Can J Diabetes 37 (2013) S45–S55

Contents lists available at SciVerse ScienceDirect

Canadian Journal of Diabetes

journal homepage: www.canadianjournalofdiabetes.com

Clinical Practice Guidelines

Nutrition Therapy

Canadian Diabetes Association Clinical Practice Guidelines Expert Committee

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KEY MESSAGES

- People with diabetes should receive nutrition counselling by a registered dietitian.
- Nutrition therapy can reduce glycated hemoglobin (A1C) by 1.0% to 2.0% and, when used with other components of diabetes care, can further improve clinical and metabolic outcomes.
- Reduced caloric intake to achieve and maintain a healthier body weight should be a treatment goal for people with diabetes who are overweight or obese.
- The macronutrient distribution is flexible within recommended ranges and will depend on individual treatment goals and preferences.
- Replacing high glycemic index carbohydrates with low glycemic index carbohydrates in mixed meals has a clinically significant benefit for glycemic control in people with type 1 and type 2 diabetes.
- Intensive lifestyle interventions in people with type 2 diabetes can produce improvements in weight management, fitness, glycemic control and cardiovascular risk factors.
- A variety of dietary patterns and specific foods have been shown to be of benefit in people with type 2 diabetes.
- Consistency in carbohydrate intake and in spacing and regularity in meal consumption may help control blood glucose and weight.

Introduction

Nutrition therapy and counselling are an integral part of the treatment and self-management of diabetes. The goals of nutrition therapy are to maintain or improve quality of life and nutritional and physiological health; and to prevent and treat acute and long-term complications of diabetes, associated comorbid conditions and concomitant disorders.

It is well documented that nutrition therapy can improve glycemic control (1) by reducing glycated hemoglobin (A1C) by 1.0% to 2.0% (2–5) and, when used with other components of diabetes care, can further improve clinical and metabolic outcomes (3,4,6,7), resulting in reduced hospitalization rates (8). Furthermore, frequent follow-up (i.e. every 3 months) with a registered dietitian (RD) has been associated with better dietary adherence in type 2 diabetes (7).

Nutrition therapy provided by an RD with expertise in diabetes management (9,10), delivered in either a small group and/or an individual setting (11–13), has demonstrated benefits for those with, or at risk for, diabetes. Individual counselling may be preferable for people of lower socioeconomic status (8), while group education has been shown to be more effective than individual counselling when it incorporates principles of adult education, including hands-on activities, problem solving, role playing and group discussions (14). Additionally, in people with type 2 diabetes, culturally sensitive peer education has been shown to improve A1C, nutrition knowledge and diabetes self-management (15), and web-based care management has been shown to improve glycemic control (16). Diabetes education programs serving vulnerable populations should evaluate the presence of barriers to healthy eating (e.g. cost of healthy food, stress-related overeating) (17) and work toward solutions to facilitate behaviour change.

In general, people with diabetes should follow the healthy diet recommended for the general population in *Eating Well with Canada's Food Guide* (18). This involves consuming a variety of foods from the 4 food groups (vegetables and fruits; grain products; milk and alternatives; meat and alternatives), with an emphasis on foods that are low in energy density and high in volume to optimize satiety and discourage overconsumption. This diet may help a person attain and maintain a healthy body weight while ensuring an adequate intake of carbohydrate (CHO), fibre, fat and essential fatty acids, protein, vitamins and minerals.

Overall, nutrition counselling should be individualized, regularly evaluated and reinforced in an intensive manner (19-21), and incorporate self-management education (22). As evidence is limited for the rigid adherence to any single dietary prescription (23,24), nutrition therapy and meal planning should be individualized to accommodate the individual's age, type and duration of diabetes, concurrent medical therapies, treatment goals, values, preferences, needs, culture, lifestyle, economic status (25), activity level, readiness to change and abilities. Applying the evidence from the sections that follow, Figure 1 and Table 1 present an algorithm which allows for this level of individualization of therapy in an evidence-based framework.

Energy

As an estimated 80% to 90% of people with type 2 diabetes are overweight or obese, strategies that include energy restriction to achieve weight loss are a primary consideration (26). A modest weight loss of 5% to 10% of initial body weight can substantially improve insulin sensitivity, glycemic control, hypertension and

1499-2671/$ – see front matter © 2013 Canadian Diabetes Association
http://dx.doi.org/10.1016/j.jcjd.2013.01.019

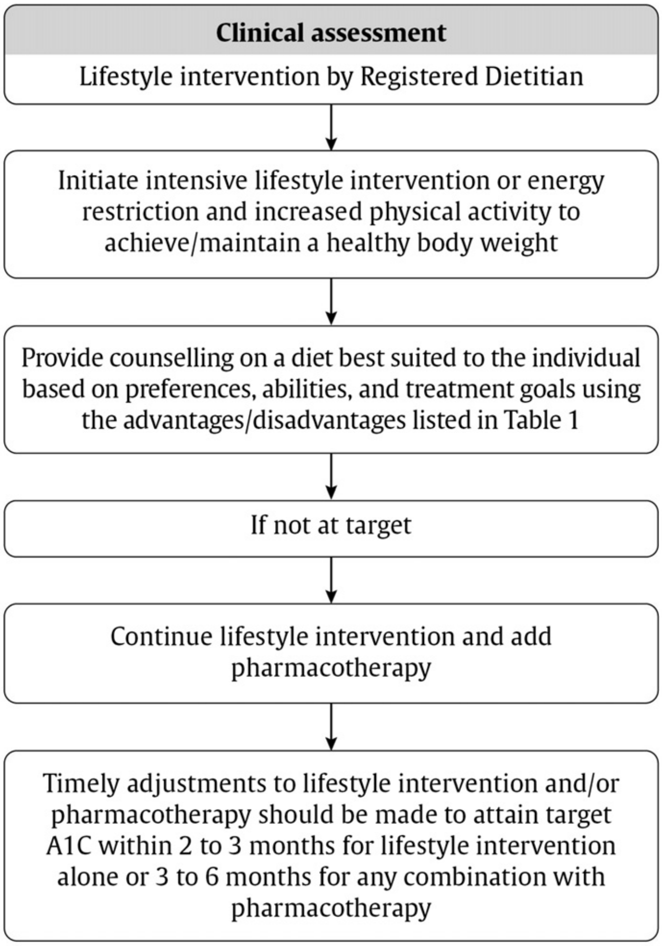

Figure 1. Nutritional management of hyperglycemia in type 2 diabetes.

dyslipidemia in people with type 2 diabetes and those at risk for type 2 diabetes (27–29). The sustainability of weight loss remains an important issue. Long-term follow-up of 7 to 10 years of intensive lifestyle intervention (ILI) programs targeting 5% to 7% weight loss in people at risk for type 2 diabetes suggests that there is some weight regain following discontinuation of the intervention, although the diabetes prevention benefits persist (30,31). Total calories should reflect the weight management goals for overweight and obese people with diabetes (i.e. to prevent further weight gain, to attain and maintain a healthy or lower body weight for the long term or to prevent weight regain).

Macronutrients

The ideal macronutrient distribution for the management of diabetes may vary, depending on the quality of the various macronutrients, the goals of the dietary treatment regimen and the individual's preferences and lifestyle.

Carbohydrate

The current recommended minimum intake for CHO is not less than 130 g/day, to provide glucose to the brain (32). A systematic review and meta-analysis of controlled feeding studies in people with type 2 diabetes found that CHO-restricted diets (mean CHO from 4% to 45% of total energy per day) improved A1C and triglycerides (TG), but not total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C) or body weight compared with higher-CHO diets over the short term (33). The long-term sustainability and safety of these diets, however, remain uncertain. Very-low-CHO diets may not ensure sufficient vitamin, mineral and fibre intake. It is recommended that the percentage of total daily energy from CHO should be no less than 45% to prevent high intakes of fat, as this is associated with reduced risk of chronic disease for adults (32). If CHO is derived from low glycemic index (GI) and high-fibre foods, it may contribute up to 60% of total energy, with improvements in glycemic and lipid control in adults with type 2 diabetes (34).

Glycemic index

The GI provides an assessment of the quality of CHO-containing foods based on their ability to raise blood glucose (BG) (35). To decrease the glycemic response to dietary intake, low-GI CHO foods are exchanged for high-GI CHO foods. Examples of typical low-GI food sources include beans, peas, lentils, pasta, pumpernickel or rye breads, parboiled rice, bulgur, barley, oats, quinoa and temperate fruit (apples, pears, oranges, peaches, plums, apricots, cherries, berries). Examples of higher-GI food sources include white or whole wheat bread, potatoes, highly extruded or crispy puffed breakfast cereals (corn flakes, puffed rice, puffed oats, puffed wheat), and tropical fruit (pineapple, mango, papaya, cantaloupe, watermelon). More detailed lists can be found in the *International Tables of Glycemic Index and Glycemic Load Values* (36).

Meta-analyses of controlled feeding trials of interventions replacing high-GI CHOs with low-GI CHOs in mixed meals have shown clinically significant improvements in glycemic control over 2 weeks to 6 months in people with type 1 or type 2 diabetes (37–39). This dietary strategy also leads to improvements in cardiovascular risk factors, such as TC, over 2 to 24 weeks (38), improvements in postprandial glycemia and high-sensitivity C-reactive protein (hsCRP) over 1 year (40) in people with type 2 diabetes, and reduces the number of hypoglycemic events over 24 to 52 weeks in adults and children with type 1 diabetes (39). Dietary advice to consume a low-GI diet was shown to sustain improvements in glycemic control and HDL-C compared with a high cereal fibre diet over 6 months (41), and to improve beta-cell function compared with a low-CHO, high monounsaturated fat diet over 1 year (42) in people with type 2 diabetes. A low-GI diet has also been shown to improve glycemic control compared with dietary advice based on the nutritional recommendations of the Japanese Diabetes Society over 3 months in Japanese people with impaired glucose tolerance (IGT) or type 2 diabetes (43) and to decrease the need for antihyperglycemic medications compared with the nutritional recommendations of the American Diabetes Association over 1 year in people with poorly controlled type 2 diabetes (44). Teaching a person to use the GI is recommended, but should be based on the individual's interest and ability.

Dietary fibre

Evidence suggests that the addition of soluble dietary fibre (e.g. eggplant, okra, oat products, beans, psyllium, barley) slows gastric emptying and delays the absorption of glucose in the small intestine, thereby improving postprandial BG control (45). In addition, cohort studies demonstrate that diets high in dietary fibre, especially cereal fibre, are associated with a decreased risk of cardiovascular disease (46). Due to the recognized beneficial effects of dietary fibre intake in people with diabetes, higher intakes than those recommended for the general population [25 g and 38 g for women and men, and 21 g and 30 g for women and men over 51 years, respectively (47)] are recommended for adults with diabetes (25 to 50 g/day or 15 to 25 g per 1000 kcal) (45,48).

Table 1
Properties of dietary interventions

Properties of dietary interventions (listed in the order they are presented in the text)			
Dietary interventions	**A1C***	**Advantages**	**Disadvantages**
Macronutrients			
Hi-CHO (low-glycemic index)	↓	↑HDL-C, ↓CRP, ↓hypoglycemia, ↓diabetes medications	–
Hi-CHO (hi-fibre)	↓	↓TC, ↓LDL-C, ↓diabetes medications	↓HDL-C, GI side effects
Hi-MUFA	↓	↓TG	–
Lo-CHO	↔	↓TG	↓Micronutrients, ↑renal load
Hi-protein	↓	↓BP, ↓TG, preserve lean mass	↓Micronutrients, ↑renal load
Long chain omega 3 fatty acids	↔	↓TG	Methyl-Hg exposure, environmental impact
Dietary patterns			
Vegetarian diets	↓	↓LDL-C, ↑HDL-C, ↓BMI, ↓non-HDL-C†, ↓TC†	↓Vitamin B12
Mediterranean diets	↓	↓BP, ↓CRP, ↓TC, ↑HDL-C, ↓ TC:HDL-C, ↓TG, major CV events	–
DASH	↓	↓Weight, ↓BP, ↓CRP, ↓LDL-C, ↑HDL-C	–
Popular weight loss diets			
Atkins diet	↔	↓Weight, ↓TC, ↑HDL-C, ↓TC:HDL-C, ↓TG	↑LDL-C, ↓ micronutrients, ↓adherence, ↑renal load
Protein Power Plan	↓	↓Weight	↓ Micronutrients, ↓adherence, ↑renal load
Ornish diet	–	↓Weight, ↓LDL-C:HDL-C	↔ FPG, ↓adherence
Weight Watchers diet	–	↓Weight, ↓LDL-C:HDL-C	↔ FPG, ↓adherence
Zone diet	–	↓Weight, ↓LDL-C:HDL-C	↔ FPG, ↓adherence, ↑renal load
Diets emphasizing specific foods			
Dietary pulses	↓	↓TC, ↓LDL-C	GI side effects
Nuts	↓	↓LDL-C, ↓apo-B, ↓apo-B:apo-A1, ↓TG	–
Meal replacements	↓	↓Weight	Temporary intervention

*↓ = <1% decrease in A1C. † adjusted for medication changes.
A1C = glycated hemoglobin; BMI = body mass index; BP = blood pressure; CHO = carbohydrate; CRP = C reactive protein; CV = Cardiovascular; FPG = fasting plasma glucose; GI = gastrointestinal; HDL = high-density lipoprotein; LDL = low-density lipoprotein; MUFA = monounsaturated fatty acid; TC = total cholesterol; TG = triglycerides.

Sugars

Added sucrose intake of up to 10% of total daily energy (e.g. 50 to 65 g/day in a 2000 to 2600 kcal/day diet) is acceptable, as there is no evidence that sucrose intake up to this level has any deleterious effect on glycemic control or lipid profile in people with type 1 or type 2 diabetes (49–51). Intake of sucrose >10% of total daily energy may increase BG and TG concentrations in some individuals (52,53).

Systematic reviews and meta-analyses of controlled feeding trials have shown that consumption of added fructose in place of equal amounts of other sources of CHO (mainly starch or sucrose) is unlikely to have any harmful effect on body weight (54,55), blood pressure (56) or uric acid (55,57), and may even lower A1C (55,58,59) in most people with diabetes. However, at doses >60 g/day or >10% of total daily energy, fructose may have a small TG-raising effect in people with type 2 diabetes (60). As a source of excess energy, fructose has also been shown to contribute to weight gain and an adverse metabolic profile in people without diabetes (54,57).

Eating Well with Canada's Food Guide recommends up to 7 to 10 servings of vegetables and fruit per day (18). Consuming naturally occurring fructose obtained from fruit does not show evidence of harm. A randomized controlled feeding trial showed that naturally occurring fructose from fruit at a level providing ~60 g/day decreased body weight without adverse effects on lipids, blood pressure, uric acid or insulin resistance compared with a low-fructose control diet under matched hypocaloric feeding conditions in overweight subjects without diabetes (61). Encouraging low-GI fruit over high-GI fruit as sources of small doses of fructose also provided glycemic benefit without adverse metabolic effects in people with type 2 diabetes over 6 months (62).

Fat

Current recommendations for the general population to consume fats in the range of 20% to 35% of energy intake apply equally to people with diabetes (47). As the risk of coronary artery disease (CAD) in people with diabetes is 2 to 3 times that of those without diabetes, saturated fats (SFAs) should be restricted to <7% of total daily energy intake (63), and trans fatty acids arising from industrial hydrogenation should be kept to a minimum. Meal plans should favour fats rich in monounsaturated fatty acids (MUFAs) (e.g. olive oil, canola oil) with up to 20% of total calories (63). Polyunsaturated fats (PUFAs), such as plant oils (e.g. canola, walnut, flax, salba) and long-chain omega-3 fatty acids (e.g. fatty fish) should be included in the diet up to 10% of total energy intake (63).

A comprehensive review found that although long-chain omega-3 fatty acids from fish oils, which include eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), do not show an effect on glycemic control, these fatty acids do improve lipid profile, modify platelet aggregation and decrease cardiovascular mortality in people with diabetes (64). In a prospective cohort study of women with type 2 diabetes, higher consumption (1 to 3 servings per month) of omega-3 long-chain polyunsaturated fatty acids (LC-PUFAs) from fish was associated with a 40% reduction in CAD compared with those with a low intake (<1 serving per month) (65). Those who consumed fatty fish >5 times per week had a 64% reduction in CAD compared with those in the low-intake category (65). A cohort analysis of the Diabetes Control and Complications Trial (DCCT) also showed that higher consumptions of omega-3 LC-PUFAs from fish are associated with a decrease in the degree of albuminuria in type 1 diabetes (66).

Large clinical outcome trials of supplementation with omega-3 LC-PUFAs have shown a significant reduction in cardiovascular events in participants, including people with diabetes who have elevated TC (67), those with chronic heart failure (68) or those who had a previous myocardial infarction (MI) (69). Although the Alpha OMEGA trial did not show a significant mortality benefit after 3.5 years of supplementation with omega-3 LC-PUFAs in all participants who had a previous MI, it did show a significant reduction in incident cardiovascular disease and death from coronary heart disease (CHD) in the subgroup of participants with diabetes (70). However, there remains uncertainty regarding the benefits of supplementation with omega-3 LC-PUFAs. The Outcome Reduction with Initial Glargine Intervention (ORIGIN) trial failed to show a cardiovascular or mortality benefit of supplementation with omega-3 LC-PUFAs in 12 536 people with or at risk for diabetes (71). When the data from this trial were included in the most recent meta-analysis, the overall risk estimates for cardiovascular events and mortality were not significant (72). There remains a need for more evidence related to the benefits of supplementation with omega-3 LC-PUFAs in people with diabetes. The Study of Cardiovascular Events in Diabetes (ASCEND) in 15 480 people with diabetes free of cardiovascular disease (clinicaltrials.gov registration number NCT00135226) will provide more data on the outcomes of supplementation with omega-3 LC-PUFAs.

Protein

There is no evidence that the usual protein intake for most individuals (1 to 1.5 g per kg body weight per day), representing 15% to 20% of total energy intake, needs to be modified for people with diabetes (73). However, this intake in grams per kg per day should be maintained or increased with energy-reduced diets.

In people with diabetes who have chronic kidney disease (CKD), targeting a level of intake that does not exceed the recommended dietary allowance (RDA) of 0.8 g per kilogram body weight per day is an important consideration (74). This level of restriction is based on evidence of reductions in end stage renal disease or mortality seen in a single randomized controlled trial in people with type 1 diabetes who have CKD (75), as well as improvements in albuminuria or proteinuria and A1C from meta-analyses of randomized controlled trials from 6 months to 4 years of follow-up in people with varying degrees of diabetic nephropathy (76). Protein quality has been shown to be another important consideration in this cohort. Several randomized trials have shown that replacement of animal protein with plant protein (mainly from soy) results in improvements in albuminuria or proteinuria, LDL-C, TG and CRP up to 4 years (77–79). Replacement of red meat with either chicken or a low-protein diet with vegetable and dairy sources of protein has also been shown to result in significant reductions in albuminuria after 4 weeks in a randomized trial (80). In patients on low-protein diets, harm due to malnutrition should not be ignored (81). Both the quantity and quality (high biological value) of protein intake must be optimized to meet requirements for essential amino acids, necessitating adequate clinical and laboratory monitoring of nutritional status in the individual with diabetes and CKD. Greater incorporation of plant sources of protein may also require closer monitoring of potassium as CKD progresses.

Macronutrient substitutions

The ideal macronutrient distribution for the management of diabetes may need to be individualized based on individual preferences and perceived palatability, as several studies suggest that wide variations can be effective (82). For example, similar beneficial effects on body weight, body composition, cardiovascular risk factors and glycemic control have been reported in individuals with type 2 diabetes who followed either a high-MUFA diet (46% CHO, 15% protein, 38% fat, half MUFAs) or a higher CHO diet (54% CHO, 15% protein, 28% fat) for 1 year (83). Similarly, 6-week crossover feeding trials comparing high MUFA with high CHO isoenergetic diets, emphasizing natural foods, vegetables and fish, showed similar energy balance, glycemic control and lipid profile (82). Furthermore, it has been shown that a high MUFA diet is as successful as a conventional diet in improving metabolic and anthropometric parameters in persons with type 2 diabetes (84). However, postprandial glucose, insulin and LDL-C concentrations are lower in response to a meal with a low GI and low glycemic load compared with a MUFA-rich meal (85).

Replacing fat with refined CHOs should be avoided as it has been shown to elevate fasting insulin, TG, postprandial glucose and insulin concentrations and to lower HDL-C (86). A 15% increase of energy from dietary protein with a parallel decrease in fat, while maintaining CHO intake constant, does not affect postprandial plasma glucose and insulin concentrations in obese individuals with type 2 diabetes and, over 4 weeks, improves TG and blood pressure (87). Furthermore, in nondiabetic adults, increasing protein intake to 1.5 to 2 g per kilogram body weight was shown to promote satiety (88) and preserve lean body mass (89), which would be of potential benefit in energy-reduced diets.

There may be benefit of replacing SFAs with PUFAs. A systematic review and meta-analysis of large clinical outcome trials replacing SFAs with PUFAs showed a 19% reduction in MI or CHD death in people with and without CHD, in which some of the trials included people with diabetes (90). This result was supported by a pooled analysis of prospective cohort studies, which showed similar reductions in the risk of CHD in people without diabetes (91). The pooled analysis, however, did not show a cardiovascular benefit of replacing SFAs with MUFAs, and neither the pooled analysis nor the Women's Health Initiative Randomized Controlled Dietary Modification Trial in postmenopausal women—of whom approximately 5% were treated for diabetes and 36% had the metabolic syndrome (92)—showed a cardiovascular benefit of replacing SFAs with CHO. The CHO in these studies, however, was not differentiated by its GI.

A 12-month study comparing a high-protein/low-fat vs. a high-CHO/low-fat diet in the treatment of type 2 diabetes showed that neither diet was superior in helping to manage type 2 diabetes (93). Rather, it is the degree of energy reduction, not the variation in diet macronutrient composition, which was related to the long-term improvement in glycemic control (93,94). Better improvement of cardiovascular risk profile has been observed with a high- vs. low-protein diet in persons with type 2 diabetes despite similar weight loss with normal renal function being maintained (95). Two eggs per day, provided as part of a high-protein, low-saturated-fat, energy-reduced diet, improved HDL-C compared with a similar low-cholesterol diet, without adversely affecting other blood lipids in individuals with type 2 diabetes (96). Adjustments in medication type and dosage may be required when embarking on a different macronutrient distribution (97) or energy reduction (98).

Intensive Lifestyle Intervention

ILI programs in diabetes usually consist of behavioural interventions combining dietary modification and increased physical activity. A multidisciplinary team, including RDs, nurses and kinesiologists, usually leads the ILI programs, with the intensity of follow-up varying from weekly to every 3 months with gradually decreasing contact as programs progress. Large, randomized, clinical trials have shown benefit of ILI programs using different lifestyle approaches in diabetes. Twenty-year follow-up of the China Da Qing Diabetes Prevention Outcome Study showed that 6 years of an ILI program targeting an increase in vegetable intake, decrease in alcohol and sugar intake, weight loss through energy restriction in overweight and obese participants, and an increase in leisure-time physical activity (e.g. 30 minutes walking per day) reduced severe retinopathy by 47%, whereas nephropathy and neuropathy outcomes were not affected compared with usual care in high-risk people with IGT (99). Interim analyses of the Look AHEAD (Action for Health in Diabetes) trial have shown that an ILI program targeting at least a 7% weight loss through a restriction in energy (1200 to 1800 total kcal/day based on initial weight), a reduction in fat (<30% of energy as total fat and <10% as saturated fat), an increase in protein (≥15% of energy) and an increase in physical activity (175 min/week with an intensity similar to brisk walking) produced sustained weight loss and improvements in fitness, glycemic control and cardiovascular risk factors (blood pressure, TG and HDL-C) compared with diabetes support and education over 4 years of follow-up in overweight people with type 2 diabetes (29). In 2012, the Look AHEAD trial was stopped early as it was determined that 11 years of an ILI did not decrease the occurrence of cardiovascular events compared to the control group and further intervention was unlikely to change this result. It was noted, however, that both groups had a lower number of cardiovascular events compared to previous studies of people with diabetes (http://www.nih.gov/news/health/oct2012/niddk-19.htm). The Lifestyle Over and Above Drugs in Diabetes (LOADD) trial showed that a 6-month ILI program of individualised dietary advice (according to the nutritional recommendations of the European Association for the Study of Diabetes) (100) improved glycemic control and anthropometric measures compared with usual care in persons with type 2 diabetes who had unsatisfactory glycemic control (A1C >7%) on optimized antihyperglycemic drug treatment (101). The Mediterranean Lifestyle Program (MLP) trial showed that a comprehensive 6-month ILI promoting a Mediterranean-style dietary pattern increased physical activity (including aerobic, strength-training and stress management exercises) and led to weight loss and improvements in glycemic control and quality of life in postmenopausal women with type 2 diabetes (102). Although the available trials suggest an overall benefit of different ILI programs in people with diabetes, the feasibility of implementing an ILI program will depend on the availability of resources and access to a multidisciplinary team.

Dietary Patterns

There are now several large studies that have suggested that a variety of dietary patterns are beneficial for people with diabetes. An individual's values, preferences and abilities may influence the decisions to use these dietary patterns.

Vegetarian diets

A low-fat, ad libitum vegan diet has been shown to be just as beneficial as conventional American Diabetes Association dietary guidelines in promoting weight loss and improving fasting BG, TC and LDL-C over 74 weeks in adults with type 2 diabetes, and, when taking medication changes into account, the vegan diet improved glycemia and plasma lipids more than the conventional diet (103). One must note that, with both diets, weekly or biweekly nutrition and cooking instruction was provided by a dietitian or cooking instructor (103). Similarly, a calorie-restricted vegetarian diet was shown to improve body mass index (BMI) and LDL-C more than a conventional diet in people with type 2 diabetes (104). While both diets were effective in reducing A1C, more participants on the vegetarian diet had a decrease in diabetes medications compared to those on the conventional diet (43% vs. 5%, respectively).

Mediterranean diets

A "Mediterranean diet" primarily refers to a plant-based diet first described in the 1960s (105). General features include a high consumption of fruits, vegetables, legumes, nuts, seeds, cereals and whole grains; moderate-to-high consumption of olive oil (as the principal source of fat); low to moderate consumption of dairy products, fish and poultry; and low consumption of red meat, as well as low to moderate consumption of wine, mainly during meals (105,106). A systematic review of randomized controlled feeding trials showed that a Mediterranean-style dietary pattern improves glycemic control and cardiovascular risk factors, including systolic blood pressure, TC, HDL-C, TC:HDL-C ratio, and TG in type 2 diabetes (107). Individually, well-powered, randomized controlled trials in people with type 2 diabetes have also shown evidence of long-term benefits. A low-CHO Mediterranean-style diet reduced A1C and delayed the need for antihyperglycemic drug therapy compared with a low-fat diet in overweight individuals with newly diagnosed type 2 diabetes at 4 years (108). The Dietary Intervention Randomized Controlled Trial (DIRECT) showed that a calorie-reduced, Mediterranean-style diet lowered fasting plasma glucose compared with calorie-reduced low-fat or low-CHO diets in a subgroup of moderately obese people with type 2 diabetes at 2 years (109). Compared with a diet based on the American Diabetes Association recommendations, both traditional and low-CHO Mediterranean-style diets were shown to decrease A1C and TG, whereas only the low-CHO Mediterranean-style diet improved LDL-C and HDL-C at 1 year in overweight persons with type 2 diabetes (110). These metabolic advantages of a Mediterranean diet appear to have benefits for the primary prevention of cardiovascular disease in people with type 2 diabetes. The Prevención con Dieta Mediterránea (PREDIMED) study, a Spanish multicentre, randomized trial of the effect of a Mediterranean diet supplemented with extra-virgin olive oil or mixed nuts compared with a low-fat control diet on major cardiovascular events in 7447 participants at high cardiovascular risk (including 3614 participants [49%] with type 2 diabetes), was stopped early for benefit. Both types of Mediterranean diets were shown to reduce the incidence of major cardiovascular events by approximately 30% without any subgroup differences between participants with and without diabetes over a median follow-up of 4.8 years (111).

DASH and low-sodium dietary patterns

Dietary approaches to reducing blood pressure have focused on sodium reduction and the Dietary Approaches to Stop Hypertension (DASH) dietary pattern. Although advice to the general population over 1 year of age is to achieve a sodium intake that meets the adequate intake (AI) target of 1000 to 1500 mg/day (depending on age, sex, pregnancy and lactation) (112), there is recent concern from prospective cohort studies that low sodium intakes may be associated with increased mortality in people with type 1 (113) and type 2 diabetes (114).

The DASH dietary pattern does not target sodium reductions but rather emphasizes vegetables, fruits and low-fat dairy products, and includes whole grains, poultry, fish and nuts. It contains smaller amounts of red and processed meat, sweets and sugar-containing beverages, total and saturated fat, and cholesterol, and larger amounts of potassium, calcium, magnesium, dietary fibre and protein than typical Western diets (115,116). The DASH dietary pattern has been shown to lower systolic and diastolic blood pressure compared with a typical American diet matched for sodium intake in people with and without hypertension, inclusive of people with well-controlled diabetes (115,116). These improvements in blood pressure have been shown to hold across high (3220 mg), medium (2300 mg), and low (1495 mg) levels of matched sodium intake (116). In people with type 2 diabetes, the DASH dietary pattern compared with a control diet matched for a moderate sodium intake (2400 mg) has been shown to decrease systolic and diastolic blood pressure, as well as decrease A1C, fasting BG, weight, waist circumference, LDL-C and CRP and to increase HDL-C over 8 weeks (117,118).

Popular weight-loss diets

Numerous popular weight-loss diets are available to people with diabetes. Several of these diets, including the Atkins, Zone, Ornish, Weight Watchers, and Protein Power Lifeplan diets, have been subjected to investigation in longer-term, randomized controlled trials in overweight and obese participants that included some people with diabetes, although no available trials have been conducted exclusively in people with diabetes. A systematic review and meta-analysis of 4 trials of the Atkins diet and one trial of the Protein Power Lifeplan diet (a diet with a similar extreme CHO restriction) showed that these diets were no more effective than conventional energy-restricted, low-fat diets in inducing weight loss with improvements in TG and HDL-C offset by increases in TC and LDL-C for up to 1 year (119). The Protein Power Lifeplan diet, however, did show improved A1C compared with an energy-reduced, low-fat diet at 1 year in a subset of participants with type 2 diabetes (120). DIRECT showed that, although an Atkins diet produced weight loss and improvements in the TC:HDL-C ratio, HDL-C and TG compared with a calorie-restricted, low-fat conventional diet, its effects were not different from that of a calorie-restricted Mediterranean-style diet at 2 years (109). Furthermore, the Mediterranean-style diet had a more favourable effect on fasting plasma glucose at 2 years in the subgroup of participants with type 2 diabetes (109). Another trial comparing the Atkins, Ornish, Weight Watchers, and Zone diets showed similar weight loss and improvements in the LDL-C:HDL-C ratio without effects on fasting plasma glucose at 1 year in overweight and obese participants, of whom 28% had diabetes (121). A common finding across most of the available trials was poor dietary adherence (119,120), although greater adherence was associated with greater weight loss and reductions in cardiovascular risk factors irrespective of the diet (121). The development of nutritional deficiencies must also be considered in the context of diets that restrict food groups. The available evidence on popular weight-loss diets supports the approach of selecting the diet best suited to the preferences and treatment goals of the individual; however, more studies conducted specifically in people with diabetes are warranted.

Diets emphasizing specific foods

A systematic review and meta-analysis of randomized controlled trials found that diets high in dietary pulses (e.g. beans, peas, chickpeas, lentils), either alone or as part of low-GI or high-fibre diets, lowered fasting BG and/or glycated blood proteins, including A1C, in people with and without diabetes (122). In addition to decreasing fasting BG, an increase in HDL-C was also found in a randomized controlled trial of a combination of dietary pulses and whole grains in partial replacement for rice in the diet of people with type 2 diabetes (123). Another systematic review and meta-analysis of randomized controlled trials found that diets high in dietary pulses reduced TC and LDL-C compared with macronutrient and energy-matched control diets in nondiabetic participants with normal to high cholesterol (124).

Table 2
Acceptable daily intake of sweeteners

Sweetener	Acceptable daily intake (mg/kg body weight/day)
Acesulfame potassium	15
Aspartame	40
Cyclamate	11
Erythritol	1,000
Neotame	2
Saccharin	5
Steviol glycosides	4
Sucralose	8.8
Tagatose	80
Thaumatin	0.9

Another novel, and yet simple, technique of encouraging intake of vegetables first and other CHOs last at each meal was also successful in achieving better glycemic control (A1C) than an exchange-based meal plan after 24 months of follow-up in people with type 2 diabetes (125).

Two ounces of mixed, unsalted nuts daily (or 50 to 75 g, depending on individual energy needs of participants) for 13 weeks as a replacement for CHO foods in people with type 2 diabetes lowered A1C, TC and LDL-C with no decrease in HDL-C, resulting in an improved TC:HDL-C ratio and no concomitant weight gain (126). In studies of shorter duration and/or with smaller sample sizes, similar results have been reported. In 1 pilot study in people with type 2 diabetes, five 28-g servings of almonds per week for 12 weeks resulted in improvements in A1C and BMI (127). In another study, 60 g of almonds per day for 4 weeks, compared to a National Cholesterol Education Program (NCEP) Step II diet, in people with type 2 diabetes, improved fasting glucose, percentage of body fat, TC, LDL-C and LDL-C:HDL-C ratio (128). Furthermore, in a pooled analysis of 25 nut intervention trials in people with normolipidemia or hypercholesterolemia, including 1 trial in people with type 2 diabetes (129), it was concluded that different types of nuts were effective in reducing TC and LDL-C, with no decrease in HDL-C, and a decrease in TG only in those with elevated TG levels. Overall, the effect of nut consumption was dose dependent, and the greatest lipid-lowering benefits were seen in those with high baseline LDL-C, low BMI and consumers of Western diets (130). While more research in people with diabetes would be beneficial, these studies support the inclusion of nuts as a dietary strategy to improve lipid and A1C levels in this population.

Special Considerations for People with Type 1 Diabetes and Type 2 Diabetes on Insulin

Consistency in CHO intake (131), and spacing and regularity in meal consumption, may help control BG levels (21,131,132). Inclusion of snacks as part of a person's meal plan should be individualized based on meal spacing, metabolic control, treatment regimen and risk of hypoglycemia, and should be balanced against the potential risk of weight gain (133,134).

Intensively treated individuals with type 1 diabetes show worse diabetes control with diets high in total and saturated fat and low in CHO (135). People with type 1 diabetes or type 2 diabetes requiring insulin, using a basal-bolus regimen, should adjust their insulin based on the CHO content of their meals. Intensive insulin therapy regimens that include multiple injections of rapid-acting insulin matched to CHO allow for flexibility in meal size and frequency (136,137). Improvements in A1C, BG and quality of life, as well as less requirement for insulin, can be achieved when individuals with type 1 diabetes (138) or type 2 diabetes (139) receive education on matching insulin to CHO content (e.g. CHO counting) (140,141). In doing so, dietary fibre and sugar alcohol should be subtracted from total CHO. In addition, new interactive technologies, utilizing mobile phones to provide information, CHO/insulin bolus calculations and telemedicine communications with care providers, have been shown to decrease both weight gain and the time required for education. They also improved individual quality of life and treatment satisfaction (142).

Other Considerations

Nonnutritive sweeteners

Acesulfame potassium, aspartame, cyclamate, neotame, saccharin, steviol glycosides, sucralose, tagatose and thaumatin have been approved by Health Canada for use as either table-top sweeteners or food additives, or for use in chewing gum (Personal Communication with Health Canada, http://www.hc-sc.gc.ca/fn-an/securit/addit/list/9-sweetener-edulcorant-eng.php, and http://www.hc-sc.gc.ca/fn-an/securit/addit/sweeten-edulcor/index-eng.php). Health Canada has set acceptable daily intake (ADI) values, which are expressed on a body weight basis and are considered safe daily intake levels over a lifetime (Table 2). These levels are considered high and are rarely achieved. Indeed, 1 can of pop contains about 42 mg Ace-K or 200 mg aspartame, 1 packet of sweeteners, 12 mg sucralose or 12 mg saccharin. Most have been shown to be safe when used by people with diabetes (143); however, there are limited data on the newer sweeteners, such as neotame and thaumatin. Stevia extracts are approved by Health Canada for use in foods and beverages. The ADI is set at 4 mg/kg/day of steviol, a level in agreement with that of the Food and Agricultural Organization (FAO) and the World Health Organization (WHO) (144). Intake of up to 1 g steviol glycosides per day was shown to be safe in people with type 1 or type 2 diabetes and was not associated with hypoglycemia or hypotension (145,146).

Sugar alcohols (erythritol, isomalt, lactitol, maltitol, mannitol, sorbitol, xylitol) are also approved for use in Canada; however, there is no ADI (except for erythritol) as their use is considered self-limiting due to the potential for adverse gastrointestinal symptoms. They vary in the degree to which they are absorbed, and their conversion rate to glucose is slow, variable and usually minimal, and may have no significant effect on BG. Thus, matching rapid-acting insulin to the intake of sugar alcohols is not recommended (147). Although there are no long-term, randomized controlled trials of consumption of sugar alcohols by people with diabetes, consumption of up to 10 g/day by people with diabetes does not appear to result in adverse effects (148).

Dietary advanced glycation endproducts

Thermal food processing at very high temperatures, such as frying, broiling and grilling, results in formation of dietary advanced glycation endproducts (dAGEs), a class of pro-oxidants of which 10% are absorbed. Meals high in dAGEs increase markers of endothelial and adipocyte dysfunction in adults with type 2 diabetes (149) and impair vascular function (150). A 4-month, randomized dietary study in 36 participants with or without type 2 diabetes showed that restricting dAGEs by cooking foods at a low temperature, preferably in liquid, improved insulin resistance in those with diabetes; however, A1C was not measured (151).

Meal replacements

Weight loss programs for people with diabetes may use partial meal replacement plans. Commercially available, portion-controlled, vitamin- and mineral-fortified meal replacement products usually replace 1 or 2 meals per day in these plans. Randomized controlled feeding trials have shown partial meal replacement plans to result in comparable (152) or better (153,154) weight loss compared with conventional reduced-calorie diets up to 1 year with maintenance up to 86 weeks in overweight people with type 2 diabetes. This weight loss results in greater improvements in glycemic control over 3 months to 34 weeks (154,155) and reductions in the need for antihyperglycemic medications up to 1 year (153,155) without an increase in adverse or hypoglycemic events (153–155).

Meal replacements have also shown benefit as part of ILIs. Overweight participants with type 2 diabetes during week 3 to week 19 on the ILI intervention arm of the Look AHEAD trial were prescribed meal replacements: Glucerna (Abbott Laboratories, Abbott Park, USA), HMR (Health Management Resources Corp., Boston, USA), Optifast (Nestlé, Vevey, Switzerland) or Slimfast (Unilever, London, UK and Rotterdam, Netherlands). Those participants in the highest quartile of meal replacement usage were approximately 4 times more likely to reach the 7% and 10% weight loss goal than participants in the lowest quartile (156). Meal replacements with differing macronutrient compositions designed for people with diabetes have shown no clear advantage, although studies remain lacking (157,158).

Alcohol

The same precautions regarding alcohol consumption in the general population apply to people with diabetes (159). Alcohol consumption should be limited to ≤2 standard drinks per day and <10 drinks per week for women and ≤3 standard drinks per day or <15 drinks per week for men (1 standard drink: 10 g alcohol, 341 mL 5% alcohol beer, 43 mL 40% alcohol spirits, 142 mL 12% alcohol wine) (160).

Alcohol ingestion may mask the symptoms of hypoglycemia (161), reduce hepatic production of glucose and increase ketones (162). Moderate alcohol consumption (6 to 18 g/day) is associated with a 25% to 66% lower risk of total and fatal CHD in persons with type 2 diabetes (163) and, consumed with food, does not cause hyperglycemia or hypoglycemia (164). Daily moderate red wine consumption for 12 months reverses the increased oxidative stress and inflammation associated with MI in persons with type 2 diabetes (165) and shows renoprotective effects and lower blood pressure after 6 months in those with nephropathy; effects not observed with white wine (166). In contrast, visual acuity declines, but retinopathy does not, with increasing amounts of alcohol intake (167). Chronic high intake (∼44 g ethanol per day) is associated with elevated blood pressure and TG in men with type 2 diabetes (168), while light to moderate intake shows an inverse association with A1C (169).

For people with type 1 diabetes, moderate consumption of alcohol with, or 2 or 3 hours after, an evening meal may result in delayed hypoglycemia the next morning after breakfast or as late as 24 hours after alcohol consumption (161,170) and may impede cognitive performance during mild hypoglycemia (171). The same concern may apply to sulphonylurea- and insulin-treated individuals with type 2 diabetes (172). Healthcare professionals should discuss alcohol use with their patients (173) to inform them of the potential weight gain and risks of hypoglycemia (172).

Vitamin and mineral supplements

People with diabetes should be encouraged to meet their nutritional needs by consuming a well-balanced diet by following *Eating Well with Canada's Food Guide* (18). Routine vitamin and mineral supplementation is generally not recommended. Supplementation with 10 μg (400 IU) vitamin D is recommended for people >50 years of age (18). Supplementation with folic acid (0.4 to 1.0 mg) is recommended for women who could become

RECOMMENDATIONS

1. People with diabetes should receive nutrition counselling by a registered dietitian to lower A1C levels [Grade B, Level 2 (3)], for those with type 2 diabetes; Grade D, Consensus, for type1 diabetes] and to reduce hospitalization rates [Grade C, Level 3 (8)].

2. Nutrition education is effective when delivered in either a small group or a one-on-one setting [Grade B, Level 2 (13)]. Group education should incorporate adult education principles, such as hands-on activities, problem solving, role playing and group discussions [Grade B, Level 2 (14)].

3. Individuals with diabetes should be encouraged to follow *Eating Well with Canada's Food Guide* (18) in order to meet their nutritional needs [Grade D, Consensus].

4. In overweight or obese people with diabetes, a nutritionally balanced, calorie-reduced diet should be followed to achieve and maintain a lower, healthier body weight [Grade A, Level 1A (28,29)].

5. In adults with diabetes, the macronutrient distribution as a percentage of total energy can range from 45% to 60% carbohydrate, 15% to 20% protein and 20% to 35% fat to allow for individualization of nutrition therapy based on preferences and treatment goals [Grade D, Consensus].

6. Adults with diabetes should consume no more than 7% of total daily energy from saturated fats [Grade D, Consensus] and should limit intake of trans fatty acids to a minimum [Grade D, Consensus].

7. Added sucrose or added fructose can be substituted for other carbohydrates as part of mixed meals up to a maximum of 10% of total daily energy intake, provided adequate control of BG and lipids is maintained [Grade C, Level 3 (50,51,54,58,60)].

8. People with type 2 diabetes should maintain regularity in timing and spacing of meals to optimize glycemic control [Grade D, Level 4 (132)].

9. Dietary advice may emphasize choosing carbohydrate food sources with a low glycemic index to help optimize glycemic control [type 1 diabetes: Grade B, Level 2 (34,35,169); type 2 diabetes: Grade B, Level 2 (41)].

10. Alternative dietary patterns may be used in people with type 2 diabetes to improve glycemic control, (including):
    a. Mediterranean-style dietary pattern [Grade B, Level 2 (107,108)]
    b. Vegan or vegetarian dietary pattern [Grade B, Level 2 (103,104)]
    c. Incorporation of dietary pulses (e.g. beans, peas, chick peas, lentils) [Grade B, Level 2 (122)]
    d. Dietary Approaches to Stop Hypertension (DASH) dietary pattern [Grade C, Level 2 (118)]

11. An intensive lifestyle intervention program combining dietary modification and increased physical activity may be used to achieve weight loss and improvements in glycemic control and cardiovascular risk factors [Grade A, Level 1A (29)].

12. People with type 1 diabetes should be taught how to match insulin to carbohydrate quantity and quality [Grade C, Level 2 (138)] or should maintain consistency in carbohydrate quantity and quality [Grade D, Level 4 (131)].

13. People using insulin or insulin secretagogues should be informed of the risk of delayed hypoglycemia resulting from alcohol consumed with or after the previous evening's meal [Grade C, Level 3 (170,172)] and should be advised on preventive actions such as carbohydrate intake and/or insulin dose adjustments and increased BG monitoring [Grade D, Consensus].

Abbreviation:
BG, blood glucose.

pregnant (18). The need for further vitamin and mineral supplements needs to be assessed on an individual basis. As vitamin and mineral supplements are regulated as Natural Health products (NHP) in Canada, the evidence for their therapeutic role in diabetes has been reviewed in the Natural Health Products chapter.

Other Relevant Guidelines

Self-Management Education, p. S26
Physical Activity and Diabetes, p. S40
Weight Management in Diabetes, p. S82
Natural Health Products, p. S97
Dyslipidemia, p. S110
Treatment of Hypertension, p. S117
Type 1 Diabetes in Children and Adolescents, p. S153
Type 2 Diabetes in Children and Adolescents, p. S163
Diabetes and Pregnancy, p. S168
Type 2 Diabetes in Aboriginal Peoples, p. S191

Related Websites

- Canadian Diabetes Association (http://www.diabetes.ca)
- Alcohol and Diabetes. Available at: http://www.diabetes.ca/for-professionals/resources/nutrition/alcohol. Accessed March 3, 2013.
- Basic Carbohydrate Counting for Diabetes Management. Available at: http://www.diabetes.ca/for-professionals/resources/nutrition/basic-carb-counting. Accessed March 3, 2013.
- Cholesterol and Diabetes. Available at: http://www.diabetes.ca/for-professionals/resources/nutrition/cholesterol-diabetes. Accessed March 3, 2013.
- Eating Away from Home. Available at: http://www.diabetes.ca/for-professionals/resources/nutrition/eating-away. Accessed March 3, 2013.
- The Glycemic Index. Available at: http://www.diabetes.ca/for-professionals/resources/nutrition/glycemic-index. Accessed March 3, 2013.
- Handy Portion Guide. Available at: http://www.diabetes.ca/diabetes-and-you/nutrition/portion-guide. Accessed March 3, 2013.
- Just the Basics: Tips for Healthy Eating, Diabetes Prevention and Management. Available at: http://www.diabetes.ca/for-professionals/resources/nutrition/just-basics. Accessed March 3, 2013.
- Sugars and Sweeteners. Available at: http://www.diabetes.ca/for-professionals/resources/nutrition/sugars-sweeteners. Accessed March 3, 2013.
- Healthier Cooking Options: Available at: http://www.diabetes.ca/for-professionals/resources/nutrition/healthier-cooking-options. Accessed March 3, 2013.
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