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UPDATE

Diet and exercise are a fundamental part of comprehensive care for type 2 diabetes

In this modern era, numerous innovative glucose-lowering medications have emerged, leading to a wide range of treatment options for type 2 diabetes mellitus. While pharmacologic interventions are crucial for achieving glycemic control in type 2 diabetes mellitus, it is essential to recognize the fundamental role of lifestyle modifications in attaining glycemic targets. Among various lifestyle modifications, dietary adjustments and exercise hold significant importance in the management of type 2 diabetes mellitus, offering numerous benefits such as improved glycated hemoglobin (HbA1c) levels and a reduced risk of cardiovascular events.

Appropriate medical nutrition therapy has been shown to reduce HbA1c levels by 0.3–2.0% in patients with type 2 diabetes mellitus[1]. Even after initiating medication, nutrition therapy continues to play a crucial role in the overall management of diabetes. In an animal study involving mice, it was observed that the use of sodium–glucose cotransporter 2 inhibitors (SGLT-2i) in conjunction with controlled feeding led to weight loss and a decrease in hepatic gluconeogenic response. However, these effects were diminished in a group of mice with unrestricted access to food[2]. This suggests that dietary control remains essential when combined with glucose-lowering medications such as SGLT-2i for optimal glycemic control.

Currently, there is no specific recommendation for the ideal percentage of calories from carbohydrates, proteins, and fats for individuals with diabetes based on existing evidence. Instead, the emphasis is on developing individualized nutrition plans. While there is no specific ideal percentage for the nutritional components in the diet of individuals with type 2 diabetes mellitus, there are general recommendations that can be followed. These recommendations emphasize the importance of consuming non-starchy vegetables, minimizing the intake of added sugars and refined grain, and opting for whole foods instead of highly processed foods[3,4]. Some studies have revealed that exogenous ketone ingestion would decrease the blood sugar level which may be related to an increase of early phase insulin[5,6]. Still, evidence for prolonged ketone ingestion for blood glucose is limited[6]. There are also several eating patterns that have been proposed for individuals with type 2 diabetes mellitus. These include the Mediterranean diet, low-carbohydrate diet, fiber-rich diet, intermittent very-low-calorie diet, and vegetarian or plant-based diet (Table 1)[7–16]. Some of these eating patterns have also been associated with a lower risk of developing type 2 diabetes mellitus in healthy individuals[8,10].

Excessive alcohol intake should be avoided in individuals with type 2 diabetes mellitus due to several reasons. First, it increases the risk of hypoglycemia in patients with type 2 diabetes mellitus. Furthermore, alcohol consumption has been associated with impaired fasting glucose in non-diabetic individuals. This suggests that alcohol may disrupt glucose homeostasis and lead to fluctuations in blood glucose levels[7,17].

To determine individual nutrition needs in individuals with type 2 diabetes mellitus requires the consideration of various factors. These factors include the patient's age, body weight, appetite, presence of diabetic complications, co-morbidities, overall health status, cultural food preferences, existing barriers to dietary changes, and access to healthy food options. Nutritional education and intervention play a vital role in the management of type 2 diabetes mellitus. Evidence has shown that frequent nutrition education or interventions can reduce the risk for diabetic kidney disease in patients with type 2 diabetes mellitus[18]. Additionally, providing nutritional counseling can help to decrease the discontinuation rate of physician visits in newly diagnosed diabetes patients[19]. In a study, dietary interventions with the support of dieticians have been shown to improve dietary habits and to reduce calorie intake in patients with type 2 diabetes mellitus[20]. Therefore, diet control is an integral part of the comprehensive care of individuals with type 2 diabetes mellitus, and the involvement of dieticians in the management of patients with diabetes is crucial. Dieticians can provide personalized nutritional guidance, monitor dietary changes, and help patients to make sustainable modifications to their eating habits.

In addition to diet control, exercise plays an important role in the management of type 2 diabetes mellitus. Previous study has shown that an exercise intervention of at least 8 weeks can lead to an average reduction of 0.66% in HbA1c levels in individuals with type 2 diabetes mellitus[21]. Regular exercise not only improves blood glucose levels but also reduces cardiovascular risk factors and contributes to weight loss. Moreover, physical activity also demonstrated the benefits for diabetic neuropathy in a previous study[22]. In that study, type 2 diabetes mellitus was associated with neuropathy and a progressive loss of corneal nerve fibers. However, engaging in physical activity has been found to prevent significant corneal nerve fiber loss in individuals with type 2 diabetes mellitus. Therefore, it is important to avoid prolonged sedentary time and to maintain regular physical activity in patients with diabetes.

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Table 1 | Studies comparing the effects of different eating patterns that provide benefits for patients with type 2 diabetes mellitus

Study	Subjects	Intervention	Component	Duration	HbA1c	FPG
Westman *et al.*[11]	29 patients with type 2 diabetes mellitus 21 patients with type 2 diabetes mellitus	LCD LGID	LCD: Aim for <20 g carbohydrates/day LGID: 55% carbohydrates	24 weeks	↓ NS	↓ ↓
Barnard *et al.*[12]	49 patients with type 2 diabetes mellitus 50 patients with type 2 diabetes mellitus	Vegan diet Conventional diet	Vegan diet: 75% carbohydrate 10% fat, 15% protein Conventional diet: 60–70% carbohydrates, <7% saturated fat, 15–20% protein	74 weeks	↓ NS	↓ NS
Esposito *et al.*[13]	108 patients with type 2 diabetes mellitus 107 patients with type 2 diabetes mellitus	Mediterranean diet LFD	Mediterranean diet: <50% of energy from carbohydrates, >30% fat (30–50 g olive oil) LFD: <30% of energy from fat, <10% saturated fat	4 years	↓ ↓	↓ ↓
Kahleova *et al.*[14]	37 patients with type 2 diabetes mellitus 37 patients with type 2 diabetes mellitus	Vegetarian diet Conventional	Vegetarian diet: 60% carbohydrates, 25% fat, 15% protein Conventional: 50% carbohydrates, 30% fat, 20% protein	24 weeks	↓ NS	↓ NS
Yamada *et al.*[15]	12 patients with type 2 diabetes mellitus 12 patients with type 2 diabetes mellitus	LCD CRD	LCD: 70–130 g/day carbohydrates CRD: Total daily calorie intake (kcal) = ideal body weight×25, 50–60% carbohydrates, <25% fat, <20% protein	6 months	↓ NS	↓ NS
Rock *et al.*[16]	67 patients with type 2 diabetes mellitus 66 patients with type 2 diabetes mellitus 65 patients with type 2 diabetes mellitus	LFD LCD Conventional diet	LFD: 60% carbohydrates, 20% fat, 20% protein LCD: 45% carbohydrates, 30% fat, 25% protein Conventional diet: 55% carbohydrates, 30% fat, 15% protein	12 months	NS ↓ NS	NS NS NS
Umphonsathien *et al.*[9]	14 patients with type 2 diabetes mellitus 14 patients with type 2 diabetes mellitus 12 patients with type 2 diabetes mellitus	VLCD (2 days/week) VLCD (4 days/week) Conventional	Very low calorie diet, 600 kcal diet per day 55% carbohydrate, 15% protein and 30% fat Conventional diet: normal diet of 1,500–2,000 kcal/day	20 weeks	NS ↓ NS	NS ↓ NS

CRD, calorie restricted diet; FPG, fasting plasma glucose; HbA1c, glycated hemoglobin; LCD, low carbohydrate diet; LFD, low fat diet; LGID, low glycemic index diet; NS, no significant change; VLCD, very low calorie diet.

Current guidelines suggest that most adults with type 2 diabetes mellitus should engage in at least 150 min of moderate to intensive exercise spread over at least 3 days per week[7]. It is advised to avoid more than 2 consecutive days without exercise. Additionally, individualized exercise intensity is encouraged, taking into account factors such as age, co-morbidities, diabetic complications, health status, and exercise preferences. For example, individuals with proliferative diabetic retinopathy should avoid vigorous exercise due to the risk of vitreous hemorrhage.

A study conducted on elderly pre-diabetic patients found that the type of exercise did not significantly affect the glucose response to exercise[23]. However, it was observed that initial poor HbA1c levels and a high body mass index were associated with a poor response to exercise in terms of blood glucose tolerance and HbA1c reduction. Therefore, in addition to exercise, weight management and glycemic control remain essential aspects of the management of type 2 diabetes mellitus.

While exercise is essential for glycemic control, it can also lead to hypoglycemia. Patients with autonomous neuropathy or those using insulin or insulin secretagogues are at a higher risk of experiencing hypoglycemia after exercise. If the pre-exercise blood glucose level is below 90 mg/dL, carbohydrate supplementation, and lowering the dosage of insulin or of insulin secretagogues should be considered[24].

In conclusion, there are numerous concepts and new approaches in the treatment of type 2 diabetes mellitus. Lifestyle modifications, particularly dietary adjustments and exercise, remain foundational components alongside the wide array of novel glucose-lowering medications. However, there is no universally ideal diet that suits every patient. Current evidence emphasizes the importance of individualized

plans for diet and exercise tailored to each individual's specific needs.

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DISCLOSURE

The authors declare no conflict of interest.
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