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DIABETES AND CARDIOVASCULAR DISEASE (ND WONG, SECTION EDITOR)

Optimal Dietary Strategies for Prevention of Atherosclerotic Cardiovascular Disease in Diabetes: Evidence and Recommendations

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Abstract

Purpose of Review This review presents the current available evidence of the effects of several dietary patterns on atherosclerotic cardiovascular disease (ASCVD) risk in patients with type 2 diabetes (T2D).

Recent Findings Evidence demonstrates improvements in cardiovascular risk factors with some dietary patterns in the general population. However, evidence is limited for glycemic control and cardiovascular benefit in patients with T2D for Dietary Approaches to Stop Hypertension and plant-based dietary patterns. Evidence suggests that carbohydrate-restricted dietary patterns improve glycemic control and decrease the use of anti-hyperglycemic medications. The Mediterranean dietary pattern has the most evidence for glycemic control and decreased ASCVD risk in patients with T2D. There is no evidence on ASCVD outcomes in patients with T2D for any other dietary pattern.

Summary The Mediterranean dietary pattern has the most evidence for cardiovascular benefit in patients with T2D. Future research should examine the effect of dietary patterns on ASCVD outcomes.

Keywords Diabetes · Cardiovascular disease · Dietary pattern · Mediterranean · DASH · Low-carbohydrate · Plant-based

Introduction

Diabetes is present in over 30 million people in the USA (9.4% of the population) of which 90–95% have type 2 diabetes (T2D) [1]. Diabetes results in a considerable burden on society due to increased medical costs, lost productivity, and reduced quality of life [1]. The financial burden is staggering with an estimated annual cost of $327 billion, including $37.3 billion in cardiovascular-related spending [2]. T2D confers an independent risk for atherosclerotic cardiovascular disease (ASCVD), which is the leading cause of death and morbidity in the USA and globally [3]. Nutrition therapy has been shown to be an essential and cost-effective tool for the optimal management of T2D, but evidence that supports specific dietary patterns to improve ASCVD outcomes in patients with T2D is sparse.

Past T2D treatment guidelines have provided recommendations for the individualization of macronutrient distribution; however, dietary patterns may benefit metabolic health more than focusing on a specific macronutrient composition for T2D management [4]. Thus, T2D treatment guidelines have shifted the focus to dietary patterns that achieve weight goals, improve glycemic control, and improve other ASCVD risk factors, such as hypertension (HTN) and dyslipidemia [5, 6•, 7, 8]. Most studies of dietary patterns and T2D have examined the effects on ASCVD risk factors whereas the effects of specific dietary patterns for improving ASCVD outcomes in patients with T2D is not well established.

This review presents the available evidence on dietary patterns recommended for the management of T2D and the improvement of ASCVD risk factors. Table 1 includes a description of the dietary patterns reviewed. While the focus of this review is optimal dietary strategies, the authors acknowledge that the increased ASCVD risk in patients with T2D is multifactorial. Other essential components for decreasing ASCVD

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Table 1 Characteristics and CV benefits of dietary patterns in people with T2D

Dietary pattern	Characteristics	Effects on CV risk factors
Mediterranean	Emphasizes olive oil as the main cooking oil; a high intake of plant-based foods (i.e., fruits, vegetables, legumes, nuts and seeds, whole grains and cereals, and potatoes); moderate consumption of fish/seafood and dairy products; low consumption of meat and meat products; and low-to-moderate red wine consumption with meals	• Decreased HbA1C • Increased HDL-C • Decreased triglycerides • Decreased BP • Lower risk of new-onset diabetes • Decreased risk of major cardiovascular events
DASH	Emphasizes increased intake of fruits, vegetables, whole grains, nuts, fish, poultry, and low-fat dairy; and decreased intake of saturated fat, red meat, sodium, sweets, and added sugar	• Weight loss and reduced waist circumference[a] • Decreased HbA1c and FPG[a] • Decreased LDL-C; increased HDL-C[a] • Decreased BP[a] • Lower risk of new-onset diabetes
Low-carbohydrate and Very-low-carbohydrate	Definitions vary, but low-CHO is typically 10–25% of total calories and very-low-CHO is < 10% of total calories [9•]; emphasizes an overall decreased intake of CHO-rich foods; CHO foods allowed include non-starchy vegetables, although some plans allow fruit and starchy vegetables; other starchy and sugary foods are discouraged; protein varies between a moderate intake in very-low-CHO plans to a high intake in low-CHO plans; fat varies between a high intake in very-low-CHO plans to a moderate intake in low-CHO plans	• Weight loss • Decreased HbA1C • Increased HDL-C and decreased triglycerides • Decreased SBP or DBP (inconsistent results in studies)
Plant-based	Includes intake of plant-based food; vegetables, fruits, grains, legumes, and nuts; vegetarian may include eggs (ovo) and dairy (lacto); vegan diet is strictly devoid of animal protein or any animal-derived products	• Weight loss • Decreased HbA1c • Decreased LDL-C and non-HDL-C • Lower risk of new-onset diabetes • Possible increase in TG and decreased HDL-C

[a] Based on evidence from one short-duration RCT of 31 patients with T2D and one RCT of DASH+exercise [6•, 10•, 11•]

risk in patients with T2D include optimal control of blood pressure (BP), lipids/lipoproteins, and weight (central obesity). In addition, physical activity level, smoking cessation, alcohol intake, and use of medications that have been shown to be cardioprotective are all significant components affecting overall ASCVD risk. Table 2 includes components of a comprehensive approach to the management of T2D to decrease ASCVD risk.

Mediterranean Dietary Pattern

The Mediterranean dietary (MedDiet) pattern is one of the most studied dietary patterns for its effects on metabolic health markers and ASCVD risk and prevention [6•]. A recent Cochrane systematic review reported a modest benefit with the MedDiet on CVD risk factors in primary prevention. In this review, the PREDIMED was the only primary prevention study that examined clinical endpoints, which demonstrated a reduced risk of stroke with the MedDiet compared with control. There was low- or very-low-quality evidence regarding the effect on clinical endpoints or CVD risk factors of the MedDiet in secondary prevention. Thus, the authors determined the available evidence continues to show uncertainty regarding the effects of a MedDiet on clinical outcomes and CVD risk factors for both primary and secondary prevention [15•]. Many meta-analyses reported a decreased incidence of T2D with a higher adherence to the MedDiet [15•, 16–20]. This has resulted in the inclusion of this dietary pattern in guidelines as an eating plan for T2D management, as well as for ASCVD prevention [5, 6•, 7].

Interestingly, of the many meta-analyses that have shown cardiovascular (CV) health benefit with the MedDiet, few have included individuals with T2D. One recent meta-analysis and one systematic review examined the effects of the MedDiet on ASCVD risk in populations that included people with diabetes [21•, 22]. Becerra-Tomás et al. completed a systematic review and meta-analysis (3 RCTs and 38 prospective cohort studies) to examine the evidence on the association of the MedDiet with total CVD, coronary heart disease (CHD), stroke, and myocardial infarction (MI) incidence, and mortality in populations that included individuals with diabetes. Based on their meta-analysis of 3 RCTs, Becerra-Tomás reported the MedDiet reduced total CVD and MI incidence. Their meta-analysis of 38 cohort studies

Table 2 Components of a comprehensive approach to the management of T2D to decrease ASCVD risk [7, 12–14]

History of complications/comorbidities
Poor glycemic control
High blood pressure
Abnormal lipid levels
Chronic kidney disease and presence of albuminuria
Erectile dysfunction
Lifestyle factors
Weight and waist circumference
Eating patterns
Physical activity
Sleep behaviors
Alcohol and tobacco use
Substance use
Behavioral and diabetes self-management skills
Screen for depression, anxiety, and disordered eating; refer as needed for additional assessment
Assess social support network
History of dietitian and/or diabetes educator education sessions
Assess diabetes self-management skills and barriers
Use of cardioprotective medications
Current medication regimen
Cardioprotective anti-hyperglycemic medications prescribed
Moderate- or high-intensity statin prescribed
In patients with elevated TGs, consider adding icosapent ethyl
Anti-hypertensive medications
Aspirin therapy, as indicated*

*Indicated for secondary prevention; may be considered for primary prevention of ASCVD among select adults who are 40 to 70 years of age and are at higher ASCVD risk without increased bleeding risk [7]

found an inverse association between the highest MedDiet adherence compared with the lowest adherence and total CVD mortality, CHD incidence, CHD mortality, stroke incidence and mortality, and MI incidence. Given the studies in this meta-analysis included participants with and without T2D, Becerra-Tomás et al. concluded that the MedDiet may confer CVD prevention in patients T2D but emphasized that further research with well-designed RCTs of individuals with diabetes is needed to provide higher quality data to "develop evidence-based dietary guidelines for diabetes management" [21•].

Franquesa et al. conducted a systematic review to examine the evidence for the effects of the MedDiet on *cardiodiabesity*, a new term that describes the significant inter-relationship of obesity, metabolic syndrome (MetS), CVD, and T2D. The authors determined there is a high level of evidence that adherence to the MedDiet positively impacts primary and secondary CVD prevention and improves health in adults with overweight and obesity. There is moderate-to-high evidence that the MedDiet improves MetS and decreases its incidence, and moderate evidence that the MedDiet prevents T2D and improves its management to reduce T2D severity and symptoms. Based on this review, there is a high level of evidence that higher adherence to the MedDiet was associated with CVD incidence reduction in high-risk individuals and the general population [22].

There are few meta-analyses that have examined the effect of the MedDiet on ASCVD risk factors specifically in individuals with T2D. Esposito et al. conducted a systematic review and meta-analysis that included 8 meta-analyses and 5 RCTs to examine the effect of the MedDiet compared with a control diet in individuals with T2D, or at increased risk for T2D, on glycemic control and ASCVD risk factors [23]. Esposito et al. conducted a meta-analysis of 3 RCTs and found a greater reduction in hemoglobinA1c (HbA1c) (mean difference [MD] − 0.47%; 95% CI − 0.56, − 0.38) with the MedDiet compared with a control diet. The authors reviewed available meta-analyses and determined that the MedDiet had more favorable effects on total cholesterol (total-C) (MD ranging from − 5.4 to − 8.9 mg/dL in 3 meta-analyses) and body weight (MD ranging from − 0.29 to − 2.2 kg in 4 meta-analyses), and a greater increase in high-density lipoprotein cholesterol (HDL-C) (MD 1.54 and 2.31 mg/dL in 2 meta-analyses) compared with control diets [23]. Similarly, Huo et al. found that, compared with control diets, the MedDiet achieved a greater reduction in HbA1c (MD − 0.30%; 95% CI − 0.46, − 0.14), body weight (MD − 0.29 kg; CI − 0.55, − 0.04), total-C (MD − 5.41 mg/dL; CI − 7.35, − 3.48), triglycerides (TG) (MD − 25.7 mg/dL; CI − 41.6, − 8.86), and both systolic (MD − 1.45 mmHg; CI − 1.97, − 0.94) and diastolic (MD − 1.41 mmHg; CI − 1.84, − 0.97) BP, and a greater increase in HDL-C (MD 2.32 mg/dL; CI 0.77, 3.87), but a non-significant reduction in low-density lipoprotein cholesterol (LDL-C) (MD − 4.25 mg/dL; CI − 9.28, 0.39) [24]. Furthermore, a meta-analysis found a 49% increased probability of remission from MetS compared with control diets and two meta-analyses showed a 19–23% reduction in new T2D incidence with greater adherence to the MedDiet [23].

There is a paucity of evidence for the MedDiet effecting ASCVD *outcomes* in people with T2D. One prospective cohort study of 1995 participants with T2D from the MOLI-SANI study found a 37% lower overall mortality and 34% reduction in CV mortality with a 2-unit increase in the MedDiet score based on the Greek Mediterranean diet score. The researchers determined the effect of the MedDiet was mainly due to moderate alcohol consumption (14.7% in the reduction of the effect), a high intake of cereals (12.2%) vegetables (5.8%), and decreased intake of dairy (13.4%) and meat products (3.4%) [25].

The proposed mechanisms for the benefits of the MedDiet are related to its key components: olive oil as the main cooking oil; a high intake of plant-based foods (i.e., fruits, vegetables, legumes, nuts and seeds, whole grains and cereals, and potatoes); moderate consumption of fish and dairy products; low consumption of meat and meat products; and low-to-moderate red wine consumption with meals [15•, 26, 27]. The protective effects of the diet appear to be most attributable to olive oil, fruits, vegetables, and legumes [28]. The plant-based foods are high in fiber and polyphenols, which have antioxidant and anti-inflammatory properties, and the higher intake of unsaturated fatty acids from olive oil and nuts may have a beneficial effect on blood lipids, as well as BP, body weight, and FPG, thereby decreasing ASCVD risk [26, 27]. The anti-inflammatory and antioxidant effects of the MedDiet also contribute to the cardiometabolic benefits in persons with T2D [27, 29]. However, as Salas-Salvadó et al. stated so eloquently, "It is recognized that the beneficial effects of the MedDiet can only be explained by the synergy between all the nutrient components included that can attenuate or exacerbate the deleterious or beneficial effects respectively produced by a single nutrient" [27]. Thus, the MedDiet is an eating plan that can improve glycemic control and other ASCVD risk factors for patients with T2D, and its implementation should be facilitated by education from a registered dietitian nutritionist (RDN) or certified diabetes educator to emphasize the importance of the totality of its food components.

Dietary Approaches to Stop Hypertension Dietary Pattern

The Dietary Approaches to Stop Hypertension (DASH) dietary pattern originated over 25 years ago as a non-pharmacological intervention to treat HTN and lower ASCVD risk. It is currently widely recommended by general dietary guidelines, as well as international diabetes and cardiovascular guidelines [5, 6•, 7, 8, 30]. Clinical trials have shown the DASH is effective in lowering BP, reducing weight, decreasing the incidence of new-onset T2D, and lowering risk of CV events in patients without diabetes [31, 32•, 33]. However, only three RCTs have examined the effects of the DASH in patients with T2D, all of which compared the DASH with an American Diabetes Association (ADA) recommended diet, were of short duration (< 12 weeks), and were conducted outside of the USA [10•, 11•, 34–36].

Interestingly, 1 small RCT is cited most often as evidence for benefit of the DASH in patients with T2D [10•, 11•]. The study had a crossover design where 31 patients with T2D followed the DASH for 8 weeks, and then control diet for 8 weeks. Calorie intake and macronutrients were not significantly different between the diet groups, and sodium intake was limited to 2400 mg per day in the DASH group. The DASH group had significantly greater reductions in HbA1c, fasting plasma glucose (FPG), systolic BP (SBP), diastolic BP (DBP), weight, waist circumference, total-C, LDL-C, and HDL-C compared with the control group. There was also a greater reduction in inflammatory biomarkers in the DASH group. The other RCTs conducted in patients with T2D following the DASH had BP as its primary endpoint. One RCT included 40 patients with T2D and uncontrolled HTN and compared the DASH plus exercise for 4 weeks with a diet similar to that recommended by the ADA [36]. The DASH+ exercise group had a significantly greater reduction in SBP and DBP, but no difference in HbA1c, FPG, or lipids. The other RCT was 12 weeks and included 80 patients with T2D and pre-HTN and compared the DASH with an ADA diet [34]. Interestingly, mean reductions in SBP and DBP were similar between the two diet groups. The only significant outcome was a lower SBP in the DASH group after 12 weeks when compared with baseline SBP [34]. A second analysis of this study reported significant reductions in total-C, TG, and very-low-density lipoprotein cholesterol from baseline to 12 weeks for both diet groups, but no significant difference in reductions when the DASH group was compared with the control group. HDL-C and LDL-C did not change from baseline in either group [35].

An umbrella review of systematic reviews and meta-analyses was conducted in patients with and without diabetes [32•]. The one meta-analysis included in the umbrella review by Chiavaroli et al. that examined the effects of the DASH on BP and lipids had only one RCT that included patients with diabetes. Significant reductions were reported for SBP, DBP, total-C, and LDL-C with no significant effects on TG or HDL-C. The authors performed a meta-analysis of two RCTs to examine the effects on HbA1c with only one of these trials including patients with T2D and the other including patients with gestational diabetes. The DASH group had a significant reduction in HbA1c (MD 0.53%; CI − 0.62, − 0.43) compared with the control group. CHD and stroke incidence were lower in the DASH groups in one meta-analysis where the majority of patients did not have diabetes (RR = 0.79 [CI 0.71, 0.88] and RR = 0.81 [CI 0.72, 0.92], respectively) [32•].

The DASH diet emphasizes an increased intake of fruits, vegetables, and low-fat dairy products. Many of these foods are rich in potassium and calcium and appear to induce natriuresis, which may be the mechanism that results in lower BP [37]. Additionally, restricting high-fat foods and refined sugars, while adding healthy fats from nuts and seeds, aids in weight loss and improvements in blood lipids in some populations. While the DASH is recommended in most nutrition guidelines for diabetes, the data to support its use over other dietary patterns is insufficient. When examining ASCVD risk factor reduction specifically, only the RCT by Azadbakht et al. was able to show a significant reduction in BP, weight, waist circumference, lipids, and inflammatory biomarkers [10•, 11•]. Only one other RCT resulted in lower BP with the DASH, but the results were confounded by the addition of exercise to the DASH intervention [36]. Although not directly linked to CV risk, improvement in glycemic control is an essential outcome for patients with T2D; however, only the small RCT by Azadhakht et al. demonstrated lower HbA1c and FPG [10•]. Based on available evidence, other dietary patterns may be more effective in lowering ASCVD risk in patients with T2D.

Low-Carbohydrate and Very-Low-Carbohydrate Dietary Patterns

The use of low-carbohydrate (CHO) and very-low-CHO dietary patterns for the management of T2D has increased in recent years [38–41]. The definition of low-CHO and very-low-CHO dietary patterns varies, which may result in confusion when instructing patients with T2D on these eating plans. In a recent consensus report on nutrition therapy for adults with pre-diabetes or T2D, a low-CHO dietary pattern was defined as 26–45% total daily energy (TDE) from CHO [6•], whereas definitions in research studies have been 21–70 g/day CHO for very-low-CHO dietary patterns and 30–40% TDE CHO for moderately CHO dietary patterns [42].

A forthcoming scientific statement on low-CHO dietary patterns from the National Lipid Association (NLA) [9•] examined the available evidence from systematic reviews and meta-analyses of RCTs comparing the effects of low-CHO and very-low-CHO dietary patterns with high-CHO, low-fat (HCLF) dietary patterns on ASCVD risk factors, including weight loss, blood lipids, blood pressure, and glycemic control, in persons with pre-diabetes and T2DM.

The results of the systematic reviews and meta-analyses demonstrated no difference for weight loss between low-CHO groups compared with HCLF groups in either short- or long-term studies or BMI and waist circumference in people with pre-diabetes or T2DM [43–50]. Similarly, no significant difference was reported for total-C and LDL-C levels [43–46, 48–51]. Conversely, a significant reduction in TG levels was reported, except in two meta-analyses [43–46, 48, 50]. A significant increase in HDL-C levels was reported, except in two meta-analyses and one critical review [43–46, 48, 50, 51]. Evidence on the effect of low-CHO dietary patterns on BP is conflicting with one meta-analysis reporting a significant difference in SBP between groups in favor of low-CHO dietary patterns, but no significant difference in DBP, and one meta-analysis reporting a significant decrease in DBP with low-CHO dietary patterns [43, 48]. Three other meta-analyses did not find a significant difference between dietary pattern groups for either SBP or DBP [44, 46, 50].

In terms of glycemic control in patients with pre-diabetes or T2D following a low-CHO compared with a HCLF dietary pattern, the evidence reviewed for the NLA scientific statement showed that one meta-analysis of RCTs by van Zuuren et al. found a significant reduction in fasting glucose with low-CHO compared with low-fat dietary patterns at ≥ 8–26 weeks, but not > 26 weeks [9•, 50]. Meta-analyses did not report a significant difference for glucose levels or insulin levels [45, 46, 51]. In short-term (≤ 6 months) studies, HbA1c was significantly lower with low-CHO compared with HCLF dietary patterns [43–45, 47–51]. At ≥ 1 year, HbA1c was similar between the low-CHO and HCLF groups, although two meta-analyses reported a significantly decreased HbA1c in the low-CHO groups at 1 year [43–50]. Despite inconsistent results on HbA1c between low-CHO and HCLF dietary patterns, a greater reduction in the use of diabetes medication was consistently reported, typically insulin [43–45, 47, 49, 50].

Similar to the NLA scientific statement, the 2019 *Nutrition Therapy for Adults with Diabetes or Prediabetes: Consensus Report* and the *Lifestyle Management: Standards of Medical Care in Diabetes* from the ADA reviewed the current evidence on low-CHO dietary patterns and reported the evidence suggests a reduction in overall CHO intake improves glycemic control and cardiometabolic risk factors in patients with T2D [5, 6•, 9•]. Thus, a low-CHO or very-low-CHO dietary pattern may be an option for adults with T2D who are not meeting glycemic control goals [5, 6•, 9•]. However, this is based on short-term studies and the evidence reviewed supported that patients struggle with long-term adherence with these dietary patterns [5, 6•, 9•]. Given that most individuals cannot adhere to the level of CHO restriction of very-low-CHO dietary patterns (< 20–50 g/day), a low- (< 130 g/day) or moderate-CHO (130–225 g/day) intake may promote more successful adherence [43]. Furthermore, very-low-CHO dietary patterns are not recommended for patients with renal disease, disordered eating patterns, women who are pregnant, or patients using sodium-glucose cotransporter 2 (SGLT2) inhibitors due to the risk of ketoacidosis [5, 6•, 9•]. Patients with T2D who choose to follow a very-low-CHO dietary pattern should be medically supervised by a knowledgeable/trained clinician due to diuresis that occurs with the diet and the potential for hypoglycemia, especially without adjustments of anti-hyperglycemic medication dosages [6•, 9•]. Education from a RDN can facilitate the replacement of CHO with unsaturated fatty acids and avoidance of excessive saturated fatty acids (SFA) and dietary cholesterol intakes in low-CHO dietary patterns [9•]. Finally, the available meta-analyses and RCTs have not examined the effect of low-CHO and very-low-CHO dietary patterns on ASCVD event outcomes in patients with pre-diabetes and T2D [9•].

Plant-Based Dietary Patterns

Vegetarian or vegan diets, also known as plant-based dietary patterns (PBDPs), refer to dietary patterns that exclude most or all animal-derived foods. While there are variations in the amount of animal products consumed, all PBDPs encourage a high consumption of fruits, vegetables, legumes, nuts and seeds, and whole grains, while discouraging the intake of refined and processed foods. PBDPs have been associated with a lower risk of T2D, CHD, obesity, HTN, and CVD mortality in patients without diabetes, and are widely recommended by international diabetes and cardiovascular guidelines for ASCVD risk reduction and glycemia management in patients with diabetes [6•, 7, 8, 52–55].

Three systematic reviews and meta-analyses have been conducted to examine the effect of PBDPs on glycemic control, cardiometabolic risk factors, and overall well-being in patients with T2D [56•, 57, 58]. The most recent and comprehensive was conducted by Viguiliouk et al. and included 9 trials of PBDPs with a median duration of 12 weeks. Mean macronutrient composition across diet groups was 62% CHO, 14% protein, and 23% fat for PBDP interventions, and 50% CHO, 19% protein, and 31% fat in the control group. When compared with various control diets, PBDPs significantly reduced HbA1c (MD − 0.29%; CI − 0.45, − 0.12), FPG (MD − 10.1 mg/dL; CI − 17.82, − 2.34), body weight (MD − 2.15 kg; CI − 2.95, − 1.34), waist circumference (MD − 2.9 cm; CI − 3.76, 1.96), LDL-C (MD − 4.6 mg/dL; CI − 7.73, − 1.55), and non-HDL-C (MD − 5.03 mg/dL; CI − 10.05, − 0.39). While there were no significant differences in fasting insulin, HDL-C, TG, or BP, it is important to note there was a mean increase in TG (MD 12.4 mg/dL; CI − 8.9, 33.7), SBP (MD 0.10 mmHg; CI − 2.33, 2.52), and DBP (MD 0.53 mmHg; CI − 0.50, 1.57) levels in the PBDP groups. When evaluating the 95% CIs, it is uncertain if the effects of PBDPs are clinically relevant with respect to reduction in ASCVD risk and given the authors' confidence in these estimates was moderate to low [56•].

A meta-analysis conducted by Yokoyama et al. that included 3 RCTs, 2 nonrandomized comparisons, and 1 cluster RCT of individuals with T2D reported only glycemic control outcomes. There was a greater reduction in HbA1c (MD − 0.39%; CI − 0.62, − 0.15) and a non-significant reduction in FPG with PBDPs compared with control diets [57]. A systematic review of 11 studies by Toumpanakis et al. reported greater reductions in HbA1c, weight loss, total-C, LDL-C, and TG with PBDPs when compared with a control diet. It was demonstrated that participants in the PBDP groups were also more likely have a reduction or discontinuation of diabetes-related medications. Greater improvements for depression and quality of life were also reported in the PBDP groups [58].

The available evidence for people with T2D demonstrates that PBDPs, when compared with control diets, resulted in reductions in HbA1c while the reduction in FPG is variable. The effect of PBDPs on other cardiometabolic risk factors was less consistent between studies, although meta-analyses demonstrated improvement for total-C and HDL-C. The trends of the effect of PBDPs on TG, HDL-C, and BP did not show consistent benefit. RCTs of PBDPs compared with control that were $\geq$ 1 year did not demonstrate a long-term benefit for all markers of cardiometabolic risk [59, 60].

Possible mechanisms for reduced ASCVD risk reported with PBDPs include a lower intake of SFA, dietary cholesterol, and heme iron from meat-derived protein, and an increase in the consumption of fiber and phytonutrients, which are associated with decreased inflammation and oxidative stress [61]. A PBDP is consistent with the nutrition recommendations of the 2019 ACC/AHA Guideline on the Primary Prevention of CVD [7]. Given that the available evidence on PBDPs includes studies with varying amounts of animal products (i.e., strict vegan to ovo-lacto-vegetarian), it is likely that encouraging patients with T2D to limit their intake of processed and red meats and increase their intake of plant-based protein foods and fish would decrease their ASCVD risk and increase adherence to the eating plan. A point of concern is that the decreased intake of animal products with PBDPs may lead to B12 deficiency. Thus, patients choosing to follow PBDPs should be educated by a RDN on adding fortified foods or B12 supplements to their eating plan, as well as to individualize an eating plan to facilitate adherence.

Other Dietary Patterns

The dietary patterns reviewed previously have the most evidence related to their effects on risk of ASCVD in patients with T2D. Other dietary patterns or strategies that have been used in the past have limited evidence to support their use for ASCVD prevention in patients with T2D. A low-fat, high-carbohydrate *Step 1* diet was recommended by the AHA to lower risk in the distant past, but recent evidence has shown that reductions in total fat intake do not result in improvements in glycemia or ASCVD risk factors in patients with T2DM [6•, 62, 63]. Current nutrition recommendations emphasize the quality of dietary fat intake (i.e., reductions in *trans* and SFA with replacement from unsaturated fat). Additionally, replacing a percentage of total daily energy from CHO with foods higher in lean protein and/or unsaturated fats may achieve greater reductions in ASCVD risk factors and improve glycemic control [6•, 9, 12]. Additionally, clinical trials of other dietary patterns have used a low-fat diet (< 30%) as a comparator, with the intervention dietary pattern most often showing greater improvement in ASCVD risk factors and glycemic control [64•, 65]. While very-low-fat/very-high-CHO dietary patterns (Ornish, Pritikin) have shown improvements in some ASCVD risk factors, these are multi-component lifestyle interventions that involve in-patient treatment stays, exercise, and stress management [6•]. Furthermore, neither have recent evidence to support their use in patients with T2D. Focusing on glycemic index (GI) is a dietary strategy that has been used to manage T2D. However, although some studies show improvement in glycemic control, the results are inconsistent [6•, 62]. The Paleolithic dietary pattern is high-protein and high-fiber and emphasizes consumption of whole foods while restricting processed foods. Currently, there is limited evidence on the

Paleolithic diet, although the evidence that is available suggests improved glycemic control, but not greater than the improvement achieved with the MedDiet [64•].

Evidence Comparing Dietary Patterns

Recent network meta-analyses (NMA) compared the impact of different dietary approaches on glycemic control (primary outcome was HbA1c), blood lipids, and weight loss in patients with T2D [9•, 64•, 65•, 66]. One NMA of RCTs ≥ 12 weeks compared the effects on glycemic control of eight dietary patterns, including low-fat, low-CHO, and moderate-CHO, high-protein, low GI, PBDPs, Paleolithic, and the MedDiet, with a control diet in patients with T2D [64•]. All eight dietary patterns compared with control significantly reduced HbA1c. Subgroup analyses found that low-CHO dietary patterns reduced HbA1c more than the other dietary patterns in smaller and shorter-term (< 12 months) studies that included patients < 60 years of age. The MedDiet and moderate-CHO dietary patterns reduced HbA1c more in larger and longer-term studies with patients > 60 years of age. Univariate meta-regression analysis showed that the mean reduction in HbA1c was significantly related to the mean difference in weight change between dietary approaches [9•, 64•]. Another NMA of RCTs ≥ 12 weeks compared the effect of the same eight dietary patterns with a control diet on LDL-C, HDL-C, and TG in patients with T2D [65•]. The results demonstrated that moderate-CHO and PBDPs were more effective at reducing LDL-C compared with the control diet. The PBDPs were also more effective at reducing LDL-C than the low-CHO, high-protein, and low-fat dietary patterns. The only dietary pattern that increased HDL-C was the MedDiet whereas the other dietary patterns had no effect or decreased HDL-C, especially the PBDPs. The MedDiet and low-CHO dietary patterns significantly reduced TG levels compared with low-fat and control dietary patterns [9•, 65•]. Furthermore, a NMA of five dietary patterns (MedDiet, low- and high-CHO, low-fat, and regular) found that the MedDiet pattern had the highest probability of being the best dietary pattern for a reduction in weight, waist circumference, HbA1c, total-C, LDL-C, and TG [9•, 66]. The NMA comparisons of dietary patterns in patients with T2D suggest that the MedDiet is the most effective for improving cardiometabolic risk factors.

Conclusion

The beneficial impact of dietary patterns as part of the foundation of lifestyle therapy for the management of T2D is recognized and continues to be researched to determine the most effective strategy to achieve glycemic control and decrease ASCVD risk, i.e., weight loss, improvement in lipids, and BP lowering. Evidence supports that many dietary patterns show benefit in reducing new-onset diabetes and improving ASCVD risk factors and clinical outcomes when studied in patients without diabetes. Recommendations for patients with T2D are frequently based on this evidence. The evidence on dietary patterns presented in this review consistently reported improvements in HbA1c and weight when used in patients with T2D, but the overall improvement in other ASCVD risk factors (i.e., lipids, BP) was not consistent. Table 1 includes a summary of the benefits reported for each dietary pattern and ASCVD risk factors.

Instead of focusing on specific macronutrients, an emphasis on dietary patterns for the management of T2D is now advised by professional organizations, with MedDiet, DASH, and PBDPs recommended most often. Components common to dietary patterns for the management of T2D include the reduction in overall CHO intake while encouraging CHO foods with a low GI (i.e., non-starchy vegetables, fruits, whole grains, and legumes); minimizing the intake of refined CHO foods, foods with added sugars, and sweetened beverages; consuming fish and lean protein foods; reducing intake of foods rich in SFA and replacing them with foods rich in mono- and polyunsaturated fatty acids; reducing foods rich in dietary cholesterol and sodium; minimizing the intake of processed meats; and avoiding foods rich in *trans* fatty acids [5, 6•, 7]. Furthermore, the ADA stated "a one-size-fits-all eating plan is not evident for the prevention or management of diabetes" [5]. Based on available evidence that included patients with T2D, it is likely that a variety of interventions will be effective in improving glycemia and decreasing ASCVD risk. The challenge for the implementation of any dietary pattern is developing effective strategies that are acceptable to patients and sustainable over time. Baseline patient knowledge, comorbidities, personal preferences, usual food intake, social support, and potential barriers should all be considered prior to recommending a specific dietary pattern. Providers typically have limited time to educate on dietary strategies. Referral to a RDN for medical nutrition therapy and education to facilitate dietary changes in patients is strongly recommended and results in greater improvements in HbA1c, weight, and lipids [5, 67, 68]. Long-term adherence can be enhanced by reassessing nutrition therapy, individualizing the implementation of the dietary pattern, and providing flexibility in food choices where possible.

Despite the evidence presented in this review, an unanswered question is whether the benefits from the dietary patterns are due to the specific composition of macronutrients and foods in each dietary pattern or simply the result of weight loss. For the DASH, PBDP, and low-CHO dietary patterns, the benefits may mostly be due to weight loss. However, the totality of the components in the MedDiet is most likely responsible for the benefits demonstrated with that dietary pattern. The MedDiet currently has the most evidence for

ASCVD risk reduction in patients with and without T2D, but even this is limited to effects on risk factors without sufficient data for reductions in outcomes. Thus, larger and longer duration RCTs are needed to determine the best dietary strategy for reducing ASCVD risk in patients with diabetes.

Compliance with Ethical Standards

Conflict of Interest Cara Liday and Carol Kirkpatrick declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
• Of importance

1. Centers for Disease Control and Prevention. National Diabetes Statistics Report, 2017. Atlanta: Centers for Disease Control and Prevention, U.S. Dept of Health and Human Services; 2017. https://www.cdc.gov/diabetes/data/statistics-report/index.html. Accessed 26 June 2019
2. American Diabetes Association. Economic costs of diabetes in the U.S. in 2017. Diabetes Care. 2018;41:917–28. https://doi.org/10.2337/dc18-1179.
3. Benjamin EJ, Virani SS, Callaway CW, Chamberlain AM, Chang AR, Cheng S, et al. Heart Disease and Stroke Statistics-2018 update: a report from the American Heart Association. Circulation. 2018;137:e67–e492. https://doi.org/10.1161/CIR.0000000000000558 Erratum in: Circulation. 2018;137:e493. doi: 10.1161/CIR.0000000000000573.
4. Mozaffarian D. Dietary and policy priorities for cardiovascular disease, diabetes, and obesity: a comprehensive review. Circulation. 2016;133:187–225. https://doi.org/10.1161/CIRCULATIONAHA.115.018585.
5. American Diabetes Association. Lifestyle management: standards of medical care in diabetes-2019. Diabetes Care. 2019;42(Suppl 1: S46–S-60. https://doi.org/10.2337/dc19-S005.
6.• Evert AB, Dennison M, Gardner CD, Garvey WT, Lau KHK, MacLeod J, et al. Nutrition therapy for adults with diabetes or prediabetes: a consensus report. Diabetes Care. 2019;42:731–54. https://doi.org/10.2337/dci19-0014. **This is an excellent review article discussing the beneficial effects of nutrition in the treatment of diabetes.**
7. Arnett DK, Blumenthal RS, Albert MA, Buroker AB, Goldberger ZD, Hahn EJ, et al. 2019 ACC/AHA guideline on the primary prevention of cardiovascular disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. J Am Coll Cardiol. 2019;74:S0735–1097. https://doi.org/10.1016/j.jacc.2019.03.010.
8. Sievenpiper JL, Chan CB, Dworatzek PD, Freeze C, Williams SL. Nutrition therapy. Can J Diabetes. 2018;42(Suppl 1):S64–79. https://doi.org/10.1016/j.jcjd.2017.10.009.
9.• Kirkpatrick CF, Bolick JP, Kris-Etherton PM, Sikand G, Aspry KE, Soffer DE, et al. Review of current evidence and clinical recommendations on the effects of low-carbohydrate and very-low-carbohydrate (including ketogenic) diets for the management of body weight and other cardiometabolic risk factors: a scientific statement from the National Lipid Association Nutrition and Lifestyle Taskforce. J Clin Lipidol. In review. **This scientific statement presents the most recent evidence on low and very-low-carbohydrate diets and their effects on cardiometabolic risk.**
10.• Azadbakht L, Fard NRP, Karimi M, et al. Effects of the Dietary Approaches to Stop Hypertension (DASH) eating plan on cardiovascular risks among type 2 diabetic patients: a randomized cross-over clinical trial. Diabetes Care. 2011;34:55–7. https://doi.org/10.2337/dc10-0676. **This is the most frequently referenced RCT for the DASH diet and T2D.**
11.• Azadbakht L, Surkan PJ, Esmaillzadeh A, Willett WC. The Dietary Approaches to Stop Hypertension eating plan affects C-reactive protein, coagulation abnormalities, and hepatic function tests among type 2 diabetic patients. J Nutr. 2011;141:1083–8. https://doi.org/10.3945/jn.110.136739 **This is the most frequently referenced RCT for the DASH diet and T2D.**
12. American Diabetes Association. Cardiovascular disease and risk management: standards of medical care in diabetes-2019. Diabetes Care. 2019;42(Suppl 1):S103–23. https://doi.org/10.2337/dc19-S010.
13. Grundy SM, Stone NJ, Bailey AL, Beam C, Birtcher KK, Blumenthal RS, et al. 2018 AHA/ACC/AACVPR/AAPA/ABC/ACPM/ADA/AGS/APhA/ASPC/NLA/PCNA guideline on the Management of Blood Cholesterol: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. Circulation. 2019;139:e1092–143. https://doi.org/10.1161/CIR.0000000000000625.
14. American Diabetes Association. Comprehensive medical evaluation and assessment of comorbidities: standards of medical care in diabetes-2019. Diabetes Care. 2019;42(Suppl 1):S34–45. https://doi.org/10.2337/dc19-S004.
15.• Rees K, Takeda A, Martin N, Ellis L, Wijesekara D, Vepa A, et al. Mediterranean-style diet for the primary and secondary prevention of cardiovascular disease. Cochrane Database Syst Rev. 2019;3:CD009825. https://doi.org/10.1002/14651858.CD009825.pub3. **This is a recent systematic review examining the effects of the MedDiet for primary and secondary prevention of ASCVD.**
16. Bloomfield HE, Koeller E, Greer N, MacDonald R, Kane R, Wilt TJ. Effects on health outcomes of a Mediterranean diet with no restriction on fat intake: a systematic review and meta-analysis. Ann Intern Med. 2016;165:491–500. https://doi.org/10.7326/M16-0361.
17. Dinu M, Pagliai G, Casini A, Sofi F. Mediterranean diet and multiple health outcomes: an umbrella review of meta-analyses of observational studies and randomised trials. Eur J Clin Nutr. 2018;72:30–43. https://doi.org/10.1038/ejcn.2017.58.
18. Koloverou E, Esposito K, Giugliano D, Panagiotakos D. The effect of Mediterranean diet on the development of type 2 diabetes mellitus: a meta-analysis of 10 prospective studies and 136,846 participants. Metabolism. 2014;63:903–11. https://doi.org/10.1016/j.metabol.2014.04.010.
19. Salas-Salvadó J, Bulló M, Estruch R, Ros E, Covas MI, Ibarrola-Jurado N, et al. Prevention of diabetes with Mediterranean diets: a subgroup analysis of a randomized trial. Ann Intern Med. 2014;160:1–10. https://doi.org/10.7326/M13-1725.
20. Schwingshackl L, Missbach B, König J, Hoffmann G. Adherence to a Mediterranean diet and risk of diabetes: a systematic review and meta-analysis. Public Health Nutr. 2015;18:1292–9. https://doi.org/10.1017/S1368980014001542.
21.• Becerra-Tomás N, Blanco Mejía S, Viguiliouk E, Khan T, Kendall CWC, Kahleova H, et al. Mediterranean diet, cardiovascular disease and mortality in diabetes: a systematic review and meta-analysis of prospective cohort studies and randomized clinical trials. Crit Rev Food Sci Nutr. 2019;1–21. https://doi.org/10.1080/

10408398.2019.1565281. **This is one of few systematic reviews and meta-analyses that included individuals with T2D in review of the MedDiet.**

22. Franquesa M, Pujol-Busquets G, García-Fernández E, Rico L, Shamirian-Pulido L, Aguilar-Martínez A, et al. Mediterranean diet and cardiodiabesity: a systematic review through evidence-based answers to key clinical questions. Nutrients. 2019;11:E655. https://doi.org/10.3390/nu11030655.
23. Esposito K, Maiorino MI, Bellastella G, Chiodini P, Panagiotakos D, Giugliano D. A journey into a Mediterranean diet and type 2 diabetes: a systematic review with meta-analyses. BMJ Open. 2015;5:e008222. https://doi.org/10.1136/bmjopen-2015-008222.
24. Huo R, Du T, Xu Y, Xu W, Chen X, Sun K, et al. Effects of Mediterranean-style diet on glycemic control, weight loss and cardiovascular risk factors among type 2 diabetes individuals: a meta-analysis. Eur J Clin Nutr. 2015;69:1200–8. https://doi.org/10.1038/ejcn.2014.243.
25. Bonaccio M, Di Castelnuovo A, Costanzo S, Persichillo M, De Curtis A, Donati MB, et al. Adherence to the traditional Mediterranean diet and mortality in subjects with diabetes. Prospective results from the MOLI-SANI study. Eur J Prev Cardiol. 2016;23:400–7. https://doi.org/10.1177/2047487315569409.
26. Esposito K, Maiorino MI, Bellastella G, Panagiotakos DB, Giugliano D. Mediterranean diet for type 2 diabetes: cardiometabolic benefits. Endocrine. 2017;56:27–32. https://doi.org/10.1007/s12020-016-1018-2.
27. Salas-Salvadó J, Becerra-Tomás N, García-Gavilán JF, Bulló M, Barrubés L. Mediterranean diet and cardiovascular disease prevention: what do we know? Prog Cardiovasc Dis. 2018;61:62–7. https://doi.org/10.1016/j.pcad.2018.04.006.
28. Grosso G, Marventano S, Yang J, Micek A, Pajak A, Scalfi L, et al. A comprehensive meta-analysis on evidence of Mediterranean diet and cardiovascular disease: are individual components equal? Crit Rev Food Sci Nutr. 2017;57:3218–32. https://doi.org/10.1080/10408398.2015.1107021.
29. Guasch-Ferré M, Merino J, Sun Q, Fitó M, Salas-Salvadó J. Dietary polyphenols, Mediterranean diet, prediabetes, and type 2 diabetes: a narrative review of the evidence. Oxidative Med Cell Longev. 2017;2017:6723931. https://doi.org/10.1155/2017/6723931.
30. Davies MJ, D'Alessio DA, Fradkin J, Kernan WN, Mathieu C, Mingrone G, et al. Management of Hyperglycemia in type 2 diabetes, 2018. A consensus report by the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD). Diabetes Care. 2018;41:2669–701. https://doi.org/10.2337/dci18-0033.
31. Schwingshackl L, Bogensberger B, Hoffmann G. Diet quality as assessed by the Healthy Eating Index, Alternate Healthy Eating Index, Dietary Approaches to Stop Hypertension score, and health outcomes: an updated systematic review and meta-analysis of cohort studies. J Acad Nutr Diet. 2018;118:74–100.e11. https://doi.org/10.1016/j.jand.2017.08.024.
32.• Chiavaroli L, Viguiliouk E, Nishi SK, Blanco Mejia SB, Rahelic D, Kahleova H, et al. DASH dietary pattern and cardiometabolic outcomes: an umbrella review of systematic review and meta-analyses. Nutrients. 2019;11:1–38. https://doi.org/10.3390/nu11020338. **This is the most recent umbrella review of the DASH diet and cardiometabolic outcomes.**
33. Esposito K, Chiodini P, Maiorino MI, Bellastella G, Panagiotakos D, Giugliano D. Which diet for prevention of type 2 diabetes? A meta-analysis of prospective studies. Endocrine. 2014;47:107–16. https://doi.org/10.1007/s12020-014-0264-4.
34. Hashemi R, Rahimlou M, Baghdadian S, Manafi M. Investigating the effect of DASH diet on blood pressure of patients with type 2 diabetes and prehypertension: randomized clinical trial. Diabetes Metab Syndr. 2019;13:1–4. https://doi.org/10.1016/j.dsx.2018.06.014.
35. Hashemi R, Mehdizadeh Khalifani A, Rahimlou M, Manafi M. Comparison of the effect of Dietary Approaches to Stop Hypertension diet and American Diabetes Association nutrition guidelines on lipid profiles in patients with type 2 diabetes: a comparative clinical trial. Nutr Diet. 2019;4:1–8. https://doi.org/10.1111/1747-0080.12543.
36. Paula TP, Viana LV, Neto AT, Leitao CB, Gross JL, Azevedo MJ. Effects of the DASH diet and walking on blood pressure in patients with type 2 diabetes and uncontrolled hypertension: a randomized controlled trial. J Clin Hypertens. 2015;17(11):895–901. https://doi.org/10.1111/jch.12597.
37. Lin PH, Allen JD, Li YJ, Yu M, Lien LF, Svetkey LP. Blood pressure-lowering mechanisms of the DASH dietary pattern. J Nutr Metab. 2012;2011:472396. https://doi.org/10.1155/2012/472396.
38. Abbasi J. Interest in the ketogenic diet grows for weight loss and type 2 diabetes. JAMA. 2018;319:215–7. https://doi.org/10.1001/jama.2017.20639.
39. Brouns F. Overweight and diabetes prevention: is a low-carbohydrate-high-fat diet recommendable? Eur J Nutr. 2018;57:1301–12. https://doi.org/10.1007/s00394-018-1636-y.
40. Paoli A, Rubini A, Volek JS, Grimaldi KA. Beyond weight loss: a review of the therapeutic uses of very-low-carbohydrate (ketogenic) diets. Eur J Clin Nutr. 2013;67:789–96. https://doi.org/10.1038/ejcn.2013.116.
41. Paoli A. Ketogenic diet for obesity-friend or foe. Int J Environ Res Public Health. 2014;11:2092–107. https://doi.org/10.3390/ijerph110202092.
42. Hallberg SJ, Dockter NE, Kushner JA, Athinarayanan SJ. Improving the scientific rigour of nutritional recommendations for adults with type 2 diabetes: a comprehensive review of the American Diabetes Association guideline-recommended eating patterns. Diabetes Obes Metab. 2019;21:1769–79. https://doi.org/10.1111/dom.13736.
43. Huntriss R, Campbell M, Bedwell C. The interpretation and effect of a low-carbohydrate diet in the management of type 2 diabetes: a systematic review and meta-analysis of randomised controlled trials. Eur J Clin Nutr. 2018;72:311–25. https://doi.org/10.1038/s41430-017-0019-4.
44. Korsmo-Haugen HK, Brurberg KG, Mann J, Aas AM. Carbohydrate quantity in the dietary management of type 2 diabetes: a systematic review and meta-analysis. Diabetes Obes Metab. 2019;21:15–27. https://doi.org/10.1111/dom.13499.
45. Meng Y, Bai H, Wang S, Li Z, Wang Q, Chen L. Efficacy of low carbohydrate diet for type 2 diabetes mellitus management: a systematic review and meta-analysis of randomized controlled trials. Diabetes Res Clin Pract. 2017;131:124–31. https://doi.org/10.1016/j.diabres.2017.07.006.
46. Naude CE, Schoonees SM, Young T, Garner P, Volmink J. Low carbohydrate versus isoenergetic balanced diets for reducing weight and cardiovascular risk: a systematic review and meta-analysis. PLoS One. 2014;9:e100652. https://doi.org/10.1371/journal.pone.0100652 Erratum in: PLoS One 2018;13:e0200284. doi: 10.1371/journal.pone.0200284.
47. Sainsbury E, Kizirian NV, Partridge SR, Gill T, Colagiuri S, Gibson AA. Effect of dietary carbohydrate restriction on glycemic control in adults with diabetes: a systematic review and meta-analysis. Diabetes Res Clin Pract. 2018;139:239–52. https://doi.org/10.1016/j.diabres.2018.02.026.
48. Schwingshackl L, Hoffmann G. Comparison of the long-term effects of high-fat v. low-fat diet consumption on cardiometabolic risk factors in subjects with abnormal glucose metabolism: a systematic review and meta-analysis. Br J Nutr. 2014;111:2047–58. https://doi.org/10.1017/S0007114514000464.

49. Snorgaard O, Poulsen GM, Andersen HK, Astrup A. Systematic review and meta-analysis of dietary carbohydrate restriction in patients with type 2 diabetes. BMJ Open Diabetes Res Care. 2017;5: e000354. https://doi.org/10.1136/bmjdrc-2016-000354.
50. van Zuuren EJ, Fedorowicz Z, Kuijpers T, Pijl H. Effects of low-carbohydrate- compared with low-fat-diet interventions on metabolic control in people with type 2 diabetes: a systematic review including GRADE assessments. Am J Clin Nutr. 2018;108:300–31. https://doi.org/10.1093/ajcn/nqy096.
51. van Wyk HJ, Davis RE, Davies JS. A critical review of low-carbohydrate diets in people with type 2 diabetes. Diabet Med. 2016;33:148–57. https://doi.org/10.1111/dme.12964.
52. Tonstad S, Stewart K, Oda K, Batech M, Herring RP, Fraser GE. Vegetarian diets and incidence of diabetes in the Adventist Health Study-2. Nutr Metabol Cardiovasc Dis. 2013;23:292–9. https://doi.org/10.1016/j.numecd.2011.07.004.
53. Chiu THT, Pan WH, Lin MN, Lin CL. Vegetarian diet, change in dietary patterns, and diabetes risk: a prospective study. Nutr Diabetes. 2018;8:12. https://doi.org/10.1038/s41387-018-0022-4.
54. Kwok CS, Umar S, Myint PK, Mamas MA, Loke YK. Vegetarian diet, Seventh Day Adventists and risk of cardiovascular mortality: a systematic review and meta-analysis. Int J Cardiol. 2014;176:680–6. https://doi.org/10.1016/j.ijcard.2014.07.080.
55. Orlich MJ, Singh PN, Sabate J, Jaceldo-Siegl K, Fan J, Knutsen S, et al. Vegetarian dietary patterns and mortality in Adventist Health Study 2. JAMA Intern Med. 2013;173:1230–8. https://doi.org/10.1001/jamainternmed.2013.6473.
56.• Viguiliouk E, Kendall CW, Kahleova H, Rahelic D, Salas-Salvado J, Choo VL, et al. Effect of vegetarian dietary patterns on cardio-metabolic risk factors in diabetes: a systematic review and meta-anaysis of randomized controlled trials. Clin Nutr. 2019;3:1133–45. https://doi.org/10.1016/j.clnu.2018.05.032. **This is a recent systematic review and meta-analysis that included individuals with T2D in review of the PBDP.**
57. Yokoyama Y, Barnard ND, Levin SM, Watanabe M. Vegetarian diets and glycemic control in diabetes: a systematic review and meta-analysis. Cardiovasc Diagn Ther. 2014;4:373–82. https://doi.org/10.3978/j.issn.2223-3652.2014.10.04.
58. Toumpanakis A, Turnbull T, Alba-Barba I. Effectiveness of plant-based diets in promoting well-being in the management of type 2 diabetes: a systematic review. BMJ Open Diabetes Res Care. 2018;6:1–10. https://doi.org/10.1136/bmjdrc-2018-000534.
59. Kahleova H, Hill M, Pelikanova T. Vegetarian vs conventional diabetic diet: 1 year follow-up. Cor Vasa. 2014;56:e140–4. https://doi.org/10.1016/j.crvasa.2013.12.004.
60. Barnard ND, Cohen J, Jenkins DJ, et al. A low-fat vegan diet and a conventional diabetes diet in the treatment of type 2 diabetes: a randomized, controlled, 74-wk clinical trial. Am J Clin Nutr. 2009;89:1588S–96S. https://doi.org/10.3945/ajcn.2009.26736H.
61. Kahleova H, Levin S, Barnard ND. Vegetarian dietary patterns and cardiovascular disease. Prog Cardiovasc Dis. 2018;61:54–61. https://doi.org/10.1016/j.pcad.2018.05.002.
62. Wheeler ML, Dunbar SA, Jaacks LM, Karmally W, Mayer-Davis EJ, Wylie-Rosett J, et al. Macronutrients, food groups, and eating patterns in the management of diabetes: a systematic review of the literature, 2010. Diabetes Care. 2012;35:434–45. https://doi.org/10.2337/dc11-2216.
63. Kodama S, Saito K, Tanaka S, Maki M, Yachi Y, Sato M, et al. Influence of fat and carbohydrate proportions on the metabolic profile in patients with type 2 diabetes: a meta-analysis. Diabetes Care. 2009;32:959–65. https://doi.org/10.2337/dc08-1716.
64.• Schwingshackl L, Chaimani A, Hoffmann G, Schwedhelm C, Boeing H. A network meta-analysis on the comparative efficacy of different dietary approaches on glycaemic control in patients with type 2 diabetes mellitus. Eur J Epidemiol. 2018;33(2):157–70. https://doi.org/10.1007/s10654-017-0352-x. **This is a recent network meta-analysis that included individuals with T2D and compared 8 dietary patterns with control.**
65.• Neuenschwander M, Hoffmann G, Schwingshackl L, Schlesinger S. Impact of different dietary approaches on blood lipid control in patients with type 2 diabetes mellitus: a systematic review and network meta-analysis. Eur J Epidemiol. 2019. https://doi.org/10.1007/s10654-019-00534-1. **This is a recent network meta-analysis that included individuals with T2D and compared 8 dietary patterns with control.**
66. Pan B, Wu Y, Yang Q, Ge L, Gao C, Xun Y, et al. The impact of major dietary patterns on glycemic control, cardiovascular risk factors, and weight loss in patients with type 2 diabetes: a network meta-analysis. J Evid Based Med. 2019;12(1):29–39. https://doi.org/10.1111/jebm.12312.
67. Møller G, Andersen HK, Snorgaard O. A systematic review and meta-analysis of nutrition therapy compared with dietary advice in patients with type 2 diabetes. Am J Clin Nutr. 2017;106:1394–400. https://doi.org/10.3945/ajcn.116.139626.
68. Sikand G, Cole RE, Handu D, deWaal D, Christaldi J, Johnson EQ, et al. Clinical and cost benefits of medical nutrition therapy by registered dietitian nutritionists for management of dyslipidemia: a systematic review and meta-analysis. J Clin Lipidol. 2018;12(5): 1113–22. https://doi.org/10.1016/j.jacl.2018.06.016.

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