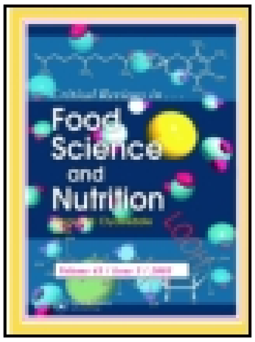

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REVIEW

Effect of different dietary patterns on glycemic control in individuals with type 2 diabetes mellitus: A systematic review

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ABSTRACT
Different dietary patterns have been positively related to the glycemic control of individuals with type 2 diabetes mellitus. However, consensual dietary pattern for these individuals is not established. We aimed to evaluate the effects of adopting different dietary patterns on glycemic control markers of individuals with type 2 diabetes mellitus. PubMed, Scopus, MEDLINE, Lilacs, Open Thesis and Google Scholar databases were searched using the Medical Subject Headings and terms related to dietary pattern and glycemic control in individuals with type 2 diabetes mellitus. Interventional studies with adults of this population without diabetes-related complications, presenting data on percentage of glycated hemoglobin, and dietary patterns were included. In vitro, animal, reviews, observational, and studies with children, adolescents, pregnant and breastfeeding women were excluded. The time of adoption dietary patterns ranged from eight weeks to four years in randomized clinical trials, and six months in the cohort study. Vegetarian, vegan, Mediterranean, and Dietary Approaches to Stop Hypertension dietary patterns reduced 0.8% on average of percentage of glycated hemoglobin, considering all included studies. It was also observed reduction in fasting glycemia and improvement in Homeostasis Model Assessment of Insulin Sensitivity. However, more randomized clinical trials are required for a full elucidation of these questions.

KEYWORDS
Feeding behavior; type 2 diabetes mellitus; glycemic control; hyperglycemia

Introduction

Type 2 diabetes mellitus (T2DM) is characterized by chronic hyperglycemia which is one of the main causes of reduction of quality of life and increase of diabetes-related complications (American Diabetes Association 2018). Lifestyle aspects such as high prevalence of sedentarism (International Diabetes Federation 2017), and adoption of non-healthy dietary patterns may favor the poor metabolic control of T2DM (Osonoi et al. 2016; Esposito et al. 2009; Savoca et al. 2004). Additionally, studies have emphasized that more attention should be given to dietary patterns in a holistic way rather than just considering isolated nutrients (Forouhi and Wareham 2014; Mozaffarian 2016; American Diabetes Association 2018).

Foods with reduced content of saturated fat and sodium, rich in dietary fibers, phytochemical compounds and antioxidants, mainly flavonoids, are present in dietary patterns that have been associated with better glycemic control in individuals with T2DM (Azadbakht et al. 2011; Chen et al. 2018; Villani et al. 2018). Studies assume that the combination of foods in these dietary patterns and the possible interaction among nutrients promote a synergistic effect on health in T2DM individuals (Hodge and Bassett 2016).

The adoption of healthy dietary patterns has proved to be beneficial for the management of glycemic control in individuals with diabetes through the combination of different food groups (Azadbakht et al. 2011; Ley et al. 2014). In addition, dietary patterns have been holistically studied, considering that a food pattern encompasses not only the food itself, but also aspects inherent to planting and harvesting, preparation, and eating environment, besides being inserted in a political and social context (Georgousopoulou et al. 2017).

Therefore, studies have been carried out to analyze the effect of the adherence to the vegetarian/vegan, Mediterranean, and Dietary Approaches to Stop Hypertension (DASH) diet patterns on the glycemic control, improvement of the lipid profile, body weight maintenance, and quality of life of individuals with T2DM (Wheeler et al. 2012; Ajala, English, and Pinkney 2013; Ley et al. 2014). In addition, lifestyle changes are crucial for metabolic control, as they may reduce the risk of diabetes complications caused by poor glycemic control (International Diabetes Federation 2017; American Diabetes Association 2018).

However, no consensual dietary pattern has been established for individuals with T2DM (Sievenpiper and

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Dworatzek 2013) due to the complexity that the interaction among nutrients and environmental factors can exert in the metabolic control. In this scenario, the present study aims to evaluate the effect of different dietary patterns on the glycemic markers of individuals with T2DM.

Methods

Research question design

The research question was defined based on the PICOS structured method: P (population), I (interventions), C (comparators), O (outcomes), S (study designs) (Centre for Reviews and Dissemination 2008). The main elements of the research are presented in Table 1.

Search strategy

This systematic review has been prepared by including publications of the PubMed, Scopus, MEDLINE, Lilacs, Google Scholar, and OpenThesis databases. The systematic search was performed on October 5, 2017. The search strategy included the following indexed terms in the Medical Subject Headings (MeSH): 'feeding behavior' combined with boolean operator OR to similar terms ('dietary pattern'; 'feeding pattern'; 'eating behavior'; 'food selection'; 'dietary habit'); AND diabetes mellitus, type 2' combined with boolean operator OR to similar terms ('type 2 diabetes mellitus'; 'type 2 diabetes'); AND glucose combined with boolean operator OR to similar terms ('glucose metabolism' OR 'insulin resistance' OR 'insulin-resistant' OR hyperglycemia OR 'glycemic control' OR 'glycaemic control' OR 'glucose intolerance' OR 'glucose metabolism disorders' OR hyperglycemia).

Selection of studies and data extraction

Eligibility criteria included interventional studies with T2DM individuals without diabetes-related complications (micro and macrovascular), that necessarily contained data on the percentage of glycated hemoglobin (%HbA1c) and description of adopted dietary patterns. *In vitro*, animal, reviews, and observational studies were excluded, as well as those that were published only in the abstract format or that had no abstract available. Moreover, studies with children, adolescents, pregnant and breastfeeding women were excluded. There was no restriction on language or period of publication. Two evaluators (G.B.C., and N.L.D.V.) independently searched for the articles, reviewed the titles and abstracts, and performed a full read of articles. Any disagreements were solved by a third-party evaluator (L.V.P.).

Data extracted from the studies included the following information: authors and year of publication; country; study objectives; sample size; inclusion and exclusion criteria; biochemical, anthropometric and dietary intake variables; sex; age; time of diabetes diagnosis; statistical analyses; and main results regarding the intervention effects of adopted dietary patterns compared to conventional controls diets for diabetes metabolic treatment. Data on dietary intervention (type of eating pattern, time of intervention and distribution of nutrients and energy), randomization, and blinding were also obtained. The data were extracted in a standardized way, based on the recommendations of the Consolidated Standards of Reporting Trials (CONSORT) tool (Moher et al. 2012). This step was carried out by three authors (G.B.C., N.L.D.V., and R.K.F.S).

The Kappa coefficient was used to determine the level of agreement between evaluators at the studies selection stages. According to Landis and Koch (1977), agreement between authors is evaluated in a range from <0 to 1, where <0 = no agreement, 0.00–0.19 = weak agreement, 0.20–0.39 = little agreement, 0.40–0.59 = moderate agreement, 0.60–0.79 = substantial agreement and 0.80–1.00 = almost perfect agreement.

The present review was elaborated according to the guidelines proposed by the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) (Moher et al. 2009).

Assessment of risk of bias

The assessment of risk of bias in included studies was performed independently by two reviewers (R.K.F.S., and P.N.B.L.) using the Cochrane Collaboration tool, with specific instruments for each type of study (Higgins and Green 2011). Specifically, for randomized clinical trials, biases of selection, performance, detection, attrition, reporting, and other types of bias were evaluated, such as the clarity of data presentation and description. The items of this evaluation were rated as low, high, or unclear risk of bias (Higgins et al. 2016).

Randomized crossover studies were evaluated using the bias analysis tool for randomized trials (RoB 2.0) of the Cochrane Collaboration, which is specific for crossover trials. Variance in the randomization process, deviations from intended interventions, loss of outcome data, evaluation of results, and selection of reported results were addressed. The items of this evaluation were rated as low or high risk of bias, or classified as 'some concerns' (Higgins et al. 2016).

Cohort-type studies were evaluated using the Risk of Bias in Non-randomized Studies – of Interventions (ROBINS-I)

Table 1. Elements of the research question according to the PICOS strategy.

Description	Abbreviation	Elements of the question
Population	P	Individuals with T2DM
Interventions	I	Adoption of dietary patterns that favor the glycemic control of individuals with T2DM
Comparators	C	Adoption of conventional controls diets for diabetes metabolic treatment
Outcomes	O	Effects of dietary patterns on variables of glycemic control of individuals with T2DM
Study designs	S	Interventional studies

T2DM, type 2 diabetes mellitus.

tool (version for cohort-type studies) of the Cochrane Collaboration. Biases of confounding, participant selection, measurement of interventions, deviations from intended interventions, loss of data, evaluation of outcomes, and selective reporting of outcomes were assessed. The items of this evaluation were classified as low, moderate, or high risk of bias (Sterne et al. 2016).

Outcome measures

The effects of dietary patterns on the metabolic control of individuals with T2DM were considered the main outcome. These effects were evaluated by percentage of glycated hemoglobin (%HbA1c), as primary measure of the glycemic control, and by the analysis of adopted dietary patterns.

Results

Characteristics of the studies

After the selection steps, seven potential studies have been selected, two of which were identified after analysis of the reference lists of previously selected studies (Barnard et al. 2006; Kahleova et al. 2011), and other two after a nonsystematic hand search in databases to identify additional studies that could not be located through the systematic search (Barnard et al. 2009; Esposito et al. 2009). When evaluating the studies in full, it was observed that the study by Barnard et al. (2009) corresponded to the follow-up of the population evaluated in the study by Barnard et al. (2006). The baseline data of these studies were presented together in the table of characterization of the studies. The selection steps of studies, according to the PRISMA method, are presented in Figure 1. Of the six studies, four were classified as randomized clinical trials (Barnard et al. 2006, 2009; Kahleova et al. 2011; Lee et al. 2016), one as a randomized crossover trial (Azadbakht et al. 2011), and one as a cohort study (Asaad et al. 2016).

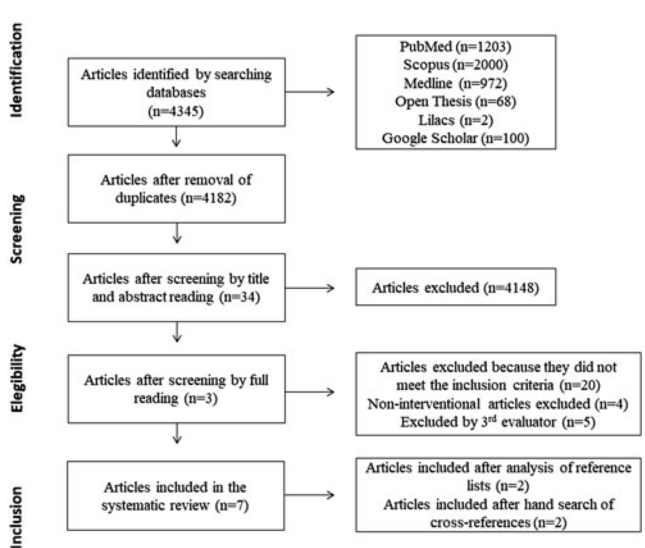

Figure 1. Flowchart of the selection stages of the studies according to the PRISMA method.

In the first selection phase, which consisted of title and abstract reading, the Kappa index was 0.761, indicating substantial agreement among the evaluators. In the second stage of selection, consisting of full text reading, the Kappa index was 0.810, which characterizes an almost perfect agreement among the evaluators.

The studies were developed in the United States (Barnard et al. 2006, 2009), Italy (Esposito et al. 2009), Iran (Azadbakht et al. 2011), Czech Republic (Kahleova et al. 2011, Canada (Asaad et al. 2016), and Republic of Korea (Lee et al. 2016). Regarding dietary patterns, four studies evaluated the vegan or vegetarian dietary pattern (Barnard et al. 2006, 2009; Kahleova et al. 2011; Lee et al. 2016); one study evaluated the DASH dietary pattern (Azadbakht et al. 2011); one study evaluated the Mediterranean-Style diet (Esposito et al. 2009); and one study evaluated a diet plan prescribed by a nutritionist, which relied on individual socioeconomic aspects, daily needs, and previous analysis of the participants' feeding using the Healthy Eating Index (HEI) tool adapted for the Canadian population (Asaad et al. 2016).

The composition and main characteristics of intervention and control diets used in randomized clinical trials included in this systematic review are presented in Table 2. The cohort study (Asaad et al. 2016) was not included in Table 2 because it did not present in its content the energy distribution of the menu plan provided to the participants. The nutritionally adequate 4-week menu plan was elaborated based on Canada's Food Guide (Health Canada 2011), and incorporated suggested foods and ingredients that were locally available, financially and physically accessible, and culturally acceptable.

Assessment of risk of bias

After evaluating randomized clinical trials for selection (random sequence generation and allocation concealment) we found that 60% of the studies were classified as low risk, and 40% as unclear risk of bias. This result is due to some studies not describing the method used to generate the allocation sequence in sufficient detail, as well as, they did not make it clear if allocation concealment was maintained (Kahleova et al. 2011; Lee et al. 2016). It is important to highlight that blinding of participants was not possible due to the nature of the intervention; therefore, the evaluation of performance bias did not apply in this case.

Although it was not possible to blind the researchers responsible for the application of dietary intervention, blinding of outcome assessment is an important aspect for the evaluation of the intervention. Regarding detection bias, 60% of the studies were rated as low risk (Barnard et al. 2006, 2009; Esposito et al. 2009), and 40% as high risk of bias (Kahleova et al. 2011; Lee et al. 2016).

Regarding attrition and reporting bias, 100% of the studies were rated as low risk because the description of loss of participants with their respective reasons was observed, along with the intention-to-treat analysis; besides, the proposed outcomes were reported. In relation to other bias, the

Table 2. Composition and characteristics of intervention and control diet of randomized clinical trials included in the systematic review.

Author (year)	Interventional dietary patterns[a]	Conventional controls diets[b]	Other characteristics
Barnard et al. (2006, 2009)	***Low-fat vegan diet*** Carbohydrates: 75% Proteins: 15% Fats: 10%	***Conventional diet*** Carbohydrates + MUFAs: 60–70% Proteins: 15–20% Saturated fats: <7%	*Low-fat vegan diet:* Rich in vegetables, fruits, and grains. Participants were asked to avoid animal products and added fats, and to favor low–glycemic index foods, such as beans and green vegetables. *Conventional diet:* Based on American Diabetes Association guidelines (ADA 2003). Cholesterol intake: $\leq$200 mg/day. Participants with a BMI > 25 kg/m2 had an energy intake deficit of 500–1000 kcal.
Esposito et al. (2009)	***Mediterranean diet*** 1500 kcal (women) 1800 kcal (men) Fats: $\geq$ 30% Complex CHO: $\leq$50%	***Low-fat diet*** 1500 kcal (women) 1800 kcal (men) Fats: $\leq$30% Saturated fats: $\leq$10%	*Mediterranean diet:* Rich in vegetables and whole grains and low in red meat, which was replaced with poultry and fish. The main source of added fat was 30 to 50 g of olive oil. *Low-fat diet:* Based on American Heart Association guidelines (Krauss et al. 2000). Rich in whole grains and restricted in additional fats, sweets, and high-fat snacks.
Kahleova et al. (2011)	***Vegetarian diet*** Carbohydrates: 60% Proteins: 15% Fats: 25%	***Conventional diabetic diet*** Carbohydrates: 50% Proteins: 20% Fats: 30% Saturated fats: $\leq$7%	*Vegetarian diet:* Rich in vegetables, grains, legumes, fruits and nuts. Animal products were limited to maximum of one portion of low-fat yogurt a day. Caloric restriction of 500 kcal/day *Conventional diabetic diet:* Based on dietary guidelines of the European Association for the Study of Diabetes. Cholesterol intake: <200 mg/day. Caloric restriction of 500 kcal/day
Azadbakht et al. (2011)	***DASH diet*** NM	***Control diet*** Carbohydrates: 50–60% Proteins: 15–20% Fats: <30% Simple sugars: <5%	*DASH diet:* Rich in fruits, vegetables, whole grains, low-fat dairy products, and low in saturated fat, total fat, cholesterol, refined grains, and sweets. Sodium intake: 2400 mg/day. *Control diet:* Similar to the Iranian dietary pattern and dietary habits.
Lee et al. (2016)	***Low-fat vegan diet*** NM	***Conventional diabetic diet*** Carbohydrates: 50–60% Proteins: 15–20% Fats: <25% Saturated fats: <7%	*Low-fat vegan diet*: Rich in whole grains, vegetables, fruit, and legumes. Participants were asked to ingest brown rice; avoid white rice, processed food made of rice flour or wheat flour, all animal food products; and favor low-glycemic index foods. The amount and frequency of food consumption, energy intake, and portion sizes were not restricted over the 12-week period. *Conventional diabetic diet:* Based on Korean Diabetes Association guidelines (Seung-Hyun et al. 2011). Participants were asked to restrict their individualized daily energy intake based on body weight, physical activity, need for weight control, and compliance. Cholesterol intake: $\leq$200 mg/day, minimal trans-fat intake

MUFAs, monounsaturated fatty acids; DASH, dietary approaches to stop hypertension; NM, not mentioned.
[a]Adoption of dietary patterns that favor the glycemic control of individuals with T2DM.
[b]Conventional controls diets for diabetes metabolic treatment.

presence of the diagnosis time of diabetes was evaluated, as well as information on the continuous use of alcohol since these are aspects that affect the outcome of the intervention. In this aspect, 60% of the studies were classified as low risk (Barnard et al. 2006, 2009; Lee et al. 2016), and 40% as high risk of bias (Esposito et al. 2009; Kahleova et al. 2011) because it did not present this information. The results of the bias risk assessment are presented in Figure 2.

The randomized crossover study, when evaluated for the randomization process, deviations from the intended intervention, missing outcome data and outcome evaluation, was rated as 'some concerns'. However, when evaluated for the selection of reported results and general bias, a high risk of bias was observed (Figure 3).

Regarding the cohort study, a risk of bias was observed after assessing the biases of confounding, lack of data, and evaluation of outcomes. However, when assessed for biases of selection, classification of interventions, deviations from intended interventions and selection of reported outcomes, the study was rated as low risk of bias (Figure 4).

General aspects

The baseline characteristics of the individuals evaluated in the studies are shown in Table 3. We observed that women corresponded to 50% or more of the participants in all studies. In addition, six out of the seven included studies had a population aged between 30 and 82 years (Barnard et al. 2006, 2009; Esposito et al. 2009; Kahleova et al. 2011; Asaad et al. 2016; Lee et al. 2016). One of the included studies did not present the age of individuals (Azadbakht et al. 2011).

The main results of each study are presented in Table 4. Regarding the variables addressed, three studies presented information about the diabetes diagnosis time, with a mean time of 9.0 years, varying between 7.0 and 10.8 years (Barnard et al. 2009; Asaad et al. 2016; Lee et al. 2016).

When duration of the proposed interventions and type of intervention were analyzed, the randomized clinical trials showed interventions varying from eight weeks to four years (Barnard et al. 2006, 2009; Esposito et al. 2009; Azadbakht et al. 2011; Kahleova et al. 2011; Lee et al. 2016). In the cohort study, the duration of the intervention was six months, and during this time, the participants received information and guidelines on healthy diet (Asaad et al. 2016).

We observed a reduction of 0.80% on average of %HbA1c, considering all studies included in this systematic review. In the four studies addressing vegan or vegetarian dietary patterns, there was a mean decrease of 0.68% of %HbA1c in the groups that underwent intervention when compared to the control diet groups, regardless of the duration of the intervention (Barnard et al. 2006, 2009; Kahleova et al. 2011; Lee et al. 2016).

The studies which offered the DASH and Mediterranean dietary patterns showed benefits for the glycemic control of T2DM individuals. Azadbakht et al. (2011) observed reduction of 1.7% and 29.4 mg/dL on average of %HbA1c and fasting glycemia, respectively, after eight weeks of intervention with DASH diet. The reduction in the %HbA1c and fasting glycemia was also observed by Esposito et al. (2009) after one (1.2% and 42 mg/dL, respectively) and four years (0,9% and 30 mg/dL, respectively) of intervention with Mediterranean dietary pattern. In addition, the adoption of the Mediterranean dietary pattern also led to increase in insulin sensitivity, as indicated by the improvement in Homeostasis Model Assessment of Insulin Sensitivity (HOMA-S) index, when compared to a conventional control diet (Esposito et al. 2009).

The food plan based on the HEI score of individuals who needed improvement in the diet quality after prior analysis of dietary habits showed benefits for glycemic control, as indicated by significant %HbA1c reductions of 0.7% and 0.5%, at three and six months of intervention, respectively. The authors adjusted the outcomes for confounding variables such as age; gender; baseline physical activity, HEI, BMI and %HbA1c (Asaad et al. 2016).

Discussion

Different dietary patterns impacted the glycemic control of individuals with T2DM, with vegan, vegetarian, DASH and Mediterranean patterns presenting the most expressive results. It is possible to observe that the dietary patterns present as common characteristics the high presence of dietary fibers, whole grains, fruits, vegetables, nuts, characteristics of a diet rich in foods with low glycemic index, and reduced fat content, especially saturated fat and cholesterol (Barnard et al. 2006, 2009; Esposito et al. 2009; Azadbakht et al. 2011; Kahleova et al. 2011; Lee et al. 2016).

Several factors may explain the effect of the vegan diet on the glycemic control, among which the nutritional characteristics of this dietary pattern, such as reduced fat content, especially saturated fat. Previous study showed a 28% reduction in the fasting plasma glucose in a 12-week low-fat vegan intervention (Nicholson et al. 1999). Besides, studies have suggested that vegan diets with reduced fat content led to decreased accumulation of intracellular fat, improving insulin sensitivity (Greco et al. 2002; Goff et al. 2005). On the other hand, studies have shown that diets rich in saturated fats (Vessby et al. 2001) and the oral intake of emulsions containing predominantly saturated fats (Xiao et al. 2006) led to decreased insulin sensitivity, as indicated by the HOMA-S index.

In addition, other characteristics of the vegan diet contributed to the glycemic control of individuals with T2DM. A diet rich in foods with low glycemic index led to a mean reduction of 0.43 points in %HbA1c (Brand-Miller et al. 2003). Also, a diet rich in high-fiber foods contributed to a reduction in plasma and urinary glucose and in the blood insulin concentrations (Chandalia et al. 2000). Despite the good results in the glycemic control of individuals with T2DM, the vegan diet pattern may present difficulties of adoption, due to the total exclusion of animal source foods, which are frequently present in the daily diet (Lee et al. 2016).

As an alternative to this question, the vegetarian dietary pattern may present as an option of easier adhesion. The Academy of Nutrition and Dietetics of the United States emphasizes that the vegetarian dietary pattern, when properly planned, have positive effects on the treatment of chronic diseases (Melina, Craig, and Levin 2016). In this sense, Kahleova et al. (2011) observed that the adherence to

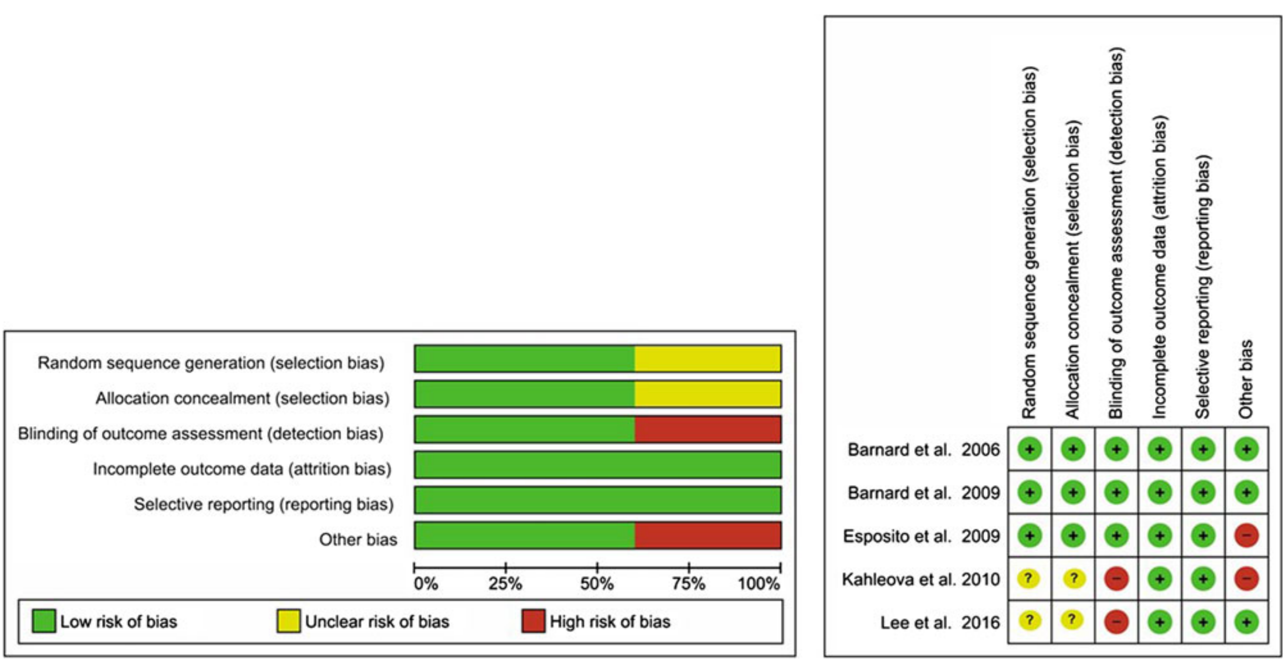

Figure 2. Bias risk assessment of randomized studies included in this review according to the Cochrane Collaboration tool.

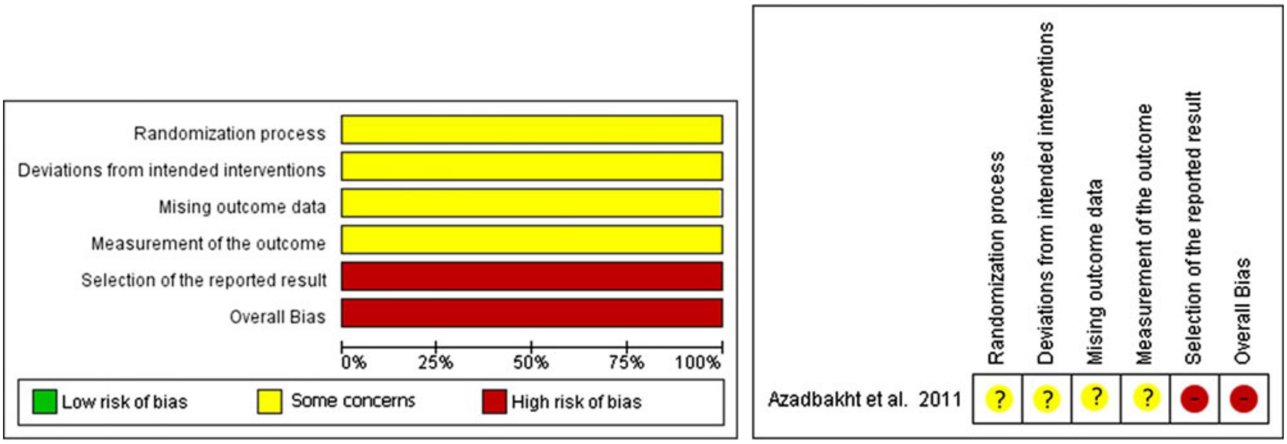

Figure 3. Bias risk assessment of randomized crossover trial according to the Cochrane Collaboration tool.

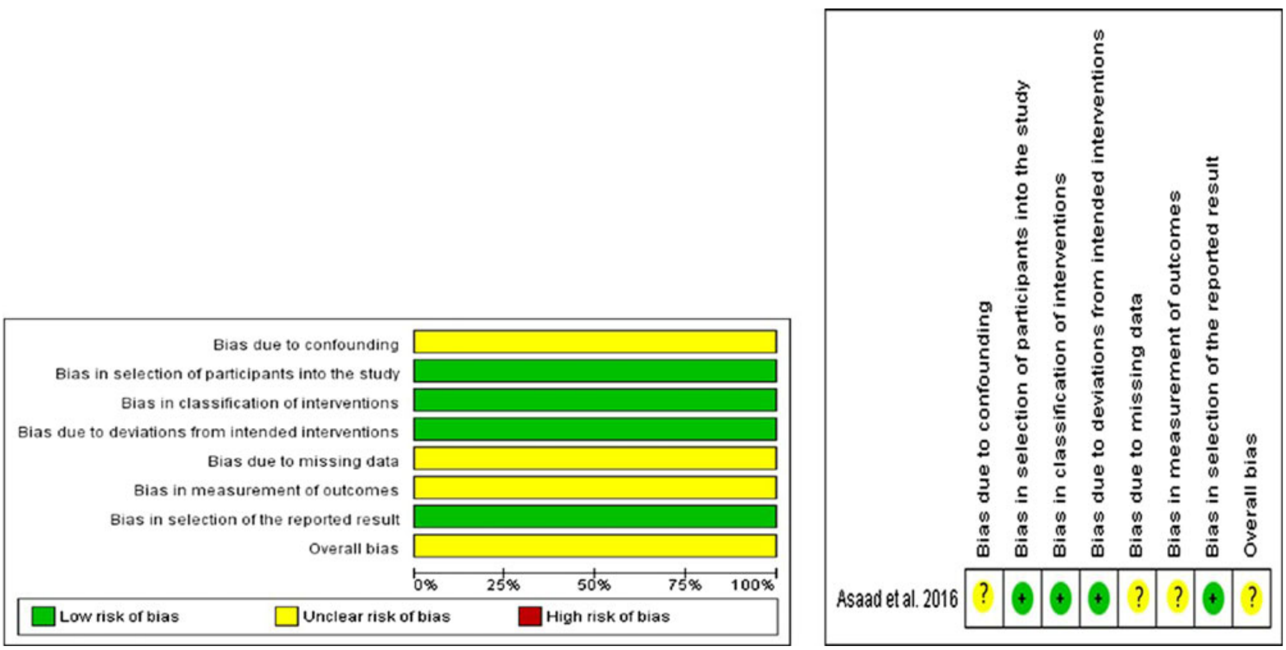

Figure 4. Bias risk assessment of the cohort study according to the Cochrane Collaboration tool.

the vegetarian dietary pattern favored the improvement of glycemic control in individuals with type 2 diabetes mellitus.

Corroborating these results, a meta-analysis found a significant association between the vegetarian dietary pattern and better glycemic control in individuals with T2DM, indicated by a mean %HbA1c reduction of 0.40 points. However, no significant decrease was observed in the fasting glycemia (Yokoyama et al. 2014). Since fasting glycemia is a less sensitive marker and %HbA1c is a better predictor of diabetes control, this result does not exclude the beneficial effects of the vegetarian diet on the T2DM treatment (Selvin et al. 2010).

In addition to the benefits of vegan and vegetarian diets for the glycemic control, studies addressed in this systematic review reported significant reductions in the BMI and waist circumference after intervention (Barnard et al. 2006, 2009; Kahleova et al. 2011; Lee et al. 2016). Currently, weight loss through reduction of the total caloric intake is considered the main way by which T2DM individuals submitted to dietary interventions, such as vegan or vegetarian diets, can achieve an adequate glycemic control (Barnard et al. 2005; Kahleova et al. 2011; Ajala et al. 2013; Mishra et al. 2013). Previous studies found similar results, such as significant body weight reduction in individuals following herbal diets, when compared to those following a conventional diet (Nicholson et al. 1999; Berkow and Barnard 2006). Since excessive adipose tissue is considered a triggering factor for insulin resistance, the weight loss observed in the studies may result in benefits for the insulin sensitivity and glycemic control (Kahn, Hull, and Utzschneider 2006), such as reduction of the doses of oral antidiabetic due to recurrent hypoglycemia in T2DM individuals (Barnard et al. 2006, 2009).

The adherence to DASH dietary pattern is often related to the nutritional management of individuals with hypertension (Sacks et al. 2001; Appel et al. 2006; Fung et al. 2008; Niknam et al. 2015) and its role in the T2DM control has also been studied (Challa and Uppaluri 2018). Considering

Table 3. Baseline characteristics of individuals with T2DM undergoing dietary interventions in the studies included in the systematic review.

Author (year)	Study design	Groups	Age (years)	Time of diagnosis of T2DM (years)	BMI (kg/m^2)	Glycemic control variables
Barnard et al. (2006, 2009)	Randomized clinical trial	Low-fat vegan diet Conventional diet	56.70 54.60	8.60 8.50	33.90 35.90	Low-fat vegan diet group %HbA1c: 8.05; FPG: 163.50 mg/dL Conventional diet group %HbA1c: 7.93; FPG: 160.40 mg/dL
Esposito et al. (2009)	Randomized clinical trial	Mediterranean diet Low-fat diet	52.40 51.90	NM	29.70 29.50	Mediterranean diet group %HbA1c: 7.75; FPG: 162.00 mg/dL Low-fat diet %HbA1c: 7.71; FPG: 159.00 mg/dL
Kahleova et al. (2011)	Randomized clinical trial	Vegetarian diet Conventional diabetic diet	54.60 57.70	NM	35.10 35.00	Vegetarian diet group %HbA1c: 7.60; FPG: 172 mg/dL Conventional diabetic diet group %HbA1c: 7.70; FPG: 172 mg/dL
Azadbakht et al. (2011)	Randomized clinical trial crossover	DASH diet Control diet	NM	NM	NM	DASH diet group %HbA1c: 7.70; FBG: 160.90 mg/dL Control group %HbA1c: 7.90; FBG: 171.80 mg/dL
Asaad et al. (2016)	Longitudinal cohort study	—	59.20	9.10	32.50	%HbA1c: 8.00
Lee et al. (2016)	Randomized clinical trial	Vegan diet Conventional diabetic diet	57.50 58.30	9.40 —	23.90 23.10	Vegan diet group %HbA1c: 7.70; FBG: 138.40 mg/dL Conventional diabetic diet group %HbA1c: 7.40; FBG: 126.30 mg/dL

T2DM, type 2 diabetes mellitus; BMI, body mass index; %HbA1c, percentage of glycated hemoglobin; FPG, fasting plasma glucose; FBG, fasting blood glucose; NM, not mentioned.

that 55% of the total energy consumed in the DASH diet comes mainly from carbohydrates of low glycemic index, following this diet may benefit individuals with T2DM, as the uptake of carbohydrates of low glycemic index helps maintain adequate blood glucose values, resulting in better glycemic control (Tyson et al. 2012).

Randomized clinical trials investigating the DASH diet's impact on the glycemic control of individuals with T2DM are scarce in the literature. In an Iranian study included in this systematic review it was observed an improvement in glycemic control markers with adoption of the DASH dietary pattern (Azadbakht et al. 2011). Moreover, the adoption of the DASH diet was associated with increased HDL cholesterol (HDL-c) levels, reduced systolic blood pressure and significant weight loss in individuals with T2DM, the latter being closely related to glycemic control (Azadbakht et al. 2011).

As the DASH diet relies on a food plan rich in fruits and vegetables, a greater intake of phytochemicals, isoflavones and phytoestrogen is observed, suggesting potential cardioprotective effect and promotion of weight loss (Azadbakht et al. 2011; Widmer et al. 2015). Even with a small number of interventional studies assessing its benefits for the T2DM population, the DASH diet is a potential strategy both for the reduction of the T2DM incidence and for the metabolic control of the disease, due to its composition (Liese et al. 2009; Barnes et al. 2013).

Dietary patterns with high amount of fibers help decrease glucose and cholesterol absorption in the intestine, resulting in lower blood concentrations of postprandial glucose and insulin and improved body weight control (Chandalia et al. 2000; Livesey and Tagami 2009; Fujii et al. 2013; Yao et al. 2014; Chen et al. 2018). Besides, fibers increase bacterial fermentation in the intestine, which prompts important processes involved in the improvement of insulin sensitivity and hindering of bile acid reabsorption, like synthesis of short-chain fatty acids, activation of the G protein-coupled receptor 43 (Gpr43) and secretion of the anorectic hormone glucagon-like peptide-1 (GLP-1) (De Vadder et al. 2014; Frota et al. 2015; Lee et al. 2016).

The Mediterranean dietary pattern is one of the most studied models in terms of health benefits and reduced risk of chronic noncommunicable diseases. The study by Esposito et al. (2009), included in this review, verified lowered fasting glycemia and %HbA1c in the group following the Mediterranean diet compared to conventional diet group. This result is corroborated by a randomized clinical trial performed in Spain, which evaluated the effect of three diet models on the metabolic control of individuals with T2DM, and found that the Mediterranean diet was associated with decreased incidence of retinopathy and diabetic nephropathy, due to better glycemic control. In addition, this study also observed an association with reduced diastolic blood pressure and HDL-c levels (Díaz-López et al. 2015).

The nutritional composition of the Mediterranean diet favors the intake of antioxidants, especially polyphenols, which have been associated with reduced risk of T2DM development and with better glycemic control in T2DM individuals, since polyphenols promote a better metabolic response to oxidative stress and inflammation, reduce the intestinal glucose absorption, and improve insulin resistance (Guasch-Ferré et al. 2017).

Extra virgin olive oil, a major component of the Mediterranean diet, is notable for containing important phenolic compounds, such as oleuropein and hydroxytyrosol, flavonoids, especially flavones, and lignans (Guasch-Ferré et al. 2017). These compounds apparently improve the response to the characteristic metabolic stress in T2DM by inhibiting the activation of the nuclear transcription factor kappa B (NF-κB), which regulates the gene expression of proinflammatory cytokines. In addition, phenolic

Table 4. Effects of dietary patterns found in dietary intake and metabolic control of individuals with T2DM in studies included in the systematic review.

Author (year)	Study design	*N* (participants)	Duration of intervention (weeks)	Variables	Main results
Barnard et al. (2006)	Randomized clinical trial	Low-fat vegan diet group ($n = 37$) Conventional diet group ($n = 37$)	22	***Glycemic control:*** %HbA1c and FPG ***Dietary pattern:*** R24h (four records) Food registry of 3 days ***Anthropometric:*** BMI and WC	• Significant reduction in %HbA1c and fasting plasma glucose in both groups. • No significant difference in %HbA1c and fasting plasma glucose between the groups after the intervention. • High fiber intake in the low-fat vegan group. • Significant reduction in BMI and WC in both groups.
Barnard et al. (2009)	Randomized clinical trial	Low-fat vegan diet group ($n = 49$) Conventional diet group ($n = 50$)	74	***Glycemic control:*** %HbA1c and FPG ***Dietary pattern:*** R24h (seven records) Food registry of 3 days ***Anthropometric:*** BMI and WC	• Significant reduction in %HbA1c in both groups. • Greater reduction in %HbA1c in the low-fat vegan group. • Greater reduction in total, saturated, monounsaturated cholesterol and fat intake • Higher fiber intake in the low-fat vegan diet group. • Significant reduction in BMI and WC in both groups.
Esposito et al. (2009)	Randomized clinical trial	Mediterranean diet ($n = 108$) Low-fat diet group ($n = 107$)	208	***Glycemic control:*** %HbA1c FPG Serum Insulin; HOMA-S; Adiponectin ***Dietary pattern:*** Food Diary ***Anthropometric:*** BMI and WC	• Significant reduction in% HbA1c and fasting plasma glucose in both groups. • Greater reduction in %HbA1c and fasting plasma glucose in the Mediterranean diet group. • Increase in adiponectin concentrations and improvement in HOMA-S in the Mediterranean diet group. • Significant reduction in BMI and WC in the Mediterranean diet group after 1 year of intervention.
Kahleova et al. (2011)	Randomized clinical trial	Vegetarian diet group ($n = 37$) Conventional diabetic diet group ($n = 37$)	24	***Glycemic control:*** %HbA1c Glucose in plasma fasting Peptide C ***Dietary pattern:*** 4 R24h Food registry of 3 days ***Anthropometric:*** BMI and WC	• Significant reduction of %HbA1c and fasting plasma glucose in the vegetarian diet group at the end of the intervention. • Higher carbohydrate intake and lower intake of protein and cholesterol in the vegetarian diet group. • Significant reduction of BMI and WC in both groups. • Greater reduction of CC in the vegetarian diet group. • Higher weight loss in the vegetarian diet group.
Azadbakht et al. (2011)	Randomized clinical trial crossover	DASH diet group ($n = 31$) Control diet group ($n = 31$)	8	***Glycemic control:*** %HbA1c Glucose in plasma fasting ***Dietary pattern:*** Food Diary of 3 days ***Anthropometric:*** Body weight and WC	• Significant reductions in %HbA1c and fasting plasma glucose in both groups. • Higher reductions in %HbA1c and fasting plasma glucose in the DASH diet group. • There were no significant differences in energy, protein, carbohydrate and fat intake between groups. • Significant reduction in body weight and WC in both groups, but higher in the DASH diet group.
Asaad et al. (2016)	Longitudinal cohort study	$n = 73$	24	***Glycemic control:*** %HbA1c ***Dietary pattern:*** 3 R24h ***Questionnaires:*** HEI, PDAQ and DSES	• Significant reductions in %HbA1c after 3 and 6 months of intervention. • At the baseline, by the HEI score the individuals 'need to improve' in relation to the quality of the diet. • Significant increase in PDAQ and DSES scores after 3 months of intervention. • Significant reduction of BMI and WC after the intervention.
Lee et al. (2016)	Randomized clinical trial	Vegan diet group ($n = 46$) Conventional diabetic diet group ($n = 47$)	12	***Glycemic control:*** %HbA1c Glucose in plasma fasting ***Dietary pattern:*** Food registry of 24h ***Anthropometric:*** BMI and WC	• Significant reductions in %HbA1c in both groups. • Higher reductions in %HbA1c in the vegan diet group. • Significant reduction in BMI and WC after intervention in the vegan diet alone.

%HbA1c, percentage of glycated hemoglobin; FPG, fasting plasma glucose; R24h, 24-hour dietary recall; BMI, body mass index; WC, waist circumference; HOMA-S, homeostasis model assessment of insulin sensitivity; HEI, healthy eating index; PDAQ, perceived dietary adherence questionnaire; DSES, diabetes self-efficacy scale.

compounds aid in the cellular production of antioxidants mediated by erythroid nuclear factor 2 (Nrf2) and improve the activity of antioxidant enzymes such as superoxide dismutase (SOD), catalase, and glutathione peroxidase (GPx) in diabetic animal models (Alam et al. 2014). However, more randomized clinical trials are needed to fully elucidate the effects of extra virgin olive oil on the glycemic control of individuals with T2DM (Widmer et al. 2015).

A different way to evaluate dietary patterns is the HEI score. Asaad et al. (2016) used this tool adapted to the Canadian population with eight components of ‘adequacy’ (whole fruits and vegetables; whole fruits; dark green and orange vegetables; total grain products; whole grains; milk and alternatives; meat and alternatives; unsaturated fats), plus three components of ‘moderation’ (saturated fats, sodium and ‘other food’) (Garriguet 2009). In this regard, the quality of the plan proposed by authors was demonstrated by a significant increase in the HEI score, which was attributed to the increased intake of fruits, vegetables and whole grains, and to the lower intake of saturated fat and sodium (Asaad et al. 2016).

In models adjusted for age, sex, and baseline variables (%HbA1c, and HEI score), a one-point increase in the HEI score predicted a 0.019-point reduction in %HbA1c. Thus, the study showed a significant mean reduction in %HbA1c after three months of intervention which was sustained after six months. Improved lipid profiles and anthropometric markers were also observed (Asaad et al. 2016).

The literature demonstrated association between higher HEI scores (adapted to different populations) and reduced risk of cardiovascular disease in individuals with T2DM (Huffman et al. 2011; Wu et al. 2016). HEI’s recommendations stimulate the consumption of vegetables, fruits, whole grains, seafood and legumes, which are sources of carotenoids, ascorbic acid, phytochemicals, dietary fiber, omega-3 fatty acids and other nutrients associated with reduced risk factors for cardiovascular disease (Wu et al. 2016).

Individuals with diabetes present increased cardiovascular risk due to disturbances caused by hyperglycemia, such as endothelial cell dysfunction, vascular smooth muscle dysfunction, impaired platelet function, and abnormal coagulation (Beckman, Creager, and Libby 2002; Emerging Risk Factors Collaboration et al. 2010). Thus, adherence to the HEI standard has proved to be beneficial for these individuals (Asaad et al. 2016).

Food pattern outcomes are influenced by non-nutritional characteristics, such as physical activity, socio-cultural, economic, and environmental aspects. In the study by Esposito et al. (2009), participants who followed the Mediterranean diet were more physically active, and their improved glycemic control was simultaneously associated with behavioral and life quality changes. Additionally, both the dose and the variety of classes of hypoglycemic agents were reduced significantly.

In this scenario, the Mediterranean diet has been described as an immaterial patrimony and addresses both nutritional aspects and healthy life habits, such as eating in company, sharing food, socializing, strengthening family ties and friendships, and participating in the meal preparation (UNESCO 2012).

The regular practice of physical exercises proposed is crucial for T2DM management due to their effect on the glycemia reduction (Colberg et al. 2010). Such effect is related to the translocation of the glucose transporter 4 (GLUT-4), which does not require insulin signaling for activation (Hayashi, Wojtaszewski, and Goodyear 1997; Pereira and Lancha 2004). Thus, changes in dietary patterns associated with physical activity improve the glycemic markers of individuals with T2DM (Asaad et al. 2016).

In the study by Asaad et al. (2016), interactive education sessions focused on planning the food menu with familiar and accessible foods were also held. In this approach, the transtheoric model was used to induce changes in the food behavior by considering individual needs, preferences, and tolerances, which increased the individual adherence to the food plan. According to Inzucchi et al. (2012), individuals with T2DM should be encouraged to consume meals that meet their nutritional needs, preferences, and cultural aspects, which requires the individuals’ involvement in health care decisions aiming at optimizing their adherence to the diet plan.

This systematic review has several strengths. First, evaluated individuals had similar age and time of T2DM diagnosis, reducing the risk of interferences of these variables in the results. Second, the results of this review were obtained by an evaluation of dietary patterns in a holistic way rather than isolated nutrients, considering individuals’ lifestyle and environmental factors, which could be helpful in the treatment and management of T2DM. However, limitations could be observed once some studies did not describe properly the method used to generate the random allocation sequence, the blinding of outcome assessment was not performed, as well as the type of intervention did not permit blinding of individuals. Also, the clinical trials included in this review involved individuals with T2DM who used oral antidiabetic drugs, nevertheless not all included studies considered this issue. In addition, geographic characteristics need to be considered, as they can interfere with the nutritional composition of foods included in the food patterns studied. Thus, clinical trials that minimize the interference of these factors in the results should be performed so that these standards can be used for therapeutic purposes.

Considering the holistic view of dietary patterns, factors that interfere with the life context of the T2DM population, such as physical activities, socioeconomic characteristics, mode of preparation, and location of meals should be considered at the time of reproduction and applicability of the results found.

Conclusion

The adoption of dietary patterns evaluated in this systematic review favored the glycemic control of individuals with T2DM, mainly by the reduction of %HBA1c, when compared to conventional diets for the metabolic treatment of individuals with T2DM adopted in the studies. In this sense, more randomized clinical trials are required for the fully elucidation of these issues in various dietary patterns, because the patterns based on vegan, and vegetarian were the most studied.

Besides, it was observed the promotion of life quality among individuals with T2DM, especially due to the nutritional characteristics of these patterns and the presence of bioactive compounds that play important roles in the organism. In addition to nutritional factors, regular physical activity and social well-being are associated with improved metabolic control in individuals with T2DM.

Notes on contributors

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References

Ajala, O., P. English, and J. Pinkney. 2013. Systematic review and meta-analysis of different dietary approaches to the management of type 2 diabetes. *The American Journal of Clinical Nutrition* 7 (3): 505–16. doi: 10.3945/ajcn.112.042457.

Alam, M., N. Subhan, M. Rahman, S. Uddin, H. Reza, and S. Sarker. 2014. Effect of citrus flavonoids, naringin and naringenin, on metabolic syndrome and their mechanisms of action. American Society for Nutrition. *Advances in Nutrition* 5:404–17. doi: 10.3945/an.113.005603.

American Diabetes Association (ADA). 2003. Evidence-based nutrition principles and recommendations for the treatment and prevention of diabetes and related complications (Position Statement). *Diabetes Care* 26 (Suppl. 1):S51–S61. doi: 10.2337/diacare.25.1.202.

American Diabetes Association (ADA). 2018. Classification and diagnosis of diabetes: Standards of Medical Care in Diabetes – 2018. *Diabetes Care* 41 (Suppl. 1):S13–S27. doi: 10.2337/dc18-S002.

Appel, L., M. Brands, S. Daniels, N. Karanja, P. Elmer, F. Sacks, and American Heart Association. 2006. Dietary approaches to prevent and treat hypertension: A scientific statement from the American Heart Association. *Hypertension* 47 (2):296–308. doi: 10.1161/01.HYP.0000202568.01167.B6.

Asaad, G., D. Soria-Contreras, R. Bell, and C. Chan. 2016. Effectiveness of a lifestyle intervention in patients with type 2 diabetes: The physical activity and nutrition for diabetes in Alberta (PANDA) trial. *Healthcare* 4 (73):1–16. doi: 10.3390/healthcare4040073.

Azadbakht, L., N. R. P. Fard, M. Karimi, M. H. Baghaei, P. J. Surkan, M. Rahimi, A. Esmaillzadeh, and W. C. Willett. 2011. Effects of the dietary approaches to stop hypertension (DASH) eating plan on cardiovascular risks among type 2 diabetic patients: A randomized crossover clinical trial. *Diabetes Care* 34 (1):55–7. doi: 10.2337/dc10-0676.

Barnard, N. D., J. Cohen, D. J. A. Jenkins, G. Turner-McGrievy, L. Gloede, B. Jaster, K. Seidl, A. A. Green, and S. Talpers. 2006. A low-fat vegan diet improves glycemic control and cardiovascular risk factors in a randomized clinical trial in individuals with type 2 diabetes. *Diabetes Care* 29 (8):1777–83. doi: 10.2337/dc06-0606.

Barnard, N., J. Cohen, D. Jenkins, G. Turner-Mcgrievy, L. Gloede, A. Green, and H. Ferdowsian. 2009. A low-fat vegan diet and a conventional diabetes diet in the treatment of type 2 diabetes: A randomized, controlled, 74-wk clinical trial. *The American Journal of Clinical Nutrition* 89 (5):1588S–96S. doi: 10.3945/ajcn.2009.26736H.

Barnard, N., A. Scialli, G. Turner-Mcgrievy, A. Lanou, and J. Glass. 2005. The effects of a low-fat, plant-based dietary intervention on body weight, metabolism, and insulin sensitivity. *The American Journal of Medicine* 118 (9):991–7. doi: 10.1016/j.amjmed.2005.03.039.

Barnes, T., J. Crandell, R. Bell, E. Mayer-Davis, D. Dabelea, and A. Liese. 2013. Change in DASH diet score and cardiovascular risk factors in youth with type 1 and type 2 diabetes mellitus: The SEARCH for Diabetes in Youth Study. *Nutrition & Diabetes* 3 (10): e91. doi: 10.1038/nutd.2013.32.

Beckman, J., M. Creager, and P. Libby. 2002. Diabetes and atherosclerosis: Epidemiology, pathophysiology, and management. *Journal of the American Medical Association* 287 (19):2570–81. doi: 10.1001/jama.287.19.2570.

Berkow, S., and N. Barnard. 2006. Vegetarian diets and weight status. *Nutrition Reviews* 64 (4):175–88. doi: 10.1111/j.1753-4887.2006.tb00200.x.

Brand-Miller, J., S. Hayne, P. Petocz, and S. Colagiuri. 2003. Low-glycemic index diets in the management of diabetes: A meta-analysis of randomized controlled trials. *Diabetes Care* 26 (8):2261–7. doi: 10.2337/diacare.26.8.2261.

Centre for Reviews and Dissemination (CRD). 2008. *Systematic reviews: CRD's guidance for undertaking reviews in health care*. 3rd ed. York, UK: CRD, University of York.

Challa, H., and K. Uppaluri. 2018. *DASH diet (Dietary Approaches to Stop Hypertension)*. Treasure Islands, FL: StatPearls Publishing.

Chandalia, M., A. Garg, D. Lutjohann, K. Von Bergmann, S. Grundy, and L. Brinkley. 2000. Beneficial effects of high dietary fiber intake in patients with type 2 diabetes mellitus. *The New England Journal of Medicine* 342 (19):1392–8. doi: 10.1056/NEJM200005113421903.

Chen, Z., M. G. Zuurmond, N. van der Schaft, J. Nano, H. A. H. Wijnhoven, M. A. Ikram, O. H. Franco, and T. Voortman. 2018. Plant versus animal based diets and insulin resistance, prediabetes and type 2 diabetes: The Rotterdam Study (CHEN). *European Journal of Epidemiology* 33 (9):883–93. doi: 10.1007/s10654-018-0414-8.

Colberg, S., R. Sigal, B. Fernhall, J. Regensteiner, B. Blissmer, R. Rubin, L. Chasan-Taber, A. Albright, and B. Braun. 2010. Exercise and type 2 diabetes: The American College of Sports Medicine and the American Diabetes Association: Joint position statement executive summary. *Diabetes Care* 33 (12):2692–6. doi: 10.2337/dc10-1548.

De Vadder, F., P. Kovatcheva-Datchary, D. Goncalves, J. Vinera, C. Zitoun, A. Duchampt, F. Bäckhed, and G. Mithieux. 2014. Microbiota generated metabolites promote metabolic benefits via gut-brain neural circuits. *Cell* 156 (1–2):84–96. doi: 10.1016/j.cell.2013.12.016.

Díaz-López, A., N. Babio, M. A. Martínez-González, D. Corella, A. J. Amor, M. Fitó, R. Estruch, F. Arós, E. Gómez-Gracia, M. Fiol, et al. 2015. Mediterranean diet, retinopathy, nephropathy, and microvascular diabetes complications: A post hoc analysis of a randomized trial. *Diabetes Care* 38 (11):2134–41. doi: 10.2337/dc15-1117.

Emerging Risk Factors Collaboration, Sarwar, N., P. Gao, S. Seshasai, R. Gobin, S. Kaptoge, E. Di Angelantonio, E. Ingelsson, D. Lawlor, and E. Selvin. 2010. Diabetes mellitus, fasting blood glucose concentration, and risk of vascular disease: A collaborative meta-analysis of 102 prospective studies. *The Lancet* 375 (9733):2215–22. doi: 10.1016/S0140-6736(10)60484-9.

Esposito, K., M. Maiorino, M. Ciotola, C. Di Palo, P. Scognamiglio, M. Gicchino, M. Petrizzo, F. Saccomanno, F. Beneduce, and A. Ceriello. 2009. Effects of a Mediterranean-style diet on the need for antihyperglycemic drug therapy in patients with newly diagnosed type 2 diabetes: A randomized trial. *Annals of Internal Medicine* 151 (5): 306–14.

Forouhi, N., and N. Wareham. 2014. The EPIC-InterAct study: A study of the interplay between genetic and lifestyle behavioral factors on the risk of type 2 diabetes in European populations. *Current Nutrition Reports* 3 (4):355–63. doi: 10.1007/s13668-014-0098-y.

Frota, K., N. Soares, V. Muniz, L. Fontenelle, and C. Carvalho. 2015. Effect of prebiotics and probiotics on the gut microbiota and metabolic changes in obese individuals. *Nutrire* 40 (2):173–87. doi: 10.4322/2316-7874.55314.

Fujii, H., M. Iwase, T. Ohkuma, S. Ogata-Kaizu, H. Ide, Y. Kikuchi, Y. Idewaki, T. Joudai, Y. Hirakawa, and K. Uchida. 2013. Impact of dietary fiber intake on glycemic control, cardiovascular risk factors and chronic kidney disease in Japanese patients with type 2 diabetes mellitus: The Fukuoka Diabetes Registry. *Nutrition Journal* 12 (1): 1–8. doi: 10.1186/1475-2891-12-159.

Fung, T., S. Chiuve, M. McCullough, K. Rexrode, G. Logroscino, and F. Hu. 2008. Adherence to a DASH-Style diet and risk of coronary heart disease and stroke in women. *Archives of Internal Medicine* 168 (7):713–20. doi: 10.1001/archinte.168.7.713.

Garriguet, D. 2009. Diet quality in Canada. *Health Reports* 20 (3): 41–52.

Georgousopoulou, E. N., D. Mellor, N. Naumovski, E. Polychronopoulos, S. Tyrovolas, S. Piscopo, G. Valacchi, F. Anastasiou, A. Zeimbekis, and V. Bountziouka. 2017. Mediterranean lifestyle and cardiovascular disease prevention. *Cardiovascular Diagnosis and Therapy* 7 (Suppl. 1):S39–S47. doi: 10.21037/cdt.2017.03.11.

Goff, L., D. Bell, P. So, A. Dornhorst, and G. Frost. 2005. Veganism and its relationship with insulin resistance and intramyocellular lipid. *European Journal of Clinical Nutrition* 59 (2):291–8. doi: 10.1038/sj.ejcn.1602076.

Greco, A., G. Mingrone, A. Giancaterini, M. Manco, M. Morroni, S. Cinti, M. Granzotto, R. Vettor, S. Camastra, and E. Ferrannini. 2002. Insulin resistance in morbid obesity: Reversal with intramyocellular fat depletion. *Diabetes* 51 (1):144–51. doi: 10.2337/diabetes.51.1.144.

Guasch-Ferré, M., J. Merino, Q. Sun, M. Fitó, and J. Salas-Salvadó. 2017. Dietary polyphenols, Mediterranean diet, prediabetes, and type 2 diabetes: A narrative review of the evidence. *Oxidative Medicine and Cellular Longevity* 2017:1. doi: 10.1155/2017/6723931.

Hayashi, T., J. Wojtaszewski, and L. Goodyear. 1997. Exercise regulation of glucose transport in skeletal muscle. *American Journal of Physiology-Cell Physiology* 273 (6 Pt 1):E103–E1051.

Health Canada. 2011. *Eating well with Canada's Food Guide*. Health Canada. Accessed May 22, 2019. http://www.hcsc.gc.ca/fn-an/food-guide-aliment/index-eng.php.

Higgins, J., and S. Green, editors. 2011. *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [updated March 2011]*. The Cochrane Collaboration. Accessed November 15, 2018. http://handbook.cochrane.org.

Higgins, J., J. Sterne, J. Savović, M. Page, A. Hróbjartsson, I. Boutron, B. Reeves, and S. Eldridge. 2016. *RoB 2.0: A revised tool for assessing risk of bias in randomized trials*. London, UK: The Cochrane Collaboration. doi: 10.1002/14651858.CD201.

Hodge, A., and J. Bassett. 2016. What can we learn from dietary pattern analysis? *Public Health Nutrition* 19 (2):191–4. doi: 10.1017/S1368980015003730.

Huffman, F., G. Zarini, E. Mcnamara, and A. Nagarajan. 2011. The healthy eating index and the alternate healthy eating index as predictors of 10-year CHD risk in Cuban Americans with and without type 2 diabetes. *Public Health Nutrition* 14 (11):2006–14. doi: 10.1017/S1368980011001054.

International Diabetes Federation (IDF). 2017. *IDF diabetes atlas*. 8th ed. Belgium, Germany: International Diabetes Federation.

Inzucchi, S., R. Bergenstal, J. Buse, M. Diamant, E. Ferrannini, M. Nauck, A. Peters, A. Tsapas, R. Wender, and D. Matthews. 2012. Management of hyperglycaemia in type 2 diabetes: A patient-centered approach: Position statement of the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD). *Diabetes Care* 35 (6):1364–79. doi: 10.2337/dc12-0413.

Kahleova, H., M. Matoulek, H. Malinska, O. Oliyarnik, L. Kazdova, T. Neskudla, A. Skoch, M. Hajek, M. Hill, M. Kahle, and T. Pelikanova. 2011. Vegetarian diet improves insulin resistance and oxidative stress markers more than conventional diet in subjects with type 2 diabetes. *Diabetic Medicine* 28 (5):549–59. doi: 10.1111/j.1464-5491.2010.03209.x.

Kahn, S., R. Hull, and K. Utzschneider. 2006. Mechanisms linking obesity to insulin resistance and type 2 diabetes. *Nature* 444 (7121): 840–6. doi: 10.1038/nature05482.

Krauss, R. M., R. H. Eckel, B. Howard, L. J. Appel, S. R. Daniels, R. J. Deckelbaum, J. W. Erdman, P. Kris-Etherton, I. J. Goldberg, T. A. Kotchen, et al. 2000. AHA dietary guidelines: Revision 2000: A statement for healthcare professionals from the Nutrition Committee of the American Heart Association. *Stroke* 31 (11):2751–66. doi: 10.1161/01.STR.31.11.2751.

Landis, J., and G. Koch. 1977. The measurement of observer agreement for categorical data. *Biometrics* 33 (1):159–74.

Lee, Y., S. Kim, I. Lee, J. Kim, K. Park, J. Jeong, J. Jeon, J. Shin, and D. Lee. 2016. Effect of a brown rice based vegan diet and conventional diabetic diet on glycemic control of patients with type 2 diabetes: A 12-week randomized clinical trial. *PLoS One* 11 (6):e0155918. doi: 10.1371/journal.pone.0155918.

Ley, S., O. Hamdy, V. Mohan, and F. Hu. 2014. Prevention and management of type 2 diabetes: Dietary components and nutritional strategies. *The Lancet in North America* 383 (9933):1999–2007. doi: 10.1016/S0140-6736(14)60613-9.

Liese, A., M. Nichols, X. Sun, R. D'agostino, and S. Haffner. 2009. Adherence to the DASH diet is inversely associated with incidence of type 2 diabetes: The insulin resistance atherosclerosis study. *Diabetes Care* 32 (8):1434–6. doi: 10.2337/dc09-0228.

Livesey, G., and H. Tagami. 2009. Interventions to lower the glycemic response to carbohydrate foods with a low viscosity fiber (resistant maltodextrin): Meta-analysis of randomized controlled trials. *The American Journal of Clinical Nutrition* 89 (1):114–25. doi: 10.3945/ajcn.2008.26842.

Melina, V., W. Craig, and S. Levin. 2016. Position of the Academy of Nutrition and Dietetics: Vegetarian diets. *Journal of the Academy of Nutrition Dietetics* 116 (12):1970–80. doi: 10.1016/j.jand.2016.09.025.

Mishra, S., J. Xu, U. Agarwal, J. Gonzales, S. Levin, and N. Barnard. 2013. A multicenter randomized controlled trial of a plant-based nutrition program to reduce body weight and cardiovascular risk in the corporate setting: The GEICO study. *European Journal of Clinical Nutrition* 67 (7):718–24. doi: 10.1038/ejcn.2013.92.

Moher, D., A. Liberati, J. Tetzlaff, and D. Altman. 2009. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Annals of Internal Medicine* 151 (4):264–9. doi: 10.1371/journal.pmed.1000097.

Moher, D., S. Hopewell, K. Schulz, V. Montori, P. Gøtzsche, P. Devereaux, D. Elbourne, M. Egger, and D. Altman. 2012. CONSORT 2010 explanation and elaboration: Updated guidelines for reporting parallel group randomised trials. *British Medical Journal* 10 (1):28–55. doi: 10.1136/bmj.c869.

Mozaffarian, D. 2016. Dietary and policy priorities for cardiovascular disease, diabetes, and obesity – A comprehensive review. *Circulation* 133 (2):187–225. doi: 10.1161/CIRCULATIONAHA.115.018585.

Nicholson, A., M. Sklar, N. Barnard, S. Gore, R. Sullivan, and S. Browning. 1999. Toward improved management of NIDDM: A randomized, controlled, pilot intervention using a lowfat, vegetarian diet. *Preventive Medicine* 29 (2):87–91. doi: 10.1006/pmed.1999.0529.

Niknam, M., M. Saadatnia, F. Shakeri, A. Keshteli, P. Saneei, and A. Esmaillzadeh. 2015. Adherence to a DASH-style diet in relation to stroke: A case-control study. *The Journal of the American College of Nutrition* 34 (5):408–15. doi: 10.1080/07315724.2014.943851.

Osonoi, Y., T. Mita, T. Osonoi, M. Saito, A. Tamasawa, S. Nakayama, Y. Someya, H. Ishida, A. Kanazawa, and M. Gosho. 2016. Relationship between dietary patterns and risk factors for cardiovascular disease in patients with type 2 diabetes mellitus: A cross-sectional study. *Nutrition Journal* 15:1–11. doi: 10.1186/s12937-016-0132-6.

Pereira, L., and A. Lancha. 2004. Effect of insulin and contraction up on glucose transport in skeletal muscle. *Progress in Biophysics & Molecular Biology* 84 (1):1–27. doi: 10.1016/S0079-6107(03)00055-5.

Sacks, F., L. Svetkey, W. Vollmer, L. Appel, G. Bray, D. Harsha, E. Obarzanek, P. Conlin, E. Miller, D. Simons-Morton, et al. 2001. Effects on blood pressure of reduced dietary sodium and the dietary approaches to stop hypertension (DASH) diet. DASH-Sodium Collaborative Research Group. *The New England Journal of Medicine* 344 (1):3–10. doi: 10.1056/NEJM200101043440101.

Savoca, M., C. Miller, and D. Ludwig. 2004. Food habits are related to glycemic control among people with type 2 diabetes mellitus. *Journal of the American Dietetic Association* 104 (4):560–6. doi: 10.1016/j.jada.2004.01.013.

Selvin, E., M. Steffes, H. Zhu, K. Matsushita, L. Wagenknecht, J. Pankow, J. Coresh, and F. Brancati. 2010. Glycated hemoglobin, diabetes, and cardiovascular risk in nondiabetic adults. *The New England Journal of Medicine* 362 (9):800–11. doi: 10.1056/NEJMoa0908359.

Seung-Hyun, K., K. Sung-Rea, K. Dong-Joon, O. Seung-Joon, L. Hye-Jin, S. Kang-Hee, W. Mi-Hye, K. Jun-Young, K. Nan-Hee, K. Jae-Taik, et al. 2011. 2011 Clinical practice guidelines for type 2 diabetes in Korea. *Diabetes & Metabolism Journal* 35 (5):431–6. doi: 10.4093/dmj.2011.35.5.431.

Sievenpiper, J., and P. Dworatzek. 2013. Food and dietary pattern-based recommendations: An emerging approach to clinical practice guidelines for nutrition therapy in diabetes. *Canadian Journal of Diabetes* 37 (1):51–7. doi: 10.1016/j.jcjd.2012.11.001.

Sterne, J., M. Hernán, B. Reeves, J. Savović, N. Berkman, M. Viswanathan, D. Henry, D. Altman, M. Ansari, I. Boutron, et al. 2016. ROBINS-I: A tool for assessing risk of bias in non-randomized studies of interventions. *British Medical Journal* 355:i4919. doi: 10.1136/bmj.i4919.

Tyson, C., C. Nwankwo, P. Lin, and L. Svetkey. 2012. The Dietary Approaches to Stop Hypertension (DASH) eating pattern in special populations. *Current Hypertension Reports* 14 (5):388–96. doi: 10.1007/s11906-012-0296-1.

United Nations Educational, Scientific and Cultural Organization (UNESCO). 2012. Intangible Heritage Lists. Accessed July 3, 2018. https://www.unesco.org.

Vessby, B., M. Uusitupa, K. Hermansen, G. Riccardi, A. A. Rivellese, L. C. Tapsell, C. Nälsén, L. Berglund, A. Louheranta, B. M. Rasmussen, et al. 2001. Substituting dietary saturated for monounsaturated fat impairs insulin sensitivity in healthy men and women: The KANWU study. *Diabetologia* 44 (3):312–9. doi: 10.1007/s001250051620.

Villani, A., J. Sultana, J. Doecke, and E. Mantzioris. 2018. Differences in the interpretation of a modernized Mediterranean diet prescribed in intervention studies for the management of type 2 diabetes: How closely does this align with a traditional Mediterranean diet? *European Journal of Nutrition*. doi: 10.1007/s00394-018-1757-3.

Wheeler, M., S. Dunbar, L. Jaacks, W. Karmally, E. Mayer-Davis, J. Wylie-Rosett, and W. Yancy. 2012. Macronutrients, food groups, and eating patterns in the management of diabetes: A systematic review of the literature, 2010. *Diabetes Care* 35 (2):434–45. doi: 10.2337/dc11-2216.

Widmer, R., A. Flammer, L. Lerman, and A. Lerman. 2015. The Mediterranean diet, its components, and cardiovascular disease. *The American Journal of Medicine* 128 (3):229–38. doi: 10.1016/j.amjmed.2014.10.014.

Wu, P., C. Huang, W. Lei, and S. Yang. 2016. Alternative health eating index and the dietary guidelines from American Diabetes Association both may reduce the risk of cardiovascular disease in type 2 diabetes patients. *Journal of Human Nutrition and Dietetics* 29 (3):363–73. doi: 10.1111/jhn.12317.

Xiao, C., A. Giacca, A. Carpentier, and G. Lewis. 2006. Differential effects of monounsaturated, polyunsaturated and saturated fat ingestion on glucose-stimulated insulin secretion, sensitivity and clearance in overweight and obese, non-diabetic humans. *Diabetologia* 49 (6):1371–9. doi: 10.1007/s00125-006-0211-x.

Yao, B., H. Fang, W. Xu, Y. Yan, H. Xu, Y. Liu, M. Mo, H. Zhang, and Y. Zhao. 2014. Dietary fiber intake and risk of type 2 diabetes: A dose–response analysis of prospective studies. *European Journal of Epidemiology* 29 (2):79–88. doi: 10.1007/s10654-013-9876-x.

Yokoyama, Y., N. Barnard, S. Levin, and M. Watanabe. 2014. Vegetarian diets and glycemic control in diabetes: A systematic review and meta-analysis. *Cardiovascular Diagnosis and Therapy* 4 (5):373–82. doi: 10.3978/j.issn.2223-3652.2014.10.04.