Chapter 6

Nutritional Management of Type 1 Diabetes

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Additional information is available at the end of the chapter

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Abstract

This chapter focuses on medical nutrition therapy (MNT) in type 1 diabetes mellitus (T1DM), which is vital to achieve metabolic control in patients suffering from this disease. The nutritional goals for people with T1DM are reviewed, which aim at maintaining near-normal blood glucose levels by coordinating insulin therapy, diet, and physical activity patterns. A nutrition prescription is given, and recommendations for appropriate MNT in type 1 diabetes are deduced. Glycemic targets in people with T1DM are highlighted; moreover, the principle of carbohydrate consistency and insulin adjustments with food intake are stressed upon. Meal planning approaches to achieve carbohydrate consistency, including carbohydrate counting, exchange system, and sample meal plans, are explained. Weight management, energy requirements, macronutrients and micronutrients needs, as well as nutritional management during exercise and supports take special attention in this chapter.

Information in this chapter is retrieved from evidence-based resources and evidence-based guidelines. If the latter are not available, information retrieved from high-quality research studies, consensus statements, and well-based experts opinions are included.

Keywords: Medical nutrition therapy, type 1 diabetes mellitus, carbohydrate consistency, meal plans

1. Introduction

Management of type 1 diabetes mellitus (T1DM) is a complex task, integrating multiple factors, but it is ultimately centered on the approach to nutrition. Proper attention to diet is a major

factor in minimizing hypoglycemia and weight gain while achieving glycemic control; the latter has been shown to markedly diminish the likelihood of chronic diabetic complications, namely, neuropathy, nephropathy, retinopathy, and coronary artery disease (CAD), in patients with type 1 diabetes [1].

2. General principles of Medical Nutrition Therapy (MNT) in type 1 diabetes

MNT is an integral component of diabetes management and diabetes self-management education. Nutrition advice should be tailored for people with T1DM based on age, medical, lifestyle, and personal factors, taking into account associated diabetes complications and other concomitant conditions for every individual. Consideration should also be given to an individual's culture and beliefs, eating patterns, and food availability [2].

The following aspects should be highly considered:

i. The nutrition prescription: ABC

Optimally manage the "ABCs" of diabetes control:

- Glycated hemoglobin (**A**1C)
- **B**lood pressure
- Low-density lipoprotein (LDL)-**c**holesterol

ii. The nutritional goals for people with type 1 diabetes [3]

- Maintain blood glucose (BG) concentrations in as physiologically a normal range as possible, by coordinating diet and physical activity patterns and insulin therapy.
- Minimize episodes of hypoglycemia.
- Maintain optimal blood pressure and lipid levels.
- Manage weight appropriately by providing adequate calories, thus also ensuring normal growth and development for children and adolescents with T1DM both physically and emotionally.
- Manage risk factors and prevent complications of diabetes.
- Improve overall health through healthful food choices.
- Address individual nutrition needs, incorporating personal and cultural preferences [3].

iii. General recommendations for MNT in type 1 diabetes

Current nutrition recommendations for children and adolescents with diabetes mellitus are rooted in the same principles as those established for all healthy children and adolescents

without diabetes. Individualized meal plans should emphasize a wide variety of healthy food choices to meet the recommended nutrient intakes for essential vitamins and minerals, energy, and fiber and to provide for normal growth and development [4].

The patient should be advised of the following:

- Adhering to the negotiated meal plan
- Adjusting food and/or insulin in response to hyperglycemia
- Adjusting insulin dose for meal size and content
- Appropriately treating hypoglycemia [5]

Glycemic targets in people with diabetes are as follows:

- Fasting BG: 90–130 mg%
- Two-hour postprandial (2 h pp); BG: less than 180 mg%
- Glucose excursion: 2 h pp more than BG before meal by 30–50 mg%
- HBA1c: less than 7 mg% [1]

MNT for type 1diabetes should consider five key aspects:

1. Establishing carbohydrate consistency at meals and snacks
2. Adjusting insulin for variations in blood glucose, food, or physical activity
3. Balancing caloric intake and expenditure for optimum weight management
4. Balancing the nutritional content of selected protein, carbohydrates, and fats
5. Adjusting meal-insulin timing [6]

2.1. Carbohydrate consistency

- Variations in food intake, particularly carbohydrate, should be minimized to avoid fluctuations in blood glucose. Reductions in medication or insulin doses are necessary when there is decrease in carbohydrate intake.
- When using a long-acting basal insulin and a rapid-acting insulin as bolus doses, this allows flexibility in adjustments of insulin dose according to carbohydrate intake. On the other hand, using fixed doses of short- and intermediate-acting insulin require more carbohydrate consistency in timing and amounts.
- Patients who use short-acting insulin analogs or who use insulin pumps may need to take additional bolus insulin injections with snacks that contain more than 10–15 g of carbohydrate [7].

2.2. Meal planning

There are several meal planning approaches to achieve carbohydrate consistency, including [8]

1. carbohydrate counting
2. the exchange system
3. sample meal plans

2.3. Carbohydrate counting

The methods for counting carbohydrate are as follows:

1. **Reading food labels:** looking at the grams of carbohydrates on the label.
2. **Using the exchange system:** estimation of carbohydrate content can be broken down into three food groups that are standardized for carbohydrate content according to particular portions, which are carbohydrate, meat and meat substitutes, and fat. Table1 shows calories and macronutrient content of exchange lists. The exchange lists also identify foods that are good sources of fiber and foods that have high sodium content [9].

Group	Carbohydrate (g)	Protein (g)	Fat (g)	Calories (Cals)
Carbohydrate group				
Starch	15	3	0–1	80
Fruit	15	0	0	60
Milk	15	8	Varies	90–150
Other carbohydrates	15	Varies	Varies	Varies
Nonstarchy vegetables	5	2	0	25
Meat and meat substitutes				
Very lean	0	7	0–1	35
Lean	0	7	3	55
Medium fat	0	7	5	75
High fat	0	7	8	100
Fat group	0	0	5	45

Table 1. Calories and macronutrient content of exchange lists

3. **Use sample meal plans:** These are defined meal menus that specify the time and amounts of food to be eaten at each meal and snack. Dietitians typically tailor the menus to incorporate food preferences and medical nutrition therapy (MNT) goals. Sample menus are created after review of a person's typical food intake; they are best suited for patients who have fairly routine eating habits and who do not eat a wide variety of foods. They also are appropriate for patients who need structured guidance on what to eat [10].

3. Insulin adjustments with food intake

3.1. Advanced carbohydrate counting

At a more advanced level, carbohydrate counting focuses on adjustment of food, insulin, and activity based on patterns from detailed logs. The patient needs to record the time of meals

and snacks, the amount and type of food eaten, the amount of carbohydrate consumed, insulin dose, physical activity, and blood glucose results. Patients should first practice eating consistent amounts of carbohydrate at meals and snacks so that baseline insulin requirements can be matched to usual carbohydrate intake using pre- and postprandial blood glucose testing results. When pre- and postprandial blood glucose levels are in the target range, then insulin-to-carbohydrate ratios can be determined as follows [11]:

Insulin-to-carbohydrate ratios

- Divide the number of grams of carbohydrate eaten at the meal by the number of units of premeal insulin (e.g., 45 g carbohydrate divided by 3 units of insulin is a 1:15 ratio). Insulin-to-carbohydrate ratios can vary with time of day and are affected by stress, illness, and variations in physical activity.
- Insulin-to-carbohydrate ratios can also be calculated using the 450–500 rule:

450–500 rule—calculate the insulin-to-carbohydrate ratio as follows:

Regular insulin-to-carbohydrate ratio = 450 divided by total daily dose (TDD) of insulin.

Rapid acting insulin-to-carbohydrate ratio = 500 divided by TDD of insulin.

- Treatment of hypoglycemia: if the patient is hypoglycemic (blood glucose <70 mg/dL), 10–30 g of fast-acting carbohydrate should be taken. Retesting and retreating is mandatory, without overtreatment, till blood glucose rises >70 mg/dL, then the patient resumes the appropriately calculated insulin doses and carbohydrate requirements [12].

3.2. Weight management in T1DM

The relative importance of caloric intake for an individual patient is dependent on several factors, including the following:

- Current weight in relationship to desirable and healthy body weight (BW)
- Fat distribution and waist circumference
- Glycated hemoglobin (A1C)

Lowering caloric intake and inducing weight loss are of major importance for overweight (body mass index [BMI] ≥25–29.9 kg/m^2) and obese (BMI ≥30 kg/m^2) patients with diabetes because the risk of comorbidities associated with excess adipose tissue increases with BMI in these ranges [13].

In children and adolescents, energy needs can be evaluated by tracking weight gain, BMI, and growth patterns on pediatric growth charts from the Centers for Disease Control and Prevention (CDC) or national growth curves [14].

3.3. Weight gain with intensive insulin therapy

Weight gain is a potential adverse effect of intensive insulin therapy and occurs when insulin dosing matches nutritional intake and glycosuria is eliminated.

If A1C is high enough to promote glycosuria, then lowering calorie intake by an additional 250–300 calories per day is necessary to prevent weight gain with intensification of diabetes therapy. Other strategies to minimize weight gain with intensive therapy are to reduce insulin doses preferentially for patterns of hypoglycemia rather than increasing meal size or adding an undesired snack. To reduce calories further, it is helpful to reduce fat intake and try to keep carbohydrate intake consistent to minimize risk of hypoglycemia [15].

3.4. Total energy expenditure

Easiest way to calculate: 20–35 Cal/kg current weight/day

If the patient's current weight is more than 30% of his ideal BW, it is better to use adjusted BW (ABW)

- ABW = (current BW – ideal BW) × 0.25 + ideal BW

4. Estimating caloric needs to promote weight loss

If 500–1000 calories are subtracted from weight maintenance calories every day, this would lead to loss of 1–2 pounds per week. Low-calorie diets (less than 1200 kcal/day) should be avoided to be sure that nutritional needs are met [16]

4.1. Nutritional content in T1DM

- The optimal macronutrient composition of the diet for patients with diabetes is controversial.
- The mix of dietary carbohydrate, protein, and fat may be adjusted to meet the metabolic goals and individual preferences of the person with T1DM, but in general, daily energy intake should be targeted to include 50–55% carbohydrate, 10–15% protein, and 30–35% fat [3].
- Low-fat, low-carbohydrate, Mediterranean, and vegetarian diet are all acceptable.
- Individualized meal planning should include optimization of food choices to meet the recommended daily allowance (RDA)/dietary reference intake (DRI) for all micronutrients [3]

4.2. Carbohydrates (CHO)

- The RDA/DRI is 60 g for infants 0–6 months, 95 g for infants 7–12 months, and 130 g for children and adolescents. Diets containing less than 130 g of CHO for children older than 1 year may not provide adequate glucose as fuel for the central nervous system without relying on gluconeogenesis from ingested protein and fat. Low-carbohydrate diets also restrict intake of essential nutrients, energy, and fiber from carbohydrates found in whole

grains, fruits, vegetables, dried peas and beans, legumes, nuts and seeds, and low-fat milk and yogurt.

- Monitoring carbohydrate, whether by carbohydrate counting, a choice, or experience-based estimation, remains a key strategy in achieving glycemic control. Monitoring carbohydrate intake is important as it directly determines postprandial blood sugar, and consequent insulin adjustment can improve glycemic control [16].
- For individuals with diabetes, the use of glycemic index and glycemic load may provide a modest additional benefit for glycemic control over that observed when total carbohydrate is considered alone. Meals with low glycemic index and glycemic load leads to better glycemic control.
- Carbohydrates from fruits, vegetables, whole grains, legumes, and low-fat milk are preferable.
- Nonnutritive sweeteners are safe when consumed within daily levels established by the US Food and Drug Administration (FDA). Consumption of nonnutritive sweeteners does not increase blood glucose concentrations or affect insulin response in adults, although no similar data are available in children. When calculating carbohydrate content of foods, one-half of the sugar alcohol content should be counted in the total carbohydrate content of the food. Careful reading of food labels is always recommended for foods containing nonnutritive sweeteners as they still contain carbohydrates [17].

4.3. Sucrose

- Intake of sucrose does not need to be restricted, although care should be taken to avoid excess calories; sucrose can be substituted for other carbohydrate sources in the meal plan or, if added, covered with insulin. Sucrose-containing foods typically provide additional calories from fats and are frequently devoid of essential nutrients. Nutrition therapy strategies should focus on consuming these foods in moderation in the context of a healthy well balanced diet. Use of added fructose as a sweetener is not recommended, as it may adversely affect lipids, but there is no need to avoid fructose occurring naturally in fruits and vegetables [18].

4.4. Fats

- Because of the increased risk of cardiovascular disease in people with T1 DM, nutrition therapy also emphasizes a diet low in *saturated fat*, as outlined by the National Cholesterol Education Program and the American Heart association, for all children and adolescents. Saturated fat intake should be less than 7% of total calories. Saturated fats (eg, in fatty and processed meats, butter, lard, hydrogenated fats, coconut and palm oils, cheese, ice cream, and other high-fat dairy products) can be replaced with monounsaturated (about 20%) and polyunsaturated fatty acids (eg, in fish, olive oil, nuts) (about 10%) due to their relatively cardioprotective profile. Sources include olive, canola and peanut oils; olives; nuts; seeds; and avocados.

- Reducing intakes of trans-fatty acids lowers low-density lipoprotein and increases high-density lipoprotein; therefore, intake of trans-fatty acids should be minimized. Added trans-fatty acids are found in margarine and processed and commercially prepared foods. Total cholesterol should be less than 200 mg daily. Dietary cholesterol is only found in foods of animal origin.
- Omega 3 fatty acids, specifically eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), have emerged as important dietary adjuncts for individuals at risk of cardiovascular disease and in adults who have already experienced a cardiovascular event. The American Heart Association currently recommends marine-derived omega-3 fatty acids as a dietary adjunct to aid in reduction of serum triglycerides, which can safely be used in children with diabetes and hypertriglyceridemia. Eating two or more servings of fish per week is recommended to provide an excellent source of omega-3 fatty acids. Other potent sources are salmon, tuna, herring, sardines, mackerel, flax seeds and oil, various nuts, and canola and soybean oil [19].

4.5. Proteins

- In individuals with normal renal function, protein intake is based on the RDA for all children and adolescents. The usual daily intake of protein should be approximately 10–25% of total caloric intake (1.1 gm/kg/d).
- Patients should be encouraged to substitute lean meats, fish, eggs, beans, peas, soy products, low-fat dairy products, legumes and nuts, and seeds for red meat.
- Protein intake should not be used to treat hypoglycemia or prevent hypoglycemia overnight.
- In patients with microalbuminuria, a reduction of protein to 0.8–1 g/kg/d of body weight may slow the progression of nephropathy. Overt nephropathy necessitates reduction of protein to 0.8 g/kg/d [20].

4.6. Fiber

- Fiber intake should be at least 14 g per 1000 calories daily, or approximately 19–38 g of fiber/day. High-fiber diets have been demonstrated to decrease postprandial glucose concentrations among adolescents with T1DM. Dietary fiber is found in whole grains, fruits, vegetables, dried peas, beans, legumes, nuts, and seeds. Soluble fiber sources should be emphasized because studies in people without diabetes show that diets high in total and soluble fiber (7–13 g) can reduce total cholesterol by 2–3% and LDL cholesterol up to 7%. Potent sources of soluble fiber include oatmeal, oat cereal, lentils, apples, oranges, pears, oat bran, strawberries, nuts, flaxseeds, beans, dried peas, blueberries, cucumbers, celery, and carrots [21].

4.7. Sodium

- A reduced sodium intake of 2300 mg per day is advised, which is the same for healthy children and adolescents. However, for individuals with hypertension, further reduction to 1500 mg/day is recommended.

- Avoidance of processed foods, restaurant and fast foods, and soda beverages and preparations containing preservatives is advisable due to high content of sodium [19].

4.8. Micronutrients

- Routine supplementation with antioxidants, such as vitamins E and C and beta-carotene, is not advised because of lack of evidence of efficacy and concerns related to long term safety.
- Low serum 25-hydroxyvitamin D concentrations are globally associated with children and adolescents with T1DM. Vitamin D screening and supplementation should therefore be considered and should be meeting the RDA of 600 IU vitamin D per day.
- Supplementation with vitamins and micronutrients in general is not necessary if a well-balanced, healthy diet is consumed unless there are underlying deficiencies [21].

5. Glycemic index

A food's GI is a numeric value that reflects its glycemic response in comparison to that of a reference food, such as pure glucose. The GI of the reference food is set at 100. When glucose is used as a reference food, foods with GI>70 are considered high-glycemic index, while Foods with GI<55 are considered low-glycemic index. Some examples of low-glycemic index foods include nonstarchy vegetables, nuts, legumes, and certain grains such as barley and converted rice. High glycemic index foods include potatoes, candies, white bread, and other refined products made from grains [22].

6. Glycemic load

Glycemic load is the product of the glycemic index value of a food and its total carbohydrate content. The concept of the glycemic load was developed because the blood glucose response is influenced not only by the quality of the carbohydrate consumed (i.e., the glycemic index) but also by the quantity of carbohydrate consumed.

The glycemic index and glycemic load may have far greater health implications than glycemic control alone. Several prospective studies have associated diets high in glycemic index and glycemic load with an increased risk of developing type 2 diabetes, coronary heart disease, and some cancers. Data also suggest that low-glycemic load diets are particularly effective among the most susceptible individuals, those who are already overweight and insulin resistant [22].

7. Eating disorders

Eating disorders are relatively common in patients with diabetes, especially in female adolescents and young adults with diabetes. Dieting or omission of insulin for weight loss and binge

eating are the most common. Eating disorders have a deleterious impact on glycemic control and on long-term outcome in these patients. It is important to evaluate patients with diabetes, especially young women, for an eating disorder (or misreporting of insulin administration) and arrange appropriate psychological and nutritional counseling and support when indicated [23,24].

8. Promoting dietary compliance

- Gradual behavioral and dietary changes should be advised to move the patient toward a more ideal diet and eating pattern.
- The patient's own food records and motivation to learn can be helpful in guiding decisions for meal planning approaches
- Motivating a patient to make a long-term commitment to dietary alterations is a challenge. Achieving and maintaining weight reduction is difficult in any obese patient. Compliance can occasionally be enhanced by the rapid and often dramatic improvements in glycemic control.
- Diabetes Education Workshops for small groups of patients is highly effective.
- Exercise can increase the degree of weight loss, and the likelihood that it will be maintained.
- Offering varieties of lists of meal plans is very helpful
- Adjustment of diet, exercise, and insulin doses according to the patient's changing lifestyle patterns is mandatory to maintain glycemic control and prevent acute and chronic complications [1,25-27].

9. Physical activity in patients with T1DM

Exercise is a significant component of diabetes management [28,29].

9.1. Benefits of exercise

- Improved glycemic control
- Weight control
- Reduction in comorbidities (hypertension, dyslipidemia, and cardiovascular disease)
- Improved mood and quality of life

9.2. General tips for physical activity in T1DM

- Patients with T1DM should engage in 30 min or more of moderate intensity physical activity on most days of the week. Individuals for whom weight loss and weight maintenance are a concern, may need 60–90 min of moderate to vigorous intensity activity 3 days a week.
- For patients who are trying to lose weight, it is preferable to adjust insulin doses rather than increase food intake to compensate for exercise.
- Timing of exercise in relation to insulin dose, type, mode of delivery, and time of injection should be considered.
- Patients with diabetes should check blood sugar levels before and after exercising, especially in the beginning of an exercise program, to evaluate glycemic response to exercise and adjust insulin regimen [28, 29].

9.3. Diabetes and sports

Athletes need additional blood glucose testing prior to exercise, during exercise (especially exercise lasting greater than 60 min), immediately after exercise, several hours after exercise, and at any time significant changes in intensity, type, or duration of exercise are made. If blood glucose is less than 100 mg/dL, CHO intake of 15–40 mg is important before exercise. If blood glucose is high, urine ketones should be tested and exercise prevented until ketones disappear by insulin and medication adjustments. In absence of ketones, exercise with caution can be allowed [28, 29].

9.4. General nutritional tips for performance of sports in T1DM

- Preactivity meals (1–2 h before exercise) should be relatively high in carbohydrate, moderate to high in protein and low in fat.
- Protein of high biological value (1 gram of protein per pound of body weight) should be used.
- Protein shake can be used before workout (a shake containing at least 6 g of amino acids—the muscle-building blocks of protein—and 35 g of carbohydrates 30–60 min before exercising increases protein synthesis more than drinking the same shake after training.
- Good-quality whey-protein powders usually contain at least 30 g of protein per serving, as well as a healthy supply of vitamins and minerals.
- Weight-gain powders can also provide a lot of high-quality protein and nutrients in each serving, but they also tend to be extremely high in calories, carbohydrates, and sugar.
- Vigorous exercise involving a muscle group shortly after having injected insulin near to that area could cause the insulin to be absorbed more rapidly than usual, increasing the chances of hypoglycemia.
- Competitive/power exercise can lead to hyperglycemia.

- Individual reactions may vary, and so it is best to verify this by checking blood glucose levels before the burst of activity and about 30 min after, to see how the body responds.
- Warming up is necessary to reduce injury

9.5. During exercise

- During exercise lasting more than 30 min, 15–30 gm CHO should be consumed every 30–60 min.
- Sport drinks, dilute juices, sport bars, and/or high fiber cookies should be carried in a food bag to be consumed during exercise.
- Keeping hydrated by drinking around 150 ml of fluid every 15 min is advised.
- CHO foods should be available during and after exercise.

9.6. After exercise

- After a period of strenuous activity or a long period of exercise, blood sugar levels can drop for up to 48 h. Management includes reducing insulin requirements or dosage of antidiabetic drugs over this period, or take more carbohydrate.
- A high-quality protein meal should be consumed after training.
- Omega-3 fatty acids are beneficial.
- Rest: a full-body workout should be followed by a day of rest or alternatively, at least 3 days of rest each week is advised [28, 29].

10. Summary and conclusion

Achieving metabolic control in patients with T1DM cannot be reached except with proper medical nutrition therapy. Nutrition advice should be customized according to age, medical condition, lifestyle, and personal factors. The nutritional goals for people with type 1 diabetes are to maintain blood glucose (BG) concentrations in a physiologically normal range as possible, by coordinating diet and physical activity patterns and insulin therapy, minimizing episodes of hypoglycemia, maintaining optimal blood pressure and lipid levels, and managing weight appropriately, and by providing adequate calories, thus also ensuring normal growth and development for children and adolescents with T1DM both physically and emotionally. Although a focus on careful carbohydrate counting is integral to insulin delivery and glycemic control for patients with T1DM, many of the other fundamental principles of nutrition management are important to be considered. The patient should be advised for adhering to the negotiated meal plan, adjusting food and/or insulin in response to hyperglycemia, as well as adjusting insulin dose for meal size and content and appropriately treating hypoglycemia. Proper estimation of energy requirements, macronutrients, and micronutrients needs as well as adjustment of MNT during exercise and sports are all of high importance. A team approach,

capitalizing on the expertise of pediatric and adult dietitians, psychologists, nurses, and physicians, can best assist patients and their families overcome challenges in their care and reach their therapeutic goals.

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