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The Association of Dietary Indices, Antioxidant Intake and Bioactive Foods with Hypertension in Diabetic Patients: A Cross-Sectional Analysis regarding Fasa PERSIAN Cohort Study

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ABSTRACT

Background: More than half of diabetic patients finally develop hypertension which remarkably increases the risk of multiple complications. This study aims to assess the association between dietary indices, antioxidant intake and bioactive foods, and hypertension in diabetic patients. **Methods**: This was a cross-sectional population-based study on baseline data of Fasa PERSIAN cohort study which was conducted on adults in Sheshdeh town and its 24 villages, in Iran from 2014 to 2016. This research included 1229 patients with diabetes. A food frequency questionnaire was used to assess three dietary indices (phytochemical index, dietary inflammatory index, and alternative healthy eating index-2010), antioxidant intake, and consumption of bioactive foods. Other lifestyle and demographic factors were also assessed. Multivariable binary logistic regression was performed to assess the associations between independent variables and hypertension. **Results**: Higher intake of garlic was significantly associated with lower odds of having hypertension after adjusting for potential confounders [adjusted odds ratio (AOR):0.84, 95% confidence interval (CI):0.73-0.97]. Furthermore, female gender [AOR:1.77, 95% CI:1.26-2.49], being older [AOR:1.09, 95% CI:1.08-1.11], having a family history of hypertension [AOR:2.42, 95% CI:1.86-3.16] and higher body mass index (BMI) [AOR:1.1, 95% CI:1.07-1.13] were predictors of having hypertension. Neither dietary indices nor antioxidant intakes were associated with having hypertension in the crude or adjusted models. **Conclusion:** Garlic consumption is negatively associated with hypertension in diabetic patients. However, female gender, old age, family history of hypertension and higher BMI are positively associated with this condition. Therefore, modifying diet and weight management are recommended for controlling hypertension in this group of patients.

Keywords: *Antioxidants; Diabetes mellitus; Diet; Garlic; Hypertension*

Introduction

Diabetes mellitus is a metabolic endocrine disorder characterized by chronic hyperglycemia. It is the consequence of impaired insulin secretion and/or impaired insulin function (Petersmann *et al.*, 2019, Rana *et al.*, 2023). The worldwide prevalence of diabetes was estimated at

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10.5% for people aged 20–79 in 2021 (Sun *et al.*, 2022). This high prevalence is alarming because it can increase the number of chronic and acute illnesses around the globe (Harding *et al.*, 2019).

It is noteworthy that more than half of the patients with diabetes finally develop hypertension (Katayama *et al.*, 2018). Presence of hypertension in diabetic patients complicates therapeutic strategies, enhances healthcare costs, and remarkably increases the risk of microvascular complications (Tsimihodimos *et al.*, 2018). For instance, the incidence of cardiovascular diseases are reported to be increased by 2-3 fold in hypertensive diabetics (Katayama *et al.*, 2018).

Lifestyle and genetic factors are considered risk factors for developing high blood pressure (Kokubo *et al.*, 2019). Lifestyle interventions including weight reduction, regular physical activity, avoiding smoking (active or passive smoking), restriction of alcohol intake as well as consuming a healthy diet can lead to prevention or management of hypertension (Kokubo *et al.*, 2019, Valenzuela *et al.*, 2021). Adherence to special diets, focus on consumption of the whole grains, fruits, vegetables, legumes, nuts and low-fat dairy products along with reduction in total fat and sodium intake are recommended in the management of hypertension (Castro *et al.*, 2015, Thout *et al.*, 2023).

Inflammation is regarded as a contributing factor to the pathogenesis of hypertension. Elevation of inflammatory markers, such as different cytokines, are reported in hypertensive patients (Xiao and Harrison, 2020). Recently, a dietary scoring system called dietary inflammatory index (DII) has been developed to assess the inflammatory potential of the diet. According to the existing evidence, it is suggested that a more pro-inflammatory diet is related to several diseases such as cardiovascular diseases and certain cancers (Phillips *et al.*, 2019).

Growing evidence has also indicated that oxidative stress plays an important role in progression of hypertension through special mechanisms (Ahmad *et al.*, 2017, Loperena and Harrison, 2017). In the pathophysiological processes of hypertension, oxidative stress has been linked to endothelial dysfunction. However, antioxidant therapy is questionable for preventing the progression of high blood pressure in humans (Ahmad *et al.*, 2017).

Besides, consuming fruits and vegetables has been associated with lower risk of several chronic diseases. These protective effects can be principally attributed to the phytochemicals which are bioactive non-nutrient compounds found in plant foods (Zhang *et al.*, 2015). It has been suggested that consuming phytochemical-rich foods may reduce the prevalence of high blood pressure (Golzarand *et al.*, 2015, Jo and Park, 2022).

There are not many studies (Delshad Aghdam *et al.*, 2021, Farvid *et al.*, 2013, Günther *et al.*, 2009) on the relationship between dietary factors and hypertension in diabetic patients. Besides, to the authors' knowledge, no study has determined the association between bioactive food consumption and DII, and high blood pressure in the exclusive population of diabetics. Therefore, the present study aims to assess the association of bioactive foods and DII as well as alternative healthy eating index-2010 (AHEI-2010), phytochemical index (PI), antioxidant intake and some other lifestyle or demographic factors with hypertension in the diabetic individuals.

Materials and Methods

Study design and participants

This study was a cross-sectional population-based survey on adults living in the small town of Sheshdeh and its 24 surrounding villages, located in Fasa city in southwest of Iran. This research used the baseline data of Fasa PERSIAN cohort study collected from September 2014 to September 2016. The complete cohort follow-up data are not yet available. The detailed protocol has been published previously (Farjam *et al.*, 2016).

All the eligible habitants were invited to Fasa PERSIAN cohort study. The target population of this study included 11,097 individuals within the age range of 35–70. Of this population, 1229 people were diagnosed with diabetes. The inclusion criteria of this study consisted of all the diabetic patients aged between 35 to 70 who participated in Fasa PERSIAN cohort study. All the other participants (healthy or diagnosed with other diseases) were excluded from

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the present research.

In the current study, diabetic patients were divided into two groups of normotensive (n=664) and hypertensive (n=565. Presence of diabetes and hypertension was based on the previous records of participants' medical history. Blood pressure and blood sugar levels were not considered as the criteria of diagnosis, because most of the patients (91% of the diabetics and 89% of the hypertensive individuals) were under treatment for their diseases.

Data collection

Before registration process, every participant filled out an informed consent from. Interviewers were trained to ask questions from the participants. All the provided questionnaires were in electronic form in order to improve the accuracy and validity of the entered data. This study is comprised of general, medical, and nutritional interviews. Demographic characteristics, family history of diseases, and lifestyle information were asked from every participant. A modified semi-quantitative 125-item food frequency questionnaire (FFQ) was administered to assess the amount of food items consumed in the past year. The FFQ was a modification of Willett format questionnaire (Willett *et al.*, 1985) based on Iranian food items. The validity and reproducibility of this modified questionnaire were assessed, and the results indicated that this FFQ was appropriate for ranking participants based on food group intake (Eghtesad *et al.*). Energy and nutrient intakes were calculated based on FFQ using Nutritionist IV software (First Data Bank, San Bruno, CA; version 3.5.2). Then, anthropometrics measurements (including weight, height, and waist circumference) were performed, and fasting blood glucose levels were determined for the patients. Blood pressure was measured in both arms, and on each side, the measurement was done twice with a 15-minute interval. Resting heart rate was also assessed in sitting position. In addition, a quality control team monitored all the aspects of data collection and specimen acquisition processes.

Calculating AHEI-2010

Scoring criteria for AHEI-2010 are described in detail by Chiuve (Chiuve *et al.*, 2012). Briefly, the score consisted of 11 components and each component scores from 0 (worst) to 10 (best). Based on the criteria, higher intakes of vegetables, fruits, whole grains, nuts and legumes, long-chain omega-3 fatty acids and polyunsaturated fatty acids received higher scores, whereas higher intakes of sugar-sweetened beverages and fruit juice, red and processed meat, trans fat and sodium received lower scores. Besides, moderate intake of alcohol is supposed to be ideal. All the 11 scores are then summed to obtain the total AHEI-2010, with a higher score indicative of a healthier diet.

Calculating DII

For calculating DII, the method of Shivappa et al. was adopted (Shivappa *et al.*, 2014). The amounts of food parameters (listed in the aforementioned study) intakes were adjusted for each individual's energy intake. A z-score was derived by subtracting "global daily mean intake" from the adjusted food parameter. It was then divided by its standard deviation (calculated from the world database). To minimize the effect of 'right skewing', this value was converted to a percentile score. After that, the resulting number was doubled, '1' was subtracted and multiplied by respective "overall inflammatory effect scores". Finally, all of the scores were summed to create the overall DII score of each participant. In this study, 32 out of 45 original food parameters were available which could be used to calculate DII. These included energy, fat, carbohydrate, protein, saturated fat, monounsaturated fatty acids, polyunsaturated fatty acids, trans fat, omega-3 fatty acids, omega-6 fatty acids, cholesterol, fiber, zinc, selenium, magnesium, iron, vitamins A, D, E, C, B_1, B_2, B_3, B_6, B_{12}, folate, β-carotene, caffeine, garlic, onion, tea, and alcohol.

Calculating PI

Dietary PI was estimated based on the method established by McCarty (McCarty, 2004). The percentage of dietary energy derived from foods rich in phytochemicals was determined to calculate this index. The foods rich in phytochemical included in PI were fruits, vegetables (excluding potatoes), whole grains, nuts, seeds, legumes, fruit and vegetable

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juices, soy products, beer and olive oil. In the calculation, the authors considered total olive oil consumption instead of extra-olive oil because data for the type of olive oil intake were not available in this study.

Ethical considerations

The cohort study was in agreement with the Helsinki declaration and Iranian national guidelines for ethics in research. The current research was approved by the Ethics Committee of Shiraz University of Medical Sciences (No. IR.SUMS.REC.1399.1096).

Data analyses

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) software, version 21.0 (IBM Corp., USA). Chi-square test was used for comparing the qualitative data, and independent-samples t-test was applied for comparing the quantitative variables between the groups. Moreover, multivariable binary logistic regression models with enter method was performed to evaluate possible associations between independent variables and having hypertension in diabetic patients. Two models were constructed for controlling potential confounders. Model 1 was adjusted for age, sex, physical activity, family history of hypertension, active smoking and energy intake. Model 2 was adjusted for all variables in model 1 plus diabetes duration, sleep duration, ethnicity, marital status, and body mass index (BMI). P-values <0.05 were considered significant.

Results

General and medical characteristics of the participants are shown in **Table 1**. Results of this study indicated that most of the population were female (72.1%), married (86.4%) and had a family history of hypertension (58.1%), and the most prevalent ethnic group was Fars (56.6%). Hypertensive diabetics in this research were significantly older (P<0.001), higher duration of diabetes (P=0.008), BMI (P<0.001), waist circumference (P<0.001), systolic and diastolic blood pressure (P<0.001) and pulse rate (P=0.001) compared with normotensive diabetics. On the other hand, physical activity (P<0.001) and sleep duration (P=0.03) were significantly lower in diabetic patients with hypertension. No significant differences were found between the groups regarding fasting blood glucose levels and smoking status (P>0.05).

Table 1. General and medical characteristics of diabetic patients with and without hypertension.

Variables	Normotensive(n=664)	Hypertensive(n=565)	P-value[a]
Gender			
Male	223 (33.6)[b]	120 (21.2)	<0.001
Female	441 (66.4)	445 (78.8)	
Ethnicity			
Fars	363 (54.7)	332 (58.7)	0.024
Turkish speaking nomads	193 (29.1)	175 (31.0)	
Arabic speaking nomads	31 (4.7)	17 (3.0)	
Others	77 (11.5)	41(7.3)	
Marital status			
Married	593 (89.3)	469 (83.0)	<0.001
Single	16 (2.4)	6 (1.1)	
Widow/widower	49 (7.4)	86 (15.2)	
Divorced	6 (0.9)	4 (0.7)	
Family history of hypertension (yes)[d]	336 (50.6)	378 (66.9)	<0.001
Active smoking (yes)[e]	132 (19.9)	91 (16.1)	0.087
Passive smoking (at home or workplace) (yes)	385 (58.2)	304 (54.0)	0.135
Age (y)	51.13±8.92	56.57±7.74	<0.001
Diabetes duration (y)	3.65±4.40[c]	4.36±4.91	0.008

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Body mass index (kg/m^2)	26.48±4.43	28.11±4.66	<0.001
Physical activity (MET.h/day)	40.00±9.44	37.73±7.85	<0.001
Waist circumference (cm)	95.98±10.91	100.76±10.86	<0.001
Sleep duration (h/day)	7.73±1.78	7.50±1.96	0.03
Systolic blood pressure (mmHg)	110.22±15.26	126.08±21.15	<0.001
Diastolic blood pressure (mmHg)	74.57±10.93	80.38±12.60	<0.001
Pulse rate (bpm)	75.38±10.61	77.48±10.82	0.001
Fasting blood glucose (mg/dl)	182.28±62.72	134.75±59.55	0.069

[a]: Independent-samples t-test was used for comparing the continuous variables, and chi-square test was applied for comparing the qualitative data; [b]: n (%); [c]: Mean±SD; [d]: [e]: Smoked at least 100 cigarettes in the life; Family history in first degree relatives; **MET**: metabolic equivalent.

Results of the multivariable logistic regression models showed that female gender [adjusted odds ratio (AOR): 1.77, 95% confidence interval (CI): 1.26-2.49], being older [AOR: 1.09, 95% CI: 1.08-1.11], having a family history of hypertension [AOR: 2.42, 95% CI: 1.86-3.16], and higher BMI [AOR: 1.1, 95% CI: 1.07-1.13] were predictors of having hypertension after adjusting for all the potential confounders (**Table 2**). Data were also stratified by menopausal status in women, and the association between gender and hypertension remained significant in this regard [AOR: 1.92, 95% CI: 1.16-3.17 for pre-menopausal women versus men; AOR: 1.84, 95% CI: 1.28-2.65 for post-menopausal women versus men] (Data not shown).

Table 2. Logistic regression models for the association between general characteristics and presence of hypertension in diabetic patients.

Variables	Crude OR (95% CI)	P-value	Model 1 Adjusted OR (95% CI)	P-value	Model 2 Adjusted OR (95% CI)	P-value
Gender						
Male	1 (Reference)	<0.001	1 (Reference)	<0.001	1 (Reference)	0.001
Female	1.88 (1.45-2.43)		1.90 (1.38-2.63)		1.77 (1.26-2.49)	
Age (y)	1.08 (1.06-1.1)	<0.001	1.09 (1.07-1.11)	<0.001	1.09 (1.08-1.11)	<0.001
Ethnicity						
Fars	1 (Reference)	0.007	1 (Reference)	0.126	1 (Reference)	0.128
Turkish speaking nomads	0.99 (0.77-1.28)		1.12 (0.85-1.48)		1.18 (0.89-1.58)	
Arabic speaking nomads	0.60 (0.33-1.10)		0.65 (0.33-1.27)		0.68 (0.34-1.34)	
Others	0.58 (0.39-0.88)		0.69 (0.44-1.08)		0.68 (0.43-1.06)	
Marital status						
Married	1 (Reference)	<0.001	1 (Reference)	0.825	1 (Reference)	0.861
Single	0.47(0.188-1.22)		0.44 (0.16-1.22)		0.50 (0.17-1.45)	
Widow/widower	2.22 (1.53-3.22)		1.07 (0.71-1.62)		1.11 (.725-1.688)	
Divorced	0.84 (0.24-3.00)		0.64 (0.17-2.40)		0.65 (0.17-2.49)	
Family history of hypertension (yes)	1.97 (1.57-2.49)	<0.001	2.40 (1.86-3.09)	<0.001	2.42 (1.86-3.16)	<0.001
Physical activity (MET.h/day)	0.97 (0.96-0.98)	<0.001	0.98 (0.97-0.99)	0.015	0.99 (0.97-1.00)	0.103
Active smoking () (yes)	0.77 (0.58-1.04)	0.088	0.96 (0.66-1.39)	0.824	0.96 (0.66-1.41)	0.844
Diabetes duration (y)	1.03 (1.01-1.06)	0.009	0.99 (0.97-1.03)	0.967	1.01 (0.98-1.04)	0.585
Body mass index (kg/m^2)	1.08 (1.06-1.11)	<0.001	1.10 (1.07-1.13)	<0.001	1.10 (1.07-1.13)	<0.001
Sleep duration (h/day)	0.93 (0.88-0.99)	0.027	0.97 (0.91-1.04)	0.440	0.98 (0.91-1.05)	0.599

Model 1 is adjusted for age, sex, physical activity, family history of hypertension, and active smoking; Model 2 is adjusted for all the variables in model 1 plus diabetes duration, sleep duration, ethnicity, marital status and body mass index; **CI**: confidence interval; **OR**: odds ratio; **MET**: metabolic equivalent; P-values provided for ethnicity and marital status are P for trend.

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In terms of dietary indices, none of the AHEI-2010, DII and PI were significantly associated with having hypertension in crude or adjusted models (P>0.05, **Table 3**). Additionally, energy intake, percentage of energy derived from macronutrients (carbohydrate, protein and fat), fiber intake, and antioxidant intakes (vitamin A, vitamin E, vitamin C, selenium and zinc) were not predictors of having hypertension (P>0.05. **Table 3**).

Table 3. Logistic regression models for the association between dietary indices, macronutrient and antioxidant intakes and selected bioactive foods, and presence of hypertension in diabetic patients.

Variables	Crude OR (95% CI)	P-value	Model 1: Adjusted OR (95% CI)	P-value	Model 2: Adjusted OR (95% CI)	P-value
AHEI-2010	1.01 (0.99-1.03)	0.125	1.02 (0.99-1.03)	0.061	1.02 (0.99-1.03)	0.074
DII	0.96 (0.92-1.01)	0.108	0.98 (0.93-1.04)	0.474	1.01 (0.95-1.07)	0.762
PI	1.00 (0.99-1.01)	0.377	1.00 (0.99-1.01)	0.370	1.01 (0.99-1.01)	0.081
Energy (kcal/day)	0.99 (0.99-0.99)	<0.001	0.99 (0.99-1.00)	0.164	0.99 (0.99-1.00)	0.176
Carbohydrate(% energy)	1.00 (0.98-1.02)	0.819	1.01 (0.98-1.03)	0.671	1.01 (0.99-1.03)	0.372
Protein (% energy)	1.04 (0.97-1.12)	0.228	1.01 (0.94-1.09)	0.812	0.99 (0.92-1.07)	0.869
Fat (% energy)	1.00 (0.98-1.02)	0.999	0.99 (0.98-1.02)	0.739	0.99 (0.97-1.01)	0.429
Fiber (g/day)	0.98 (0.98-0.99)	0.016	1.01 (0.99-1.02)	0.193	1.01 (0.99-1.02)	0.441
Vitamin A (μg/day)	1.00 (0.99-1.00)	0.939	1.00 (0.99-1.00)	0.057	1.00 (0.99-1.00)	0.096
Vitamin E(mg/day)	0.96 (0.93-0.99)	0.004	1.01 (0.97-1.05)	0.769	0.99 (0.95-1.03)	0.573
Vitamin C (mg/day)	0.99 (0.99-1.00)	0.123	1.00 (0.99-1.00)	0.538	1.00 (0.99-1.00)	0.939
Selenium (μg/day)	0.98 (0.98-0.99)	<0.001	0.99 (0.99-1.00)	0.409	0.99 (0.98-1.00)	0.077
Zinc (mg/day)	0.92 (0.89-0.96)	<0.001	1.02 (0.97-1.08)	0.403	0.99 (0.94-1.05)	0.795
Garlic (g/day)	0.88 (0.78-0.99)	0.037	0.87 (0.75-0.99)	0.042	0.84 (0.73-0.97)	0.014
Onion (g/day)	0.99 (0.99-1.00)	0.128	1.00 (0.99-1.00)	0.731	0.99 (0.99-1.00)	0.446
Cruciferous vegetables (g/day)	0.99 (0.98-1.00)	0.186	0.99 (0.98-1.00)	0.168	0.99 (0.98-1.00)	0.067
Olive (g/day)	0.97 (0.93-1.01)	0.164	0.98 (0.93-1.02)	0.324	0.96 (0.92-1.01)	0.130
Fish (g/day)	0.99 (0.98-1.01)	0.930	1.01 (0.99-1.03)	0.113	1.01 (0.99-1.02)	0.386
Soybean and soy protein (g/day)	0.97 (0.95-1.00)	0.072	0.99 (0.96-1.02)	0.428	0.99 (0.96-1.02)	0.672
black tea (cup/day)	0.99 (0.95-1.03)	0.658	1.02 (0.97-1.06)	0.452	1.02 (0.98-1.07)	0.351

Model 1 is adjusted for energy intake, age, sex, physical activity, family history of hypertension, and active smoking; Model 2 is adjusted for all the variables in model 1 plus diabetes duration, sleep duration, ethnicity, marital status and body mass index; **CI**: confidence interval; **OR**: odds ratio; **AHEI**: alternative healthy eating index; **DII**: dietary inflammatory index; **PI**: phytochemical index.

Results of the analysis of bioactive foods revealed that higher intake of garlic was significantly associated with lower odds of hypertension in both crude and adjusted models (AOR: 0.84, 95% CI: 0.73-0.97 for model 2). However, the associations were not significant (P>0.05) for other food intakes (onion, cruciferous vegetables, olive, fish, soya, and tea) (**Table 3**).

Discussion

Results of the present study indicated that female gender, being older, positive family history of hypertension, and higher BMI were significantly associated with having hypertension in diabetic patients. Findings from a cross-sectional study which was carried out in adults in Isfahan, Iran, indicated that hypertensive patients were significantly older, had higher BMI, and had a higher family history of hypertension compared with normotensive participants. However, male gender was more prevalent in hypertensive subjects (Eghbali *et al.*, 2018). Moreover, results of a cross-sectional study in urban population of Varanasi, India, demonstrated that factors such as male gender, the eldest age group, and overweight

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or obese had higher odds for hypertension (Singh *et al.*, 2017).

The incidence of hypertension is rising greatly among the elderly population. Increased inflammation and oxidative stress that play a role in aging process can contribute to the development of hypertension (Buford, 2016).

The effect of gender on hypertension is poorly elucidated. Various studies have described gender differences as a cardiovascular risk factor. But, their findings are sometimes contradictory (Doumas *et al.*, 2013). It has been reported that some biological factors protect women against hypertension before menopause (Everett and Zajacova, 2015). For instance, high estrogen concentration in premenopausal women decreases aortic stiffness. However, abrupt decrease in estrogen level after menopause results in an elevated cardiovascular risk (Doumas *et al.*, 2013). The contrary result obtained from the present study should be more extensively investigated in the population of diabetic patients with hypertension.

Family history is frequently used as an alternative indicator to investigate the relationship between genetic factors and diseases. As mentioned earlier, both genetic and environmental factors lead to an increased risk of hypertension (Peng *et al.*, 2019).

There is also a great body of evidence that suggests excess weight gain is a main contributor to high blood pressure. Physical compression of the kidneys with fat, activation of the renin-angiotensin-aldosterone system, and elevated activation of sympathetic nervous system are some of the proposed mechanisms for obesity-induced hypertension (Hall *et al.*, 2015).

Bioactive foods are substances with strong anti-oxidative, anti-inflammatory, antithrombotic, antihypertensive and immune-modulating properties (Mozaffari-Khosravi *et al.*, 2009, Parihar and Parihar, 2019). In the current study, higher intake of garlic was significantly associated with lower odds of hypertension in the diabetic population. Similar to the findings of this study, treatment with raw crushed garlic in patients with metabolic syndrome significantly decreased blood pressure (Choudhary *et al.*, 2018). In addition, a cross-sectional study of Chinese adults without hypertension reported that a more frequent raw garlic consumption was negatively associated with prehypertension (Zhang *et al.*, 2020).

Possible mechanisms of garlic consumption on reduction of blood pressure include inhibiting angiotensin-converting enzyme, increasing the concentration of nitric oxide, and producing hydrogen sulfide by erythrocytes (Rohner *et al.*, 2015, Xiong *et al.*, 2015). It has been reported that hydrogen sulfide induces dilatation of blood vessels in smooth muscle cells (Rohner *et al.*, 2015). Allicin is the primary and most biologically active ingredient in garlic, responsible for its pharmacological functions (Savairam *et al.*, 2023, Xiong *et al.*, 2015).

None of the dietary indices (i.e. AHEI-2010, DII and PI) in the present study were significantly associated with high blood pressure in diabetic patients. In agreement with this finding, in a cross-sectional study performed on adults without chronic diseases, DII score was not associated with blood pressure of the participants (Muhammad *et al.*, 2019). In another study on normotensive subjects, the prospective association between dietary PI and the risk of hypertension were assessed. However, in this study the odds of hypertension were significantly lower for higher quartiles of dietary PI after controlling for confounders (Golzarand *et al.*, 2015). Furthermore, in a previous study, the association between adherence to Dietary Approaches to Stop Hypertension (DASH) diet and high blood pressure was investigated in youth with diabetes. The findings demonstrated that a higher DASH score was inversely associated with hypertension in type 1 diabetic patients, whereas no associations were found in type 2 diabetic individuals (Günther *et al.*, 2009). Failure to obtain significant results in dietary indices in the current study may be explained by cross-sectional design of the research as well as the lack of information concerning the type of diabetes of the individuals.

Results of the present study regarding dietary antioxidant intakes showed that these nutrients

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were not predictors of having hypertension in diabetic individuals. Findings of a former cross-sectional study on type 2 diabetic patients showed that the total antioxidant capacity of the patient's diet was inversely associated with hypertension (Farvid *et al.*, 2013). A further study that assessed the associations between serum antioxidant vitamins and blood pressure reported that levels of vitamin C, α-carotene, and β-carotene were negatively related to blood pressure, while levels of vitamins A and E directly related to blood pressure (Chen *et al.*, 2002). Although oxidative stress is discovered to be involved in the pathophysiology of high blood pressure (Ahmad *et al.*, 2017), not all hypertensions are linked to oxidative stress (Baradaran *et al.*, 2014). Furthermore, if an antioxidant is not restored after scavenging the free radicals, it will start to be a pro-oxidant (Baradaran *et al.*, 2014).

The population-based design of this study, its relatively large sample size, providing questionnaires in electronic form (for improving the accuracy and validity of the entered data), as well as controlling for potential confounders were the strengths of the present work. Besides, this study was notable due to exploring the relationships between various dietary factors and hypertension in the population of diabetics. This study had also certain limitations. The principal limitation was the cross-sectional nature of the research that precluded definite causal inferences which may also be a source of recall bias. Furthermore, in the data collection forms no information was available regarding the type of diabetes regarding the participants. Therefore, the researchers could not interpret the results separately for each type of diabetes. Finally, the patients were not newly diagnosed, and nutritional recommendations were not given to them.

Conclusion

In conclusion, it seems that higher garlic consumption is inversely associated with having hypertension in diabetic patients. However, being female and older, having a family history of hypertension, and higher BMI are positively associated with this health problem. Therefore, modifying diet and weight management under the supervision of an experienced dietitian are recommended for controlling hypertension in this group of patients. Further studies with prospective or interventional designs are required to confirm these results.

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Authors' contributions

Homayounfar, R. and Farjam, M. designed and conducted the research. Moazen, M. and Kazemi, A. analyzed and interpreted data, wrote the article, and had the primary responsibility for final content. Babajafari, S. designed the study, interpreted the data and revised the manuscript. All authors read and approved the final manuscript.

Conflict of Interest

The authors declared no conflict of interests.

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