Original Article

Relationship between Dietary Patterns and Incidence of Type 2 Diabetes

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Abstract

Introduction: Increasing rate of type 2 diabetes (T2D) prevalence during the recent years has caused concern about significant risks for the public health. Dietary patterns have recently attracted great attention in the evaluation of the relationship between diet and health. In the present study, we investigated the relationship between the major identified dietary patterns and T2D. **Methods:** In this matched case–control study, 315 individuals (125 newly diagnosed cases and 190 controls); 18–60 years of age were selected. A valid semiquantitative food frequency questionnaire was used to collect dietary intakes of individuals. Anthropometric characteristics and blood pressure were measured with standard instructions and body mass index and waist to hip ratio were calculated. Factor analysis was used to identify major dietary patterns. The relationship between major food patterns and T2D was assessed by logistic regression analysis. **Results:** Two dietary patterns were identified: healthy and Western dietary patterns. The second tertile of the healthy dietary pattern had significantly association with decreased risk of T2D in the crude model (Odds ratios [OR]: 0.51, 95% Confidence interval [CI]: 0.29–0.9; *P* for trend = 0.018), Model II (OR: 0.5, 95% CI: 0.27–0.9; *P* for trend = 0.019), and Model III (OR: 0.56, 95% CI: 0.23–1.4 *P* for trend = 0.048). The inverse association of the second tertile of Western dietary pattern score with the T2D was significant in crude (OR: 9.25, 95% CI: 4.95–17.4; *P* for trend <0.001) and multivariable-adjusted model (OR: 16.65, 95% CI: 2.99–92.84; *P* for trend <0001). **Conclusions:** Our study found an inverse relationship between adherence of healthy pattern and direct association with Western dietary pattern and the risk of T2D.

Keywords: *Dietary patterns, factor analysis, incidence, type 2 diabetes*

Introduction

Increasing rate of type 2 diabetes (T2D) prevalence during the recent years has caused concern about significant risks for the public health.[1] The World Health Organization projects that diabetes will be the 7th leading cause of death in 2030.[2] Furthermore, it has been predicted that developing countries will constitute 77.6% of all patients with diabetes until 2030.[2,3] Iran was among the countries with the greatest number of patients with diabetes in the Middle East and North Africa in 2015, the main reasons of which include unhealthy diet, obesity, sedentary life, and aging.[4] T2D is one of the major causes of health problems such as cardiovascular diseases, stroke, renal damage, blindness, leg amputation, and diabetic complications, which are inherently disabling, costly, and often fatal.[5,6] In terms of economic costs, treatment costs of a patient with diabetes are 2–4 times more than that of an ordinary patient in all health-care systems.[6] Diabetes imposes high indirect costs compared to other diseases, the prevention and control of which is considered a priority in all countries, including Iran.[6-8] Several lifestyle-related factors affect the incidence of T2D.[9] For example, obesity and overweight significantly increase the risk of T2D, also physical inactivity is a primary factor that independently increases the risk of T2D.[10] Another major factor is chronic oxidative stress resulted from retention of blood glucose, especially after eating and production of ROS that leads to progressive decline of β-cell function and, finally, T2D.[11] Fortunately, lifestyle-related factors including diet and physical activity can be improved, and the incidence of T2D resulted from these factors can be significantly prevented.[9,10] Preventing and controlling T2D through dietary improvement has an important role in energy balance, insulin resistance, and blood glucose control.[2]

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Dietary patterns, including healthy, Mediterranean, traditional, and Western dietary patterns, have recently attracted great attention in the evaluation of the relationship between diet and health.[12] Since foods are not used alone and nutrients are metabolized all together, it seems more difficult to assess the relationship between nutrients and the incidence of diseases compared to a more comprehensive view to diet as a dietary pattern.[13] Dietary patterns may affect health more than certain nutrients or nutritional groups.[13] Supporting evidence is available that indicates the relationship between high consumption of calorie or foods and high glycemic index and increased risk of T2D.[14] However, the existence of a relationship between other dietary factors and T2D is not completely specified yet.[15] The quality of diet compounds correlates with the risk of T2D, disease progress, and its side effects. In addition, recognition of one desirable food pattern has become a priority in public health to prevent T2D.[13] By studying dietary patterns, the total diet of individuals can be considered beyond studying the consumption of nutrients and food groups.[13] As mentioned in the Dietary Guidelines for Americans in 2010, public health recommendations can be easily made through the analyses of dietary patterns.[16] Furthermore, it is easier for people to comprehend health recommendations as dietary patterns than nutrients.[13]

In the present study, we investigated the relationship between the major identified dietary patterns and T2D.

Methods

Study design and participants

This matched case–control study investigated the association between dietary patterns and the incidence of T2D among Iranian adults. Samples of the case included individuals aged between 18 and 60 years if their T2D based on the fasting plasma glucose ≥126 mg/dl and 2-h plasma glucose (2 h-PG) postoral glucose tolerance test ≥200 mg/dl[17] is recognized recently (within 6 months of recruitment). The samples of healthy individuals also included aged between 18 and 60 years based on fasting plasma glucose ≥100 mg/dl and 2-h plasma glucose (2 h-PG) postoral glucose tolerance test ≥200 mg/dl.[17] Individuals with chronic diseases or history of chronic diseases (cardiovascular diseases, renal disease, liver diseases, and cancers), type 1 diabetes, gestational diabetes, and people following special dietary patterns or taking drugs that affect their weight and diet, pregnant and breastfeeding women were excluded from the study. People with a family history of diabetes, hypertension (14/9 mmHg), and people who did not respond to more than 35 food items of foods available in the food frequency questionnaire (FFQ) or people whose received energy reported by them was beyond 800–4200 kcal[18] were excluded from the study.

Since the data collected in this study were analyzed through factor analysis, three food groups were considered for each individual.[19] The individuals who participated in this study included 315 adults (125 individuals in the case and 190 participants in the control group).

Participants in the case group were selected through simple sampling method among patient with diabetes identified in the Isfahan Center of Metabolism and Endocrinology and by two-stage cluster sampling among patients who have referred to the private office of endocrinologists to increase the external validity of the sampling.

Participants in the control group were also selected through two-stage cluster sampling from parents of students that have performed blood glucose checkup during the past 6 months. At the beginning of the study, informed consent was obtained from all participants.

Ethical issues

The study was approved by the Medical Ethics Committee of Isfahan University of Medical Sciences (Ethical cod#IR. MUI. REC.1395.3.409).

Dietary assessment

Dietary intake information was collected through conducting personal interviews and a semi-quantitative FFQ, including 168 food items.[19] The participants were asked about consumption frequency of each item in the questionnaire over the period of 1 year, (for the case group, the year before diagnosing disease and for the control group, the year before the interview) and consumption frequency (times per day, week, month, or year) based on the type of food. The size of standard units and items reported based on household measures was converted to gram using instructions of nutritionist four scales.[20] Then, the amount of food intake of each person was reported based on their daily intake in gram. To determine energy, micronutrients and macronutrients then gram equivalent of intake for each food item available in the semiquantitative food frequency, we used the data included in the food ingredients table adapted for Iranian food items.

Assessment of other variables

Anthropometric measurements of individuals were performed using the standard methods. Weight (kg) with the minimum coverage was measured and recorded using one seca scale with 100 g accuracy. Height (cm) was measured in a standing position without shoes, while the shoulders were in normal position using a seca scale. Body mass index (BMI) (kg/m^2) was calculated by dividing weight in kilograms by the square of height in meters. Waist circumference (cm) was measured using a metal anthropometric tape without any pressure to the body surface at the midpoint between the last rib and the upper part of the pelvis at the end of a normal exhalation. When it was hard to measure the narrowest area of the waist in individuals, waist circumstance was measured exactly under the last rib since in most people, the waist would be the narrowest area between the iliac crests and the lower ribs.[21] Hip circumstance (cm) was measured using metal anthropometric tape and with the accuracy of 0/1 cm in a standing position and without any extra cover in the head area of the biggest hip bone that is equal to the biggest circumstance of the thigh bone.

Daily physical activity (MET_h/week) was measured through a valid and reliable physical activity questionnaire[22] and information about population characteristics, socioeconomic characteristics such as marital status (single/married), academic degree (under the diploma, diploma, diploma to bachelor, and higher than bachelor's degree), and smoking (yes/no) were collected through personal questioning. Blood pressure (mmHg) was measured twice with 10-min intervals from the left arm using a mercury manometer while the person was sitting and calm.

Statistical analysis

To analyze the data, SPSS (version 19.0, SPSS Inc., Chicago, Illinois, USA) was used in this study. Numerical variables were reported as mean and standard deviation, while nonnumerical variables were reported as numbers and percentages. Data normality was assessed using the Kolmogorov–Smirnov test and the Q-Q plot. The applicability of factor analysis method was measured using the KMO measure of sample size adequacy and Bartlett's test. Then, means adjusted for energy were calculated for each group. Dietary patterns were identified using factor analysis (principal component analysis with varimax rotation) on groups adjusted for energy. We classified 168 food items to 41 predetermined food groups based on the similarity of nutrients and the results of previous studies.[19] To determine the number of factors (dietary patterns), scree diagram, and eigenvalues were used. Varimax rotation method was used to interpret the factors to extract the final factors and interpret food patterns based on factor loadings of nutrients in extracted factors. The score of each person for one special dietary pattern was calculated by multiplying the number of nutrients by the pattern in the estimation of parameter and then calculated factor scores of each dietary pattern were categorized by tertiles. Means of quantitative variables between tertiles of each dietary pattern were compared using ANOVA. Qualitative variables were compared between tertiles using the Chi-square test. Adjusted mean of food for age, sex, and energy between tertiles of food intakes was compared using ANCOVA. To compare other variables between two groups, independent samples *t*-test was used. To study the relationship between identified dietary patterns and T2D, logistics regression was used. First, in the Model I (crude model), the risk of T2D between tertiles of identified dietary patterns was calculated. Then in the adjusted models, this relationship was calculated, Model II adjusted for the demographic variables including sex (male/female), age (year), marriage (single/married), and academic education (%), Model III adjusted for lifestyle variables including BMI (kg/m^2), WC (cm), cigarette smoking (yes/no), physical activity (MET_h/wk), and Model IV adjusted for energy intake (kcal/day), and affective nutrients including saturated fatty acids, dietary fiber, carbohydrate, Vitamin B1, Zinc, and Chromium. The significance level was considered to be 0.05 in this study.

Results

Characteristics of participants in case and control groups are presented in Table 1. There was no significant difference in age, gender, academic degree, and marital status between cases and controls, while smoking ($P < 0.01$) and weight, BMI, waist circumstances, and waist–hip ratio in patient with diabetes were significantly higher but physical activity lower than those in control group ($P < 0.001$ for all).

Using factor analysis, we identified two major dietary patterns in participants [Table 2]. The factor 1 was loaded by majority of healthy food items (fish, low-fat dairy product, fruits, vegetables, and…) and factor 2 was loaded by majority of Western diet food items (processed meats, red meats, refined grains, and…).

General characteristics of the participants and food intakes among tertiles of major dietary patterns are presented in the Table 3. Participants who were in the highest tertile of the Western dietary pattern had lower physical activity compared with those in the lowest tertile ($P = 0.001$). Participants in the highest tertile of Western pattern intake had more weight and BMI than those in the lowest tertile ($P < 0.001$). In terms of gender and smoking ($P < 0.001$), a significant difference was found between Western pattern tertiles.

Sexual distribution and academic education were significantly different between individuals in tertiles of healthy dietary pattern ($P < 0.001$).

Table 1: Baseline characteristics of the study population in case and control groups[a]

	Cases (*n*=125)	Controls (*n*=190)	*P*[b]
Age (years)	47.5±5.07	46.51±4.3	0.064
Sex, female (%)	76.0	77.4	0.774
Marital status, single (%)	8.8	8.9	0.989
Academic education (%)	80	80	0.415
Smoking, smoker (%)	11.2	2.6	0<0.01
BMI (kg/m^2)	28.5±2.3	24.07±3.05	<0.001
WC (cm)	96.9±8.9	81.66±8.81	<0.001
WHR	0.92±0.07	0.82±0.061	<0.001
Weight (kg)	76.3±9.6	64.32±9.18	<0.001
Physical activity (MET_h/week)	864.92±584.23	2608.68±2467.71	<0.001

[a]Data are shown as mean±SD (95% CIs), and number (proportions); [b]Significance is resulted from independent *t*-test and Chi-square test. SD=Standard deviation, CI=Confidence interval, BMI=Body mass index, WHR=Waist-hip ratio, WC=Waist circumference

Table 2: Factor-loading matrix for major dietary patterns[a]

Food groups	Dietary patterns	
	Western	Healthy
Processed meats	0.481	-
Red meats	0.571	-
Organ meats	-	-
Fish	-	0.415
Poultry	-	0.313
Eggs	0.590	-
Butter	0.461	-
Margarine	-	-
Low-fat dairy products	-	0.429
High-fat dairy products	-	-
Tea	0.633	-
Coffee	-	0.463
Fruit	-	0.465
Fruit juices	-	0.530
Cruciferous vegetables	0.214-	0.362
Yellow vegetables	-	-
Tomatoes	-	0.601
Green leafy vegetables	0.378-	0.388
Other vegetables	-	0.604
Legumes	0.453-	-
Garlic	0.222-	-
Potatoes	0.526	-
French fries	-	-
Whole grains	-	-
Refined grains	0.623	-
Pizza	-	-
Snacks	0.342	-
Nuts	-	0.302
Mayonnaise	-	0.312
Dried fruit	-	0.423
Olives	-	0.626
Sweets and desserts	0.429	-
Hydrogenated fats	0.677	-
Vegetable oils	0.664	-
Sugars	-	-
Condiments	-	0.535
Soft drinks	0.571	-
Yogurt drink	-	0.221
Broth	-	0.228
Salt	-	-
Pickles	0.391	-
Percentage of variance (%)	22.84	18.7

[a]Values <0.20 were excluded for simplicity. The symbol "-" shows individuals adhering this dietary pattern have lower intakes of these food groups

Odds ratios (OR) for T2D across the tertiles of two major dietary patterns are reported in Table 4. Compared with the lowest tertile, the second tertile of the healthy dietary pattern had significantly associated with decrease risk of T2D in the crude model (OR: 0.51, 95% Confidence interval [CI]: 0.29–0.9; *P* for trend = 0.018), Model II that adjusted for sex, age, marriage, education (OR: 0.5, 95% CI: 0.27–0.9; *P* for trend = 0.019), Model III that adjusted for BMI, WC, cigarette smoking, and physical activity (OR: 0.56, 95% CI: 0.23–1.4 *P* for trend = 0.048), and in the final fully adjusted Model IV, the association was protective but marginally significant (OR: 0.72, 95% CI: 0.21–2.48; *P* for trend = 0.064). The direct association of the second tertile of Western dietary pattern score with the T2D was significant in crude (OR: 9.25, 95% CI: 4.95–17.4; *P* for trend < 0.001) and in fully final adjusted Model IV (OR: 16.65, 95% CI: 2.99–92.84; *P* for trend <0001).

Discussion

In the present study, two dominant dietary patterns were identified: healthy pattern and Western pattern. The healthy pattern was inversely associated with the risk of T2D, while the Western pattern was a significant relationship with increased risk of T2D.

A number of research studies conducted in the Western societies have shown that Western dietary pattern including higher intake of red meat, processed meat, and refined grains is significantly associated with increased risk of T2D.[23,24] For example, in the 12-years cohort prospective study, van Dam *et al*. investigated dietary pattern of 42,504 American white men at the age range of 40–75 years old using the FFQ. After controlling the confounders, the risk of T2D increased 60% in people adherent to the western-like dietary pattern.[23] As well as, Fung *et al*. who studied 80029 women at the age range of 38–63 years old suggested that the risk of T2D increased about 1/5 times in case of the consumption of Western dietary pattern.[24]

Since the majority of the above-mentioned studies have been conducted in Western societies, they cannot be generalized to other societies. The rapid process of change in lifestyle, diets, and physical activity that have been occurred as a result of extended urbanization, improved economic status, change of work pattern toward jobs, and change in the processes of producing and distributing nutrients during the recent years in developing countries like Iran have led people to more consumption of fast food and processed foods. However, less diversity and difference in the type of processed meat products and other food products in Iran can be one of the reasons for more different and lower consumption compared to Western societies.

The results obtained from a cross-sectional ATTICA study after 1-year FFQ analysis of 3000 individuals aged 18–89 years showed that there is a positive relationship between consumption of red meat and higher levels of blood glucose and insulin.[25]

Several mechanisms may explain effect of meat intake on T2D.[26,27] Meat is a main source of saturated fatty acids and could increase the risk of T2D through obesity,

Table 3: Characteristics and dietary intakes of study participants across tertiles (T) of dietary pattern scores

	Healthy pattern score				Western pattern score			
	T1 (lowest)	T2	T3 (highest)	*P* trend	T1 (lowest)	T2	T3 (highest)	*P* trend
Age (years)	47.1±4.2	46.9±4.7	46.7±4.9	0.821	46.9±4.2	46.5±4.57	47.2±5.1	0.537
Sex, female (%)	88.6	79	62.9	<0.001	88.6	81.9	60	<0.001
Marital status, single (%)	5.7	8.6	12.4	0.348	5.7	8.6	12.4	0.158
Academic education (%)	35.3	40	59.1	<0.001	49.5	36.2	48.6	0.458
Smoking, smoker (%)	6.7	4.8	6.7	0.799	2.9	1.9	13.3	0.001
BMI (kg/m^2)	26.2±3.5	26.1±3.7	25.1±3.3	0.054	24.8±3.6	25.5±3.5	27.1±3.3	<0.001
Weight (kg)	68.2±11.3	69.5±10.8	69.4±11	0.634	64.8±9.5	67.4±9.7	74.9±11.1	<0.001
Physical activity (MET_h/wk)	1849.5±2381.7	1914.2±1992.1	1986.4±2006.8	0.898	2363±2169.9	2080.3±2603.7	1306.8±1220.6	<0.001
Total energy (kcal/day)	1928.1±727.2	2134.8±775.1	2726.4±898	<0.001	1730.4±255.6	2072.1±621.9	2986.8±788.9	<0.001
Carbohydrate	264.2±99.5	296.8±101	376.5±116.1	<0.001	255.5±232.3	294.4±94.2	387.5±105.5	<0.001
SFA	21.19±12.9	24.6±15.2	31.1±15.6	<0.001	17.3±10.8	22.5±12	37.1±14.8	<0.001
Vitamin B1	1.5±0.6	1.6±0.5	1.9±0.6	<0.001	1.5±0.7	1.6±0.4	1.93±0.5	<0.001
Dietary fiber	13.1±4.6	17.6±5	24.4±9.7	<0.001	18.5±15.7	17.9±7.1	18.6±7.6	0.799
Zinc	7±3.3	8.2±2.9	11.4±3.9	<0.001	8.2±3.9	8.4±3.3	10.1±4.1	<0.001
Chromium	0.03±0.02	0.03±0.03	0.04±0.04	0.148	0.04±0.02	0.04±0.03	0.02±0.03	<0.001

BMI=Body mass index, SFA=Saturated fatty acid

Table 4: Multivariable-adjusted odds ratios (95% confidence intervals) for type 2 diabetes mellitus across tertile (T) categories of dietary pattern scores

Model	Healthy pattern score				Western pattern score			
	T1 (lowest)	T2	T3 (highest)	*P* trend	T1 (lowest)	T2	T3 (highest)	*P* trend
Model I[a]	1.00	0.58 (0.33-1)	0.51 (0.29-0.9)	0.018	1.00	1 (0.59-1.9)	9.28 (4.95-17.4)	<0.001
Model II[b]	1.00	0.57 (0.32-0.99)	0.5 (0.27-0.9)	0.019	1.00	1.05 (0.54-2.02)	13.32 (6.5-27.29)	<0.001
Model III[c]	1.00	0.4 (0.16-0.99)	0.56 (0.23-1.4)	0.048	1.00	0.73 (0.28-1.9)	18.6 (5.35-64.5)	<0.001
Model IV[d]	1.00	0.36 (0.12-1.6)	0.72 (0.21-2.48)	0.064	1.00	0.54 (0.18-1.6)	16.65 (2.99-92.84)	0.001

[a]Crude model, [b]Adjusted for sex, age, marriage, education, [c]Also adjusted for BMI, WC, cigarette smoking, and physical activity, [d]Additionally adjusted for energy intake, saturated fatty acids, dietary fiber, carbohydrate, Vitamin B1, zinc, and chromium. BMI=Body mass index, WC=Waist circumference

hyperglycemia, and hyperinsulinemia.[23] Many processed meats have nitrites and nitrates that can be converted to nitrosamines through interaction with amino compounds. Nitrosamines have been demonstrated to be toxic to beta cells and subsequently to increase the risk of T2D in animal studies.[28]

In our study, similar to many studies, eggs were in the Western dietary pattern. Egg consumption is one of the main sources of dietary cholesterol.[29] Several studies reported that egg consumption associated with an increased risk of T2D. However, the findings were inconsistent.[30] Of course, it was specified that the relationship between dietary cholesterol and the risk of T2D can be different between different populations due to different environmental and genetic factors.[31]

In the present study, the vegetable oil group included liquid vegetable oils, hydrogenated fats, and butter was in a pattern that increased the risk ofT2D. Iranian populations mainly use corn and sunflower oils for cooking. These oils lead to increase in intake of (n-6 polyunsaturated fatty acids) PUFAs and n-6/n-3 ratio. Diets rich in n-6 PUFA are established to promote adiposity[32] and the n-6/n-3 ratio influences the function of adipose tissue.[33] In addition, high-fat foods have high energy density and cause obesity through damage to appetite control center.[34] Overweight and obesity are major risk factors for type 2 diabetes.[34]

Also, refined grains, snacks, potatoes, sweets and desserts, and soft drinks, which are main components of Western diet, were in Western dietary pattern in our study. Several studies have shown that adherence the dietary pattern of “soft drinks” and intake food sources such as refined grains, sweets, chocolates, sweetened beverages with high levels of fasting insulin plasma, and can increase insulin resistance.[25,26]

Meta-analysis of cohort studies and some previous studies has revealed that the healthy dietary pattern including low-fat dairy products, fruits, vegetables, olives, and white meats was associated with reduced risk of T2D.[35,36]

Different studies have reported different effects of fish intake on the risk of T2D.[37] In fact, these differences can be due to the geographical diversity of the studied regions. Fish intake in Europe and North America was followed by the risk of T2D, while in Asian countries, it was correlated with the decreased risk of T2D.[37] Although the reason has not been identified yet, it might be due to the difference in type of the consumed fish, type of cooking as well as the difference in the type and level of exposure to some levels of some contaminants.[37] In our study, one of the factors that caused protective effect of the healthy pattern was probably the presence of fish in this pattern.

The presence of low-fat dairy in the healthy dietary pattern of the present study also might have affected the significant decrease in the risk of T2D by this pattern and generally more intake of dairy was associated with lower risk of T2D.[34]

One of the advantages of the present study is the inclusion of criteria so that some important factors such as family record, hypertension, other chronic diseases, and intake of drugs that affected their risk of T2D, apart from their lifestyle, were almost controlled. In the other hand, selecting patients afflicted with T2D who were under the supervision of Endocrinologists consequently decreased the possibility of change in their dietary patterns due to illness. Limitations of this study are small sample size and using 1-year FFQ that might have caused error in measuring dietary intake.

Conclusions

With regard to recommendations presented based on the analyses of dietary patterns, people can select nutrients without decreasing the general quality of their diet with more flexibility to achieve the long-term adherence to one healthy dietary pattern. Few people follow healthy diets and consequently, the effect of adherence to these patterns in societies, especially in developing societies, has been left ambiguous, and more studies are required in this regard. Furthermore, to study the effect of dietary patterns on peoples' health more precisely, evaluating biomarkers related to chronic diseases, including T2D can be useful.

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Conflicts of interest

There are no conflicts of interest.

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