REVIEW ARTICLE

How dietary patterns could have a role in prevention, progression, or management of diabetes mellitus? Review on the current evidence

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Objective: To investigate the role of dietary patterns in prevention and management of type 2 diabetes mellitus. **Materials and Methods:** A systematic review of databases which were published in ISI, Cochrane Central Register of Controlled Trials databases, PubMed, Iran Medex, and MagIran was performed. "Diabetes" and "dietary pattern" were used as the keywords. **Results:** A total of 58 studies which aimed to focus on diabetes mellitus, insulin resistance, metabolic syndrome, dietary pattern, and other related key words were reviewed. More than 47,447 articles were found and 46,709 entries of the extracted studies were excluded on the basis of the title and abstracts. The major dietary patterns were: "Healthy," "Western," "Traditional," "Prudent," "Unhealthy," "Mediterranean," "Modern," and "Dietary Approach to Stop Hypertension" (DASH) diets. Comparison of the effects of different diets revealed that dietary patterns containing fiber-rich foods have a protective role in managing diabetes mellitus. "Healthy," "Mediterranean," "Prudent," and "DASH" dietary patterns were associated with lower risk of hyperglycemia. **Conclusions:** The adherence to the "Mediterranean," "Prudent," or "DASH" diets could control hyperglycemia. The higher intake of vegetables, fruits, nuts, whole grains, and lower intake of red meat could reduce the risk of type 2 diabetes mellitus.

Key words: Dietary pattern, glycemic control, Healthy dietary pattern, Mediterranean dietary pattern, Prudent dietary pattern, type 2 diabetes mellitus, Western dietary pattern

INTRODUCTION

Diabetes mellitus (DM) is a popular lifelong metabolic disease, and probably will remain the most frequent cause of death in the following decades.[1] Diabetes as a concerned epidemic problem is increasing all over the world.[2-10] Statistical estimations show that the number of diabetic individuals will be 65% of the world population (380 millions) by 2025.[11] The prevalence of this disease will become about twofold in the coming 20 years.[12] The prevalence of DM is as much as nearly 5% of the world population[12] and it has doubled during the recent 20 years.[13] It is the fifth cause of death in the USA[14] and one of the four causes of non-communicable disorders in different age groups.[15] Asian countries also have high prevalence of diabetes. Incidence rate of 10.6 per 1000 persons was observed in an Iranian survey.[16]

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Data show that almost 15–20% of population in different areas may have either DM or impaired glucose tolerance (IGT) in 2025.[12] Lifestyle modification could reduce the risk of diabetes by 30–67%, and surprisingly, this reduction maintains even after removing the lifestyle modifications.[16,17] Lifestyle modification can decrease diabetes risk by about 58% among subjects with IGT. These modifications consist of physical activity and changes in dietary habits, which are 27% more useful than taking various medications. Most of the assessments revealed that broad preventive population-based strategies are critical to challenge the pandemic of DM.[18] DM is a multi-factorial disorder in which both genetic and environmental factors have major roles.[18,19] Besides urbanization and technology development, the rapid nutritional and lifestyle transition faced by us doubles the burden of diseases. Poor quality of diet and nutritional habits have potential effects on the obesity-based chronic diseases.[2,20-23] Diet has a major role in preventing and managing hyperglycemia and DM.[1,24,25] Previous focus of nutrition science was on the amount and distribution of nutrients and food components. However, this approach has been replaced by a focus on a combination of nutrients and considering foods and food components together. Different unknown components and various interactions of food

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components provide the idea of focusing on dietary patterns instead of food components or nutrients.[26,27] Dietary pattern approach helps in assessing the entire diet,[27] which is also more understandable compared to just focusing on nutrient- or food-based approach to make recommendation for population.[28] Dietary pattern as a new focus in nutritional epidemiology is a suitable approach that covers biological native interactions of nutrient components in different food groups in relation with various disorders. Dietary pattern reflects an individual's food consumption and its change during the life span,[29,30] so it provides comprehensive information about dietary habits and identifies more effective recommendations to manage different chronic diseases. The complex interactions are shown in numerous dietary patterns such as "Mediterranean," Dietary Approaches to Stop Hypertension (DASH), "Prudent," "Western," "Traditional," and "Healthy" dietary patterns.[26]

Therefore, we aimed to assess the relationship between different dietary pattern and the prevalence of type 2 DM and also assess the effect of different eating habits on managing type 2 DM in this review paper.

MATERIALS AND METHODS

We reviewed all the study designs (prospective cohort study, clinical trials, cross-sectional studies) and focused on the available sources between 1992 and 2011, including journals, electronic books, seminars, and symposium contexts. The search focused on databases published in Cochrane Central Register of Controlled Trials databases, PubMed, Iran Medex, and MagIran using the keywords: Diabetes mellitus, insulin resistance, metabolic syndrome, and dietary pattern. We also studied food, insulin resistance (IR), fasting blood glucose (FBG), and Homeostasis Model Assessment of Insulin Resistance (HOMA-IR) as the basic related features of DM[26] and metabolic syndrome.[27] The relevance of surveys was found with a hierarchical approach on the basis of titles, abstracts, and full text of articles. Our search was limited to English materials We excluded letters, and studies focusing on single nutrients and food items, children, adolescents, and animal studies. The information had been summarized based on fixed protocol: Lead author, country, year of publication, sample size, sex and age of subjects, assay method, follow-up duration, outcome measure, race/ethnic, dietary pattern, effect size measurements [odds ratio (OR)/relative risk], and confounding factors adjustments.

In the initial search, we found more than 569 articles in PubMed on DM and dietary pattern, 23,296 entries on DM and diet, 344 articles on dietary pattern and IR, 10,359 entries on diet and IR, and 12,879 articles on DM and food. After scanning the articles, 46,709 of the extracted studies were excluded on the basis of the title, abstract, and their major purposes which were limited to the single nutrients and food items.

RESULTS AND DISCUSSION

Mediterranean dietary pattern

This food habit emphasizes on good source of monounsaturated fatty acids (MUFA) from olive oil, accompanied with intake of vegetables, nuts, seeds, fruits, and whole grains, and reduction in the consumption of red meat and unhealthy fats. High content of fiber, magnesium, polyphenol, and antioxidants makes this diet as a useful approach to control hyperglycemia and weight maintenance.[28,31,32]

The results of a large Spanish cohort study among 13,380 men and women showed that adherence to the Mediterranean diet could decrease the risk of type 2 DM by 83%.[33] This inverse association between Mediterranean dietary pattern and the prevalence of type 2 DM was observed in various multiethnic studies. Several epidemiological studies explained lower odds of having DM[34] and inverse relation between glucose level,[35-37] insulin,[31,37-39] and HOMA-IR (as one of the basic features of metabolic syndrome and type 2 DM)[31,33,36,40-42] following adherence to the Mediterranean dietary pattern even after controlling different confounding agents.[43-48] Higher adherence to the Mediterranean dietary pattern score in normoglycemic persons decreased fasting glucose, insulin, and IR. However, this reduction was not significant after multiple adjustments were made for diabetic patients and subjects with impaired fasting glucose (IFG).[43] The aforementioned findings are observed in elderly group[49] and high-risk persons with cardiovascular risk factors and in also those with history of myocardial infarction.[31,50-52] Another cohort study on 7751 subjects in different ethnics compared four dietary patterns: 1."Mediterranean-like diet" containing rice, pasta, vegetables, fruits, and wine; 2. "Healthy pattern" that includes whole bread, fruits, vegetables, low-fat dairies, and little alcohol; 3. "Sweet pattern" rich in white bread, processed meat, and high-fat dairy products; and 4. "Unhealthy eating pattern" high in white bread, processed meat, fries, and full-cream milk. Results showed that healthy diet is the best pattern in lowering the incidence of DM.[53] Panagiotakos *et al.* observed a lower OR of diabetes among Greek adults with high score of adherence to the Mediterranean dietary pattern.[54] The comparison of the effects of "Mediterranean hypocaloric" diet and "very-low-carbohydrate hypocaloric" diet on fasting plasma glucose, serum insulin level, and insulin 2 h post-load concentration and HOMA-IR did not show a significant difference even after 8 weeks weight loss in obese women.[55] A longitudinal clinical trial for 54 months revealed that consuming a

Mediterranean diet could decrease HOMA-IR and serum glucose and serum insulin levels in persons with metabolic syndrome.[56] As patients with metabolic syndrome are at high risk for developing type 2 diabetes, following the Mediterranean diet can have a protective effect in this regard. Table 1 shows the different studies which evaluate the effects of "Mediterranean" dietary pattern on type 2 DM.

Prudent and Western dietary pattern

Several studies have focused on the association between lower risk of type 2 DM and adherence to the "Prudent pattern." Prudent pattern is another dietary pattern which is characterized by higher consumption of whole grains, vegetables, fruits, poultry/sea foods, legumes, and coffee.[3,58,59] In an American prospective cohort study among 42,504 men, higher adherence to the Prudent pattern reduced the risk of DM by 16%, however, after 12 years of follow-up. However, "Western dietary pattern" increased the risk to almost 60%.[3] Western dietary pattern contains red and processed meat, butter, French fries, refined grains, deserts, potatoes, sweets, high-fat dairy, and soda.[3,58,59] The results were similar to the findings of the "Atherosclerosis Risk in Communities (ARIC)" study[60] and al so, the observations of Fung *et al*. in the Nurses' Health Study (NHS) following 12 years.[58] In another study, the "Conservative " and "Prudent " patterns were compared. "Conservative" eating pattern, which contains butter, potatoes, and whole milk, has been correlated positively with the risk of diabetes by 50% while adherence to the "Prudent" dietary pattern reduced this risk by 28%.[59] Two cross-sectional studies of Villegas et al. defined usual dietary pattern of adults in three clusters, which correspond to "Traditional," "Prudent," and "Alcohol and convenience" diets. "Traditional" pattern had high percent of fat in total calorie intake; predominantly fat intake was in the forms of saturated fatty acids (SFA) and MUFA, in contrast to "Prudent" diet which was characterized as a pattern rich in polyunsaturated fatty acids (PUFA), high P/S ratio, fiber, and antioxidant vitamin sources. "Alcohol and convenience" diet included the highest intake of alcohol, protein, cholesterol, vitamin B-complex, iron, phosphorus, selenium, zinc, and the lowest amount of PUFA and antioxidant vitamins. Analysis showed the lowest IR and hemoglobin A1C (HbA1C) level in subjects adhering to the "Prudent dietary pattern."[61,62] An Iranian nested cross-sectional study among 425 subjects with IGT (25–35 years old) showed the association between plasma glucose as one of the major features of metabolic syndrome and five eating patterns: 1. "Western" pattern (rich in sweets, butter, soda, mayonnaise, sugar, cookies, tail of a lamb, hydrogenated fat, and eggs); 2. "Prudent" pattern (contains fish, peas, honey, nuts, juice, dry fruits, vegetable oil, liver and organic meat, and coconuts); 3. "vegetarian" pattern (includes potatoes, legumes, fruits, rice, green leafy vegetables, and fruits); 4. "high-fat dairy" pattern (high in fatty dairies); and 5. "chicken and plant" pattern (rich in chicken, fruits, green leafy vegetables, and mayonnaise). After controlling various confounding factors, results revealed that "vegetarian" diet can reduce blood glucose level significantly.[63] Different studies that assessed the effects of "Prudent" and "Western" patterns among type 2 DM are shown in Table 2.

"Healthy," "Western," and "Traditional" dietary patterns

Food items of similar dietary patterns are different, based on geographic and ethnic characters. "Traditional" pattern is characterized by higher consumption of refined grains, potato, tea, whole grains, hydrogenated fats, legumes, and casserole,[64] or it can be defined as a pattern rich in high-fat sandwich spreads, red meat, potatoes, butter and lard, low-fat fish, sandwich meat, and sauces.[65] Healthy diet usually contains higher intake of whole meal bread, fruit and vegetables, and polyunsaturated margarine, besides lower consumption of red meat, sweet foods, and wine and beer,[53] or food rich in fruits, vegetables, tomato, poultry, legumes, tea, fruit juices, and whole grains.[66]

Pattern rich in red meat, processed meat, French fries, high-fat dairy products, refined grains, and sweets and desserts,[3] or sweets, butter, soda, mayonnaise, sugar, cookies, tail of a lamb, hydrogenated fat, and eggs,[63] and refined grains, red meat, butter, processed meat, high-fat dairy, sweets and desserts, pizza, potato, eggs, hydrogenated fats, and soft drinks[66] is called as a "Western" dietary pattern.

In a cross-sectional study of 486 Iranian women between 40 and 60 years of age, three dietary patterns were determined by using the factor analysis method: 1. "Healthy" pattern defined by frequent consumption of fruits, green leafy and cruciferous vegetables, tomatoes, legumes, tea, and poultry; 2. ready-to-use food items as the main footsteps of modernization or so-called as "Western" dietary pattern; and 3. "Iranian traditional" pattern consists of whole and refined grains, potatoes, legumes, tea, hydrogenated fats, and broth. The highest OR of IR and syndrome X was observed in people with the adherence to the highest quintile of "Western" diet. This result is similar to the result of Fung *et al*. who observed a positive association between "Western" pattern adherence and insulin level.[67] It should be mentioned that "Healthy" pattern can reduce risk of IR by 45%, while adherence to the "Western" dietary pattern increases this risk to 15%.[66]

Mcnaughton et al. in an Australian cohort study (Whitehall II) observed higher incidence of type 2 diabetes and higher value of HOMA-IR by adherence to the highest quartile of a diet rich in soft drinks, sugar-sweetened beverages, burgers and sausages, snacks, and white bread, and low intake of fiber food sources, by 2.95 times.[68] A multiethnic Hawaiian survey revealed that higher ORs for type 2 DM

were associated with "animal" foods, "local ethnic" dishes, and "Western" dietary pattern. "Animal" and "local ethnic" dishes included high intake of cabbage, rice, shell fish, corned beef plus "Hawaiian and Filipino" dishes.[69] The study showed that people with "Modern" dietary pattern had a lower postprandial plasma glucose, after adjusting the confounding factors in the analysis in brief more consumptions of vegetables, vegetable oil/vinegar dressing, fruits, cereals, rice, pasta, and poultry against "Traditional" diet (contains red meat, high-fat meat sandwich, butter and lard, potatoes, low-fat fishes, and sauces). This study showed that eating pattern can affect 2 h plasma glucose independent of subject's tolerance.[65] Analysis of dietary intake among 1508 Samoan and American Samoan subjects derived two major diets as "Neo-traditional pattern" and "Modern pattern." "Neo-traditional pattern" is rich in local dishes such as coconut products, lobster, starchy vegetables, crab, and low consumptions of soda and chips, while "Modern dietary pattern" contains processed and ready-to-use foods like cake, butter, eggs, and chips. In contrast with "Neo-traditional" pattern, "Modern" pattern represented lower serum glucose concentration and metabolic syndrome in Samoan men and women.[70] The effects of "Healthy," "Western," and "Traditional" dietary patterns among type 2 DM were evaluated in various studies whose characters are reflected in Table 3.

"DASH" dietary pattern

Besides the first known effect of DASH on blood pressure control,[71-77] the other useful potent roles of its main components, such as low-fat dairies and fiber-based foods, were observed on lipid profile[74,78] and features of metabolic syndrome.[74,79] DASH can also reduce the coronary heart disease.[80] In recent years, several surveys assessed DASH effects on blood glucose and incidence of type 2 DM. In the insulin resistance atherosclerosis study (IRAS) of 862 subjects from three different ethnics (Hispanic, non-Hispanic White and Black), "DASH" diet lowered the risk of diabetes incidence by as much as 36% in Whites against Black and Hispanic participants.[81] The effect of "DASH" diet on FBG was shown in two randomized clinical trial studies. In one study, three diets were prescribed for 116 men and women during 6 months. These diets consisted of "weight reducing" diet, "DASH" diet, and "control" diet. The "weight reducing" diet is defined as a diet with lower calorie contents and more "consumption of healthy food items"(such as vegetables, fruits, and low-fat Dairies) Subjects in the "control group" followed their usual eating habits. The significant reduction of FBG in both sexes with "DASH" diet emphasized on its safe effects to modify metabolic syndrome features.[74] The other cross-over randomized clinical trial (RCT) assessed the effects of "DASH" diet on HbA1C and fasting blood sugar (FBS) levels in diabetic patients. Reduction in FBG and HbA1C following adherence to the DASH diet showed that DASH eating pattern is a useful strategy in controlling blood glucose among type 2 diabetic patients.[57] Table 4 reflects the characters of related studies.

Other dietary habits

In Panagiotakos' study, a positive correlation between red meat intake and Homeostasis Model Assessment of Insulin. Resistance and Insulin Secretory Capacity (HOMA-IR, HOMA-B), insulin, and blood glucose levels was observed among 2832 subjects without cardiovascular disorders. [43] However, there was no significant relationship between healthy food groups such as vegetables, legumes, and fruits consumption and glycemic control after controlling for potential confounders.[82] Reverse association between DM incidence and dietary pattern rich in "meat and milk" was observed in another study.[83] The "Traditional" pattern was compared with "meat and alcohol" and "Korean healthy" dietary patterns in a cross-sectional study. White rice was the dominant food item in all three diets. But noodle and dumpling in "Korean" pattern and processed meat products in "meat and alcohol" eating habit showed significantly different effect on FBG. "Meat and alcohol" dietary pattern increased the risk of high blood glucose by 33%.[84] Furthermore, data from the Puerto Rican elder inhabitants with rice and bean rich diet were studied in a longitudinal investigation among 1167 subjects. Analysis of their eating habits extracted three main patterns: "meat and French fries," "Traditional pattern" (rice, beans, and oils), "sweets, sugary beverages, and dairy desserts." After controlling the confounders, just "sweet" diet had a negative significant association with fasting serum sugar.[85] A cross-sectional study among 984 Iranian women revealed that the clusters of diet containing "fish, vegetables, legumes, cereals, and fruits," and diet rich in "dairy products and eggs" could decrease FBS. However, diet rich in "red or white meat, meat products, and potatoes," "pasta" and "sweet" patterns had unfavorable effects.[86] A reverse association of habitual diet with hyperglycemia and hyperinsulinemia was also observed in a nested cross-sectional survey of six dietary patterns among Sweden adults. Data showed lower hyperinsulinemia in women with higher milk-fat–based food habits against taking white bread items, in common.[87] He *et al*. derived four dietary patterns after analysis of semi-quantitative food frequency questionnaire among 20,210 Chinese adults: "Western Adopter"(Western-like pattern), "Green Water" (high vegetables and low animal food style in the southeast area), "New Affluence" (rich in animals and soy products which is used by well-to-do individuals), and "Yellow Earth" [high carbohydrate (CHO) and low fruits, vegetables, and animal dishes, which is common in the northwest area]. Comparing "Green Water consumer," the prevalence of IGT in "Yellow Earth" and "New Affluence" escalated

Table 1: Characteristics of various studies that evaluated the effects of "Mediterranean" dietary pattern on diabetes mellitus type 2

Source	Country, year	Sex	Age	Sample size (n)	Study design	Follow-up duration	Outcome measure	Dietary assessment tool	Race/ ethnic	Dietary pattern	Adjusted OR/RR (0.95 CI)	Adjustment	Ref.
González *et al.*	Spain, 2008	F/M	20–90	13,380	Prospective cohort study	4.4 years	Incidence of diabetes	FFQ (136 items)	White	Mediterranean food pattern	0.17 (0.04–0.72)	Sex, age, education, energy, BMI, physical activity, sedentary habits, smoking, history of DM and HTN	[45]
Mozaffarian *et al.*	Italy, 2007	F/M	59	8291	RCT	3.5 years	Incident diabetes	Full-scale diet questionnaires	White	Mediterranean diet	0.65 (0.49–0.85)	Age, sex, smoking, time from MI, BMI, exercise tolerance, ischemia symptoms, cardiovascular symptoms, history of HTN and MI, taking drug, consumption of cheese and wine	[51]
Panagiotakos *et al.*	Greece, 2005	F/M	20–89	1528/1514	Cross-sectional study (ATTICA)	12 months	The prevalence of diabetes	FFQ	White	Mediterranean diet	21%	Demographical, lifestyle, and clinical characters	[57]
Panagiotakos *et al.*	Greece, 2007	F/M	18–89	1528/1514	Epidemiological study (ATTICA)	2 years	HOMA-IR	Semi-quantitative FFQ (156 food groups)	White	Mediterranean pattern	−0.7 ± 0.07	Age, sex, BMI, physical activity, smoking, presence of HTN and hypercholesterolemia	[43]
Panagiotakos *et al.*	Greece, 2007	F/M	65–100	97/53	Cross-sectional study (ATTICA)	2 years	Risk of DM	Semi-quantitative FFQ (15 food groups)	White	Mediterranean pattern	21/14%	Age, sex, physical activity, smoking	[49]
Gu *et al.*	USA, 2010	F/M	□65	2778	Longitudinal study	4 years	Fasting insulin	Semi-quantitative FFQ (61 food groups)	Non-Hispanic Black Hispanic, non-Hispanic White or other	Mediterranean pattern	0.66 (0.41–1.04)	Age, gender, race, education, BMI, smoking, alcohol drinking, caloric intake, medical comorbidity index, and APOE genotype	[44]
Tzima *et al.*	Greece, 2007	F/M	20–89	698/1064	Population-based cohort study (ATTICA)	2 years	HOMAR insulin	FFQ	White	Mediterranean pattern	βcoefficient ± SEM − 0.26 ± 0.2 − 0.17 ± 0.1	Age, sex, BMI	[48]
Toobert *et al.*	USA, 2003	F	50–75	279	Randomized clinical trial	6 months	HbA1C	-	White	Mediterranean pattern	–	-	[33]
Esposito *et al.*	Italy, 2009	F/M	35–70	901	Cross-sectional study	1 month	HbA1C	Semi-quantitative FFQ	White	Mediterranean pattern	8.2 ± 1.3	Age, energy, BMI, waist circumference, WHR, physical activity, smoking status, HTN, DM medication, and HDL, TG, and glucose concentrations	[42]

Table contd...

Table 1: Continued.....

Source	Country, year	Sex	Age	Sample size (n)	Study design	Follow-up duration	Outcome measure	Dietary assessment tool	Race/ ethnic	Dietary pattern	Adjusted OR/RR (0.95 CI)	Adjustment	Ref.
Brunner *et al.*	UK states, 2008	F/M	50	7731	Cohort study (Whitehall II)	15 years	New incidence of diabetes	FFQ (127 items)	White, South Asian, Afro-Ca Caribbe-an	Unhealthy (n = 2665), sweet (n = 1042), Mediterranean like (n = 1361), Healthy (n = 2663)	11.16 (0.83, 1.61) 1.04 (0.75, 1.43) 0.74 (0.58, 0.94)	Age, sex, ethnicity, energy, social position, smoking status, physical activity	[53]

FFQ = Food frequency questionnaire; HOMA-IR = Homeostasis Model Assessment of Insulin Resistance; RCT = Randomized clinical trial; HbA1C = Hemoglobin A1C

Table 2: Characteristics of various studies that evaluated the effects of "Prudent" and "Western" dietary patterns on diabetes mellitus type 2

Source	Country, year	Sex	Age	Sample size (n)	Study design	Follow-up duration	Outcome measure	Dietary assessment tool	Race/ethnic	Dietary pattern	Adjusted OR/RR (0.95 CI)	Adjustment	Ref.
van Dam *et al.*	USA, 2002	M	40–75	42,504	Prospective cohort study	12 years	Risk for type 2 diabetes mellitus	Semi-quantitative FFQ (131 food groups)	Predominantly White	Prudent pattern Western Pattern	0.84 (0.70–1.00) 1.59 (1.32–1.93)	Energy, physical activity, cigarette smoking, alcohol consumption, hypercholesterolemia, HTN, history of DM	[3]
Fung *et al.*	USA, 2004	F	30–55	121,700	Prospective study (NHS)	14 years	Risk of type 2 diabetes	FFQ (61 items)	White	Prudent pattern Western Pattern	0.89 (0.78–1.02) 1.49 (1.26–1.76)	Age, history of DM and hypercholesterolemia and HTN, smoking, menopausal status, energy, physical activity, alcohol intake, BMI	[58]
Amini *et al.*	Iran, 2010	F/M	25–35	425	Nested cross-sectional study	3 months	Plasma glucose	FFQ (39 items)	White	Western pattern Prudent pattern Vegetarian pattern High-fat dairy pattern Chicken and plant pattern	0.81 (0.44–1.47) 0.73 (0.39–1.37) 2.26 (1.25–4.06) 0.78 (0.43–1.38) 0.89 (0.51–1.58)	Sex, age, education, physical activity	[63]

FFQ = Food frequency questionnaire

Table 3: Characteristics of various studies that evaluated the effects of "Healthy" and "Western" and "Traditional" dietary patterns on diabetes mellitus type 2

Source	Country, year	Sex	Age	Sample size (n)	Study design	Follow-up duration	Outcome measure	Dietary assessment tool	Race/ ethnic	Dietary pattern	Adjusted OR/RR (0.95 CI)	Adjustment	Ref.
Montonen *et al.*	Finnish, 2005	F/M	40–69	4304	Cohort Study	6 years	Risk of type 2 diabetes	FFQ (23 food groups)	White	Prudent patternConservative pattern	0.72 (0.53–0.97) 1.49 (1.11–2.00)	Age, sex, BMI, energy intake, smoking, history of DM, geographic area, cholesterol and HTN	[59]
Villegas *et al.*	Ireland, 2004	F/M	59–60	1473	Cross-sectional study	4 years	HbA1C	FFQ (147 items)	White	Traditional dietPrudent dietAlcohol and convenience foods	5.05 5.01 4.92	Age, kcal/d, physical activity, alcohol activity, smoking, education and income level, occupation, HTN, WHR, BMI	[62]
Villegas *et al.*	Ireland, 2004	F/M	60	527/491	Cross-sectional study	-	Insulin resistance	FFQ	White	Traditional Irish diet Prudent dietOther (high alcohol and convenience foods)	10.53 (0.33–0.85) 0.49 (0.16–1.49)	Age, sex, energy, BMI, waist circumference, preexisting CVD, smoking, physical activity, and socioeconomic status	[61]
Mcnaughton *et al.*	UK, 2008	F/M	35–55	7339	Cohort study (Whitehall II)	2 Years	Incidence of type 2 diabetes	FFQ (198 items)	Australian	Healthy dietary pattern Western dietary pattern Traditional dietary pattern	0.70/0.38	Age, sex, energy, ethnicity, employment, smoking, alcohol, physical activity, blood pressure, BMI	[66]
Esmaillzadeh *et al.*	Iran, 2006	F	40–60	486	Cross-sectional study	12 months	Insulin resistance	FFQ (168 items)	White	Healthy dietary pattern Western dietary pattern Traditional dietary pattern	0.55 (0.28–0.85) 1.15 (0.93–1.74) 1.04 (0.65–1.20)	Age, smoking, physical activity, estrogen use, menopausal status, history of DM and stroke, energy, BMI	[65]

FFQ = Food frequency questionnaire; HbA1C = Hemoglobin A1C

Table 4: Characteristics of various studies that evaluated the effects of "DASH" dietary pattern on diabetes mellitus type 2

Source	Country, year	Sex	Age	Sample size (n)	Study design	Follow-up duration	Outcome measure	Dietary assessment tool	Race/ethnic	Dietary pattern	Adjusted OR/RR (0.95 CI)	Adjustment	Ref.
Liese *et al.*	USA, 2009	F/M	40–69	862	Nested cross sectional (IRAS)	12 months	Incidence of type 2 diabetes	Semi-quantitative FFQ (114 food groups)	White Black, Hispanic, non-Hispanic	DASH diet	0.64 (0.37–1.13)	Age, sex, race/ethnicity/clinic , glucose tolerance status, history of DM, education, smoking status, energy intake and expenditure	[80]
Azadbakht *et al.*	Iran, 2011	F/M	14–60	18/13	Randomized cross-over clinical trial	8 weeks	FBG change A1C change	3-day diet self-report	White	DASH eating pattern Control diet	29.4 ± 6.3/12.8 ± 6.7 1.7 ± 0.1/0.5 0 .02	-	[81]
Azadbakht *et al.*	Iran, 2005	F/M	14–60	82/34	Randomized clinical trial	6 months	FBS	-	White	Control diet Weight reducing diet DASH diet	94 ± 25/99 (91–108) 90 ± 22/94 (87–107) 106 ± 34/84 (78–103)	-	[73]

FFQ = Food frequency questionnaire; FBS = Fasting blood sugar; FBG = Fasting blood glucose; DASH = Dietary approaches to stop hypertension

to ratios of 1.22 and 2.05, in sequence.[88] Risk of DM in Caucasian, Japanese, American, and Native Hawaiian participants in a 14-year follow-up survey showed a significant difference according to sex, and their three dietary designs included: "fat and meat," "vegetables," and "fruit and milk" dietary patterns. The hazard ratios for type 2 diabetes among women/men who adhered to the fifth quartiles of mentioned diets were 1.22/1.40, 1.02/0.86, and 0.85/0.92, respectively. These ratios were significant in all ethnics, except for "Native Hawaiian" subjects.[89] Another multiethnic population-based cohort study among 6814 White, Black, Hispanic, and Chinese subjects, which was conducted during 5 years, revealed two patterns which were defined as: 1. Beans, tomatoes, refined grains, high-fat dairy, red meat and 2. whole grain, fruit, nuts/seeds, green leafy vegetables, low-fat dairy, and low-risk food patterns as the common dietary habits. Adherence to the first diet was accompanied with 18% higher risk ratio, while the others reduced the risk by 15%.[90] The results of a study among 7500 Chinese revealed that "high dairy milk" dietary pattern had decreased diabetes incidence by almost 22%, in contrast to "meat, fruit, and vegetable rich pattern" which increased the relative risk to 1.05.[64]

All the mentioned studies in this review paper had used factor analysis and cluster analysis. These analyses detect dietary patterns from the existing data with no any prior assumption of disease. Besides these posteriori methods, another method for evaluating the overall diet is based on our previous knowledge about the effects of dietary components on health and disease. which is a prior method. This method is based on scoring different components of a diet according to the scientific evidence regarding diet–disease relationship and dietary recommendations.[27] Healthy Eating Index (HEI) is an example of this prior method. This index shows how well a diet follows the US dietary guidelines.[91] High "diet quality index" which is defined based on dietary variety, and high intake of whole grain, lean protein, low-fat dairy, and high-fiber food items was associated with OR of type 2 DM by 0.38 in men and OR for pre-diabetes by 0.66 in women.[92] Alternative Healthy Eating index (AHEI) is defined based on its association with various disorders, which consists of nine chief components of diet quality such as intake of vegetables, nuts, fruits, soybean, the white-to-red meat ratio, trans fatty acids, polyunsaturated to saturated fatty acids ratio (P/S ratio), alcohol drinking, and taking multivitamin, and it is a suitable substitute for HEI. In a prospective study, Fung *et al*. assessed AHEI among 80,029 women. Data show that high index can lower the incidence of type 2 diabetes by 36% during 18 years.[93] The cluster analysis on dietary intake of 1052 Italians derived five main components which included: "common" (low in fat but rich in MUFA

Table 5: Characteristics of various studies that evaluated the effects of different dietary patterns on diabetes mellitus type 2

Source	Country, year	Sex	Age	Sample size (n)	Study design	Follow-up duration	Outcome measure	Dietary assessment tool	Race/ethnic	Dietary pattern	Adjusted OR/RR (0.95 CI)	Adjustment	Ref.
He *et al.*	China, 2009	F/M	45–69	20,210	Cross-sectional study	12 months	The prevalence of diabetes mellitus IFG IGT	Semi-quantitative FFQ	Yellow (Asian)	Green Water Yellow Earth Western Adopter New Affluence	1.0 1.12 (0.93–1.35) 1.24 (1.04–0.49) 0.99 (0.78–1.26)	Area, age, sex, smoking, alcohol drinking, physical activity, history of DM	[87]
Mizoue *et al.*	Japan, 2006	M	47–59	2106	Cross-sectional survey	4 years	Glucose tolerance status	FFQ (45 items)	Yellow (Asian)	DFSA dietary pattern Animal food dietary pattern Dietary pattern Japanese	0.50 (0.28–0.91) 0.73 (0.38–1.40) 0.96 (0.54–1.69)	Hospital, age, occupation, history of DM, BMI, smoking, physical activity	[4]
Erber *et al.*	Hawaii, 2009	F/M	45–75	29,759 Caucasians, 35,244 Japanese Americans, 10,509 Native Hawaiians	Multiethnic cohort study	14 years	The prevalence of diabetes mellitus	FFQ	Caucasians, Japanese, Americans, Native Hawaiians	Fat and meat dietary pattern Vegetables dietary pattern Fruit and milk dietary pattern	1.22 (1.06–1.40)/1.40 (1.23–1.60) 1.02 (0.91–1.14)/0.86 (0.77–0.95) 0.85 (0.76–0.96)/0.92 (0.83–1.02)	Ethnicity, BMI, physical activity, education, energy, smoking, alcohol intake, marital status, HTN	[88]
Hodge *et al.*	Australia, 2007	F/M	27–75	19,738/17,049	Cohort study	4 years	Risk for type 2 diabetes mellitus	FFQ (121 items)	Australian	Factor 1: Olive oil, legumes, vegetables; avoidance of: biscuits, cakes and pastries, margarine, tea Factor 2: Salad and vegetable Factor 3: Meat, pastries, fried eggs and fish and potatoes Factor 4: Frequent fruit	1.14	Age, energy, family history of DM, country of birth	[5]

Table contd...

Table 5: Continued....

Source	Country, year	Sex	Age	Sample size (n)	Study design	Follow-up duration	Outcome measure	Dietary assessment tool	Race/ethnic	Dietary pattern	Adjusted OR/RR (0.95 CI)	Adjustment	Ref.
Nettleton *et al.*	USA, 2008	F/M	45–84	2177 Whites, 1205 Blacks, 1016 Hispanics, 613 Chinese	Multiethnic population-based cohort study	5 years	Incidence of type 2 diabetes	FFQ (120 items)	White, Black, Hispanics, Chinese	Beans, tomatoes, refined grains, high-fat dairy, red meat Whole grain, fruit, nuts/ seeds, green leafy veg, low-fat dairy Low-risk food pattern	1.18 (1.06–1.32) 0.85 (0.76–0.95) 0.87 (0.81–0.99)	Energy intake, study center, age, sex, race/ ethnicity	[89]
Villegas *et al.*	China, 2010	F	40–70	74,942	Population-based prospective cohort study	6.9 years	Incidence of T2DM	FFQ (77 items) and 24-h dietary recalls	Yellow (Asian)	High staple food pattern High dairy milk pattern High meat and fruit and vegetable food groups	1 0.78 1.05	Age, energy, physical activity, alcohol consumption, smoking, education, income, occupation, HTN, WHR, BMI	[90]
Fung *et al.*	USA, 2007	F	38–63	80,029	Prospective study	18 years	Incidence of type 2 diabetes	FFQ (116 items)	White	Alternate Healthy Eating Index (AHEI)	0.64 (0.58–0.71)	Age, energy, smoking, BMI, physical activity, family history, menopause, postmenopausal hormone use	[93]
Mcnaughton *et al.*	UK, 2009	F/M	≥25	4141/3100	Population-based cross-sectional study	-	The prevalence of type 2 diabetes	FFQ (74 items)	Australian	Dietary Quality Index (DQI)	0.70 (0.22, 2.28)/ 0.38 (0.18–0.80)	Age, education, energy, smoking, physical activity, TV viewing time, BMI, menopausal status	[92]
Heidemann *et al.*	Germany, 2005	F/M	35–65	27,548	Nested case–control study (EPIC)	12 months	HbA1C	Semi-quantitative FFQ (48 food groups)	White	Food group quartile	0.27 (0.13–0.64)	Age, sex, activity, smoking status, educational level, BMI, WHR	[96]

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Table 5: Continued....

Source	Country, year	Sex	Age	Sample size (n)	Study design	Follow-up duration	Outcome measure	Dietary assessment tool	Race/ethnic	Dietary pattern	Adjusted OR/RR (0.95 CI)	Adjustment	Ref.
Song *et al.*	Korea, 2010		20 years or more	4730	Cross-sectional study	-	High FBG (≥110 mg/dl)	Single 24-h recall (23 food groups)	Yellow (Asian)	Traditional Meat and alcohol Korean healthy	1 1.33 (1.01e1.75) 1.02 (0.81e1.28)	Age, gender, education, region, smoking, and physical activity	[83]
Noel *et al.*	USA, 2009	F/M	45–75	1167	Longitudinal investigation		Fasting serum glucose	Semi-quantitative FFQ (126 food groups)	Hispanic	1. Meat, processed meat, and French fries 2. Rice, beans, and oils (Traditional pattern) 3. Sweets, sugary beverages, and dairy desserts	6.8 (6.4–7.1) 6.8 (6.4–7.1) 6.4 (6.1–6.7)	Age, sex, smoking, alcohol use, education, physical activity, energy, acculturation, taking medication and multivitamin, BMI	[84]
Agajani Delavar *et al.*	Iran, 2009	F	30–50	984	Cross-sectional study	6 months	FBS	FFQ	White	Component 1 = fish, vegetables, legumes, cereals, and fruits Component 2 = red or white meat and meat products and potatoes Component 3 = pasta Component 4 = dairy products and eggs Component 5 = sweets	−0.096 −0.043 0.007 −0.028 0.057	Physical activity, energy intake, years of school, income, and BMI	[85]
Wirfalt *et al.*	Sweden, 2001	F/M	45–68	2959/2040	Nested cross-sectional Study	12 months	Hyperglycemia and hyperinsulinemia	7-day menu and diet history questionnaire	White	1. Many foods and drinks 2. Fiber bread 3. White bread 4. Milk fat	1.64 (1.24–2.17) 0.70 (0.50–1.00) 1.02 (1.89–1.39) 0.40 (0.84–0.58)	Age, energy, body fat percentage, past diet change, diet interviewer, and season of data collection	[86]

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Table 5: Continued....

Source	Country, year	Sex	Age	Sample size (n)	Study design	Follow-up duration	Outcome measure	Dietary assessment tool	Race/ethnic	Dietary pattern	Adjusted OR/RR (0.95 CI)	Adjustment	Ref.
Panagiotakos *et al.*	Greece, 2007	F/M	18–89	1528/1514	Cross-sectional study	-	Blood glucose	Semi-quantitative FFQ (156 items)	White	1. Fish, vegetables, legumes, cereals, and fruits 2. Potatoes, red or white meat, and meat products 3. Bread, pasta 4. Dairy products and eggs 5. Sweets 6. Alcoholic beverages	0.489 ± 0.429 −0.232 ± 0.425 −0.563 ± 0.433 0.528 ± 0.436 0.358 ± 0.434 1.553 ± 0.431	Age, sex, physical inactivity, smoking, years of school, income, medication or use of special diet, and BMI	[46]
Dibello *et al.*	American Samoa, 2009	F/M	≥18	1508	Cross-sectional study	2 years	Serum glucose	FFQ (42 items), 24-h recall	American Samoa and Samoa	Neo-traditional pattern Modern pattern	1.05 (0.79–1.39) 0.99 (0.77–1.29)/0.74 (0.51–1.06) 1.08 (0.77–1.51)	Age, sex, smoking, physical activity, and energy intake	[69]
Kim *et al.*	Hawaii, 2008		18–95	1257	Cross-sectional study	3 years	The prevalence of type 2 diabetes	FFQ	Caucasian, Filipino, Native Hawaiian, Japanese	1 .Healthy diet 2. Animal foods and local ethnic dishes 3. Western diet	0.99 1.34 1.09	Age, sex, income, physical activity, smoking, energy	[67]
Yu *et al.*	China, 2011	F/M	25–74	690	Prospective cohort study	8 years	Incident type 2 diabetes	FFQ (266 items)	Yellow (Asian)	More snacks and drinks More vegetables, fruits, and fish More meat and milk products More refined grains	0.86 0.76 1.39 1.02	Age, sex, BMI, waist-to-hip ratio, smoking, alcohol intake, participation in exercise, and history of diabetes	[82]
Williams *et al.*	UK, 2000	F/M	40–65	802	Cohort population-based study	-	Hyperglycemia	FFQ	White	Diet 1 Diet 2 Diet 3 Diet 4	28%	-	[95]

Table contd...

Table 5: Continued...

Source	Country, year	Sex	Age	Sample size (n)	Study design	Follow-up duration	Outcome measure	Dietary assessment tool	Race/ethnic	Dietary pattern	Adjusted OR/RR (0.95 CI)	Adjustment	Ref.
Wirfalt *et al.*	Sweden, 2001	F/M	45–68	1122	Cross-sectional study	-	Hyperglycemia and hyperinsulinemia	FFQ	White	Many foods and drinks Fiber bread White bread Milk fat	1.64 11.39 0.58	Physical activity, smoking, alcohol, total fat and fiber intake, fatty acid ratios, folic acid, magnesium, antioxidants	[86]

FFQ = Food frequency questionnaire; FBS = Fasting blood sugar; HbA1C = Hemoglobin A1C; FBG = Fasting blood glucose

and CHO), "animal products" (high in animal protein, SFA, and cholesterol), "starch" (rich in vegetable protein and starch), "vegetal/fat"(high in olive oil and seeds), and "vitamin/fiber"(rich in fruits and vegetables). Leite *et al*. observed the lowest IGT prevalence by adherence to "starch" pattern, in contrast to "animal" food pattern.[94] In the four dietary patterns derived from population-based cohort study, a negative association between commonly consumed fiber-based foods and white meat in "Diet 1" and diet rich in cake, vegetable, and cheese pattern named as "Diet 2" with IGT was seen. There was also a 28% reduction in diabetes incidence following adherence to the diet containing fiber-based foods and white meat.[27,95] Sex difference in relation to dietary pattern and features of metabolic syndrome was reflected significantly in Malmo Diet and Cancer Study of Swedish adults. Risk of hyperglycemia accompanying dietary pattern rich in meat and dairies increased by 64% among men, while it was not significantly associated with hyperglycemia among women[27] However, Heidemann revealed that those in the highest quartiles of diet rich in fruits and poor in meat, beer, and soft drink had lower incidence of type 2 DM by 0.27.[96] In Framingham Offspring Study, "fruits, reduced fat dairy, and whole grains," "refined grains and sweets," "beer" and "soda" diets were extracted. Data revealed that adherence to "soda" pattern is accompanied by higher fasting insulin level. A pattern high in fruits, vegetables, whole grains, and reduced fat dairy protects against insulin resistance compared to sweet food pattern and soda pattern which are associated with insulin resistance.[97] Table 5 shows the different surveys that assess the effects of various dietary patterns among type 2 DM patients.

CONCLUSION

Dietary intakes have important roles against insulin resistance, and in the prevention and management of hyperglycemia.[31] Epidemiological studies revealed that dietary patterns high in fiber-rich food items such as vegetables, fruits, whole grains, seeds and nuts, plus white meat sources like poultry and fish could have protective effects against the incidence of DM. However, dietary patterns rich in processed meat and red meat, refined cereals, and SFAs are associated with higher risk of DM.[28] Healthy patterns, Mediterranean, and Prudent dietary patterns also are protective dietary patterns against DM. However, adherence to Western dietary pattern is associated with higher risk of diabetes.[86,98,99] These results are in line with Iranian dietary pattern surveys which emphasize on adherence to Healthy pattern to manage abnormal glucose homeostasis.[66] It is suggested to see the relationship of different dietary patterns and the incidence of type 2 diabetes in cohort studies among different populations in future studies.

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