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Review

Dietary patterns and type 2 diabetes: A narrative review

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ABSTRACT

The global prevalence of type 2 diabetes (T2D) continues to rise, posing a significant public health challenge worldwide. In recent years, modifications to dietary patterns have emerged as a promising strategy for the prevention and management of T2D. Evidence suggests that different dietary patterns exert varying effects on key metabolic indicators such as blood glucose, glycated hemoglobin (HbA1c), and insulin sensitivity. This narrative review summarizes current findings on the associations between several major dietary patterns—including vegetarian, omnivorous, low-carbohydrate, Mediterranean, Dietary Approaches to Stop Hypertension (DASH), and Western diets—and T2D-related outcomes, while also identifying limitations in the existing literature. Healthy dietary patterns, particularly vegetarian, low-carbohydrate, Mediterranean, and DASH diets, have been shown to effectively reduce HbA1c levels, enhance insulin sensitivity, and support weight management. In contrast, excessive consumption of Western diets and ultra-processed foods is consistently linked to a heightened risk of T2D. However, inconsistencies in study design, population characteristics, and definitions of dietary patterns hinder direct comparisons across studies. To advance the field, future research should prioritize long-term, standardized, and cross-national randomised controlled trials to elucidate the distinct nutritional and biological mechanisms underlying each dietary approach. These efforts are crucial for developing practical, evidence-based dietary guidelines aimed at reducing the global burden of T2D.

Introduction

Type 2 diabetes (T2D) is a chronic metabolic disorder characterized by impaired insulin utilization and/or insufficient insulin secretion, leading to sustained hyperglycemia. It represents one of the most pressing global public health challenges, with both prevalence and incidence rates continuing to rise. According to the International Diabetes Federation Diabetes Atlas, the number of adults living with diabetes reached 536.6 million in 2021 and is projected to increase to 783.2 million by 2045 [1]. As far as both the prevention and management of T2D are concerned, dietary patterns play a crucial role, primarily through the strategic combination and regulation of nutrient intake. Recent evidence highlights that dietary pattern modification and nutritional optimization are effective strategies for reducing T2D risk and constitute essential components of comprehensive diabetes management [2]. Specific dietary approaches, including vegetarian, Mediterranean, and Dietary Approaches to Stop Hypertension (DASH) patterns, have demonstrated similar benefits in improving glycaemic control, decreasing dependence on antidiabetic medications, and mitigating T2D risk [3]. For example, adherence to a vegetarian diet in combination with physical activity has been shown to enhance insulin sensitivity and reduce both glycated hemoglobin (HbA1c) levels and insulin resistance compared to conventional diabetes diets [4]. Likewise, the Mediterranean dietary pattern has been associated with significant reductions in HbA1c and low-density lipoprotein cholesterol (LDL-C) levels among individuals with T2D [5].

Understanding and addressing detrimental dietary behaviors are equally important for optimizing T2D outcomes and preventing complications. Diets high in sugar and fat and low in fiber have been linked to the development and exacerbation of T2D. Excessive caloric intake and overnutrition contribute to insulin resistance through various physiological pathways, resulting in impaired insulin secretion, poor glycemic control, obesity, and increased risk of nephropathy and cardiovascular diseases [2]. High saturated fat intake, in particular, has been identified as a critical factor contributing to insulin resistance in individuals with T2D [6]. Moreover, obesity is a well-established risk factor for T2D, and when both conditions co-exist, they compound impairments in insulin action and β-cell function. This interaction intensifies insulin resistance in hepatic tissues and significantly influences the transition from prediabetes to overt T2D [7,8]. This narrative review therefore, aims to explore how different dietary patterns

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relate to T2D risk and to critically evaluate the existing body of evidence to inform future research directions and dietary interventions in the context of T2D prevention and management.

Overview of associations between diet and T2D

Diets play an important role in influencing the onset and risk of T2D (Table 1, Fig. 1). A growing body of evidence indicates that vegetarian, low-carbohydrate, Mediterranean, and DASH dietary patterns exert beneficial effects on metabolic indicators among individuals with T2D, particularly in improving HbA1c levels. Features of these dietary patterns are shown in Table 2. All of them share core principles, including a high intake of vegetables and fruits, increased dietary fiber, reduced total fat intake, and a consistent limitation of saturated fats and red meat. However, the extent to which differences in baseline glycemic control, participant characteristics, and intervention protocols influence these outcomes remains unclear. Conversely, numerous observational studies have identified a significant association between Western dietary patterns—characterized by high consumption of red and processed meats, refined sugars, and fried foods—and an elevated risk of T2D. Similarly, the consumption of ultra-processed foods (UPFs) has been positively correlated with increased T2D incidence. Nevertheless, the observational nature of many of these studies introduces potential confounding by uncontrolled variables such as lifestyle and physical activity levels, limiting the ability to infer causality. As a result, it remains uncertain whether unhealthy diets directly cause T2D or primarily contribute to the deterioration of glycemic control over time. In an earlier study [9], maintaining carbohydrate control for a duration of up to 6 mo was found to result in significant improvements in HbA1c levels, underscoring the importance of long-term, sustainable dietary management in T2D interventions. T2D is also closely linked to obesity, wherein excess adipose tissue promotes insulin resistance through inflammatory and immune-mediated mechanisms. Physical activity plays a complementary role by enhancing insulin sensitivity and mitigating metabolic risks [10]. Accordingly, many intervention studies employ durations of at least 6 mo to better assess the real-world impact of dietary adherence while highlighting the critical role of sustained lifestyle modification [4,11–13].

From a long-term health management perspective, consistent adherence to a healthy dietary pattern is considered vital for both the prevention and treatment of T2D. Achieving adequate glycaemic control not only reduces T2D risk but also enhances insulin sensitivity and lowers the likelihood of diabetes-related complications [2]. Diets characterized by restricted carbohydrate intake and elevated fiber content have been shown to reduce T2D risk in high-risk populations and improve HbA1c levels and cardiovascular health parameters [9,14]. Comparative analyses suggest that both low-carbohydrate diets (LCDs) ($<$25% of total energy intake) and Mediterranean diets confer greater short-term ($\leq$12 mo) improvements in HbA1c relative to other dietary patterns, likely due to improved carbohydrate regulation and higher fiber intake [5,15].

T2D is increasingly recognized as a metabolic disorder accompanied by chronic inflammation. Excessive macronutrient intake may stimulate pro-oxidative and pro-inflammatory responses, leading to the elevated production of reactive oxygen species (ROS) in adipose tissue. This, in turn, activates oxidative stress and inflammatory signaling pathways, resulting in increased levels of tumor necrosis factor-alpha and interleukin-6, which inhibit insulin signaling and are associated with higher body mass index (BMI) [16,17]. Additionally, sustained intake of high-fat and high-glycaemic foods can elevate fasting insulin levels—often without concurrent increases in blood glucose—leading to enhanced adipocyte storage activity and exacerbated insulin resistance [18]. Obesity and insulin resistance are both critical in the progression of T2D, with insulin resistance occurring predominantly in overweight and obese individuals. These conditions, driven by excessive caloric intake, increase the risk of visceral fat accumulation and hepatic and muscular triglyceride deposition, thereby promoting β-cell dysfunction and accelerating T2D development [8,17]. Accordingly, this review recognizes diet-induced obesity and increased BMI as central risk factors in T2D pathogenesis. Recently, Mohammad [19] noted that a fiber-rich, low-fat, and balanced diet is widely regarded as a primary strategy for T2D prevention and management. Effective interventions also emphasize the synergistic effect

Table 1
The impact of different dietary aspects on T2D and the underlying mechanism of action

Dietary aspect	Potential impact on T2D	Mechanisms of action
Carbohydrate quantity	High intake of refined carbohydrates increases T2D risk; moderate restriction may improve glycaemic control	Excess glucose elevates postprandial blood sugar and insulin demand; low intake reduces glycaemic excursions
Carbohydrate quality	Low-glycaemic index/load carbs (e.g., whole grains, legumes) reduce T2D risk	Slower glucose absorption improves insulin sensitivity and reduces postprandial spikes
Dietary fiber	High fiber intake is protective against T2D	Dietary fiber improves insulin sensitivity, modulates gut microbiota, slows glucose absorption
Total fat intake	Excess total fat may contribute to insulin resistance (context-dependent)	Excess total fat intake may lead to lipid accumulation in liver and muscle, impairing insulin action
Fat quality	Unsaturated fats (MUFA/PUFA) reduce risk; saturated and trans fats increase risk	Unsaturated fats improve lipid profile and insulin function; saturated fats promote inflammation
Protein intake	Adequate intake may support glucose regulation; excess from red/processed meats increases risk	Plant-based proteins may enhance insulin sensitivity; red meats linked to inflammation and oxidative stress
Energy density	Increases risk of T2D through obesity and metabolic overload	Excess energy intake promotes weight gain, visceral fat accumulation, and systemic insulin resistance
Micronutrient intake	Deficiencies in magnesium, vitamin D, chromium, etc. linked to higher T2D risk	These nutrients play roles in insulin secretion and glucose metabolism
Meal frequency and timing	Irregular meals and late-night eating may worsen insulin sensitivity	Irregular meals and late-night eating disrupt circadian rhythm and insulin-glucose homeostasis
Ultra-processed food (UPF) intake	High UPF intake significantly increases T2D risk	UPFs are energy-dense, low in fiber and micronutrients, and may alter gut microbiota and satiety signaling
Sugar-sweetened beverage consumption	Strongly associated with increased T2D risk	Rapid glucose absorption increases insulin demand; high fructose intake linked to hepatic insulin resistance
Alcohol consumption	Moderate intake may be neutral or protective; heavy use increases risk	Excess alcohol impairs hepatic glucose metabolism and contributes to weight gain

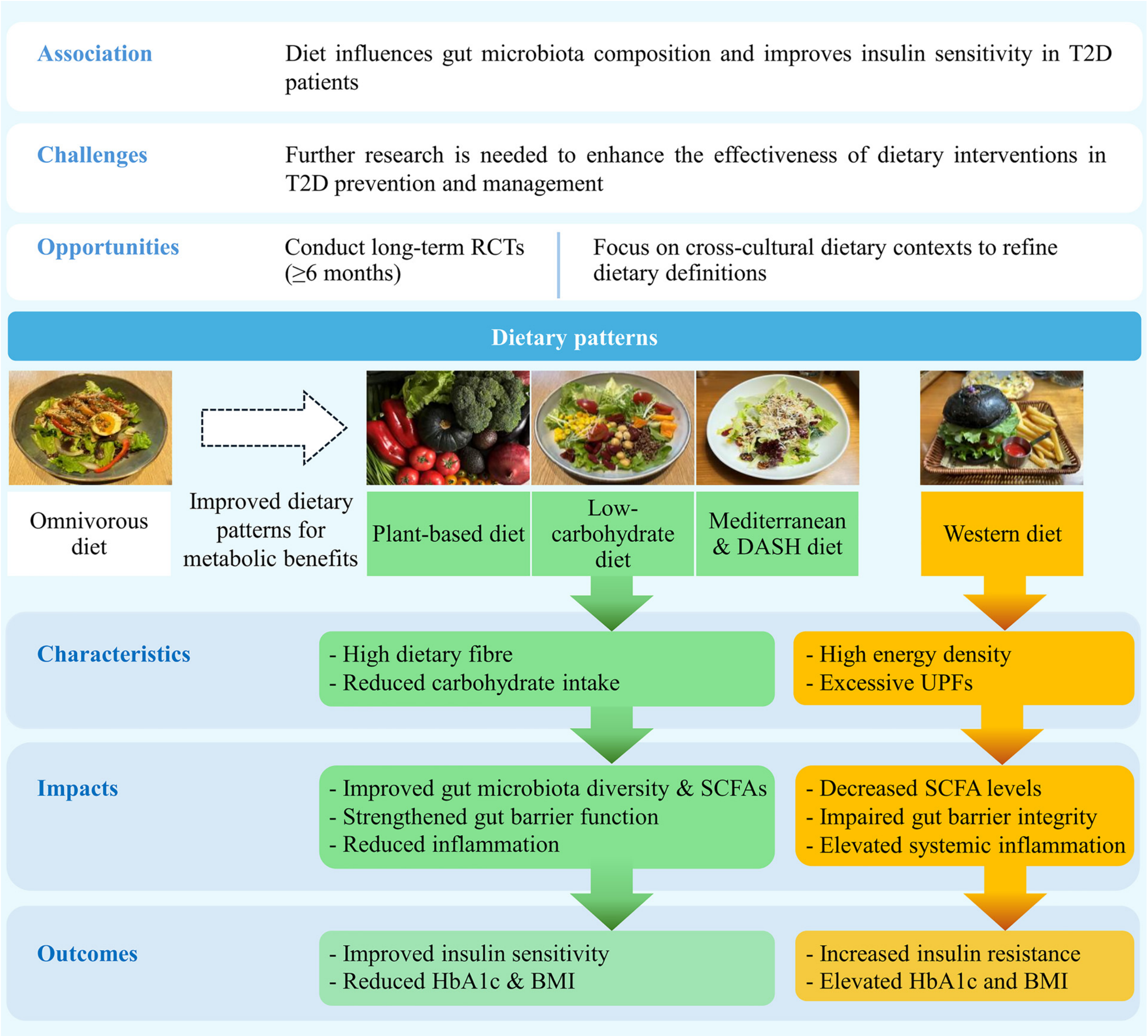

Fig. 1. A summary of the impact of dietary patterns on the risk of T2D.

of a balanced diet and physical activity in BMI control and glycemic regulation. However, several studies suggest that the association between the Western dietary pattern and T2D risk extends beyond low fiber intake. The potential metabolic harm of UPFs—typically high in sugar, fat, and additives—has emerged as a significant concern [20–22].

Dietary patterns and the risk of T2D

Plant-based diets

A vegetarian diet generally refers to a plant-based dietary pattern that restricts or excludes animal products (such as meat, fish, and poultry) and emphasizes foods rich in dietary fiber, including vegetables, fruits, whole grains, legumes, nuts, and seeds [23]. A previous study by Tonstad et al. [24] has demonstrated the potential of vegetarian diets in promoting weight management and preventing obesity. These benefits are partly attributed to the high fiber content of vegetarian diets, which may reduce fasting plasma total cholesterol by limiting gastrointestinal cholesterol absorption, thereby enhancing glycemic control and lowering T2D risk [23]. Craig [25] further noted that vegetarian diets are typically low in saturated fat and cholesterol; however, individuals following such diets should carefully monitor their intake of critical nutrients such as vitamin B12 and omega-3 fatty acids to prevent potential deficiencies.

Evidence from randomized controlled trials (RCTs) supports the beneficial effects of vegetarian diets in individuals with T2D. In a study comparing a vegetarian diet with a conventional diet aligned with the American Diabetes Association guidelines, Barnard et al. [12] found that the vegetarian group exhibited significantly greater intakes of total dietary fiber, vegetables, and fruits. These dietary changes were accompanied by improvements in HbA1c levels (−0.4%), total cholesterol, and LDL-C. Similarly, in an RCT involving obese patients with T2D, Kahleova et al. [4] reported that adherence to a vegetarian diet combined with personalized physical activity over 13 to 24 wk led to a 43% reduction in the use of diabetes medication, along with notable improvements in HbA1c (−0.65%), insulin sensitivity, and BMI. Consistent findings from meta-analyses support these observations. For example, Yokoyama

Table 2
Features of major dietary patterns

Dietary pattern	Key features
Omnivorous diet	– Includes both plant-based and animal-based foods (e.g., meat, dairy, eggs) – Nutrient composition varies widely depending on dietary quality – May range from healthy (e.g., balanced or prudent diets) to unhealthy (e.g., Western diet) – Often used as the baseline or control diet in studies
Plant-based diet	– Emphasizes fruits, vegetables, legumes, whole grains, nuts, and seeds – Excludes or limits animal products (meat, fish, dairy) – Typically high in fiber and phytonutrients – Low in saturated fat and cholesterol – May pose a risk of vitamin B12, omega-3, and iron deficiencies if not well-planned
Western diet	– High in red and processed meats, refined grains, sweets, sugary beverages, and fried foods – Contains high levels of saturated fat, added sugars, and sodium – Low in fiber, fruits, and vegetables – Associated with obesity, insulin resistance, and increased T2D risk
Prudent diet (e.g., Mediterranean and DASH diets)	– Rich in vegetables, fruits, whole grains, legumes, and healthy fats – Low intake of red meats, processed foods, and saturated fat – DASH diet emphasizes low sodium and adequate intake of potassium, calcium, and magnesium – Associated with improved insulin sensitivity, glycemic control, and cardiovascular health
Low-carbohydrate diet	– Limited carbohydrate intake (typically less than 45% of total energy; ketogenic diets often below 10%) – Emphasizes protein and fat intake from animal or plant sources – Can improve HbA1c and promote weight loss – Long-term effects and safety, particularly regarding cardiovascular and renal health, remain under investigation

et al. [26] reported that vegetarian diets rich in whole grains, fruits, and vegetables improved insulin sensitivity and HbA1c levels in individuals with diabetes; whereas Lee and Park [27] found that adherence to similar vegetarian dietary patterns was associated with a lower risk of developing T2D. However, despite the consistent emphasis on dietary fiber, the biological mechanisms by which specific types and quantities of fruits and vegetables mitigate T2D risk remain unclear. As Cooper et al. [28] pointed out, this knowledge gap limits the effective implementation of high-fiber dietary interventions in clinical settings.

Omnivorous diets

An omnivorous diet includes both animal-based foods (e.g., meat, eggs, and dairy) and plant-based foods (e.g., grains, vegetables, and fruits) and represents the most common dietary pattern globally. However, due to its broad scope, the health impact of an omnivorous diet largely depends on its specific composition. For instance, a prudent omnivorous diet may offer health benefits, whereas a Western-style omnivorous diet high in processed foods and saturated fats may increase disease risk. Consequently, this section does not evaluate the omnivorous diet as a distinct intervention but rather uses it as a reference dietary pattern to examine associations with T2D risk and management. Many studies compare omnivorous diets with vegetarian diets, typically treating the former as the control group. In a cross-sectional study involving 4384 participants, Chiu et al. [29] reported that even among those with predominantly plant-based diets, individuals consuming an omnivorous diet exhibited a higher risk of T2D compared to vegetarians. In another study involving obese individuals, Slywitch et al. [30] found that higher BMI was associated with increased HbA1c levels among both omnivores and vegetarians, along with elevated markers of inflammation and oxidative stress (e.g., gamma-glutamyl transferase and ferritin), suggesting a greater metabolic burden and heightened T2D risk. Supporting this, a meta-analysis by Austin et al. [31] of seven RCTs showed that regular consumption of animal-based foods (e.g., red meat, poultry, fish, or processed meats) was associated with less effective BMI control compared to a plant-based diet. Notably, when interventions extended beyond 16 wk, differences in metabolic outcomes were primarily attributed to food types rather than caloric intake. These findings suggest that omnivores are at a higher risk of developing T2D than vegetarians, likely due to higher intake of saturated fats and lower intake of dietary fiber—dietary characteristics that may promote insulin resistance and chronic inflammation [18,30].

Nevertheless, vegetarian diets are not without limitations. Long-term adherence may result in insufficient intake of certain nutrients, particularly vitamin B12 and omega-3 fatty acids [25,32]. Furthermore, the heterogeneity in defining omnivorous diets across studies complicates the interpretation of their health effects. Most existing research evaluates omnivorous diets as comparator groups rather than as independent dietary patterns, leaving their direct relationship with T2D risk insufficiently characterized [29–31]. In contrast, a meta-analysis by Ajala et al. [33] indicated that dietary patterns incorporating animal-based foods—such as the Mediterranean diet (HbA1c reduction of −0.47%) and high-protein diets (−0.28%)—also yielded substantial improvements in glycemic control compared to control diets. These findings suggest that health benefits can be achieved within omnivorous dietary patterns through careful selection and balance of food components. However, the magnitude of benefit often depends on the nature of the control diet, potentially influencing study outcomes. Thus, the impact of dietary patterns on T2D prevention and management is contingent upon their specific composition. In practical terms, an omnivorous diet should prioritize plant-based foods to replicate the metabolic advantages associated with vegetarian diets [32].

Western diets

The Western diet, characterized by high consumption of UPFs, sugary beverages, refined grains, red and processed meats, and fried foods, is typically low in dietary fiber, fruits, and vegetables. This dietary pattern has been consistently associated with an increased risk of T2D, particularly among individuals with overweight or obesity [20]. Willey and coworkers [34], in a cross-national analysis of 611 participants from nine countries, found that diets rich in sugar, fat, and calories—typical of Western dietary patterns—were positively associated with elevated HbA1c and fasting blood glucose levels. These glycaemic markers are critical predictors of T2D onset, especially when coupled with excess caloric intake and poor metabolic regulation. Shu and coworkers [22], in a cross-sectional study, further substantiated these findings, reporting that an energy-dense Western dietary pattern, characterized by excessive consumption of saturated fats and red meat, was significantly associated with increased odds of obesity and hypertension (odds ratio = 1.28, 95% CI: 1.103–1.697), both of which are established risk factors for T2D. Complementing this, a meta-analysis by Maghsoudi et al. [21] indicated that high intake of red meat, fried foods, and processed products conferred a 30% greater risk of developing T2D (risk ratio = 1.30, 95% CI: 1.18−1.43).

UPFs—defined as industrial formulations typically containing refined ingredients (e.g., sugars, oils, salts) along with additives such as flavor enhancers, preservatives, and emulsifiers—have emerged as a central component of the Western diet [35]. Regular consumption of UPFs has been shown to compromise overall diet quality and is strongly associated with increased adiposity and metabolic dysfunction. Rauber et al. [36] reported a positive association between UPF consumption and elevated BMI in a cohort of UK adults, supporting growing concerns about their obesogenic potential. Several epidemiological studies have consistently demonstrated the relationship between UPF consumption and T2D incidence. For instance, Levy et al. [37] found that individuals in the highest quintile of UPF intake had a 44% increased risk of developing T2D (hazard ratio [HR] = 1.44, 95% CI: 1.04−2.02) compared to those in the lowest quintile. Similarly, Chen et al. [38] observed a 46% higher T2D risk (HR = 1.46, 95% CI: 1.39−1.54) among individuals with the highest UPF intake. Llavero-Valero et al. [39] further confirmed this relationship, reporting that UPF consumption was independently associated with increased T2D risk (HR = 1.65, 95% CI: 1.14−2.38), even after adjusting for confounding factors such as BMI, physical activity, and total energy intake. A recent meta-analysis by Lane et al. [40] reinforced these findings, concluding that UPF consumption was associated with an increased T2D risk (risk ratio = 1.12, 95% CI: 1.11−1.13), in addition to elevated risks for cardiovascular mortality, mental health disorders (e.g., anxiety), and obesity. These associations are likely mediated by the pro-inflammatory and insulin-resistant effects of high intake of added sugars, saturated fats, and sodium, which are prevalent in Western-style diets [16−18]

Despite compelling evidence, assessing the impact of unhealthy dietary patterns on T2D risk faces several methodological challenges. Most dietary data are derived from self-reported instruments such as Food Frequency Questionnaires, which are inherently susceptible to recall bias and misreporting. Additionally, significant heterogeneity in regional dietary practices and cultural contexts limits the comparability and generalizability of findings across studies [21,40]. For example, while both Chen et al. [38] and Llavero-Valero et al. [39] identified a positive association between UPF consumption and T2D, inconsistencies in the operational definitions of UPFs across studies undermine direct comparison. Although Willey et al. [34] provided valuable cross-country insights into common dietary behaviors and their relationship with glycaemic markers, the specific mechanisms linking Western diets and UPF consumption to T2D—particularly their effects on biomarkers such as HbA1c and BMI—remain inadequately elucidated. Future longitudinal and mechanistic studies are necessary to better define these associations and inform targeted dietary interventions.

Low-carbohydrate diets

LCDs, defined as dietary patterns that significantly restrict carbohydrate intake while increasing fat and/or protein intake, have garnered attention as an intervention for improving glycemic control and promoting weight loss in individuals with T2D [41,42]. The underlying mechanism is based on the reduction of postprandial glucose excursions and subsequent improvement in insulin sensitivity. In a single-blind RCT by Wang et al. [43], a LCD providing 39% of total energy from carbohydrates over a 3-mo period resulted in a significant reduction in HbA1c levels (−0.63%), insulin requirements, and BMI. Similarly, Saslow et al. [44], a pilot RCT involving overweight and obese individuals with T2D, demonstrated that a very low-carbohydrate ketogenic diet (20−50 g/d) led to a 0.6% decrease in HbA1c over 3 mo. Notably, 44% of participants were able to reduce or discontinue at least one diabetes medication, highlighting the therapeutic potential of carbohydrate restriction in select patient populations. Recently, a meta-analysis by Silverii et al. [45], which included 37 RCTs encompassing 3301 patients with T2D, reported that LCDs (26%−45% of energy from carbohydrates) produced a greater reduction in HbA1c (−0.17%) at 3 mo compared to balanced diets (45%−60% carbohydrate). More stringent carbohydrate restriction (<26% of energy) yielded more pronounced short-term benefits; however, these differences attenuated over time and were no longer statistically significant at 6 to 12 mo of follow-up. In alignment, Goldenberg et al. [46] found that while LCDs were more effective than low-fat or Mediterranean diets in achieving HbA1c <6.5% at 6 mo, this advantage diminished by 12 mo, suggesting possible issues with long-term adherence and metabolic sustainability.

Overall, current evidence indicates that LCDs can yield meaningful short-term improvements in glycemic control and body weight among T2D patients. However, these findings must be interpreted with caution. Many studies are of limited duration, involve small sample sizes, and often exclude individuals with advanced beta-cell dysfunction. As such, the generalizability of results to all T2D populations remains uncertain. Moreover, there is insufficient evidence regarding the long-term safety of LCDs, particularly concerning renal function, cardiovascular health, and micronutrient adequacy. Practical challenges such as dietary adherence, sustainability, and patient acceptability also complicate the broader implementation of LCDs in clinical practice. Long-term studies with larger cohorts are required to evaluate the safety, efficacy, and metabolic durability of LCDs across diverse populations, particularly among those with differing levels of insulin secretion and comorbidities [45,46].

Prudent diets

Prudent dietary patterns, such as the Mediterranean and DASH diets, have gained increasing recognition for their roles in the prevention and management of T2D. These dietary approaches emphasize nutrient-dense, minimally processed foods with cardiometabolic benefits, including improvements in insulin sensitivity, glycemic control, and weight management.

Mediterranean diet

The Mediterranean diet is a predominantly plant-based dietary pattern characterized by high intakes of vegetables, fruits, whole grains, legumes, nuts, and olive oil as the primary source of monounsaturated fatty acids (MUFA). It also includes moderate consumption of fish and poultry, and limited intake of red meat, processed foods, and sweets [47]. Several studies have demonstrated the protective role of the Mediterranean diet in T2D prevention and management. Shai et al. [48] and Risérus et al. [49] emphasized that diets rich in MUFA, particularly from olive oil, may confer metabolic benefits comparable to low-fat diets and are associated with a reduced risk of T2D. Moreover, the inclusion of whole grains and low-glycaemic index carbohydrates supports improved glycaemic control and enhances insulin sensitivity [50].

Apart from this, cross-sectional data from Esposito et al. [51] indicated that higher adherence to the Mediterranean diet was significantly associated with lower HbA1c levels, reduced BMI, and decreased prevalence of metabolic syndrome in individuals with T2D. Importantly, the study found that these benefits were contingent on dietary adherence and the relative intake of whole grains and MUFA, even after adjusting for confounding factors such as age, BMI, and total caloric intake. Further evidence comes from a RCT by Elhayany et al. [5] demonstrated that a low-carbohydrate Mediterranean diet (comprising 35% low-glycaemic index carbohydrates and 45% fat, predominantly MUFA) combined with moderate physical activity (30–45 min, at least three times per week) led to significant improvements in glycaemic control (HbA1c reduction of −2.0%) and lipid profile (notably LDL-C reduction) in overweight patients with T2D, compared with the standard American Diabetes Association dietary recommendations.

DASH diet

The DASH diet was initially developed to manage hypertension but has shown potential benefits for T2D management due to its emphasis on whole foods. It is characterized by high intakes of fruits, vegetables, and low-fat dairy products, along with adequate potassium, magnesium, and calcium intake, and limited consumption of saturated fat and added sugars [52]. In a single-centre RCT, Ard et al. [11] found that adherence to a low-sodium DASH diet, in conjunction with regular physical activity, improved insulin sensitivity and promoted healthier BMI trajectories in individuals with insulin resistance. Similarly, Lien et al. [13] reported that DASH-style interventions, which prioritized increased consumption of fruits and vegetables while restricting total fat to ≤25% of daily energy, significantly lowered both systolic and diastolic blood pressure in patients with metabolic syndrome. Importantly, Azadbakht et al. [53] conducted an 8-wk randomized crossover trial and found that participants on the DASH diet experienced greater reductions in HbA1c (−1.7%), fasting plasma glucose, and LDL cholesterol compared to those consuming a traditional high-carbohydrate diet (50%–60% of energy from carbohydrates). These findings suggest that the DASH diet, particularly when paired with sodium restriction, can be beneficial for glycemic regulation in individuals with T2D.

Despite these promising results, the role of the DASH diet in T2D management has been less extensively studied in comparison to its effects on blood pressure. Many existing studies have not directly assessed its impact on glycaemic biomarkers such as HbA1c or insulin resistance [11,13]. Furthermore, most clinical trials emphasize caloric restriction or macronutrient composition without adequately addressing the contribution of specific food groups or meal patterns, limiting the practicality and reproducibility of such interventions in real-world settings [4,5,12,53]. Emerging evidence also supports the notion that moderate carbohydrate restriction (50–130 g/d) over a period exceeding 6 mo can favorably impact glycemic outcomes in T2D patients, particularly when integrated within a structured dietary framework such as DASH or Mediterranean-style diets [9]. However, further long-term, large-scale trials are needed to clarify the independent effects of these prudent dietary patterns on diabetes-specific outcomes and their efficacy across diverse patient populations.

Impact of dietary patterns on the gut microbiota-inflammation axis

The association between dietary patterns and T2D may be partly explained by the modulation of gut microbiota through dietary intake. Growing evidence suggests that gut microbiota produce signaling molecules through the fermentation of complex carbohydrates and play a key role in maintaining host immune and metabolic functions. These activities can improve glycemic control in T2D patients by enhancing microbial diversity [54–56]. Among microbial metabolites, short-chain fatty acids (SCFAs) are particularly important, acting as signaling molecules that influence lipid metabolism, glucose regulation, and insulin sensitivity through interactions with host metabolic pathways [57]. SCFA production is closely linked to dietary fiber intake. Increased consumption of dietary fiber enhances microbial diversity and promotes the generation of SCFAs such as acetate, propionate, and butyrate, which have been shown to reduce inflammatory markers (e.g., interleukin-6, tumor necrosis factor-alpha) in individuals with T2D [58,59].

Based on these mechanisms, dietary patterns rich in fiber—such as plant-based and prudent diets, including the Mediterranean and DASH diets—have been shown to positively modulate the gut microbiota-inflammation axis. These diets contribute to improved insulin sensitivity and glucose homeostasis. For example, Zhao et al.[60] found that increased fiber intake enriched intestinal probiotics that produce SCFAs, particularly acetate and butyrate, which enhanced intestinal secretion of glucagon-like peptide-1 and peptide YY, promoting insulin secretion and improved glucose metabolism. The Mediterranean diet, rich in microbial-accessible carbohydrates, supports the fermentation activity of gut microorganisms, thereby strengthening the intestinal barrier, improving mucosal immunity, and regulating systemic inflammatory responses [61]. Similarly, the DASH diet has been shown to improve glycaemic control by limiting the translocation of bacterial endotoxins such as lipopolysaccharides into circulation, thus attenuating chronic inflammation [62]. LCDs may also enhance insulin sensitivity by reducing gut-derived pro-inflammatory metabolites such as branched-chain amino acids [63].

In contrast, the Western diet lacks these beneficial properties. It is characterized by high energy density and excessive consumption of UPFs. It has been shown to significantly alter gut microbiota composition by reducing microbial diversity and depleting probiotic populations [64]. It also increases the abundance of pro-inflammatory taxa, including members of the *Ruminococcus* genus and phylum *Proteobacteria*, leading to decreased SCFA production in T2D patients [65,66]. Furthermore, common emulsifiers found in UPFs, such as polysorbate-80 and carboxymethylcellulose, can impair intestinal mucosal integrity, increase gut permeability, and promote systemic exposure to lipopolysaccharides, triggering low-grade inflammation and contributing to insulin resistance [67,68]. Based on the evidence presented in the literature, dietary patterns offer a valuable adjunctive intervention in T2D management by modulating the gut microbiota-inflammation axis, ultimately reducing systemic inflammation and improving metabolic control. Future research should aim to elucidate the specific mechanisms linking individual microbial species, microbial metabolites, and host inflammatory responses under different dietary patterns to inform the development of more precise dietary interventions [54,55].

Opportunities and challenges for future research

Synthesizing from the findings presented in preceding sections on various dietary patterns and their impacts on T2D (Table 3), few limitations in existing research are identified for future investigation. One major limitation observed across numerous studies is the frequent combination of dietary interventions with other lifestyle modifications—most notably physical activity—which complicates the isolation of the independent effects of diet on glycemic control and anthropometric outcomes such as BMI [4,5,11,13]. While such multimodal interventions reflect real-world clinical practice, they reduce the internal validity and hinder precise evaluation of dietary patterns as standalone strategies. Additionally, the heterogeneity in study design—including variations in geographic context, sample size, intervention duration, and assessment

Table 3
Metabolic outcomes of various dietary patterns

	Study design (duration)	Key healthy impact	References
Plant-based diet (vegetarian diet)	RCT (74 wk)	Improved HbA1c, total cholesterol, and LDL-C	[12]
	RCT (24 wk)	Improved HbA1c, insulin sensitivity, and BMI	[4]
	Meta-analysis	Indicate increased insulin sensitivity and improved HbA1c levels	[26]
Low-carbohydrate diet	RCT (3 mo)	Improved HbA1c	[44]
	Single-blind RCT (3 mo)	Improved HbA1c and BMI	[43]
	Meta-analysis	Improved HbA1c in short-term (3–6 mo)	[45]
	Meta-analysis	Improved HbA1c in short-term (6 mo)	[46]
Prudent diets (Mediterranean, DASH)	Cross-sectional analysis	Reduced risk of metabolic syndrome. Improved HbA1c and BMI	[51]
	Prospective randomized intervention (1 y)	Improved HbA1c and LDL-C levels in overweight T2D participants	[5]
	Single-centre RCT (6 mo)	Improved insulin sensitivity and BMI	[11]
	RCT multicenter (6 mo)	Lowered systolic and diastolic blood pressure	[13]
	RCT crossover (8 wk)	Improved HbA1c, fasting glucose, and LDL-C levels	[53]

tools—significantly restricts comparability across studies and undermines the generalizability of the evidence base (Table 4). These inconsistencies also challenge the development of standardized dietary guidelines for T2D management. Another fundamental gap lies in the limited understanding of the underlying nutritional and biological mechanisms through which specific dietary patterns influence T2D risk and progression. Although some evidence points to the benefits of high-fiber and plant-based nutrients in enhancing insulin sensitivity and reducing systemic inflammation, the exact physiological pathways remain poorly elucidated and are often inferred rather than directly measured [4,11,26–28].

To enhance the quality and translational value of dietary research in T2D, future studies must address several critical areas. Firstly, there is a need for longer-term RCTs—ideally with a minimum duration of 6 mo—that investigate the independent efficacy of well-defined dietary interventions, with precise documentation of macronutrient composition and food sources [43,44,53]. Secondly, mechanistic studies should be expanded to explore how various dietary components—particularly those within vegetarian, Mediterranean, and DASH patterns—modulate metabolic pathways relevant to glucose homeostasis, insulin signaling, and adiposity [5,12]. Thirdly, outcomes assessment should be broadened to include a comprehensive set of metabolic indicators beyond glycemic control, such as HbA1c, BMI, fasting insulin, lipid profiles, and inflammatory markers, to provide a more holistic evaluation of intervention efficacy [11,12,51]. Finally, a concerted effort is needed to standardize definitions and classifications of dietary patterns, especially those labelled as “omnivorous” or “Western,” to facilitate cross-cultural comparisons and establish clearer causal relationships between dietary intake and T2D outcomes [34,38,39]. Addressing these methodological and conceptual limitations will be essential to advancing evidence-based, culturally adaptable dietary guidelines for the prevention and management of T2D.

Concluding remarks

Evidence from existing literature indicates that plant-based dietary patterns—such as vegetarian, Mediterranean, and DASH diets—consistently demonstrate beneficial effects in the prevention and management of T2D. These dietary approaches, which are rich in dietary fiber, low-glycemic index carbohydrates, and unsaturated fats, contribute to improved glycemic control, enhanced insulin sensitivity, and reduced cardiometabolic risk. LCDs have

Table 4
Features and limitations of different dietary intervention study designs

Dietary pattern	Country	Sample size (n)	Limitations	References
Plant-based diet (vegetarian diet)	United States	49*	More than half of the participants in each group required medication adjustments during study period."	[12]
	Czech Republic	37*	Difficult to completely isolate dietary effect	[4]
Low-carbohydrate diet	United States	16*	Overweight T2D individuals only; longer-term effects unclear	[44]
	China	24*	Short intervention duration (3 mo); dependence on patients self-recorded diets and home glucometer	[43]
Prudent diets (Mediterranean, DASH)	Italy	901	Apparent HbA1c benefit could reflect difference in medicine	[51]
	Israel	61*	Detailed carbohydrate intake unreported; intervention combined with physical activity	[5]
	United States	52*	Non-diabetic individuals; combined with physical activity	[11]
	United States	399*	Metabolic indicators are secondary observations; physical activity included	[13]
	Iran	31*	Small sample size (n = 31) and short 8 wk duration	[53]
Western diets	China	1918	Cross-sectional design assessed by the food frequency questionnaire (FFQ); no detailed information on participants' glucose-lowering therapies	[22]
	United Kingdom	21 730	UPF exposure based on one self-reported 24 h recall	[37]
	Spain	20 060	Prospective cohort design; reliance on the FFQ	[39]
	United States	198 636	FFQ-based intake; largely educated adults (≥50% health professionals); limited generalizability	[38]

*Indicates the sample size of the dietary intervention group.

also shown promise, particularly in the short-term reduction of HbA1c levels; however, the long-term sustainability, safety, and metabolic impact of sustained carbohydrate restriction remain areas requiring further investigation through robust clinical trials. Conversely, unhealthy dietary patterns, including the Western diet and high consumption of UPFs, are consistently associated with an elevated risk of T2D. These diets are typically characterized by excessive intakes of sugar, saturated fats, and sodium, coupled with low fiber density and high energy content. Such nutritional imbalances contribute to the development of obesity and insulin resistance, which are key pathophysiological drivers of T2D and its related complications.

Despite the growing body of evidence supporting dietary modification as a critical component of T2D management, current research is constrained by methodological heterogeneity. Variations in study design, inconsistent definitions of dietary patterns, differences in cultural dietary norms, and limited duration of intervention studies hinder the ability to draw definitive conclusions regarding causal relationships and underlying biological mechanisms. To overcome these limitations, future research should prioritize long-term, multicenter RCTs with standardized definitions and culturally sensitive adaptations of dietary interventions. Such studies are essential to accurately elucidate the independent effects of specific dietary patterns on T2D outcomes and to inform the development of practical, replicable, and high-adherence dietary strategies for global T2D prevention and management.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

CRediT authorship contribution statement

Da Gong: Writing – review & editing, Writing – original draft. **Wing-Fu Lai:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization.

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