to obesity.

The National Weight Control Registry has enrolled over 3,000 subjects successful at long-term maintenance of weight loss (314). A group of ~800 people who lost an average of 30 kg and maintained a minimum weight loss of 13.6 kg (30 lb) for 5 years were identified from the registry (315). Slightly more than half lost weight through formal programs, and the remainder lost weight with a program of their own. Average energy consumption was ~1,400 kcal/day, with 24% of energy derived from fat. Average energy expenditure through added physical activity was 2,800 kcal/week. Importantly, nearly 77% of this sample of people who were successful in achieving and maintaining weight loss reported a triggering event that preceded the weight loss. The most common triggering events were acute medical conditions and emotional problems. Thus a new diagnosis of type 2 diabetes could trigger lifestyle changes that result in reduced fat and energy intake, increased physical activity, and associated weight loss.

Structured programs to produce lifestyle change. The recently completed Diabetes Prevention Program (DPP) demonstrated long-term benefit in people with glucose intolerance from structured, intensive lifestyle programs (316,317). In the DPP, participants randomly assigned to an intensive lifestyle intervention that included a low-fat diet, increased physical activity, educational sessions, and frequent follow-up were able to lose 7% of body weight in the first year and sustain a 5% weight loss over an average follow-up period of 3 years. DPP program participants received training in diet, exercise, and behavior modification from case managers who met with them for at least 16 sessions in the first 24 weeks and monthly thereafter. With intensive life-

style intervention, the risk of developing diabetes was reduced by 58% relative to standard care. Wing et al. (318) demonstrated a 2.5-kg weight loss and Tuomilehto et al. (319) documented a 3.5-kg weight loss at 2 years with such programs, and also demonstrated that lifestyle changes reduce the risk of developing diabetes. A recently initiated clinical trial called Look AHEAD (Action for Health in Diabetes) will assess the long-term effects of diet and exercise in type 2 patients with diabetes.

For weight loss, dietary fat is probably the most important nutrient to be restricted. Spontaneous food consumption and total energy intake are increased when the diet is high in fat and decreased when the diet is low in fat (259,260). Moreover, epidemiological studies have demonstrated that dietary fat intake is positively associated with adiposity and BMI (320,321). In healthy individuals, simply reducing the fat content of the diet can result in reduced energy intake and weight loss of 2–3 kg (260,322,323). Toubro and Astrup (283) compared the efficacy of an ad libitum, low-fat, high-carbohydrate diet with that of a fixed−energy intake diet for long-term maintenance of weight loss. Both treatment groups attended reinforcement sessions 2–3 times weekly. At 1-year follow up, the ad libitum group had maintained a greater weight loss than the fixed−energy intake group.

Exercise improves insulin sensitivity, can acutely lower blood glucose in patients with diabetes, and may also improve cardiovascular status. Exercise by itself has only a modest effect on weight (324). Exercise is to be encouraged, but like behavioral therapies, may be most useful as an adjunct to other weight-loss strategies, such as dietary fat reduction. Exercise is, however, important in long-term maintenance of weight loss (325,326).

Behavioral approaches to weight loss include strategies such as self-monitoring of food intake and exercise, nutrition education, stimulus control, preplanning of food intake, and self-reinforcement. Weight loss with behavioral therapy alone has been modest (327,328); behavioral approaches may be most useful as an adjunct to other weight-loss strategies.

Other nutrition interventions. Standard weight-reduction diets, meal replacements, and very-low-calorie diets (VLCDs) are other nutrition options. Standard weight-reduction diets provide 500–1,000 fewer calories than are estimated to be necessary for weight maintenance. An ADA technical review paper on the prevention and treatment of obesity (326) concluded when such diets are used alone in patients with type 2 diabetes as well as in the general population, participants generally lose ~10% of initial body weight (329). However, an average of 33% of the lost weight is usually regained in the year after treatment, and almost all of the lost weight may be regained within 5 years (330). Nevertheless, standard weight-reduction diets may still be recommended for overweight patients with type 2 diabetes as some people can lose weight with them and maintain the weight loss, particularly if they increase their physical activity.

Structured meal replacements provide a defined amount of energy (usually 200–300 calories), often as a prepackaged meal, snack bar, or formula product. Most of the energy is derived from protein and carbohydrate. Vitamins, minerals, and fiber may also be included. Use of meal replacements once or twice daily to replace a usual meal can result in significant weight loss (331–335). Presumably the meal replacement causes a reduction in energy intake by eliminating the choice of type and amount of food. Weight loss can be as much as 11% of starting weight at 2 years, but meal replacement therapy must be continued if weight loss is to be maintained; attrition may occur in about 33% of patients (331).

VLCDs provide 800 or fewer calories daily, primarily from protein and carbohydrate, with mineral and vitamin supplementation. These diets can produce substantial weight loss and rapid improvements in glycemia and lipemia in patients with type 2 diabetes (301,336). Of note, reductions in glycemia occur before significant weight loss, suggesting that caloric restriction plays an important role in correcting hyperglycemia. Unfortunately, when VLCDs are stopped and self-selected meals are reintroduced, weight gain is common (337,338). Most people treated with VLCDs are not able to maintain long-term weight loss. Thus VLCDs appear to have limited utility in the treatment of type 2 diabetes and should be considered only in conjunction with a structured weight-maintenance program.

Pharmacological therapy. If energy balance is regulated by a hypothalamic control center that produces and responds to biochemical signals, it might be possible to influence the control center pharmacologically. This possibility first received attention with the publication of a landmark study by Weintraub, who described the effects of fenfluramine and phentermine to induce weight loss (339). When the study was published in 1992, it initiated widespread increased use of fenfluramine and phentermine (fen-phen) for weight loss and maintenance (340). Before the withdrawal of fenfluramine because of cardiac effects, the combination of fenfluramine and phentermine was demonstrated to have beneficial weight-loss effects in type 2 diabetic subjects (341).

Since the withdrawal of fenfluramine and its dextroenantiomer dexfenfluramine, only a limited number of weight-loss medications remain available in the U.S. Some are listed in Table 5. Phentermine continues to be available, but appears to have limited efficacy when used as a single agent. Sibutramine suppresses the appetite by inhibiting reuptake of serotonin and norepinephrine in the central nervous system. A 24-week, placebo-controlled study compared sibutramine

Table 5 —*Selected weight-loss drugs available in the U.S.*

Drug	Mechanism of action	FA Labeling
Phentermine	Nonadrenergic; appetite suppression and/or stimulation of metabolic rate	Short-term usage
Sibutramine	Serotonin and norepinephrine reuptake inhibition; appetite suppression	Safety and effectiveness beyond 1 year not determined
Orlistat	Inhibition of pancreatic lipase; partial malabsorption of fat	Safety and effectiveness beyond 2 years not determined

and diet to placebo and diet in type 2 diabetic subjects (342). Subjects treated with sibutramine lost 4.0 kg more weight, but did not have a significant improvement in HbA_{1c} levels when compared to subjects treated with placebo. Orlistat is a medication that inhibits pancreatic lipase and causes malabsorption of a portion of ingested fat. In a 1-year, placebo-controlled study comparing orlistat and diet to placebo and diet in type 2 diabetic subjects, the orlistat group lost 6.2% of initial body weight as compared to 4.3% weight loss in the placebo group (343). In the orlistat group, HbA_{1c} decreased by 0.2%, whereas in the placebo group it increased by 0.3%. In a second 1-year, placebo-controlled study of orlistat, a diabetic subgroup experienced a reduction in HbA_{1c} that was 0.5% more with orlistat than with placebo (344).

The available data suggest that weight loss medications may be useful in the treatment of overweight patients with type 2 diabetes. However, the effect of these medications is modest. The data also suggest that these drugs work best in conjunction with lifestyle strategies. In addition, like antihypertensive and antihyperlipidemic medications, these medications must be continued to maintain any beneficial effect. As more is learned about the regulation of energy balance, new weight-loss drugs should become available.

Gastric reduction surgery. Gastric reduction surgery can be an effective weight loss treatment for severely obese patients (including those with type 2 diabetes) (345–347). A National Institute of Health Consensus Development Panel has recommended that such surgery be considered in patients with type 2 diabetes and with a BMI $\geq$35 kg/m^2 (348). The two surgical procedures most widely used are vertical banded gastroplasty and gastric bypass. Both procedures involve creation of a small (25–50 ml) gastric pouch to receive food. This small pouch permits consumption of small meals without epigastric pain or vomiting. Larger meals or large fluid intakes cause pain and vomiting.

In a series of 70 obese patients treated with vertical banded gastroplasty, median weight losses 1 and 3 years after surgery were 37 and 32 kg, respectively (345). In a large series of 515 obese patients treated with gastric bypass, mean weight losses at 1 and 3 years were 50 and 45 kg, respectively, and weight loss was well maintained in 44 patients who achieved 10 years of follow-up (346). Within the subgroup of 137 patients in this study who had type 2 diabetes, 107 (78%) experienced clinical remission of diabetes. From a group of 500 patients consecutively treated with laparoscopic adjustable gastric band surgery, 50 patients with type 2 diabetes were studied preoperatively and again 1 year after surgery (347). Their postoperative mean weight loss was 27 kg, with significant improvement in all measures of glucose metabolism and remission of diabetes in 32 (64%) patients, major improvement in control of diabetes in 13 (26%), and no change in 5 (10%).

Potential adverse effects of gastric reduction surgery include perioperative mortality in 1–2% of patients, wound dehiscence, vitamin and mineral deficiencies, cholelithiasis, inability to eat certain types of food (particularly meat, untoasted bread, and raw fruit), and persistent vomiting (345–348). Prophylactic treatment with ursodiol may prevent gallstone formation (349).

It is unfortunate that there are no data comparing medical and surgical approaches to weight loss in obese patients with type 2 diabetes; thus the relative benefits and risks of surgical approaches are uncertain. In the absence of data defining benefits and risks, gastric reduction surgery probably should be considered unproven in treating diabetes.

There is strong evidence for the following statements:

- In insulin-resistant individuals, reduced energy intake and modest weight loss improve insulin resistance and glycemia in the short term.
- Structured programs that emphasize lifestyle changes, including education, reduced fat (<30% of daily energy) and energy intake, regular physical activity, and regular participant contact can produce long-term weight loss of 5–7% of starting weight.
- Exercise and behavior modification are most useful as adjuncts to other weight-loss strategies. Exercise is helpful in maintaining weight loss.
- Nutrition interventions, such as standard weight-reduction diets, when used alone are unlikely to produce long-term weight loss. Structured, intensive lifestyle programs are necessary.
- Optimal strategies for preventing and treating obesity long-term have yet to be defined.

There is some evidence for the following statement:

- Currently available weight-loss drugs have modest beneficial effects in patients with diabetes. These drugs should be used only in people with BMI >27.0 kg/m^2.

There is limited evidence for the following statement:

- Gastric reduction surgery can be considered for patients with diabetes and a BMI >35.0 kg/m^2. Long-term data comparing the benefits and risks of gastric reduction surgery to those of medical therapy are not available.

Micronutrients and diabetes

Adequate intake of micronutrients within the range of Dietary Reference Intake (DRI) prevents deficiency diseases and is important in maintaining the health and well-being of patients with diabetes. Nutrient recommendations for adults, adolescents, and children with type 1 or type 2 diabetes and for women with diabetes during pregnancy and lactation are similar for people with or without diabetes (350–355). However, uncontrolled diabetes is often associated with micronutrient deficiencies (356,357).

Individuals with diabetes should be educated about the importance of acquiring daily vitamin and mineral requirements from natural food sources, and about the potential toxicity of megadoses of vitamin and mineral supplements. In select groups, such as elderly individuals, pregnant or lactating women, strict vegetarians, or individuals on calorie-restricted diets, supplementation with a multivitamin preparation is advisable (16). However, vitamin and mineral supplementation in pharmacological dosages should be viewed as a therapeutic intervention and, as with medications, be subjected to placebo-controlled trials to demonstrate its safety and efficacy.

To determine how much of a specific micronutrient an individual needs on a daily basis, four estimates of DRIs have been made by the Institute of Medicine's Food and Nutrition Board: Estimated Average Requirement (EAR), the Recom-

Table 6 —*Adult DRIs for select vitamins and minerals*

	RDA	Tolerable upper intake level	Adverse effects upon which upper intake level is based
Vitamin A	700 μg/day for women 900 μg/day for men	3,000 μg/day	
Vitamin B_6	1.3 mg/day	100 mg/day	Sensory neuropathy
Vitamin B_{12}	2.4 μg/day	Insufficient data to set upper intake level	
Folic acid	400 μg/day of dietary folate equivalents	1,000 μg/day from fortified food and supplement intake (exclusive of food intake)	
Niacin	14 mg/day niacin equivalents for women, 16 mg/day niacin equivalents for men	35 mg/day niacin equivalents	Flushing
Riboflavin	1.1 mg/day for women, 1.3 mg/day for men	Insufficient data to set upper intake level	
Thiamin	1.1 mg/day for women, 1.3 mg/day for men	Insufficient data to set upper intake level	
Vitamin C	75 mg/day for women, 90 mg/day for men	2,000 mg/day	Diarrhea and other gastrointestinal disturbances
Vitamin E	15 mg/day α-tocopherol	1,000 mg/day	Hemorrhage
Calcium	1,000 mg/day for adults <age 50 years, 1,200 mg/day for adults >age 50 years	2,500 mg/day	
Chromium	Insufficient data to set RDA; adequate intake is 25 μg/day for women and 35 μg/day for men	Not established	
Iron	8 mg/day for men and postmenopausal women, 18 mg/day for premenopausal women	45 mg/day	Gastrointestinal disturbances
Magnesium	320 mg/day for women, 420 mg/day for men	350 mg/day from supplements (exclusive of intake from food and water)	
Selenium	55 μg/day	400 μg/day	Selenosis
Vanadium	Insufficient data to set RDA or adequate intake	1.8 mg/day	
Zinc	8 mg/day for women, 11 mg/day for men	40 mg/day	Interference with the absorption of copper

From the Institute of Medicine Food and Nutrition Board.

mended Dietary Allowance (RDA), the Adequate Intake (AI), and the Tolerable Upper Intake Level (UL). The RDA is a daily intake level that is sufficient to meet the nutrient requirement of nearly all (97–98%) healthy individuals within a specific age, sex, life stage, and physiological state; the UL is the largest amount of a nutrient that is likely to pose no risk of adverse health effects for almost all the general population (350–353). Table 6 provides RDAs for certain vitamins and minerals and upper limits for those deemed harmful at high dosages.

Evaluation of the micronutrient status of patients with diabetes begins with a careful clinical history and should include a food/nutrition history to document use of "health food"; over-the-counter vitamin, mineral, and herbal supplements; food supplements; and methods of preparing food. Laboratory evaluation of micronutrient status is confounded by methodological problems and, as a result, does not always define micronutrient deficiencies. For example, wide seasonal variations for vitamin D occur in some parts of the country, and serum measurements of intracellular cat ions poorly reflect body stores. However, measurements of serum folate, vitamin B_{12}, vitamin D, calcium, potassium, magnesium, and iron concentrations may be clinically useful.

Antioxidants and vitamins. An Institute of Medicine report concluded that consuming megadoses of dietary antioxidants—vitamin C, vitamin E, selenium, beta carotene, and other carotenoids—has not been demonstrated to protect against cardiovascular disease, diabetes, or various forms of cancer, nor does megavitamin use necessarily prevent basic nutritional deficiencies. In fact, the opposite may be true. High dosages of antioxidants may lead to health problems, including diarrhea, bleeding, and toxic reactions (350). Although results from a large number of population-based studies have suggested a link between antioxidants and a lower incidence of certain

chronic diseases, the Institute of Medicine's comprehensive review of the scientific evidence concluded it was not certain that antioxidants were responsible for any benefit.

Antioxidants. Because diabetes may be a state of increased oxidative stress, there has been interest in prescribing antioxidant vitamins to patients with diabetes. Large observational studies have shown a correlation between dietary or supplemental consumption of antioxidants and a variety of clinical outcomes, such as prevention of disease states (358–377). However, large, placebo-controlled clinical trials have failed to show a benefit from antioxidants and, in some instances, have suggested adverse effects (378–383). Of particular interest is the Heart Outcomes Prevention Evaluation Trial, which included 9,541 subjects, 38% of whom had diabetes (378). Supplementation with vitamin E (400 IU/day) for 4.5 years did not result in any significant benefit.

Several placebo-controlled studies of small numbers of subjects have found beneficial effects of antioxidants on physiological and biochemical end points (384–388). However, most of these findings have not been confirmed. In addition, concern remains about potential long-term toxicity of antioxidants. Two trials with beta carotene found an unexpected increase in the incidence of lung cancer in those randomized to beta carotene (380,382).

Folate. The role of folate in preventing birth defects is widely accepted and has been the impetus for folate fortification of wheat and grain products in the U.S. (351). Because of the association between elevated serum homocysteine levels and cardiovascular disease, there has been increasing interest in folate supplementation to lower homocysteine (389). However, the role of folate supplementation in reducing cardiovascular events is far from settled. It is noteworthy that there are no health concerns with folate supplementation, except for aggravating vitamin B_{12} deficiency and occasionally causing seizures in people with epilepsy and marginal folate status who are receiving anticonvulsants. Folate supplementation trials are currently ongoing and are likely to yield important information.

B vitamins. The role of vitamins B_1, B_6, and B_{12} in the treatment of diabetic neuropathy has not been established; therefore, supplementing diet with B vitamins cannot be recommended as a standard or routine therapeutic option (356,357). It has been suggested from some studies that nicotinamide might preserve β-cell mass in newly diagnosed type 1 diabetic subjects, but the number of subjects enrolled in these studies has not been large enough and the treatment effect was not clear enough to warrant application of the findings (390,391).

Minerals. Deficiencies of certain minerals, such as potassium and magnesium, and possibly zinc and chromium, may predispose a person to carbohydrate intolerance. Whereas the need for potassium or magnesium replacement is relatively easy to detect based on low serum levels of these minerals, the need for zinc or chromium supplementation is more difficult to detect (356,357).

Chromium. There have been two randomized, placebo-controlled studies in Chinese diabetic subjects where chromium supplementation has had beneficial effects on glycemia (392,393). However, the study populations may have had marginal baseline chromium status. In the first study (392), the chromium status was not evaluated either at baseline or after supplementation. Other smaller studies have also suggested a role for chromium supplementation in the management of diabetes (394), glucose intolerance (395), gestational diabetes (396), and corticosteroid-induced diabetes (397). Results from these studies indicate that the dosage and formulation of chromium used significantly influences the outcome. In one study of patients with diabetes (392), 1,000 μg/day of chromium picolinate was more effective than 200 μg/day. Similarly, in gestational diabetes, 8 $\mu g \cdot kg^{-1} \cdot day^{-1}$ of chromium was more effective than 4 $\mu g \cdot kg^{-1} \cdot day^{-1}$ (396). In contrast, two well-designed studies in the U.S. (398,399) and two in Finland (400,401) failed to demonstrate any significant benefit of chromium supplementation in patients with diabetes. The latter studies used chromium chloride, which may not be as bioavailable as chromium picolinate. At the present time, benefit from chromium supplementation in diabetic individuals has not been conclusively demonstrated.

The Institute of Medicine Food and Nutrition Board's DRIs found insufficient evidence to set an estimated average requirement for chromium. An adequate intake was determined based on estimated mean intakes. The adequate intake for adult men >51 years is 30 μg/day and for women >51 years is 20 μg/day. However, few serious adverse effects have been associated with excess intake of chromium from food, and therefore a tolerable upper intake level has not been established (352).

Zinc. Another area of current interest in micronutrient supplementation is the role of zinc in diabetic individuals. Small studies in older subjects with diabetes have suggested some benefit from zinc supplementation in healing skin ulcerations (356,357). A more recent placebo-controlled trial with a formulation of zinc and rabbit prostatic extracts found a significant reduction in HbA_{1c} in subjects randomized to the active treatment arm (402). However, in that study, those randomized to the active treatment had higher baseline HbA_{1c} levels than those randomized to placebo.

Calcium. The rationale for recommending daily intakes of 1,000–1,500 mg of calcium, especially in older subjects with diabetes (403), is based on the recommendations of the Institute of Medicine Food and Nutrition Board (353) and the National Institutes of Health Consensus Development Panel on Osteoporosis Prevention, Diagnosis, and Therapy (404). This recommendation appears to be safe and likely to reduce the incidence of osteoporosis in older individuals. Vitamin D is also required for optimal calcium absorption, and a recommended vitamin D intake of 400–600 IU/day has been established for adults (353,404). The uncertainty of the value of calcium supplementation in younger individuals and potential long-term benefits have been discussed in a critical review by Kanis (405).

Vanadium. The role of vanadium salts in diabetes has been explored in several small studies. There is no clear evidence of efficacy and there is a potential for toxicity (406–409).

Herbal preparations. A full review of herbal preparations and issues is outside the scope of this technical review paper. A variety of herbal preparations have been shown to have modest short-term beneficial effects on glycemia. Of these, the best studied is American ginseng (410,411). Many herbal supplements used to treat obesity also have caffeine and ephedrine-containing herbs in them. Commercially

available products are not well standardized, varying greatly in content of active ingredients. In addition, some herbal preparations have been found to surreptitiously include pharmaceutical agents that produce hypoglycemia. Herbal preparations also have the potential to interact with other medications. Therefore, it is important that health care providers know when their patients with diabetes are using these products.

There is some evidence for the following statements:

- There is no clear evidence of benefit from vitamin or mineral supplementation in patients with diabetes who do not have underlying deficiencies. Exceptions include folate for prevention of birth defects (strong evidence) and calcium for prevention of bone disease (some evidence).
- Although difficult to ascertain, if deficiencies of vitamins and minerals are identified, supplementation can be beneficial.
- Routine supplementation of the diet with antioxidants is not advised because of uncertainties related to long-term efficacy and safety.

The following statements are based on expert consensus:

- Select populations, such as elderly individuals, pregnant or lactating women, strict vegetarians, and people on calorie-restricted diets, may benefit from supplementation with a multivitamin preparation.
- In individuals with diabetes, there is no evidence to suggest long-term benefit from herbal preparations.

Alcohol and diabetes

According to data for the period 1989–1991, alcohol accounts for ~2.5% of energy intake in U.S. adults (412) compared with the previous ~5% based on NHANES II data (1976–1980) (413). It is not clear whether this change is attributable to decreased intake or to methodological differences in the measurement of alcohol intake. Nearly 67% of the adult U.S. population are reported to drink alcoholic beverages, whereas 33% claim to abstain from them (414). People with diabetes undoubtedly fall into both categories.

The alcohol in distilled spirits (hard liquor), wine, and beer is ethanol (ethyl alcohol, C_2H_5OH). It is the by-product of the oxidation of sugars by yeast enzymes (fermentation). One drink or alcoholic beverage is commonly defined as 12-oz beer, 5-oz glass of wine, or 1.5-oz glass of distilled spirits, each of which contains ~15 g of alcohol. The cardioprotective effects of alcohol are not determined by the type of alcoholic beverage (415,416). A summary of ecological, case-control, and cohort studies concluded that all alcoholic drinks are linked with lower risk of coronary heart disease, so that much of the benefit is from the alcohol itself rather than other components of each type of drink (415).

The same precautions that apply to the general population regarding the use of alcohol apply to individuals with diabetes. Abstention from alcohol should be advised for women during pregnancy and for people with medical problems such as pancreatitis, advanced neuropathy, severe hypertriglyceridemia (417), or alcohol abuse. The *Dietary Guidelines for Americans* (16) recommends no more than two drinks per day for adult men and no more than one drink per day for adult women. After consuming comparable amounts of alcohol, women have higher blood ethanol concentrations than men, even with allowances for size differences. Women, compared to men, have an increased bioavailability of alcohol resulting from decreased gastric first-pass metabolism and decreased gastric alcohol dehydrogenase activity; this may contribute to the enhanced susceptibility of women to the effects of alcohol (418).

Alcohol and blood glucose levels. Alcoholic beverages can have both hypo- and hyperglycemic effects in patients with diabetes, depending on the amount of alcohol acutely ingested, if alcohol is consumed with or without food, and if alcohol use is chronic or excessive. Moderate (419) or severe hypoglycemia (420), no hypoglycemia (421,422), and hyperglycemia (423,424) have all been reported in patients with diabetes after alcohol ingestion. Ingestion of moderate amounts of alcohol has also been shown to blunt the awareness of hypoglycemia in type 1 diabetic subjects (425).

Moderate amounts of alcohol can enhance the glucose-lowering action of exogenous insulin and certain oral glucose-lowering agents. Although alcohol does not affect the rate and degree of decline in plasma glucose, it appears to alter the phase of glucose recovery by interfering with hepatic gluconeogenesis. The hypoglycemia induced by alcohol is not ameliorated by glucagon because it is caused by indirect impairment of gluconeogenesis and is not associated with excessive insulin secretion (420).

In type 1 and type 2 diabetic subjects, it has been shown that ingesting moderate amounts of alcohol with food has no acute effect on blood glucose or insulin levels (419,421,422,426–434). The risk of alcohol-induced hypoglycemia during fasting is modest for type 2 diabetic individuals, and is probably present only if they are being treated with insulin or insulin secretagogues.

Relationship of alcohol to other health risks. Heavy or excessive alcohol consumption is a leading, avoidable cause of death in the U.S. There may be additional specific adverse effects of chronic alcohol consumption for patients with diabetes. In people with type 2 diabetes, chronic alcohol ingestion (customary intake of ~45 g/day) causes deterioration in long- and short-term glucose metabolism (423). Therefore metabolic control should be carefully monitored if alcohol is an important component of a patient's diet. The effects induced by excess alcohol are reversed after abstinence from alcohol for 3 days (423,424).

Epidemiological evidence in nondiabetic individuals suggests that light-to-moderate alcohol ingestion in adults is associated with decreased risk of type 2 diabetes (435–437) and stroke (438) and increased insulin sensitivity (439–441), although insulin sensitivity may be attenuated by central adiposity (441). In adults with diabetes, chronic intake of light-to-moderate amounts of alcohol (5–15 g/day) is associated with a decreased risk for coronary heart disease, perhaps because of the concomitant increase in HDL cholesterol (442–444). Prospective, long-term studies are needed to confirm these observations.

Alcohol ingestion increases the capacity for lipoprotein synthesis, especially of VLDL particles. This increase in synthesis is enhanced by a genetic predisposition, high-fat diet, and diabetes (445). Increased lipoprotein synthesis may be more an effect of chronic or excessive alcohol intake, as nondiabetic subjects with fasting hypertriglyceridemia who, in one

study, consumed the equivalent of two alcoholic beverages did not demonstrate an acute increase in triglycerides (417). This suggests that even people with hypertriglyceridemia may occasionally use alcohol in moderation.

There appears to be a U- or J-shaped relationship between alcohol intake and blood pressure. Light-to-moderate amounts of alcohol do not raise blood pressure (446–451). However, a strong association exists between chronic, excessive intake of alcohol (>30–60 g/day) and blood pressure elevation in men and women. Each additional 10-g increment of alcohol intake above 30 g/day increases systolic blood pressure by an average of 1–2 mmHg and diastolic blood pressure by 1 mmHg (452). In addition to being a risk factor for hypertension, alcohol may interfere with antihypertensive therapy and may be a risk factor for stroke (446,452).

There is strong evidence for the following statements:

- If individuals choose to drink alcohol, daily intake should be limited to one drink for adult women and two drinks for adult men. One drink is defined as a 12-oz beer, 5-oz glass of wine, or 1.5-oz glass of distilled spirits.
- The type of alcoholic beverage consumed does not make a difference.
- When moderate amounts of alcohol are consumed with food, blood glucose levels are not affected.
- To reduce risk of hypoglycemia, alcohol should be consumed with food.
- Ingestion of light-to-moderate amounts of alcohol does not raise blood pressure; excessive, chronic ingestion of alcohol raises blood pressure and may be a risk factor for stroke.
- Pregnant women and people with medical problems such as pancreatitis, advanced neuropathy, severe hypertriglyceridemia, or alcohol abuse should be advised to not ingest alcohol.

There is some evidence for the following statement:

- There are potential benefits from the ingestion of moderate amounts of alcohol, such as decreased risk of type 2 diabetes, coronary heart disease, and stroke.

The following statement is based on expert consensus:

- Alcoholic beverages should be considered an addition to the regular food/meal plan for all patients with diabetes. No food should be omitted.

Special considerations

Type 1 diabetes. Nutrition recommendations for a healthy lifestyle for the general public are also appropriate for individuals with type 1 diabetes. What differs for individuals requiring insulin is the integration of an insulin regimen into their lifestyle. With the many insulin options available, if an individual's preferred meal routine and food choices are known, an appropriate insulin regimen can usually be developed. The food/meal plan should be based on an assessment of the individual's appetite, preferred types of food, and usual eating and exercise schedule, and should reflect cultural and ethnic preferences. The food/meal plan should be shared with the entire health professional team so that insulin therapy can be integrated into the individual's preferred food and physical activity patterns (4–6).

As discussed in the CARBOHYDRATE AND DIABETES section, above, for individuals requiring insulin, the total carbohydrate content of meals and snacks is the first priority and determines the premeal insulin dosage and postprandial glucose response (62–76,81). Glycemic index and usual fiber content of meals and snacks do not affect the premeal insulin dosage (73,81). Subjects in the DCCT who reported following their meal plan at least 90% of the time and adjusted their premeal insulin based on changes in usual carbohydrate intake had HbA_{1c} levels 1.0% lower than those who reported following their meal plan less often (13). For individuals who are on fixed insulin regimens and do not adjust premeal insulin dosages, consistency of carbohydrate intake is the first priority (77).

Improved glycemic control with intensive insulin therapy is often associated with an increase in body weight (453–455). In DCCT subjects, a BMI >30 kg/m^2 has been associated with increases in lipids and blood pressure (456). In the Pittsburgh Epidemiology of Diabetes Complications study, moderate weight gain did not adversely affect lipid profiles if glycemic control was improved (457). Given the potential for weight gain to adversely affect glycemia, lipemia, blood pressure, and general health, the prevention of weight gain is desirable. Because strategies effective in preventing weight gain have not been defined, treatment of the adverse metabolic effects of weight gain is indicated (456).

For individuals with type 1 diabetes, attention also must be paid to nutrition therapy for improving lipids and blood pressure control, and, if present, reducing microalbuminuria. (See MEDICAL NUTRITION THERAPY FOR THE TREATMENT/PREVENTION OF ACUTE COMPLICATIONS OF DIABETES AND COMORBID COMPLICATIONS, below, for the conditions comorbid with diabetes).

Hypoglycemia is more frequent in individuals with type 1 diabetes as blood glucose levels and HbA_{1c} are reduced (458), and needs to be treated appropriately to prevent cognitive changes, rebound hyperglycemia, and weight gain. With hypoglycemia, 10 g of oral glucose can raise blood glucose levels by ~40 mg/dl (2.2 mmol/l) over 30 min, and 20 g of oral glucose can raise blood glucose levels by ~60 mg/dl (3.3 mmol/) over 45 min (459). With both treatments, however, glucose levels begin to fall 60 min after glucose ingestion. Although glucose may be the preferred treatment choice, any form of carbohydrate will raise blood glucose (460). In one study, adding protein to the treatment of hypoglycemia did not affect the response to carbohydrate treatment or prevent later-onset hypoglycemia (203). (See MEDICAL NUTRITION THERAPY FOR THE TREATMENT/PREVENTION OF ACUTE COMPLICATIONS OF DIABETES AND COMORBID COMPLICATIONS, below, for more details on the treatment/prevention of acute complications of diabetes.)

Additional carbohydrate may be needed for unplanned exercise. Carbohydrate supplementation is based on the blood glucose level before exercise, previous experience with the particular form of exercise, and the individual's insulin regimen (461). Exercise of moderate intensity increases glucose uptake by 2–3 $mg \cdot kg^{-1} \cdot min^{-1}$ above usual requirements (e.g., a 70-kg person would need 8.4–12.6 g of carbohydrate per hour of exercise) (10–15 g). During high-intensity exercise, glucose uptake increases by 5–6 $mg \cdot kg^{-1} \cdot min^{-1}$; however, exercise of this intensity usually cannot be sustained for long intervals (462). For planned exercise, reduction in the insulin dosage may be the

preferred choice to prevent hypoglycemia (463). Regardless, carbohydrate-containing food should be readily available during and after exercise (461,464).

Carbohydrate is needed during exercise lasting longer than 60–90 min (465,466) as well as after such exercise to replenish muscle glycogen stores (467). Fluid intake is also essential. It has been found that 6–8% carbohydrate solutions are absorbed better and cause less gastric upset than regular soft drinks and fruit juices, which are 13–14% carbohydrate solutions (464).

Type 2 diabetes. Nutrition recommendations for a healthy lifestyle for the general public are also appropriate for individuals with type 2 diabetes. Because most type 2 patients with diabetes are overweight and resistant to insulin, MNT should emphasize lifestyle strategies that result in reduced energy intake (468–470), usually through reducing the fat content of the diet, and increased energy expenditure through exercise (471). Most patients with diabetes also have dyslipidemia and hypertension, making reductions in dietary intake of saturated fat, cholesterol, and sodium desirable. Therefore, the emphasis of nutrition therapy for type 2 diabetes is on lifestyle strategies to reduce glycemia, dyslipidemia, and blood pressure. These strategies should be implemented as soon as the diagnosis of diabetes is made (472).

Moderate amounts of short-term weight loss improve metabolic abnormalities in many individuals with type 2 diabetes (473), but not in all (474). Moderate amounts of weight loss, especially of intra-abdominal fat, reduce insulin resistance and help correct dyslipidemia (475,476). Intentional weight loss is also associated with reductions in mortality in overweight individuals with diabetes (477). However, the best strategy for accomplishing and maintaining weight loss is unclear and may vary from person to person.

In the UKPDS, before being randomized into study groups, subjects received 3 months of intensive nutrition therapy, which resulted in an ~2% reduction in HbA_{1c} and a mean 5% weight loss (14). The initial glucose response was reported to be more related to the decreased energy intake, with the decrease in body weight being a secondary response. Fasting plasma glucose levels of 100 mg/dl (5.6 mmol/l) were maintained only in individuals who continued a restricted energy intake; once caloric intake was increased, fasting plasma glucose levels increased, even when weight loss was maintained.

Increased physical activity is important for the maintenance of weight loss. Furthermore, increased physical activity can improve glycemia (478), decrease insulin resistance (479,480), and reduce cardiovascular risk factors in women with diabetes (481) and may independently reduce the risk of mortality in men with type 2 diabetes (482). A minimum cumulative total of 1,000 kcal/week from physical activities is recommended (471).

Food intake frequency—three meals or smaller meals and snacks—is not associated with long-term differences in glucose, lipid, or insulin responses (483,484). Therefore, division of food intake should be based on individual preferences.

Food containing carbohydrate is an important component of a healthy diet. Individuals with type 2 diabetes may benefit by knowing what types of food contain carbohydrate (starches, fruits, starchy vegetables, milk, sweets), portion sizes, and the number of servings for meals and, if desired, for snacks. The effect of carbohydrate on blood glucose and plasma lipids may depend on the severity of glucose intolerance (57). With the use of pre- and postmeal blood glucose monitoring data, it can be determined if adjustments in food/meal planning will be helpful or if medication(s) need to be combined with nutrition therapy.

When individuals with type 2 diabetes require insulin, consistency in the timing of meals and carbohydrate content becomes important. As with type 1 diabetes, flexible insulin dosing regimens allow for variations in food intake and a more flexible lifestyle. Treatment with sulfonylureas and other insulin secretagogues also requires consistency in timing and carbohydrate content of meals. Short-acting insulin secretagogues may allow for greater flexibility in mealtimes. People with type 2 diabetes are more resistant to hypoglycemia than people with type 1 diabetes; nevertheless, when type 2 patients with diabetes being treated with insulin or insulin secretagogues may need to reduce medication dosages if they are not able to eat.

MEDICAL NUTRITION THERAPY FOR SPECIAL POPULATIONS

Children and adolescents with diabetes

Most diabetes cases diagnosed in children are type 1 diabetes, although the prevalence of type 2 diabetes in youth is increasing (485–488). Nutrition recommendations for children and adolescents with type 1 diabetes should focus on achieving blood glucose goals without excessive hypoglycemia (489–492). This can be accomplished through individualized food and meal planning, flexible insulin regimens and algorithms, self-blood glucose monitoring, and education promoting decision making based on outcomes (493). Nutrition recommendations for youth with type 2 diabetes focus on a healthy lifestyle and treatment goals to normalize glycemia (494).

There is no research on the nutrient requirements for children and adolescents with diabetes; therefore, nutrient recommendations are based on requirements for all healthy children and adolescents (350–353,495). Children and adolescents should achieve healthful eating habits to ensure adequate intake of essential vitamins and minerals. In general, U.S. children are not eating the recommended amounts of fruits and vegetables (496), although children with diabetes may be doing somewhat better than the general population in some areas. A 1996 report (178) on dietary intake of children with type 1 diabetes, ages 4–9 years, found that their energy, vitamin, and mineral intakes were adequate, whereas fiber intake was less than recommended. Of concern was a reported mean saturated fat intake that exceeded the National Cholesterol Education Program (NCEP) recommendations (497). Many children consumed levels of saturated fat well above recommendations. The Food Guide Pyramid, which is a broad tool encompassing food preferences and differences in food choices among various segments of the population, can be used to increase selection of fruits, vegetables, whole grains, and nuts and reduce intake of total and saturated fat (498).

Energy. Many children with type 1 diabetes present at diagnosis with weight loss that must be restored through insulin initiation, hydration, and adequate energy intake. The best method for estimating a

child or adolescent's energy needs is a food/nutrition history of a typical daily intake as obtained from a 24-h recall or 3-day food record, provided that growth and development are within normal limits. The typical daily energy intake can be compared to reference intakes for normal growth and development. An evaluation of weight gain and growth begins at diagnosis by recording height and weight on the Centers for Disease Control pediatric growth charts (499). Adequacy of energy intake can be evaluated by following weight gain and growth patterns on a regular basis.

Consideration of a child's appetite must be given when determining energy requirements and the nutrition prescription. Because energy requirements change with age, physical activity, and growth rate, an evaluation of height, weight, and energy intake is recommended every 3–6 months (29). Achieving good metabolic control is essential to normal growth and development (489). However, the practice of withholding food or having the child eat consistently without an appetite for food in an effort to control blood glucose is discouraged.

Macronutrients. Macronutrient composition of the nutrition prescription is individualized according to blood glucose and plasma lipid goals and requirements for growth and development. Children and adolescents with type 1 diabetes are not at high risk for developing lipid abnormalities, but should be screened and monitored according to guidelines issued by the NCEP in the report of its Expert Panel on Blood Cholesterol Levels in Children and Adolescents (497) and by the American Academy of Pediatrics (500). The stepwise approach to dietary management of lipid abnormalities suggested by the NCEP recommends a reduction in total fat, saturated fat, and cholesterol for children over age 2 years.

Fiber. Dietary fiber recommendations for children with diabetes are the same as for nondiabetic children. It has been recommended that children older than age 2 years increase their intake of dietary fiber to an amount equal to or greater than their age plus 5 g/day (501).

Physical activity. Physical inactivity is associated with adverse health effects (502). Intervention strategies for the entire family that promote lifelong physical activity may help children overcome these adverse effects. Physical activity may also provide a lipid-lowering effect in adolescents with diabetes (503).

Type 2 diabetes in youth. Successful treatment of type 2 diabetes in children and adolescents with nutrition therapy and exercise is comprised of the cessation of excessive weight gain with normal linear growth and the achievement of blood glucose and HbA_{1c} goals (494). Nutrition recommendations for children and adolescents with type 2 diabetes should also address comorbidities, such as hypertension and dyslipidemia (494). Behavior modification strategies to decrease intake of high-calorie, high-fat food while encouraging healthy eating habits and regular physical activity for the entire family should be considered. Regular exercise in obese children, without dietary intervention, has been shown to lead to favorable changes in plasma triglycerides, serum insulin concentrations, and percent body fat (504). However, the benefits of exercise were lost when the children became less active. Intervention strategies should be culturally appropriate, sensitive to family resources, provided to all caregivers, and followed consistently by all health care providers.

Adolescents whose parents have type 2 diabetes have more risk factors—higher BMI, plasma cholesterol, plasma triglycerides, serum insulin, plasma glucose, and insulin-resistance index and lower plasma HDL cholesterol—compared with adolescents whose parents do not have diabetes (505). These risk factors can be detected early and provide incentive for interventions, such as control of weight gain and increased exercise.

There is some evidence for the following statements:

- Individualized food/meal plans, insulin regimens using basal and bolus insulins, and insulin algorithms can provide flexibility for children with type 1 diabetes and their families to accommodate irregular meal times and schedules, varying appetite, and varying activity levels.
- Blood glucose monitoring data can be used to integrate an insulin regimen into the meal/snack and exercise schedules.
- Nutrient requirements for children and adolescents with type 1 or type 2 diabetes appear to be similar to those for same-age nondiabetic children and adolescents.
- In obese children, increased physical activity improves plasma lipids and insulin sensitivity.

The following statement is based on expert consensus:

- Successful lifestyle treatment regimens for youth with type 2 diabetes have not been defined.

Pregnant and lactating women

During pregnancy, the goals of nutrition are similar for women with and without diabetes. MNT goals are to provide adequate maternal and fetal nutrition, energy intake for appropriate maternal weight gain (506), and any necessary vitamin and mineral supplements. For pregnancy complicated by diabetes, nutrition therapy should also attempt to achieve and sustain optimal maternal blood glucose control. A favorable pregnancy outcome is defined as gestational duration of 39–41 weeks and live birth of an infant weighing 6.6–8.8 lb. (3–4 kg) (355).

Weight gain/energy requirements. Infant birth weight is related to maternal size and weight gain during pregnancy. Recommended weight gain goals are based on pregravid BMI and should be steady and progressive (355). For obese women (BMI >30 kg/m^2), a relatively small weight gain of ~7 kg is recommended during pregnancy (507). For underweight women (BMI <19.8 kg/m^2), greater weight gain (up to 18 kg) is recommended. A normal-weight woman should gain 1.4–2.3 kg/month during the first trimester and 0.5–0.9 kg/week during the rest of her pregnancy. Overweight women should gain weight at $<50\%$ of these rates (355).

Energy intake should be sufficient to promote appropriate weight gain. Unless a woman begins pregnancy with depleted body reserves, energy needs do not increase in the first trimester. An additional 300 kcal/day are suggested during the second and third trimesters for increases in maternal blood volume and breast, uterus, and adipose tissue; placental growth; fetal growth; and amniotic fluids (508). Obese women with ample body fat stores may require fewer calories. Studies have reported successful pregnancy outcomes for women with energy intake of only 100 kcal/day above prepregnancy intake during the second and third trimesters (509). Energy estimates must be

individualized based on a food/nutrition assessment, physical activity, and weight gain patterns during pregnancy.

Protein requirements and vitamin and mineral supplementation. In addition to adequate energy intake, pregnant women need to eat a balanced diet with adequate protein. Protein requirements for women with diabetes during pregnancy are the same as for nondiabetic women during pregnancy—0.75 $g \cdot kg^{-1} \cdot day^{-1}$ plus an additional 10 g/day (508).

A balanced diet resulting in appropriate weight gain generally supplies all the vitamins and minerals needed for pregnancy. However, assessment of the pregnant woman's eating patterns may yield specific individual needs. Although abnormal folate metabolism does not appear to occur in pregnant women with diabetes (510), 400 μg/day of folic acid from fortified food and/or as a supplement as well as food folate from a varied diet is recommended for all women of childbearing age who are capable of becoming pregnant for the prevention of neural tube defects and other congenital abnormalities (351,511–514). Low-dosage iron supplementation (30 mg/day) during the second and third trimesters is often recommended (508). The average zinc intake of pregnant women is 11 mg/day, whereas the RDA is 15 mg/day (515). Zinc supplementation for women with low pregravid weight and low plasma zinc levels leads to infants with a higher birth weight (516). Food is considered the optimal vehicle for nutrient intake. However, prenatal vitamin and mineral supplements are often prescribed because of uncertainty of nutritional status and intake.

Nonnutritive sweeteners. The FDA has approved four nonnutritive sweeteners for general use: saccharin, aspartame, acesulfame-K, and sucralose. These sweeteners appear to be safe for use during pregnancy. However, moderation is often recommended (517,518).

Although saccharin can cross the placenta and remain in fetal tissues because of slow fetal clearance (519), there is no evidence that saccharin causes ill effects. If a woman chooses to use saccharin during pregnancy, the evidence suggests it is safe.

In animal studies, aspartame use has shown no risk to the fetus when ingested in amounts three times the ADI (520,521). Phenylalanine, aspartate, and methanol are dietary components of aspartame. Maximum maternal plasma phenylalanine concentrations occurring after ingestion of aspartame would be less than those after ingestion of protein food, making it highly unlikely that customary intakes of aspartame would raise fetal levels to a toxic range. Clinical trials with single and repeated doses of aspartame have shown that aspartame has minimal impact on serum concentrations of aspartate, phenylalanine, and methanol, and no clinical effects in healthy women and women heterozygous for phenylketonuria (520). Aspartate does not cross the placenta at any intake level less than enormous amounts (100 times normal) (521,522). Plasma methanol does not increase significantly after an aspartame load. Thus, if placental transport of these compounds occurs, the amount is not clinically significant (523).

Multigenerational studies of rats that received acesulfame-K and sucralose have shown no adverse effects on fertility, number of offspring, birth weight, mortality, or fetal development (169,524). Acesulfame-K and sucralose are thus considered safe during pregnancy.

Pregnancy with prior onset of type 1 or type 2 diabetes. For women with type 1 (525) or type 2 diabetes, achieving optimal glycemic control before and after conception has been shown to lower the incidence of birth defects and spontaneous abortion (526). Prepregnancy nutrition therapy includes an individual prenatal food/meal plan to optimize blood glucose control. During pregnancy, the distribution of calories and carbohydrates in the meal plan should be based on the woman's food and eating habits, blood glucose records, and the expected physiological effects of pregnancy on her body. Regular meals and snacks are important to avoid hypoglycemia made more likely by the continuous fetal draw of glucose from the mother. Moreover, the accelerated starvation of pregnancy leads to fat catabolism, ketonemia, and ketonuria after only 12–14 h of fasting. This ketonemia has been associated with lower intelligence scores in offspring at ages 2–5 years (527,528).

An evening snack is usually necessary for pregnant women with diabetes to decrease the potential for overnight hypoglycemia and fasting ketosis. Blood glucose monitoring and daily food records provide valuable information for insulin and meal plan adjustments.

Gestational diabetes. Prevention of adverse perinatal outcomes is the primary focus of antepartum management of gestational diabetes (526). Women who fail to achieve or maintain glycemic goals or who show signs of excessive fetal growth with nutrition therapy should be considered for pharmacological therapy with insulin (529–531). Results from a single study have suggested that glyburide may be an alternative strategy that merits future consideration (532). Intensive treatment of hyperglycemia in women with gestational diabetes can reduce the risk of infants having excessive fetal size for gestational age. However, the perinatal outcomes of small-for-gestational-age neonates in pregnancies with gestational diabetes may be worse with intensive therapy than for appropriate size and large-for-gestational-age neonates (533).

The goal of nutrition therapy for women with gestational diabetes is to promote nutrition necessary for maternal and fetal health, with adequate energy levels for appropriate gestational weight gain, achievement and maintenance of normoglycemia, and absence of ketones. Carbohydrate is distributed throughout the day among three small-to-moderate-size meals and two to four snacks. An evening snack may be needed to prevent accelerated ketosis overnight. Specific nutrition/food recommendations are determined and modified based on individual assessment and self−blood glucose monitoring data (518).

Diets containing 40–45% of total energy intake from carbohydrate have been shown to reduce postprandial glucose levels (534–536), with carbohydrate being less well tolerated at breakfast than at other meals (534). Nutrition management should include evaluation of the individual glycemic response to food at different times of the day (537,538). If insulin therapy is added to nutrition therapy, a primary goal must be to maintain carbohydrate consistency at meals and snacks to facilitate insulin adjustments.

Several research studies have focused on use of energy-restricted diets during pregnancy. Hypocaloric diets (<1,200 calories per day) in obese women with gestational diabetes have been shown to result in ketonemia and ketonuria (539). In one study, a modest energy reduction (33% calorie restriction of estimated energy needs or ~1,600–1,800 kcal/day) resulted in reduced mean blood glucose

levels without elevations in plasma free fatty acids or ketonuria, whereas a more severe energy reduction (50% calorie restriction) increased ketonuria by about twofold (540). Energy intake should maintain desirable weight gain during pregnancy. Daily food records, weekly weight checks, and ketone testing can be used to determine individual energy recommendations and if a woman is undereating to avoid insulin therapy (541,542).

Regular aerobic exercise has been shown to lower fasting and postprandial glucose concentrations and may be used as an adjunct to nutritional therapy to improve maternal glycemia (529). Other benefits of exercise during pregnancy include cardiovascular fitness (543) and reduced discomfort in later pregnancy. The optimal frequency and intensity of exercise for lowering maternal glucose concentrations have not been determined, but it appears that a minimum of three episodes of exercise per week, each >15 min, is required to modify maternal glucose levels. In addition, 2–4 weeks of regular exercise may be required before a lowering of glycemia is seen (529). Insufficient evidence exists to recommend any specific type of exercise as being superior to another in the management of gestational diabetes.

Blood glucose data allow evaluation of the effectiveness of nutrition therapy and the need for pharmacological therapy. Postprandial glucose levels may be more closely related to fetal risks than are fasting levels (544,545). Pre-breakfast ketone measurements are recommended for patients receiving hypocaloric or carbohydrate-restricted diets to allow the detection and treatment of ketones. However, the effectiveness of ketone monitoring in improving fetal outcomes has not been demonstrated (529).

Although most women with gestational diabetes return to normal glucose tolerance postpartum, they are at increased risk of developing gestational diabetes in subsequent pregnancies and type 2 diabetes later in life. Evidence suggests that a single birth results in a 2–3 kg higher average body weight for the mother, and thus increases the risk of becoming overweight after delivery. Body weight changes during the postpartum period are likely to be a combination of retention of gestational weight gain and weight changes caused by the lifestyle alterations associated with child rearing (546). Lifestyle behaviors aimed at reducing weight and increasing physical activity may be beneficial to reduce the subsequent risk of developing diabetes.

Lactation. Breastfeeding is recommended for women with preexisting diabetes or gestational diabetes (547,548), although achieving desired metabolic control during lactation may be difficult for women with type 1 diabetes. Breastfeeding lowers blood glucose, often requiring insulin-treated women to eat a snack containing carbohydrate either before or during breastfeeding. Evening or late night snacks may also be necessary (547). Energy requirements during the first 6 months of lactation require an additional ~200 calories above the pregnancy meal plan. However, an energy intake of 1,800 kcal/day usually meets the nutritional requirements for lactation and may allow a slow weight loss of 1–2 lb/month (549). Although not all women lose weight while breastfeeding, it is normal for weight loss to occur as maternal fat stores are mobilized. Overweight women may lose up to 2 kg/month without affecting milk volume.

There is strong evidence for the following statements:

- Nutrient requirements during pregnancy and lactation are similar for women with and without diabetes. For all women of childbearing age who are capable of becoming pregnant, 400 μg/day of folic acid from fortified food and/or a supplement as well as folate from a variety of types of food is recommended for the prevention of neural tube defects and other congenital abnormalities in any potential offspring.
- Because previous gestational diabetes is a risk factor for subsequent development of impaired glucose tolerance and type 2 diabetes, lifestyle modifications aimed at reducing weight or preventing weight gain and increasing physical activity after pregnancy is recommended.
- Use of nonnutritive sweeteners is safe during pregnancy.
- As with nondiabetic women, diabetic women should avoid alcoholic beverages during pregnancy.

There is some evidence for the following statements:

- In women with type 1 or type 2 diabetes, MNT is important in achieving and maintaining optimal glycemic control during pregnancy.
- MNT for gestational diabetes focuses on food choices for appropriate weight gain, normoglycemia, and absence of ketones. For some women, modest energy and carbohydrate restriction may be appropriate.
- To prevent ketosis, adequate energy intake and appropriate distribution of meals and snacks is important. An evening snack may be needed to prevent accelerated ketosis overnight.
- Although regular exercise has been shown to lower fasting and postprandial glucose concentrations, there is insufficient evidence to recommend any specific type of exercise in the management of gestational diabetes.
- Successful lactation requires planning and coordination of care following delivery.

The following statement is based on expert consensus:

- There is inadequate evidence to support the benefit of prenatal vitamin-mineral supplementation; however, these supplements are often prescribed because of uncertainty about nutritional status and intake.

Older adults with diabetes

Aging is associated with many biological changes that may predispose the older adult to nutritional deficiencies (550, 551). These include alterations in taste, smell, mastication and salivary flow, gastric acidity, hepatic function, and renal function. In addition, difficulty in preparing food, polypharmacy, and alcoholism are common problems in elderly individuals and may interfere with adequate nutrition. Given these concerns, it is prudent that any nutritional intervention start with a thorough assessment that includes a clinical and nutritional history and a psychosocial and environmental evaluation (552).

There is limited research on the changing nutritional needs with aging and virtually none in aging diabetic subjects. Therefore, nutritional recommendations for older adults with diabetes must be extrapolated from what is known for the general population. The most reliable indicator of poor nutritional status in an elderly individual is probably change in body weight. In general, involuntary

gain or loss of >10 pounds or 10% of body weight in less than 6 months should be evaluated to determine if the reason is nutrition related (552).

Energy intake/nutrient requirements. Because of the changes in body composition (i.e., loss of lean body mass) and exercise patterns, the energy requirements of older adults are 20–30% lower than those of younger adults (553). However, it has been suggested that the current RDA for energy may underestimate the energy needs of healthy elderly individuals (554). Nevertheless, in one cross-sectional study, the resting metabolic rate was lower in elderly subjects, even after adjustment for body composition (555).

The need for weight loss in overweight older adults should be carefully evaluated. Older patients with diabetes, especially those in nursing homes, tend to be under- rather than overweight (556). Low body weight has been associated with greater morbidity and mortality in this age group (557). Aging does not appear to alter the synthesis or breakdown rate of proteins when results are adjusted for fat-free mass (553,558). Similarly, the age-related changes in appearance of free fatty acids and fat oxidation can be attributed to reduced lean body mass (559). Finally, older men do not demonstrate an impairment in energy conservation or disposition during experimental conditions of underfeeding or overfeeding (560,561).

In long-term care settings, malnutrition and dehydration may develop because of lack of food choices, poor quality of food, and unnecessary restrictions. Specialized diabetic diets do not appear to be superior to standard (regular) diets in such settings (562). Therefore, it is recommended that residents be served the regular menu with consistent amounts of carbohydrate (+/−15 g) for meals and snacks (563,564). It may often be preferable to make medication changes to control blood glucose than to implement food restrictions.

The recommended macronutrient composition of the diet and the individualization of carbohydrate and fat components for older adults do not differ from the general recommendations for patients with diabetes. However, any increase in dietary fiber should be done cautiously in elderly individuals, especially in those who are not ambulatory or are likely to become dehydrated (552). Because of reduced alcohol tolerance with age, alcohol ingestion by elderly patients should be looked at carefully.

Micronutrients. Restricting sodium intake to <2,400 mg/day (the current limit recommended for the management of hypertension and congestive heart failure) may predispose older subjects who enjoy salty food to further limit their caloric intake and increase their risk of nutritional deficiencies. Older subjects are more likely to have deficiencies in micronutrients such as thiamine, vitamin B_{12}, folate, vitamin C, and vitamin D (565–570). Calcium, zinc, and magnesium deficiencies are also common (571–573). All older adults should be advised to have a calcium intake of at least 1,200 mg/day. The Baltimore Longitudinal Study of Aging found that daily intake and plasma levels of certain antioxidants, such as vitamin A and vitamin E, were suboptimal in the elderly population (574). In the Framingham Study, poor intake of folate, vitamin B_6, and vitamin B_{12} was related to higher plasma homocysteine concentrations and increased prevalence of carotid artery stenosis (569,575). In a study in healthy elderly subjects supplemented with chromium picolinate (1,000 μg/day), chromium did not alter insulin sensitivity, serum lipid profile, or body composition (576).

Vitamin D deficiency has been found in 8% of nursing home residents; 17% of those had evidence of secondary hyperparathyroidism (571). Minority populations, such as elderly Hispanic adults, may have low serum vitamin B_{12}, vitamin C, and folate levels compared to elderly white adults (568).

Use of nutritional supplements is appropriate when the patient cannot achieve nutritional needs through food. Daily supplementation with 1,000–1,500 mg of elemental calcium is probably safe and may reduce the risk of osteoporosis (352).

Physical activity. Exercise training can significantly reduce the decline in maximal aerobic capacity (VO_2) that occurs with age (577), improve risk factors for atherosclerosis (578), slow the decline in age-related lean body mass, decrease central adiposity (579), and improve insulin sensitivity, all of which are beneficial for the older adult with diabetes. However, because of the potential risks of exercise (cardiac ischemia, musculoskeletal and foot injuries, and hypoglycemia in patients treated with insulin or insulin secretagogues), an evaluation and education session should be undertaken before initiating an exercise training program. Physical activity should increase gradually, and appropriate stretching, warm-up, and cool-down periods should accompany all exercise (579).

There is strong evidence for the following statements:

- Energy requirements for older adults are less than those for younger adults.
- All older adults should be advised to have a calcium intake of at least 1,200 mg/day.
- Physical activity should be encouraged in elderly individuals.
- Undernutrition is more likely than overnutrition in older adults, and therefore caution should be exercised when prescribing weight-loss diets.

There is some evidence for the following statements:

- A daily multivitamin supplement may be appropriate for elderly individuals, especially for those with reduced energy intake.
- The imposition of dietary restrictions on elderly, diabetic residents in long-term care health facilities is not warranted. Residents with diabetes should be served regular (unrestricted) menus, with consistency in the amount and timing of carbohydrate.

The following statement is based on expert consensus:

- There is no evidence to support the prescribing of diets such as "no concentrated sweets" or "no sugar added," which are often served to elderly individuals in long-term care facilities.

MEDICAL NUTRITION THERAPY FOR THE TREATMENT/PREVENTION OF ACUTE COMPLICATIONS OF DIABETES AND COMORBID CONDITIONS

Acute complications

Hypoglycemia. Hypoglycemia is primarily an issue for individuals taking injected insulin, although those taking insulin secretagogues can also be affected. Changes in food intake, physical activity,

and medication(s) can contribute to the development of hypoglycemia. Two treatment modalities are the ingestion of carbohydrate and an adjustment in medication(s). A logistic regression analysis of 6,425 self-monitored blood glucose events in 93 adults with type 1 diabetes showed that more insulin, less food, or more exercise predicted 61% of all blood glucose values <70 mg/dl (<3.9 mmol/l), but did not predict severe hypoglycemia (580).

Although rigid definitions of hypoglycemia are useful for epidemiological studies, more flexible definitions are needed in the management of diabetes. In general, a glucose level ≤50 mg/dl (≤2.8 mmol/l) should be treated promptly (459). However, even a level of 60–80 mg/dl (3.3–4.4 mmol/l) may require a management decision (e.g., carbohydrate ingestion, deferral of exercise, change in insulin dosage) (459).

Treatment of hypoglycemia requires ingestion of glucose or carbohydrate-containing food. The glycemic response correlates better with the glucose content than with the carbohydrate content of the food (581). Although any carbohydrate will raise glucose levels, glucose is preferred (460,581). Treatment of insulin-induced hypoglycemia with 20 g glucose has been shown to produce a greater rise in plasma glucose than treatment with 20 g carbohydrate from orange juice or milk (581), a difference presumably attributable to the fact that some of the carbohydrate in juice is fructose and some of the carbohydrate in milk is galactose, and neither is as effective as glucose in raising plasma glucose levels. In another study (460), type 1 diabetic subjects with induced hypoglycemia who were treated with 15 g carbohydrate from glucose solution or tablets, sucrose solution or tablets, or corn syrup had alleviation of symptoms in 10 min. Treatment with 15 g carbohydrate from glucose gel or orange juice was less effective in alleviating their symptoms. Although pure glucose may be the preferred treatment, any form of carbohydrate that contains glucose will raise blood glucose levels.

In a study of insulin-induced hypoglycemia (582), 10 g oral glucose raised plasma glucose from 60 mg/dl (3.3 mmol/l) to 97 mg/dl (5.4 mmol/l) over 30 min, with the glucose level starting to decline after 60 min; 20 g oral glucose raised plasma glucose from 58 mg/dl (3.2 mmol/l) to 122 mg/dl (6.8 mmol/l) over 45 min, with the glucose level again starting to decline after 60 min. Although 10–20 g glucose may be an effective treatment for adults (0.3 g/kg body wt in children), these amounts of glucose are only temporarily effective. If glucagon is required, a standard dosage of 1.0 mg (15 μg/kg in children) produces rapid and substantial hyperglycemia, with glucose levels beginning to fall after ~1.5 h (459). Treatment with glucagon is also a temporary measure. Treatment of hypoglycemia requires continued evaluation of glycemia to determine if additional carbohydrate is needed to prevent recurrent hypoglycemia.

Adding protein to carbohydrate in the treatment of hypoglycemia does not accelerate the treatment response to carbohydrate and does not prevent subsequent hypoglycemia (201). Adding fat, however, may retard the acute glycemic response. Furthermore, during hypoglycemia, gastric emptying rates are twice as high as during euglycemia (56,583), and are similar for liquids and solid food (56).

Treatment of sulfonylurea-induced hypoglycemia in type 2 patients with diabetes differs from insulin-induced hypoglycemia. Sulfonylurea-induced hypoglycemia can be prolonged and recur and therefore requires more persistent treatment. However, type 2 diabetic subjects, compared to type 1 diabetic subjects, release counterregulatory hormones at higher plasma glucose levels and maintain glucagon response to hypoglycemia, reducing their risk of severe hypoglycemia (584).

There is strong evidence for the following statements:

- Glucose is the preferred treatment for hypoglycemia, although any form of carbohydrate that contains glucose may be used.
- Ingestion of 15–20 g of glucose is effective treatment for hypoglycemia, but blood glucose may be only temporarily corrected.

There is some evidence for the following statements:

- The form of the carbohydrate—liquid or solid—used to treat hypoglycemia does not make a difference.
- Adding protein to the carbohydrate does not assist in the treatment of hypoglycemia or prevent subsequent hypoglycemia.

The following statement is based on expert consensus:

- Initial response to treatment for hypoglycemia should be seen in ~10–20 min; however, blood glucose should be evaluated again in ~60 min, as additional treatment may be necessary.

Acute illness. Acute illness in individuals with type 1 diabetes can result in diabetic ketoacidosis. To prevent ketoacidosis, individuals with type 1 diabetes need to know how to handle illnesses appropriately. During acute illnesses, with the accompanying increases in counterregulatory hormones, the need for insulin continues and additional insulin is often required. Testing blood glucose and blood or urine for ketones, drinking adequate amounts of fluids, and ingesting carbohydrate, especially if blood glucose level is <100 mg/dl (<5.5 mmol/l) are important actions during an acute illness.

Fluid intake should be increased to prevent dehydration. To avoid depletion of intravascular volume, replacement fluids containing sodium, such as broth, tomato juice and sports drinks, are helpful.

In adults, ingestion of 150–200 g carbohydrate daily (45–50 g or three or four carbohydrate choices every 3–4 h) will reduce or prevent starvation ketosis (585–588). If regular food is not tolerated, liquid or soft carbohydrate-containing food, such as sugar-sweetened soft drinks, juices, soups, and ice cream, should be eaten. However, if nausea, vomiting, or obtundation prevents fluid and carbohydrate intake, prompt consultation with a health care professional is advisable. Most importantly, individuals with type 1 diabetes should not omit insulin. Supplemental insulin may also be required.

There is strong evidence for the following statements:

- During acute illnesses, individuals with type 1 diabetes should continue insulin.
- During acute illnesses, testing blood glucose and blood or urine ketones, drinking adequate amount of fluids, and ingesting carbohydrate are important.

There is some evidence for the following statement:

- During acute illness, oral ingestion of ~150–200 g of carbohydrate per day should be sufficient, along with medication adjustments, to keep glucose in the goal range and to prevent starvation ketosis.

Hypertension

MNT for the management of hypertension has focused on reducing weight (589–591) and sodium intake (592–594). Other variables that have been considered include alcohol intake (595), potassium (592,596) and calcium levels (597–599), and diet composition (total fat, saturated fat, cholesterol) (600). Few studies have been done exclusively in diabetic subjects. However, there is no compelling reason to believe that differences exist between diabetic and nondiabetic individuals with regard to the benefits of weight reduction. The response to sodium reduction may be greater in subjects who are salt sensitive, a factor that may apply to many individuals with diabetes (601,602). Currently there is no available routine clinical measure to identify individuals who may be salt sensitive.

Sodium. Several meta-analyses and reviews have examined the relationship between sodium intake and blood pressure (603–605). A review of 32 trials covering 2,635 subjects concluded that moderate reduction of dietary sodium lowers systolic and diastolic blood pressure (603). The mean effect was modest, with a reduction of 5 mmHg systolic and 2 mmHg diastolic in hypertensive subjects and a reduction of 3 mmHg systolic and 1 mmHg diastolic in normotensive subjects. It should be noted that there was a wide variation in the blood pressure responses to alterations in sodium intakes. A similar conclusion was reached in a meta-analysis of 56 trials (26 studies in hypertensive and 28 in normotensive subjects) (604). Mean reduction in daily urinary sodium excretion was 95 mmol/day in 1,131 hypertensive subjects and 125 mmol/day in 2,374 normotensive subjects. In hypertensive subjects, the mean decrease in blood pressure per each 100 mmol decrease in sodium intake per day was 4 mmHg systolic and 1 mmHg diastolic. In the normotensive subjects, the mean decrease was 1 mmHg systolic and only negligible for diastolic.

The Dietary Approaches to Stop Hypertension (DASH) study evaluated the effect of three dietary patterns on blood pressure: *1*) a control diet that was similar to a traditional American diet, *2*) a diet high in fruit and vegetables, and *3*) the DASH diet, which was higher in fruits, vegetables, and low-fat dairy products, and lower in total fat, saturated fat, and cholesterol (606–609). Sodium intake, physical activity, and body weight remained constant. Compared to the control diet, both of the other diets were associated with lower systolic and diastolic blood pressure over the 8-week study periods. The DASH diet lowered systolic and diastolic blood pressure by 6 and 3 mmHg more, respectively, than the control diet. Although the DASH diet was effective in all subgroups, systolic blood pressure in blacks and hypertensive individuals decreased more than in whites and nonhypertensive individuals. In another study, the effects of three levels of sodium intake were compared in 412 subjects randomly assigned to the control or DASH diet (610). Within the assigned diet, subjects ate food with high (150 mmol/day Na [3.6 g Na or 8.7 g NaCl]), intermediate (100 mmol/day Na [2.4 g Na or 6 g Na]), and low (50 mmol/day Na) levels of sodium for 30 days each. Weight remained stable in all subjects. Reducing the sodium intake from the high to the intermediate level reduced systolic blood pressure by 2.1 mmHg ($P < 0.001$) during the control diet and by 1.3 mmHg ($P = 0.03$) during the DASH diet. Reducing the sodium intake from the intermediate to the low level caused additional reductions of 4.6 mmHg during the control diet ($P < 0.001$) and 1.7 mmHg during the DASH diet ($P < 0.01$). Therefore, the lower the sodium intake, the greater the lowering of blood pressure. The effects of sodium reduction were greater in hypertensive participants, blacks, and women.

Weight. In patients with diabetes, there is a general association between weight reduction and a reduction in blood pressure, but there is a great deal of variability in the response. Reductions in blood pressure occur before (and without) desirable body weight is achieved. In a meta-analysis of 11 weight loss trials, the average systolic and diastolic blood pressure reductions per kilogram of weight loss were 2 and 1 mmHg, respectively (611).

Alcohol. An association between high alcohol intake (more than three drinks per day) and elevated blood pressure has been reported in a number of observational studies (612,613). However, large studies do not show much difference in blood pressure among people who consume less than three drinks per day compared to nondrinkers (614).

Potassium, magnesium, and calcium. Clinical trials have reported a beneficial effect of potassium supplementation on blood pressure (596,615). Evidence for a beneficial effect from calcium and magnesium supplementation is not consistent (615). Because a high dietary intake of potassium, magnesium, and calcium can be achieved from food sources, it is recommended that appropriate types of food rather than supplements be used to increase the intake of these minerals (20).

There is strong evidence for the following statements:

- In both normotensive and hypertensive individuals, a reduction in sodium intake lowers blood pressure. The goal should be to reduce sodium intake to 2,400 mg sodium (100 mmol sodium) or 6,000 mg sodium chloride (salt) per day. In nondiabetic subjects, this reduction in sodium intake lowered systolic blood pressure by 4–5 mmHg.
- A modest amount of weight loss beneficially affects blood pressure.
- Drinking small-to-moderate amounts of alcohol will not adversely affect blood pressure levels.

There is some evidence for the following statement:

- A low-fat diet that includes fruits and vegetables (five to nine servings per day) and low-fat dairy products (two to four servings per day) will be rich in potassium, magnesium, and calcium and will modestly reduce blood pressure and body weight.

Dyslipidemia

Dyslipidemia (abnormal lipid levels, lipoprotein composition, or both) is often found in individuals with type 1 or type 2 diabetes before the initiation of therapy for hyperglycemia. For most individuals with type 1 diabetes, effective insulin therapy returns lipid serum levels to normal and usually lowers plasma triglycer-

ides; LDL cholesterol may decrease modestly as well (212).

For all individuals with diabetes, elevated LDL cholesterol is identified as the primary target of cholesterol-lowering therapy (8,212). Therapy begins with a multifaceted lifestyle approach. In adult individuals with elevated LDL cholesterol levels, saturated and trans fatty acids should be limited to <10% and preferably to <7% of energy intake (17,18), cholesterol intake should be limited to <200 mg/day, and modest weight loss and physical activity should be encouraged. The LDL cholesterol response should be evaluated after 6 weeks (18). If the LDL cholesterol goal is not achieved, LDL cholesterol–lowering therapy should be intensified by reinforcing the need for dietary reduction in saturated fat and cholesterol. Adding plant stanols/sterols (2 g/day) has been reported to lower total cholesterol by 10–32 mg/dl and LDL cholesterol by 8–29 mg/dl (251,253,255). Increasing soluble fiber intake (10–25 g/day) can also be suggested (18). A recent meta-analysis concluded that for every gram of increase in soluble fiber, LDL cholesterol would be expected to decrease by an average of 2.2 mg/dl—an effect that is small within the practical range of soluble fiber intake (126). The LDL cholesterol response should be monitored again after 6 weeks, and if the LDL goal is not achieved, weight management and physical activity should be intensified and drug therapy considered. It is recommended that adherence to therapeutic lifestyle changes be monitored every 4–6 months (18).

Obese individuals with type 1 diabetes (456) and many individuals with type 2 diabetes (616–621) manifest a dyslipidemia consisting of increased plasma triglycerides, reduced serum HDL cholesterol levels, and small, dense serum LDL cholesterol particles that persist despite improved glycemic control. This dyslipidemia is strongly associated with increased body adiposity that is abdominal (visceral) in distribution (622,623). Dietary fat restriction and weight loss will lead to decreased plasma triglycerides and a modest lowering of LDL cholesterol (300,326,475). Regular physical activity also reduces plasma triglycerides (461,471,481) and improves insulin sensitivity (624). However, with one exception (624), most studies have not shown improvements in HDL cholesterol from exercise in individuals with type 2 diabetes. This may be because of the relatively modest exercise intensities used (461).

In type 2 diabetic subjects with mild-to-moderate elevations of plasma triglycerides and low HDL cholesterol, replacing saturated fat with carbohydrate has been shown by most (217,219,625–628), but not all (629,630), studies to result in improvements in LDL cholesterol, with beneficial or neutral effects on plasma triglycerides and HDL cholesterol. Monounsaturated fat can also be substituted for saturated fat (90,227–229). However, increased dietary fat may cause weight gain and, although controversial, also cause insulin resistance (96–100).

If goals for serum lipid levels are not achieved with lifestyle improvement, including MNT and exercise, lipid-lowering medications should be added (18,212). Maximal changes in nutrition typically reduce LDL cholesterol 15–25 mg/dl (0.40–0.65 mmol/l) (631). Therefore, if LDL cholesterol exceeds the goal by >25 mg/dl (0.65 mmol/l), pharmacological therapy is likely to be necessary (632–634).

For patients with persistently elevated plasma triglycerides despite the addition of medication, supplementation with fish oils that include n-3 fatty acids may be recommended. However, fish oils may increase LDL cholesterol, the levels of which should then be monitored (236,237). Patients with plasma triglycerides >1,000 mg/dl are at increased risk for chylomicronemia syndrome and pancreatitis and should restrict all types of dietary fat (635,636) and institute lipid-lowering medication, such as a fibric acid derivative or perhaps niacin (637).

There is strong evidence for the following statements:

- For individuals with diabetes and elevated LDL cholesterol, saturated fatty acids and transunsaturated fatty acids should be limited to <10% and perhaps to <7% of energy, and if replaced, can be substituted by carbohydrates or monounsaturated fats.
- For individuals with diabetes and elevated plasma triglycerides, reduced HDL cholesterol, and small dense LDL cholesterol (the metabolic syndrome), improved glycemic control, modest weight loss, restricted intake of saturated fats, increased physical activity, and incorporation of monounsaturated fats may be beneficial.
- LDL cholesterol lowering can be enhanced by the addition of plant stanols/sterols and by an increase in soluble (viscous) fiber.
- Individuals with plasma triglycerides >1,000 mg/dl should restrict all types of dietary fat (except for n-3 fatty acids) and be treated with medication to reduce plasma triglycerides.

There is limited evidence for the following statement:

- Supplementation with fish oils containing n-3 fatty acids may benefit those with resistant hypertriglyceridemia.

Nephropathy

In individuals with type 1 or type 2 diabetes, microalbuminuria predicts the later development of macroalbuminuria and overt nephropathy. Once clinical nephropathy has developed, end-stage renal disease is almost always the consequence. Recommended treatments focus on reversing or at least retarding the progression of proteinuria and preventing nephropathy. Improved glycemic control, reduction of blood pressure—particularly by the use of ACE inhibitors and MNT—all are important in this regard (638).

Several dietary factors have been identified as having a role in the prevention of nephropathy. Animal studies have suggested a beneficial effect from energy (639,640) and sodium (641) restriction and supplementation with vitamin C (642) and vitamin E (642,643). Human studies have identified associations between urinary microalbumin and dietary saturated fat (193) and between glomerular filtration rate (GFR) and total fat (644). However, the majority of human studies have focused on dietary protein.

Several studies have attempted to reduce protein intake in people with type 1 or type 2 diabetes and microalbuminuria. The achieved protein reductions (measured by urine urea nitrogen) were 1.2 g (645), 1.1 (646), 0.8 (647), and 0.8 $\cdot$ kg^{-1} $\cdot$ day^{-1} (achieved by only half of subjects) (648). Even with small reductions in protein intake, the GFR improved significantly in all four studies and the albumin excretion rate was reduced significantly in three. In a dosage-response analysis (645), a 0.1 g $\cdot$ kg^{-1} body wt $\cdot$ day^{-1}

change in intake of animal protein was related to an 11.1% change in albuminuria.

Many studies have been conducted in type 1 diabetic subjects with macroalbuminuria (overt nephropathy). The achieved protein reductions were 0.8 (647), 0.9 (649), 0.7 (650), 0.7 (651), and 0.7 g · kg^{-1} · day^{-1} (652). In the latter two studies, reduced protein intake slowed the rate of decline in the GFR significantly over 33–35 months ($P < 0.05$ and $P < 0.001$, respectively). However, in one of the studies (652), antihypertensive treatment might have been responsible for part of the beneficial effect on the GFR.

A few studies have explored the potential beneficial effects of plant protein rather than animal protein. When predominantly plant protein replaced animal protein in three studies of type 1 diabetic subjects, the amount of protein consumed was also reduced significantly (653–655). Any beneficial effects may have been from reduction in the amount or change in the protein source. In the only published study (656) comparing approximately equivalent amounts of animal and plant protein, type 1 diabetic subjects were normoalbuminuric, normotensive, and not hyperfiltering, so that renal benefits may not have been expected. Long-term clinical trials are needed to determine whether reductions in certain types of protein (plant versus animal) or changes in various plant proteins such as soy or various animal proteins will have a beneficial effect on diabetic nephropathy.

Because of the small number of clinical studies and their methodological problems (e.g., food intake not closely controlled, lack of success in reducing protein to prescribed levels), there is insufficient evidence to make definite recommendations for patients with diabetes and microalbuminuria or clinical nephropathy. There is, however, suggestive evidence that even small reductions in dietary protein intake from usual amounts (e.g., achieved reduction of 0.8–1.0 g · kg^{-1} body wt · day^{-1} in people with microalbuminuria, 0.8 g · kg^{-1} body wt · day^{-1} or lower for people with clinical nephropathy) will retard the progression of renal disease. However, reduction of protein intake should be done in the context of overall good nutrition. A dietitian familiar with MNT for both diabetes and renal diseases should be involved in developing the reduced-protein diet.

There is some evidence for the following statements:

- In patients with diabetic nephropathy, reduction of dietary protein to 0.8–1.0 g · kg^{-1} body wt · day^{-1} for people with microalbuminuria and 0.8 g · kg^{-1} body wt · day^{-1} for people with overt nephropathy may slow the progression of nephropathy.

There is limited evidence for the following statement:

- There is insufficient evidence to make recommendations regarding the source of dietary protein (animal versus plant).

Catabolic illness

The catabolic state induced by injury, inflammation, or severe illness is associated with special nutrition considerations. Most studies of nutrient needs are in nondiabetic subjects, but the results are likely applicable to patients with diabetes. Many of the changes in nutrient requirements appear to be cytokine mediated. Cytokines reduce albumin production, decrease plasma levels of some trace proteins through tissue redistribution, induce negative nitrogen balance, and alter intermediary metabolism in such a way as to increase glucose levels through the actions of the counterregulatory hormones (657). These changes, as well as altered fluid balance, make nutritional assessment difficult during times of critical illness. Overall, catabolic disease states result in a change in body compartments that may be characterized by an increased extracellular fluid compartment (frequently with an actual increase in body weight) and an associated shrinkage of body fat and body cell mass (body cell mass is defined as the actively functioning protein-rich tissue and associated intracellular fluid) (658).

The magnitude of recent weight loss, taking into account the presence of excess fluid that is often present in critically ill patients, along with the presence or absence of clinical markers of stress and the amount of time the patient will be unable to eat should determine the need for nutritional intervention (657). A recent weight loss of >10% of usual weight necessitates a thorough nutritional assessment; an unintentional loss of 10–20% suggests moderate protein-calorie malnutrition, and a loss of >20% usually indicates severe malnutrition (659). Numerous studies have shown that the needs of most hospitalized patients can be met by providing 25–35 kcal/kg body wt (657). Care should be taken not to overfeed the patient, as this can exacerbate hyperglycemia, cause abnormal liver function, and increase oxygen consumption and carbon dioxide production (657).

Protein needs are ~1.0 g/kg body wt for mildly stressed patients and 1.5 g/kg body wt for moderately to severely stressed patients with normal hepatic and renal function. This intake of protein will not decrease protein catabolism, but will result in an increase in protein synthesis. At least 30% of total energy should be given as lipids (659).

For the hospitalized patient with diabetes who requires parenteral or enteral nutrition, the goal is to provide adequate nutrition while avoiding extremes of hyper- and hypoglycemia. For stressed hospitalized patients, a reasonable aim is to maintain glucose levels at 100–200 mg/dl (5.6–11.1 mmol/l) (659). As with solid food, the total grams of carbohydrate in the feeding will have the greatest impact on the blood glucose response (660). The enteral route is preferred if the gastrointestinal tract is functional. A standard enteral formula (50% carbohydrate) or a lower carbohydrate (33–40% carbohydrate) formula may be used in individuals with diabetes (660). Careful monitoring of vital signs, hemodynamic data, weight, fluid balance, plasma glucose and electrolytes, and acid-based status is essential (659). Medications, usually insulin, may need to be adjusted to maintain glycemic control.

There is limited evidence for the following statements:

- Careful monitoring of nutritional status indicators (e.g., change in body weight) and glycemia are necessary to ensure that nutrient needs are being met and hyperglycemia is prevented. The energy needs of most hospitalized patients can be met by providing 25–35 kcal/kg body wt.
- Protein needs are 1.0–1.5 g/kg body wt, with the higher end of the range being for more stressed patients.

DIABETES PREVENTION — The importance of preventing diabetes in high-risk individuals is highlighted by the substantial increase in the prevalence of diabetes in the U.S. over an 11-year period (661,662). From the most recent data available, the increase in the prevalence of diabetes continued unabated well through the late 1990s (663) and, most likely, continues to the present day.

Genetic susceptibility appears to play a powerful role in the occurrence of type 2 diabetes in certain populations; however, given that population gene pools shift quite slowly, the current epidemic likely reflects marked changes in lifestyle. Lifestyle changes that are characterized by decreased physical activity and increased energy consumption have together promoted obesity, which is a remarkably strong risk factor for diabetes that itself is influenced by both genes and behavior.

Weight loss

Excess body fat is perhaps the most notable modifiable risk factor for the development of type 2 diabetes (664). It is estimated that the risk of type 2 diabetes attributable to obesity is as much as 75% (92). A striking increase in the prevalence of obesity, as well as diabetes, was reported between NHANES II and III. As of the early 1990s, over 50% of the U.S. adult population was overweight (665). If the prevalence of obesity continues to increase, it is expected that the prevalence of diabetes in the population will also increase.

Numerous interventions focusing on weight loss through hypocaloric, low-fat diets, increased physical activity, and a variety of behavior change strategies have emerged (316,318,327,338,666,667). It is unfortunate that preventing obesity and effectively reducing body weight have proven difficult to accomplish and particularly challenging to maintain over the long term. Accordingly, pharmacological agents to enhance weight reduction and maintenance of weight loss have recently been recommended for individuals at high risk for obesity-related conditions when other weight-loss methods have failed (668–671).

Despite these difficulties, several recent studies have demonstrated the potential for moderate, sustained weight loss to substantially reduce risk for type 2 diabetes (672–677). Wannamethee and Shaper (678) reported increased risk for diabetes in men who gained weight over a 12-year period of follow-up. Overweight men who lost weight had a reduced risk of diabetes. In the Framingham Study cohort, sustained weight loss over two consecutive 8-year periods led to a 37% lower risk of diabetes; however, those who regained the lost weight failed to experience any reduction in diabetes incidence (677).

Clinical trial data also support the potential for weight loss to reduce risk for diabetes. In the Malmo Feasibility Study (673), both weight reduction and increased fitness were associated with reduced incidence of diabetes in a lifestyle intervention group when compared to a control group. In the Da Qing Study, diet, exercise, and diet plus exercise all reduced the incidence of diabetes compared to the control condition (672). In the Swedish Obese Subjects Study, obese individuals with sustained weight loss 2 years after bariatric surgery demonstrated substantially lower risk of type 2 diabetes and hyperinsulinemia compared to control subjects (676). Results from a 2-year clinical trial showed reduced risk for progression from impaired glucose tolerance to diabetes among individuals randomized to orlistat compared to those randomized to behavioral therapy (675).

The Finnish Diabetes Prevention Study (319) included 522 overweight individuals with impaired glucose tolerance randomized to control or intensive lifestyle intervention, which included weight reduction (5% or more), reduction of total (<30% of energy intake) and saturated fat (<10% of energy intake), increased fiber (>15 g/1,000 kcal), and increased physical activity (>4 h/week). The subjects in the intervention group were more likely to report changes in dietary and exercise habits than subjects in the control group. Success in achieving goals in the intervention group varied from 25% (fiber intake) to 86% (exercise). The cumulative incidence of diabetes after 4 years was 11% in the intervention group and 23% in the control group. The risk of diabetes was reduced by 58% in the intervention group, an outcome directly associated with changes in lifestyle.

In the U.S., the DPP study tested the safety and efficacy of pharmacological therapy and lifestyle modification of weight management and physical activity (316). The study was recently completed, approximately 1 year earlier than planned, because of the remarkable success of both interventions (317). The DPP study included 3,234 individuals of diverse ethnic backgrounds (45% minority inclusion), all of whom had impaired glucose tolerance at study entry. Participants randomly assigned to intensive lifestyle reduced their risk of developing type 2 diabetes by 58% over nearly 3 years of follow-up. Significant risk reduction was observed across subgroups of ethnicity, age, gender, BMI, and fasting glucose. Among individuals over age 60 years, the risk reduction was 71%. On average, individuals in the lifestyle intervention group reduced their percent calories from fat from ~34 to ~27.5%; maintained their physical activity at ~30 min/day, usually with walking or other moderate intensity physical activity; and lost 5–7% of their baseline body weight. Of interest was the finding that the pharmacological agent tested, metformin, reduced diabetes risk by 31%, which was less than the risk reduction observed for the lifestyle intervention. However, unlike lifestyle, metformin was not uniformly successful. Although effective in men and women and in all ethnic groups, metformin was relatively ineffective in the older volunteers and in those who were less overweight.

The consistency of beneficial effects of lifestyle interventions used in the Finnish Diabetes Study and the DPP is further supported by an analysis of data from the Nurses' Health Study (679) in which individuals categorized as low risk based on a BMI <25 and a set of related lifestyle variables experienced reduced risk for diabetes incidence over 16 years of follow-up. Thus there is clearly strong evidence that comprehensive lifestyle interventions reduce the incidence of type 2 diabetes. Additional work in the area of increasing adherence and long-term success of intervention strategies for sustained lifestyle change is needed (680).

Exercise

Although obesity is generally regarded as the salient modifiable risk factor for type 2 diabetes, decreased physical activity also has been identified as a diabetes risk factor, independent of its impact on energy balance. A relationship between physical activity and type 2 diabetes was suggested by studies in societies that had abandoned traditional lifestyles typically involving large amounts of habitual physical activity

and subsequently experienced major increases in rates of type 2 diabetes. More recently, the fact that an active lifestyle may prevent or delay the development of type 2 diabetes has been demonstrated in a number of prospective studies (681–685). Protection from diabetes appears to occur from moderate intensity activities, such as brisk walking, as well as from participation in vigorous physical activity. Moreover, physical activity may provide some protection against mortality at all levels of glucose tolerance, as has been demonstrated in middle-aged men (686). Of interest in this regard is a large prospective observational study demonstrating that cardiorespiratory fitness levels in men influence the effects of obesity on health (687). No elevated mortality risk in obese men was observed if they were physically fit, and lean men had increased longevity only if they were physically fit. Thus moderate-to-high cardiorespiratory fitness may reduce mortality risk across all categories of body composition.

Dietary fat

Dietary fat intake appears to be an important determinant of diabetes risk, independent of total caloric intake. Using a case-control design, increased intake of dietary fat was associated with occurrence of diabetes among second-generation Japanese-American men (688). After adjustment for total caloric intake and obesity, Marshall et al. (93) reported increased incidence of diabetes with increased intake of dietary fat. However, three large prospective studies that relied on patient-report of physician-diagnosed diabetes did not detect an effect of dietary fat on diabetes incidence, or else suggested differential effects of various subtypes of dietary fat (118,119,689). Results from two recent studies (690,691) suggest that increased intake of polyunsaturated fat may be associated with reduced risk of type 2 diabetes, independent of BMI, total energy intake, physical activity, and other potential confounders. Potential mechanisms underlying these findings are unclear.

Several studies have identified dietary fat as a contributor to insulin resistance independent of obesity (92–100), but other studies do not support this (690–692). Nevertheless, it appears that all types of dietary fat, except n-3 fatty acids, may have an adverse effect on insulin sensitivity. Results are most consistent for an adverse effect of saturated fats. These effects may be enhanced among individuals with obesity (99) or low levels of physical activity (98,99).

Although early animal studies suggested a potential deleterious effect of dietary fat on insulin secretion (693), recent studies in human populations have failed to demonstrate either clinically or statistically significant effects (694,695).

In total, the impact of dietary fat on diabetes risk appears to lie primarily in the impact of high-fat diets on long-term energy balance. Other specific metabolic effects of dietary fat may occur, but seem likely to play only a minor role in overall diabetes risk.

Whole grains/fiber

Recent studies have provided preliminary evidence for reduced risk of diabetes with increased intake of whole grains and dietary fiber (27,696,697). In both the Nurses' Health Study (27) and the Iowa Women's Health Study (697), increased intake of whole grain food was associated with significant reductions in incidence of type 2 diabetes. A higher glycemic load, calculated and applied to food frequency data, was related to increased incidence of diabetes in men (118) and women (119). The glycemic load is defined as the product of the glycemic index value of a food and its carbohydrate content in an average serving. It incorporates both the quality and quantity of carbohydrate consumed. However, glycemic load or glycemic index was not related to diabetes incidence in the Iowa Women's Health Study (697).

Micronutrients

Selected micronutrients may affect glucose and insulin metabolism, but the data are scarce or inconsistent. Within the range that can be obtained from food intake, men with higher plasma concentrations of α-tocopherol experienced reduced risk for diabetes compared to men with lower concentrations of α-tocopherol (374). Results of studies that evaluated effects of vitamin E on insulin sensitivity have been equivocal (363,698,699). Insufficient intake of magnesium, zinc, and chromium have been implicated as possible risk factors for the development of diabetes (118,697,700–703); however, neither the efficacy nor the safety of supplemented intake has been established.

Alcohol

When compared to abstinence and heavy drinking, moderate alcohol intake has been related to improved insulin sensitivity (439–441) and reduced risk for diabetes (437) However, insufficient data exist to support a specific recommendation for moderate alcohol intake for prevention of type 2 diabetes, and potential adverse effects of heavy drinking must be carefully considered.

Cow's milk

Type 1 diabetes accounts for ~10% of all diabetes and, like type 2 diabetes, has both genetic and environmental determinants. Early introduction of cow's milk in infants may be an environmental factor contributing to the development of childhood diabetes, but the research evidence has been equivocal (704–710). Currently there are no clear dietary determinants of type 1 diabetes.

Youth onset type 2 diabetes

Although most of the diabetes diagnosed in children is type 1 diabetes, recently non–type 1 phenotypes, particularly among minority youth, have been reported. As such, youth-onset type 2 diabetes is a relatively new area of research. Obesity and physical inactivity seem likely to play an important role in development of this condition; however, no sufficient data have been collected from youth to justify any clear recommendations for the prevention of diabetes in youth at this time.

There is strong evidence for the following statements:

- Sustained, modest weight loss of ~5–7% of body weight through reduced energy intake, reduced intake of dietary fat, and increased physical activity will reduce the risk for developing type 2 diabetes.
- Structured programs that emphasize lifestyle changes are necessary to accomplish these objectives.
- All individuals, especially family member of individuals with type 2 diabetes, should be encouraged to engage in regular physical activity to decrease the risk of developing type 2 diabetes. Both moderate and vigorous exercise decrease the risk of impaired glucose tolerance and type 2 diabetes.

Table 7 —*Major nutrition recommendations*

Nutrition Recommendations	Grading
Carbohydrate	
• Foods containing carbohydrate from whole grains, fruits, vegetables, and low-fat milk are important components and should be included in a healthy diet.	A
• With regard to the glycemic effects of carbohydrates, the total amount of carbohydrate in meals or snacks is more important than the source or type.	A
• Because sucrose does not increase glycemia to a greater extent than isocaloric amounts of starch, sucrose and sucrose-containing foods do not need to be restricted by people with diabetes, however, they should be substituted for other carbohydrate sources or, if added, be covered with insulin or other glucose-lowering medication.	A
• Nonnutritive sweeteners are safe when consumed within the ADI levels established by the FDA.	A
• Individuals receiving intensive insulin therapy should adjust their premeal insulin dosages based on the carbohydrate content of meals.	B
• Although the use of low–glycemic index foods may reduce postprandial hyperglycemic, there is not sufficient evidence of long-term benefit to recommend use of low-glycemic index diets as a primary strategy in food/meal planning.	B
• As far the general public, consumption of dietary fiber is to be encouraged; however, there is no reason to recommend that people with diabetes consume a greater amount of fiber than other Americans.	B
• Individuals receiving fixed daily insulin dosages should try to be consistent in day-to-day carbohydrate intake.	C
• Carbohydrate and monounsaturated fat should together provide 60–70% of energy intake. However, the individual's metabolic profile and need for weight loss should be considered when determining the monounsaturated fat content of the diet.	E
• Sucrose and sucrose-containing foods should be eaten in the context of a healthy diet.	E
Protein	
• In individuals with controlled type 2 diabetes, ingested protein does not increase plasma glucose concentrations, although ingested protein is just as potent a stimulant of insulin secretion as carbohydrate.	B
• For persons with diabetes, especially those not with less-than-optimal glucose control, the protein requirements may be greater than the RDA, but not greater than usual intake.	B
• For individuals with diabetes, there is no evidence to suggest that usual protein intake (15–20% of total daily energy) should be modified if renal function is normal.	E
• The long-term effects of diets high in protein and low in carbohydrate are unknown. Although such diets may produce short-term weight loss and improved glycemia, it has not been established that weight loss is maintained long-term. The long-term effect of such diets on LDL cholesterol is also a concern.	E
Fat	
• In all, <10% of energy intake should be derived from saturated fats. Some individuals (i.e., those with LDL cholesterol ≥100 mg/dl) may benefit from lowering saturated fat intake to <70% of energy intake.	A
• Dietary cholesterol intake should be <300 mg/day. Some individuals (i.e., those with LDL cholesterol ≥100 mg/dl) may benefit from lowering dietary cholesterol to <200 mg per day.	A
• To lower LDL cholesterol, energy derived from saturated fat can be reduced if weight loss is desirable or replaced with either carbohydrate or monounsaturated fat if weight loss is not a goal.	B
• Intake of transunsaturated fatty acids should be minimized.	B
• Reduced-fat diets when maintained long term contribute to modest loss of weight and improvement in dyslipidemia.	B
• Polyunsaturated fat intake should be ~10% of energy intake.	C
Energy balance and obesity	
• In insulin-resistant individuals, reduced energy intake and modest weight loss improve insulin resistance and glycemia in the short-term.	A
• Structured programs that emphasize lifestyle changes including education, reduced fat (<30% of daily energy) and energy intake, regular physical activity, and regular participant contact, can produce long-term weight loss on the order of 5 to 7% of starting weight.	A
• Exercise and behavior modification are most useful as adjuncts to other weight-loss strategies. Exercise is helpful in maintenance of weight loss.	A
• Standard weight-reduction diets, when used alone, are unlikely to produce long-term weight loss. Structured, intensive lifestyle programs are necessary.	A
Micronutrients	
• There is no clear evidence of benefit from vitamin or mineral supplementation in people with diabetes who do not have underlying deficiencies. Exceptions include folate for prevention of birth defects and calcium for prevention of bone disease.	B
• Routine supplementation of the diet with antioxidants is not advised because of uncertainties related to long-term efficacy and safety.	B

Continued on following page

Table 7 —*Continued*

Nutrition Recommendations	Grading
Alcohol	
• If individuals choose to drink alcohol, daily intake should be limited to one drink for adult women and two drinks for adult men. One drink is defined as a 12-oz beer, a 5-oz glass of wine, or 1.5-oz glass of distilled spirits.	B
• To reduce risk of hypoglycemia, alcohol should be consumed with food.	B
Children and adolescents with diabetes	
• Individualized food/meal plans and intensive insulin regimens can provide flexibility for children and adolescents with diabetes to accommodate irregular meal times and schedules, varying appetite, and varying activity levels.	E
• Nutrient requirements for children and adolescents with type 1 or type 2 diabetes appear to be similar to requirements for same age nondiabetic children and adolescents.	E
Pregnancy and lactation	
• Nutrition requirements during pregnancy and lactation are similar for women with and without diabetes.	E
• Medical nutrition therapy for gestational diabetes focuses on food choices for appropriate weight gain, normoglycemia, and absence of ketones.	E
• For some women with gestational diabetes, modest energy and carbohydrate restriction may be appropriate.	E
Older adults	
• Energy requirements for older adults are less than for younger adults.	A
• Physical activity should be encouraged	A
• In the elderly, undernutrition is more likely than overnutrition and therefore caution should be exercised when prescribing weight-loss diets.	E
Acute complications	
• Glucose is the preferred treatment for hypoglycemia, although any form of carbohydrate that contains glucose may be used.	A
• Ingestion of 15–20 g of glucose is an effective treatment for hypoglycemia, but blood glucose may be only temporarily corrected.	B
• During acute illnesses, testing blood glucose and blood or urine for ketones, drinking adequate amounts of fluids, and ingesting carbohydrate are important.	B
• Initial response to treatment for hypoglycemia should be seen in ~10–20 min; however, blood glucose should be evaluated in ~60 min, as additional treatment may be necessary.	E
Hypertension	
• In both normotensive and hypertensive individuals, a reduction in sodium intake lowers blood pressure.	A
• A modest amount of weight loss beneficially affects blood pressure.	A
• The goal should be to reduce sodium intake 2,400 mg (100 mmol) or sodium chloride to 6,000 mg per day.	E
Dyslipidemia	
• For persons with elevated LDL cholesterol, saturated fatty acids and transsaturated fatty acids should be limited to <10% and perhaps to <7% of energy.	B
• Energy derived from saturated fat can be reduced if weight loss is desirable or replaced with either carbohydrates or monounsaturated fats if weight loss is not a goal.	E
• For individuals with elevated plasma triglycerides, reduced HDL cholesterol, and small dense LDL cholesterol (the metabolic syndrome), improved glycemic control, modest weight loss, dietary saturated fat restriction, increased physical activity, and incorporation of monounsaturated fats may be beneficial.	B
Nephropathy	
• In individuals with microalbuminuria, reduction of protein to 0.8–1.0 g · kg^{1} · body weight per day and in individuals with overt nephropathy, reduction to 0.8 g · kg^{1} · body wt per day, may slow the progression of nephropathy.	C
Catabolic illness	
• The energy needs of most hospitalized patients can be met by providing 25–35 kcal/kg body wt.	E
• Protein needs are between 1.0 and 1.5 g/kg body wt, with the higher end of the range being for more stressed patients.	E
Prevention of diabetes	
• Structured programs that emphasize lifestyle changes including education, reduced fat and energy intake, regular physical activity, and regular participant contact can produce long-term weight loss of 5–7% of starting weight and reduce the risk for developing diabetes.	A
• All individuals, especially family members of individuals with type 2 diabetes, should be encouraged to engage in regular physical activity to decrease risk of developing type 2 diabetes.	B

Scientific principles ranked based on the American Diabetes Association grading system. The highest ranking, A, is assigned when there is supportive evidence from multiple, well-conducted studies; B is an intermediate rating; C is a lower ranking; and E represents recommendations based on expert consensus.

There is some evidence for the following statements:

- Increased intake of whole grains and dietary fiber may reduce diabetes risk.
- Reduced intake of total fat, particularly saturated fat, may improve insulin sensitivity and reduce risk for diabetes, independent of weight loss.

There is limited evidence for the following statement:

- Increased intake of polyunsaturated fat, in the context of appropriate total energy intake for weight management, may reduce the risk for type 2 diabetes.

The following statements are based on expert consensus:

- No nutritional recommendations can be made for the prevention of type 1 diabetes. Breastfeeding may be beneficial.
- Although increasing obesity in youth may be related to an increase in the prevalence of type 2 diabetes, particularly in minority adolescents, there is insufficient data at present to warrant any specific recommendation for the prevention of type 2 diabetes in youth. Increased physical activity, reduced energy and fat intake, and resultant weight management may prove to be beneficial.

SUMMARY— Major nutrition recommendations are listed in Table 7. The major nutrition recommendations listed in Table 7 are classified according to the level of evidence using the American Diabetes Association evidence grading system. The principles reviewed in the above technical review paper are the basis for the recommendations. MNT for people with diabetes should be individualized, with consideration given to each individual's usual food and eating habits, metabolic profile, treatment goals, and desired outcomes. Monitoring of metabolic parameters, including glucose, HbA_{1c}, lipids, blood pressure, body weight, and renal function, when appropriate, as well as quality of life is essential to assess the need for changes in therapy and to ensure successful outcomes. Ongoing nutrition self-management education and care need to be available for individuals with diabetes. Finally, many areas of nutrition and diabetes require additional research.

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