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Association between plant-based dietary patterns and hypertension among adults with type 2 diabetes in Azar cohort study in northwestern Iran: a cross-sectional study

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ABSTRACT

Objectives Most previous research on plant-based diets and hypertension primarily focused on the general population, with limited data available among adults with type 2 diabetes (T2DM). Therefore, the present study was designed to investigate the association between plant-based dietary patterns and hypertension among adults with T2DM.

Design Cross-sectional study.

Setting The AZAR cohort is part of the Persian Cohort, an Iranian screening programme, and includes participants who were residing in Shabestar county, East Azerbaijan Province, Iran for a minimum of 9 months

Participants A total of 1947 participants with T2DM were included in the current analysis.

Outcome measures Hypertension was the outcome measure. This was defined as blood pressure ≥140/90 mm Hg, self-reported physician-diagnosed hypertension (supported by medical records) or use of antihypertensive medications.

Results The mean age of the participants was 54.90±8.25 years, with 61% being female. The prevalence of hypertension among the participants was 48.6% (n=946). Adherence to plant-based diet index (PDI) showed a significant inverse association with hypertension in the crude model (OR: 0.60, 95% CI: 0.46 to 0.80, P-trend<0.001), but this association became non-significant after adjusting for confounders (OR: 0.88, 95% CI: 0.63 to 1.24, P-trend: 0.54). Moreover, healthful plant-based diet index displayed a significant positive association with hypertension in unadjusted analysis (OR: 2.03, 95% CI: 1.52 to 2.70, P-trend<0.001), which also disappeared after controlling for potential confounders (OR: 0.86, 95% CI: 0.61 to 1.21, P-trend: 0.35). However, no significant relationship was found between adherence to unhealthful plant-based diet index and hypertension in crude or fully adjusted models. Findings remained consistent across different subgroups, as well as sensitivity analyses.

Conclusions The present study did not find a significant association between adherence to PDIs and hypertension in T2DM patients. Future studies are needed to investigate this association and to explore potential mechanisms linking plant-based dietary pattern with hypertension in diverse populations.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Several sensitivity and subgroup analyses were performed to ensure the robustness of the results.
⇒ The availability of comprehensive and detailed data on both dietary and non-dietary variables made the adjustment of a large number of confounders possible.
⇒ A satisfactorily-reproducible and valid Food Frequency Questionnaire was used to estimate the dietary intake of patients.
⇒ Causal relations cannot be inferred due to the cross-sectional design of the study.
⇒ This study was conducted among adults with type 2 diabetes mellitus; therefore, our findings are less generalisable to either healthy populations or patients with other metabolic diseases.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) remains a significant public health concern, affecting more than 536 million adults in 2021. It is estimated to increase to approximately 700 million by 2045.[1] The risk of hypertension is particularly increased in adults with T2DM.[2] It has been documented that hypertension is responsible for 25% of cardiovascular events and 30% of mortality rates among diabetic patients.[3] Among the modifiable risk and preventive factors in the development and prevention of hypertension, the role of diet is crucial. Over the past decades, many epidemiological studies have investigated the association of food items,[4 5] food groups,[6 7] nutrients[8 9] and dietary patterns[10 11] with hypertension in the general population. However, the generalisability of dietary recommendations and nutritional guidelines obtained from these studies to the diabetic population is questionable due to their altered metabolism of carbohydrates and other macronutrients. Therefore, there is a need for additional studies that examine the relationship between diet and diseases, specifically hypertension, among this population.

Plant-based dietary patterns are becoming increasingly popular due to their potential to prevent or manage several chronic diseases. Previous studies have documented that following plant-based dietary patterns is associated with a lower risk of cardiovascular disease (CVD), cancer, T2DM and mortality.[12–14] Earlier research has shown that consuming different types of plant foods can lead to distinct health outcomes. For instance, high-quality plant-based foods, such as whole grains and nuts, have been linked to positive health outcomes.[6 7] On the other hand, low-quality plant-based foods, such as sugar-sweetened beverages and refined grains, have been associated with adverse health endpoints.[15 16] Therefore, adherence to plant-based diet indices (PDIs), as developed by Satija *et al*[17], can be rigorously evaluated, taking into account the quality of plant-based foods.

In the epidemiological studies of the general population, the association of PDIs with blood pressure (BP) has been inconsistent.[14 18 19] In terms of diabetic patients, only one small study among women has examined the association of PDIs with CVD risk factors.[20] Overall, less is known about the relation between PDIs and hypertension among adults with diabetes, especially in Middle Eastern countries. In those populations, most energy intake comes from refined starches, hydrogenated fats, sugar and potatoes ; besides, the consumption of fruits, vegetables and whole grains is low.[21 22] In this view, larger studies can provide valuable information on the association between dietary factors and health outcomes among diabetic patients. Therefore, this study was conducted to assess the association of PDIs with hypertension in patients with T2DM.

METHODS

Study design and participants

We used data from population-based Azar cohort study,[23] conducted as part of the Prospective Epidemiological Research Studies in Iran (Persian cohort).[24 25] Azar cohort study began in October 2014 which primary objective was to investigate the main risk factors associated with non-communicable diseases. The study design has been previously described in detail.[23–25] In summary, a total of approximately 15 000 community residents aged 35–70 years who were living in Shabestar county for at least 9 months were recruited. Individuals with severe psychiatric or physical illnesses were not included in the study.

In the current analysis, we included participants with T2DM at baseline. According to the diagnostic criteria established by the American Diabetes Association, individuals were identified as having T2DM if their fasting blood glucose (FBG) concentration exceeded 126 mg/dL, or if they reported being previously diagnosed with T2DM.[26 27] The participants were excluded if they were pregnant, had missing data for BP, had renal failure or hepatitis at baseline, or reported implausible daily energy intakes (<800 or >4200 kcal/day). Finally, individuals with possible type 1 diabetes, defined by the use of insulin and age at diabetes onset <30 years, were also considered as exclusion criteria.[28] After exclusions, a total of 1947 participants with T2DM were included in the current analysis.

Patient and public involvement

Patients and the public were not engaged in the design, implementation, reporting or dissemination of this research.

Assessment of dietary intake

The dietary intake of the participants was collected by face-to-face interview using a 130-item semiquantitative Food Frequency Questionnaire (FFQ), designed and validated for Iranian adults.[29] Participants were asked about their usual consumption of each food item over the past year, indicating the frequency (daily, weekly, monthly or yearly) and portion size for each item. To aid in the estimation of portion sizes, the participants were shown physical models of portion sizes or an album containing images of standard portions of various food items. The reported frequencies and portion sizes for each food item were then converted to grams per day. The USDA Food Composition Tables (USDA-FCT) were used to determine the daily energy and nutrient intakes from food items.[30] Standard, non-branded foods from the USDA-FCT that closely matched Iranian food items in terms of ingredients and macronutrients, as confirmed by four nutritionists, were selected. For Iranian foods not listed in the USDA-FCT, energy content was estimated by calculating the weighted average of key ingredients. Additionally, local food items were compared with standard FFQ items based on their main ingredients.

Assessment of PDI score

To calculate the PDIs, we followed established methods and categorised foods into 18 groups based on their nutritional and culinary similarities (online supplemental table 1).[17] We further classified these 18 food groups into three larger categories of healthy plant foods (vegetables, whole grains, legumes, fruits, vegetable oils, nuts and tea/coffee), unhealthy plant foods (refined grains, fruit juices, sugar-sweetened beverages, potatoes, sweets and desserts) and animal foods (animal fats, eggs, dairy, seafood, meat and miscellaneous animal-based foods). The intake of 18 food groups was classified into quintiles (Q) and a score between 1 and 5 was assigned to each quintile. For PDI, healthy and unhealthy plant foods received positive scores (ie, Q1=1, Q2=2, Q3=3, Q4=4, Q5=5), while animal foods received reverse scores (ie, Q5=1, Q4=2, Q3=3, Q2=4, Q1=5). For healthful plant-based diet index (hPDI), healthy plant foods were assigned positive scores and unhealthy plant and animal foods were assigned reverse scores. For unhealthful plant-based diet index (uPDI), unhealthy plant food groups were given positive scores and healthy plant and animal food groups were given reverse scores. The scores of 18 food groups were summed to derive PDI, hPDI and uPDI, ranging from 18 to 90. A higher index represented greater adherence.

Assessment of blood pressure

The BP of each participant was measured twice, while they were in a seated and comfortable position after resting for at least 5 min, following the Persian cohort protocol.[24] The patients rested for 10 min between each measurement. The average of the two measurements taken on each arm was used to determine BP. Hypertension was defined as an systolic blood pressure (SBP) of 140 mm Hg or higher, or a diastolic blood pressure (DBP) of 90 mm Hg or higher,[31 32] self-reported history of hypertension (providing medical documents as evidence) or use of antihypertensive drugs.

Assessment of other variables

A baseline questionnaire was used to obtain data on sociodemographic and lifestyle characteristics (sex, age, education level, marital status, smoking habits, alcohol consumption, physical activity levels, and duration of diabetes), comorbidities (CVD, cancer, hypertension and long-standing illness) and drug use (anti-hypertensive drugs, lipid-lowering drugs, oral glucose-lowering drugs and insulin). The height of the participants was measured using a mounted tape measure, with their arms hanging freely by their sides, and recorded to the nearest of 0.5 cm accuracy. Weight was measured using a scale (Seca755, Germany), with participants wearing light clothing and no shoes and recorded to an accuracy of 0.1 kg. Body mass index (BMI) was calculated by dividing weight (in kg) by the square of height (in metres). A non-stretchable measuring tape was used to measure waist circumference according to National Institutes of Health guidelines. The Metabolic Equivalent of Task (MET-hour per day) was applied as a metric for assessing levels of physical activity.

Statistical analysis

First, the participants were divided into quintiles based on their total PDIs scores. Then, the characteristics of the study participants were presented across the PDIs quintiles as means±SD for continuous variables and percent for categorical variables. Logistic regression analysis was employed to assess the association between PDIs and hypertension in crude and adjusted models. In model 1, we controlled for age (continuous), sex (male/female), energy intake (continuous), physical activity (continuous), marital status (single/married), education level (illiterate/university graduated/non-university education), duration of diabetes (continuous), smoking (yes/no), alcohol use (yes/no) and medication use (yes/no). In model 2, we additionally controlled for BMI (continuous) to obtain an obesity-independent association. In all these analyses, the first quintile of the PDIs was used as the reference group. Also, the same set of covariates was used to examine the linear associations per 5-unit increase in PDIs and odds of hypertension. Moreover, to examine the robustness of the findings, several sensitivity analyses were performed. First, individuals with a history of CVD and cancer were excluded. Second, newly-diagnosed diabetic patients (participants with no prior diagnosis of diabetes with FBG values more than 126 mg/dL were considered as newly diagnosed diabetic patients[26]) were also excluded. To clarify the effect of drugs in statistical analyses, we performed a sensitivity analysis without adjustment for lipid-lowering drugs, hypoglycaemic drugs and insulin. Moreover, a subgroup analysis was done based on medication use (antihypertensive drugs, lipid-lowering drugs, hypoglycaemic drugs and insulin). Furthermore, stratified analyses were conducted to examine potential risk modifiers, such as age, sex, BMI and smoking status. These analyses allowed us to assess the impact of these factors on the relationship between PDIs and hypertension. The data analysis was conducted using the SPSS software V.19.0 (SPSS Inc., Chicago, Illinois), with p values considered significant at <0.05.

RESULTS

Of the 1947 participants, 1194 (61%) were female, with a mean age of 54.9 years. The prevalence of hypertension among the participants was 48.6% (n=946). The median (range) of PDI, hPDI and uPDI in the present study was 53 (31–79), 54 (32–72) and 54 (29–74), respectively. Online supplemental table 2 presents the general characteristics of the participants categorised into quintiles of PDI, hPDI and uPDI. Compared with individuals in the lowest quintile, those in the highest quintile of PDI had higher BMI and waist circumference and younger age and were more likely to be male, smokers and physically active. Compared with individuals in the lowest quintile, those in the highest quintile of hPDI were older, had a higher BMI and were more likely to be female, non-smokers, non-drinkers, single, less physically-active and illiterate. Participants with higher scores on uPDI were older, had a higher BMI and were more likely to be non-smokers, illiterate and non-drinkers than participants with lower scores. The dietary intakes of the participants based on quintiles of PDI scores are provided in online supplemental table 3. Individuals with higher adherence to PDIs tended to consume more carbohydrates and less protein, animal fat, dairy, eggs, seafood and miscellaneous animal-based foods. Those in the highest quintiles of hPDI and uPDI consumed less energy and micronutrients compared with those in the lowest quintiles. However, individuals with the highest PDI scores tended to consume more energy and micronutrients. Table 1 presents the crude and multivariable-adjusted ORs and 95% CIs for hypertension in relation to quintiles of PDI, hPDI and uPDI. A significant inverse association was observed between adherence to PDI and the odds of hypertension in the crude model (OR: 0.60, 95% CI: 0.46 to 0.80, P-trend <0.001). However, this association became non-significant after controlling for potential confounders (OR: 0.88, 95% CI:

Table 1 Multivariable-adjusted ORs and 95% CIs for the association between PDIs and hypertension

	Total population						
	Quintile 1	**Quintile 2**	**Quintile 3**	**Quintile 4**	**Quintile 5**	**P-trend**	**Per 5-score increase in PDIs**
PDI							
Participants	409	427	377	321	413		
Crude model	1	0.80 (0.60, 1.04)	0.88 (0.66, 1.17)	0.69 (0.51, 0.93)	0.60 (0.46, 0.80)	<0.001	0.87 (0.81, 0.94)
Model I*	1	0.93 (0.69, 1.26)	1.16 (0.85. 1.59)	0.95 (0.68, 1.33)	0.98 (0.70, 1.36)	0.97	1.00 (0.92, 1.10)
Model II†	1	0.88 (0.65, 1.19)	1.07 (0.78, 1.47)	0.86 (0.61, 1.21)	0.88 (0.63, 1.24)	0.54	0.97 (0.89, 1.06)
hPDI							
Participants	358	466	311	402	410		
Crude model	1	1.28 (0.97, 1.70)	1.58 (1.16, 2.15)	1.63 (1.22, 2.18)	2.03 (1.52, 2.70)	<0.001	1.19 (1.11, 1.27)
Model I*	1	0.95 (0.70, 1.29)	1.02 (0.73, 1.44)	0.91 (0.66, 1.27)	0.92 (0.66, 1.28)	0.59	0.97 (0.90, 1.05)
Model II†	1	0.92 (0.68, 1.26)	0.98 (0.70, 1.39)	0.85 (0.61, 1.19)	0.86 (0.61, 1.21)	0.35	0.96 (0.88, 1.04)
uPDI							
Participants	376	442	301	471	357		
Crude model	1	0.86 (0.65, 1.13)	0.91 (0.67, 1.24)	1.23 (0.94, 1.61)	1.21 (0.90, 1.61)	0.01	1.07 (1.00, 1.14)
Model I*	1	0.88 (0.65, 1.19)	0.82 (0.59, 1.15)	1.07 (0.79, 1.46)	1.00 (0.71, 1.41)	0.52	1.01 (0.93, 1.09)
Model II†	1	0.91 (0.67, 1.23)	0.82 (0.59, 1.16)	1.02 (0.74, 1.39)	0.97 (0.68, 1.37)	0.83	0.99 (0.92, 1.07)

*Adjusted for age, energy intake, sex, education status, smoking status, alcohol use, marital status, physical activity, diabetes duration and medication use (lipid-lowering and hypoglycaemic drugs and insulin).
†Adjusted for age, energy intake, sex, education status, smoking status, alcohol use, marital status, physical activity, diabetes duration, medication use (lipid-lowering and hypoglycaemic drugs and insulin) and BMI.
CI, confidence interval; hPDI, healthful plant-based diet index; OR, odds ratio; PDI, plant-based diet index; uPDI, unhealthful plant-based diet index.

0.63 to 1.24, P-trend: 0.54). In terms of hPDI, a significant positive association was observed in the crude model (OR: 2.03, 95% CI: 1.52 to 2.70, P-trend <0.001), which also got non-significant after adjusting for confounders (OR: 0.86, 95% CI: 0.61 to 1.21, P-trend: 0.35). There was no significant association between uPDI and the likelihood of hypertension in both crude (OR: 1.21, 95% CI: 0.90 to 1.61, P-trend: 0.01) and fully adjusted (OR: 0.97, 95% CI: 0.68 to 1.37, P-trend: 0.83) models. Furthermore, when the PDIs were modelled continuously, every 5-point increase in PDI score was associated with lower odds of hypertension, while each 5-point increase in hPDI and uPDI scores was associated with higher odds of hypertension. However, non-significant associations were reached after controlling for potential confounders.

When individuals with CVD or cancer were excluded, no significant association was observed between PDI and hypertension in the fully adjusted models. Similar to the main analysis, the association of PDIs with hypertension was not significant when a sensitivity analysis was performed without adjustment for lipid-lowering drugs, hypoglycaemic drugs and insulin. Additionally, after excluding newly-diagnosed diabetic patients, the association between PDIs and odds of hypertension remained non-significant in fully adjusted models (online supplemental table 4). Moreover, subgroup analysis by age, sex, smoking status, medication use (users of anti-hypertensive drugs, lipid-lowering drugs, hypoglycaemic drugs and insulin vs those not taking these drugs) and BMI also showed no significant association between PDIs and hypertension in fully adjusted models in all strata (online supplemental table 5).

DISCUSSION

In this large cross-sectional study of T2DM patients, we found that greater adherence to the PDIs was not associated with the odds of hypertension. This finding was consistent across various subgroups and was further supported by sensitivity analyses.

Hypertension is a major public health challenge worldwide, particularly among diabetic patients, and is a modifiable risk factor for CVD and mortality.[3 33] Therefore, finding appropriate approaches to prevent or manage this disease is of great importance. Previous studies have more often investigated the association of nutrients or foods with hypertension in the general population, and little attention has been paid to dietary patterns, especially in diseased populations. To our knowledge, this is the first large study evaluating the association between PDIs and hypertension among the diabetic population in the Middle East, with its special dietary properties.

The results of our study indicate that there is no significant association between PDIs and hypertension in T2DM patients. Our results are in agreement with a previous study that reported no association of PDIs with SBP and DBP. However, this study had a smaller sample size and only diabetic women were investigated.[20] Moreover, they did not consider several main confounders, such as smoking, marital status and medication use in their statistical analysis. Lack of controlling for such confounders might underestimate or overestimate the independent association of PDIs with BP. Findings of Kharameh cohort study, conducted among 3678 adults with chronic diseases, showed that there was no significant association between PDIs and BP.[34] Similarly, in another cross-sectional study performed on the general population, no significant relationship was found between PDIs and BP.[35] Lopez *et al* [19] conducted a cross-sectional study in a sample of commercial taxi drivers using primary data collected in a South African cohort. They reported a non-significant association between hypertension and PDIs. Unlike our findings, the INTERMAP study documented a significant inverse association between hPDI and BP, whereas uPDI was positively associated with BP. However, no significant association was found between PDI and BP.[36] This discrepancy might be partially attributed to differences in analytical approaches employed. For instance, we applied multiple logistic regression analysis to explore the relationship between PDIs and hypertension, while multiple linear regression analysis was used in the INTERMAP study.[36] Moreover, a modified version of PDI, hPDI and uPDI, according to US and Chinese Dietary Guidelines, was used in the INTERMAP study. In a prospective cohort study of Korean adults, greater adherence to hPDI was linked to a reduced risk of hypertension, whereas uPDI was associated with a higher risk of hypertension. However, no significant association was observed for PDI.[18] Dissimilarities in the study design, health condition of the study population and dietary habits could account for the inconsistencies between our study and the cohort of Kim *et al*.[18] In a cross-sectional study involving 527 middle-aged adults, higher adherence to uPDI was linked to higher odds of hypertension, but no significant relationship was found for hPDI and PDI.[37] In this study, hypertension was defined as an SBP of 130 mm Hg or higher and a DBP of 80 mm Hg or higher. Therefore, differences in the definition of hypertension could explain the inconsistent findings. According to the findings of longitudinal analyses from the China Health and Nutrition Survey involving 4775 participants, individuals with higher adherence to PDI had a 37% lower risk of developing hypertension.[38] In their study, unlike ours, 24-hour recalls were used to assess dietary intakes. In addition, PDIs were created based on 17 food groups and miscellaneous animal-based foods and fruit juice were not considered.

Due to the limited evidence, we compared our findings with studies conducted in non-diabetic populations. However, this comparison is difficult because the metabolism of macronutrients, lifestyle and demographic characteristics in diabetic patients are different from those of other people. For instance, patients with T2DM often have lower levels of physical activity compared with their healthy counterparts.[39] Moreover, psychological factors such as stress or depression, which are more common in populations with T2DM, can influence lifestyle choices and health outcomes.[40]

In the current study, surprisingly, we found a significant positive association between hPDI and hypertension in the unadjusted analysis. However, in the fully adjusted model, these associations became non-significant. Such changes in the results demonstrate how unadjusted analyses can be misleading due to confounding factors. Previous literature has also made a strong argument for the importance of using adjusted models rather than crude ones in scientific analysis.[41 42] Those with high hPDI scores may also have different lifestyle or demographic characteristics, such as higher average age, which independently contributes to hypertension risk. It is also possible that individuals consuming healthy plant foods, due to limited nutrition knowledge, may prepare or consume these foods in ways that affect their nutritional quality, such as overcooking the vegetables, which can lead to nutrient loss. However, for these findings, this explanation alone may be less plausible. Alternatively, reverse causality may better explain the findings, as individuals experiencing declining health or early symptoms of hypertension, even without a formal diagnosis, might shift towards a healthier plant-based dietary pattern in an effort to improve their health. This possibility highlights the complexity of interpreting dietary patterns in observational studies and underscores the need for prospective cohort studies to fully understand the association of PDIs with hypertension in patients with T2DM.

In our study, individuals with higher adherence to hPDI and uPDI tended to consume less energy and micronutrients compared with those with lowest adherence. However, individuals with the highest PDI scores consumed more energy and micronutrients than those with lower scores. These findings were unexpected and should be interpreted in the light of the following: first, individuals with higher hPDI or uPDI scores may consume specific types of foods that are lower in energy and micronutrient density compared with individuals with the highest PDI scores. Overall, higher hPDI scores might be associated with greater intakes of fruits and vegetables, which are low in energy, but rich in water and various micronutrients. However, individuals with higher hPDI scores may limit the consumption of energy-dense, micronutrient-rich animal-based foods. When we examined the distribution of animal-based food groups across quintiles of the hPDI, we found that those with greater adherence to hPDI tended to consume smaller quantities of high-calorie, nutrient-dense animal-based foods. Similarly, those with higher uPDI scores might consume more processed plant-based foods, which, while unhealthy, can sometimes be low in micronutrients and energy density compared with other types of plant-based foods. Second, foods classified as 'healthy' or 'unhealthy' in the dietary indices might have a wide range of nutrient densities. For example, a food item classified under uPDI could be an energy-dense processed food or a lower-energy snack. This variation may contribute to differences in energy and micronutrient intake between quintiles. Taken together, these findings underscore the complexity of food patterns and the importance of considering the types of foods and potential classification challenges, when interpreting energy and micronutrient intake within PDIs.

In the present study, a significant inverse association was observed between adherence to PDI and the odds of hypertension in the crude model. As previously mentioned, individuals with the highest PDI scores tended to consume more energy and micronutrients. It may seem counterintuitive that patients in the highest quintile of PDI, with greater total energy intakes, would have lower odds of hypertension in the crude model. This discrepancy may be explained by lifestyle confounding factors that were not accounted for in unadjusted analyses and may contribute to the inverse association obtained in the crude model. Moreover, not all high-calorie plant foods are harmful to cardiovascular health. For instance, nuts, seeds and dehydrated whole grains are calorie-dense, yet rich in heart-healthy nutrients. Such foods might increase energy intake while still be protective against hypertension, which could explain the lower odds of hypertension in those with high PDI scores prior to adjustment. Additionally, while high energy intake is generally associated with elevated sodium intake and higher BMI, participants in the highest PDI quintile may be consuming plant-based foods with higher nutrient density, including potassium, magnesium and fibre, which are known to lower BP. Available evidence suggests that these nutrients reduce the potential risk of hypertension which is typically associated with higher energy intake.

Strengths and limitations

This study has several strengths. It is the first study to examine the association between PDIs and hypertension in a large sample of T2DM patients. We performed several sensitivity and subgroup analyses to ensure the robustness of the results. The availability of comprehensive and detailed data on both dietary and non-dietary variables enabled us to adjust for a large number of confounding factors, resulting in reliable independent associations. Furthermore, we used a satisfactorily-reproducible and valid FFQ to estimate the dietary intake of patients. The study was conducted in the Middle East region, where information on dietary intakes and their association with diseases is scarce. The use of PDI enabled us to reduce the problem of collinearity that can occur when evaluating foods and nutrients.

While interpreting the findings of the present study, several points should be considered. First, the lack of significant association between PDIs and hypertension was probably due to the small variation in the intake of some foods. For example, the range of whole grain and fruit consumption across quintiles of hPDI was low (51.07 g/day compared with 28.2 g/day for whole grain and 656.4 g/day compared with 567.5 g/day for fruits). A small variation in dietary intakes of food groups in a population reduces the power of the study to find real-world significant associations. This low variability in hPDI was also reported in a study conducted by Mokhtari *et al*,[37] in which a non-significant association was reported. In contrast, this study found wider variations in food group intakes across quintiles of uPDI (450.8 g/day compared with 234.1 g/day for refined grains), which may explain the significant positive association observed between uPDI and the odds of hypertension.[37] Several hypotheses can account for the low variability in dietary intake observed in our population. People with diabetes often receive specific dietary guidelines from their healthcare providers to help manage their condition. This may lead to a uniform diet among patients. Furthermore, less dietary variability may be attributable to cultural dietary preferences, limited access to a wide range of foods and dietary habits established over generations. Additionally, economic constraints may play a role in shaping a diet focused primarily on staple foods with fewer high-cost items. Second, the non-significant associations in our study might be explained by reverse causation bias or random measurement error. Participants might have altered their healthy lifestyle factors, such as diet and have consumed higher amounts of healthy foods after developing hypertension or other long-standing health conditions. In this case, although the results remained unchanged after the exclusion of cancer and cardiovascular patients, the existence of reverse causality bias cannot be ruled out. Moreover, measurement errors are unavoidable in dietary assessment and may introduce bias in the estimation of the association between a risk or protective factor and a disease or render a true association statistically non-significant. Third, the observational nature of the study prevents inferring causality; therefore, additional studies with prospective designs are needed to establish causality. Fourth, all 18 food groups were given equal weight, regardless of the strength of evidence or the association of the individual food groups with hypertension risk. Fifth, although several confounders were controlled for, residual confounding is still possible. Finally, our study was conducted among adults with T2DM; therefore, our findings are less generalisable to healthy populations and patients with other metabolic disorders.

CONCLUSION

In summary, our study did not find any significant association between adherence to PDIs and the odds of hypertension. Further studies with a prospective design are needed to investigate the potential relationship between PDIs and hypertension.

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Contributors SK and MS-A contributed to the conception and design of the study. EF helped with the acquisition of data. SK, SN and EF conducted the statistical analyses, wrote the draft of the manuscript and participated in interpreting the results. MS-A supervised the whole study, helped with the statistical analyses and edited the manuscript. All authors reviewed and approved the final version of the manuscript. EF is the guarantor and had full access to all the data and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The research followed the guidelines outlined in the Declaration of Helsinki, and all protocols involving human participants were approved by the Bioethics Committee of Tabriz University of Medical Sciences, Tabriz, Iran (Ethics Number: IR.TBZMED.REC. 1402.298). Written informed consent was obtained from each participant.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The data supporting the findings of this study are accessible upon reasonable request. These data were obtained from the Vice Chancellor for Research, Tabriz University of Medical Sciences, Tabriz, Iran and are subject to restrictions due to the licensing agreement for this study. As a result, the data are not publicly available. However, interested parties may obtain the data from the authors with the appropriate permission from the Vice Chancellor for Research.

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