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Original Article

Adherence to dietary approaches to stop hypertension (DASH), Mediterranean diet, and plant-based dietary pattern with systolic and diastolic blood pressure: A cross-sectional analysis

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Abstract

Background: Dietary patterns based on plant foods are proposed as a means of controlling blood pressure. This study aimed to assess the adherence to Dietary Approaches to Stop Hypertension (DASH), Mediterranean, and plant-based dietary pattern and their association with systolic (SBP) and diastolic (DBP) blood pressure among patients with hypertension participated in the SUMS Employees Health Cohort Study (SUMS EHCS).

Methods: This cross-sectional study included 226 adults with hypertension, enrolled in the SUMS EHCS. The score of DASH, Mediterranean, and plant-based dietary patterns were measured, using a- 116 item food frequency questionnaire (FFQ). Plant-based dietary indices were measured and comprised of total (t-PDI), healthy (h-PDI), and unhealthy (u-PDI) plant-based dietary index. The association of each dietary score with SBP and DBP were analyzed by multivariate linear regression after adjusting for age, sex, educational level, marital status, smoking, BMI, energy intake, physical activity, having other diseases, and family history of hypertension.

Results: The means of SBP and DBP were 127.82±15.87 and 83.51±11.22 mmHg, respectively. No significant association was seen between DASH or Mediterranean score with SBP and DBP after controlling the confounders. Although, t-PDI was significantly associated with both SBP (β; -0.53, 95% CI; -0.91, -0.15) and DBP (β; -0.30, 95% CI; -0.54, -0.03), h-PDI and u-PDI was not significantly associated with blood pressure after taking all the potential confounders into account.

Conclusion: No significant associations could be found between DASH, Mediterranean, and healthy or unhealthy plant-based dietary index, and blood pressure levels among hypertensive individuals.

Keywords: Dietary approaches to stop hypertension (DASH), Mediterranean, Plant-based dietary pattern, Blood pressure, Hypertension.

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Hypertension or elevated blood pressure is a chronic and age-related medical condition, which often entails debilitating cardiovascular and renal complications (1). It is recommended to change health behaviors, such as physical activity, weight management, eating habits, smoking cessation, moderate alcohol consumption, as well as stress management and promoting adequate sleep with circadian rhythms. These health behavior changes are at the first line of intervention to prevent and control hypertension (2). Clinical studies have shown that a plant-based diet is an effective lifestyle intervention for treating high blood pressure (3, 4).

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Some possible mechanisms for controlling hypertension following consumption of plant-based foods are lower energy, lower sodium, increased potassium, reduced oxidative stress, increased bioavailability of the vasodilator nitric oxide, and improvement of gut microbiome (4-8). A plant-based diet that is increasingly seen as a healthier alternative to meat, is a wide range of dietary patterns that contain plant-based foods. Among these diets, we can mention the Mediterranean diet, Dietary Approach to Stop Hypertension (DASH) diet, and vegetarian diet in which animal foods are eliminated or limited (3). The Mediterranean diet is a traditional eating habit in the countries bordering the Mediterranean Sea, and includes plenty of fresh fruit, vegetables, nuts and seeds, beans and whole grains; olive oil as the main source of fats; fish and other seafood and poultry in small to moderate amounts, limiting consumption of red and processed meat, sugary sweets, processed foods and some low-fat dairy products. It also accentuates on minimally processed plant-based foods. Following a Mediterranean diet, the risk of cardiovascular disease and cancer will be reduced and cognitive health will be improved, as shown in many studies over several decades. Recent Systematic Review and Meta-Analysis have been shown a positive association between the Mediterranean diet and blood pressure in adults' population, in comparison with a low-fat diet (9). Another dietary pattern, DASH, recommends higher consumption of fruits, vegetables and low-fat dairy products. Moreover, it contains whole grains, poultry, fish and nuts. DASH diet efforts to reduce the consumption of red meat, sweets, sugary drinks, total fat, saturated fat and cholesterol. Therefore, the intake of potassium, calcium, magnesium, fiber and plant-based protein is improved in the DASH diet, while refined carbohydrates and saturated fat decreased. DASH diet is recommended as a non-pharmacological treatment for hypertension, by American Heart Association (AHA). In patients with hypertension, the DASH diet significantly reduced systolic (SBP) and diastolic (DBP) blood pressure compared to a typical American diet. DASH diet not only reduces blood pressure but also improves insulin sensitivity, inflammation, oxidative stress, fasting glucose and total cholesterol. However, non-significant impacts of the DASH diet on blood pressure, fasting blood glucose and total cholesterol were reported by some studies (10). Considering the contribution of plant-based foods to reduce high blood pressure, the current study aimed to assess the adherence to DASH, Mediterranean, and plant-based dietary pattern and their association with SBP and DBP among patients with hypertension participated in the SUMS Employees Health Cohort Study (SUMS EHCS).

Methods

Study design and participants: This cross-sectional study was conducted on the baseline data of the SUMS EHCS. Launched in 2017, the SUMS EHCS addressed health issues in the employee population. The subjects who are included in this cross-sectional study, enrolled in the SUMS EHCS, aged 25-64 years, a known case of hypertension and were taking antihypertensive medications. Moreover, the exclusion criteria were pregnancy, breastfeeding, following a specific diet, and incomplete questionnaire. Finally, all eligible employees, 226 adults with hypertension were included in this cross-sectional study. The Ethics Committee of Shiraz University of Medical Sciences approved this study (IR.SUMS.SCHEANUT.REC.1400.050). All participants in the cohort study signed a written form after being informed about the purpose and procedure of the study.

Data collection: Following the published guidelines and procedures of the PERSIAN cohort (11), trained interviewers collected all data. The participant's characteristics were obtained by data gathering sheet that included demographic variables such as age, sex, education level, and marital status. Furthermore, the data of smoking, physical activity level, having other diseases, and family history of hypertension were gathered for all participants.

Anthropometric parameters: Weight measurement was done in the lightest garments using a digital scale with an accuracy of 100 g. Participants were asked to stand in the middle of the scale. Height measurement was done without shoes or hat using a stadiometer with an accuracy of 0.01 centimeters. Participants were asked to stand straight along the wall, heels, shoulders and back touching the wall, to measure the height. Moreover, body mass index (BMI) was calculated by dividing the weight (kg) by height (m) squared.

Dietary intakes: A 116 item semi-quantitative Food Frequency Questionnaire (FFQ) was employed to evaluate the dietary intake of the participants, that its validity and reliability have been verified in a previous study (12). Then, energy and nutrient intake were roughly calculated by nutritionist IV software (version 7.0; N-square computing, Salem, OR, USA).

Assessment the score of DASH diet: Eight components of the diet have been used to score DASH, which includes a large intake of fruits, vegetables, nuts and legumes, whole grains, and dairy products as well as low intakes of sugar sweetened beverages and sweets, sodium, and red or processed meat (13). In this study, total dairy intake was used rather than the consumption of low fat one, due to the lack of data about fat content in dairy products. First, subjects were classified based on the deciles of food consumption. They would receive a score of 10 if they were on the highest decile of whole grains, nuts and legume, fruits, vegetables, and dairy products. If they were in the lowest deciles, they receive a score of 1. Furthermore, they would receive a score of 10 if they were on the lowest decile of red or processed meats, sodium, and sugar-sweetened beverages and sweets. They also receive a score of 1 if they were in the highest decile. To calculate the DASH dietary score, a total score of 8-80 was created for all foods and nutrients.

Assessment the score of Mediterranean diet: Eight components of the diet have been used to score Mediterranean dietary pattern, which includes fruits and nuts, vegetables, fish and seafood, whole grains, legumes, ratio of MUFA to SFA, red meat and poultry, and dairies (14). In this study, total dairy intake was used rather than the consumption of low fat one, due to the lack of data about fat content in dairy products. First, subjects were categorized into tertile levels of food and nutrient consumption. They would receive a score of 2 if they were on the highest tertile of fruits and nuts, vegetables, fish, whole grains, legumes, and ratio of MUFA to SFA, and receive a score of 0 if they were on the lowest tertile. Furthermore, they would receive a score of 2 if they were on the lowest tertile of red meat and poultry, and dairies, and received a score of 0 if they were on the highest tertile. To calculate the Mediterranean diet score, a total score of 0-16 was created for all foods and nutrients.

Assessment the score of plant-based dietary indices: Total plant-based dietary index (t-PDI), healthy plant based dietary index (h-PDI), and unhealthy plant-based dietary index (u-PDI) were developed according to 18 food groups which were categorized by nutrient content (15). A further classification was made by dividing the 18 food groups into three groups: healthy plant foods, unhealthy plant foods and anima foods. The healthy plant foods included whole grains, fruits, vegetables, nuts, legumes, tea, coffee, and vegetable oils; unhealthy plant foods included refined grains, potatoes, sugar-sweetened beverages, refined fruit juices, desserts, and sweets; and animal foods included egg, dairy, fish and seafood, poultry, red meat, animal fats, and other animal foods. Subjects have been classified into a quintile of food consumption. To measure t-PDI score, if they were in the top quintile of healthy and unhealthy plant foods, they would receive a score of 5. The score of 1 represented the bottom quintile. Additionally, if they were in the bottom quintile of animal food groups, they would receive a score of 5. The score of 1 represented the top quintile. To measure h-PDI score, if they were in the top quintile of healthy plant foods, they would receive a score of 5. The score of 1 represented the bottom quintile. Additionally, if they were in the bottom quintile of unhealthy plant foods and animal foods, they would receive a score of 5. The score of 1 represented the top quintile. To measure u-PDI score, if they were in the top quintile of unhealthy plant foods, they would receive a score of 5. The score of 1 represented the bottom quintile. Additionally, if they were in the bottom quintile of healthy plant foods and animal foods, they would receive a score of 5. The score of 1 represented the top quintile. The final score of each index of t-PDI, h-PDI, and u-PDI were computed by summing up the scores of all foods, which were in a range of 18 to 90.

Measuring blood pressure: An experienced technician measured blood pressure, using a Rister Precision-N sphygmomanometer. Before blood pressure was measured, participants were given a period of relaxation for ten minutes. For each person, their blood pressure was checked four times. The blood pressure is measured two times by means of the bronchoal vein on right arm and two times on left arm.

Statistical analysis: SPSS software (Ver 22 for Windows; SPSS Inc., Chicago, USA) was used to analyze all data. The normality of the variables was checked using the Kolmogorov–Smirnov test. Multivariate linear regressions were applied to find the association of adherence to DASH, Mediterranean, and plant-based dietary scores with SBP and DBP, after controlling for age, sex, marital status, education level, smoking, BMI, energy intake, physical activity level, having other diseases, and family history of hypertension. A $p < 0.05$ was considered statistically significant.

Results

The means of SBP and DBP were 127.82±15.87 and 83.51±11.22 mmHg, respectively. The mean±SD of the age of the participants was 46.48±7.16 years. Females were 50.9% of the participants. Table 1 shows the characteristics of the study subjects. More than 80% of participants had family history of hypertension.

The characteristics of the participants across the quartiles of dietary DASH score, Mediterranean Score, t-PDI, h-PDI, and u-PDI are shown in table 2. The energy intakes in 3rd and 4th quartiles of DASH, Mediterranean, and t-PDI scores were significantly higher than 1st and/or 2nd quartiles.

However, the energy intake in 4th quartile of both h-PDI and u-PDI were lower than 1st and/or 2nd quartiles. Moreover, the mean BMI level in 4th quartile of u-PDI was lower than 1st quartile. DBP was also higher in the 1st quartile of DASH score compared to 2nd and in the 1st quartile of h-PDI compared to 4th quartile. The results showed significant differences in physical activity level across the quartiles of Mediterranean score; smoking across the quartiles of t-PDI; age and sex across the quartiles of h-PDI; and education level across the quartiles of u-PDI. As shown in table 3, the linear regression analysis showed that neither DASH score nor Mediterranean score was significantly associated with SBP and DBP after adjusting for age, sex, marital status, education level, smoking, energy intake, physical activity level, having other diseases, family history of hypertension, and BMI. Significant reverse associations were found between t-PDI and both SBP (β; -0.53, 95% CI; -0.91, -0.15) and DBP (β; -0.30, 95% CI; -0.54, -0.03) after taking all the potential confounders into account. However, this reverse association did not remain statistically significant for h-PDI and u-PDI following adjusting for confounders.

Table 1. Characteristics of study participants

Age (years)		46.48±7.16*
Sex	Male	111 (49.1)**
	Female	115 (50.9)
Marital status	Single	21 (9.2)
	Married	189 (83.6)
	Widow	7 (3.1)
	Divorced	9 (4.0)
Education (years)		14.36±3.66
Smoking	Yes	16 (7.1)
	No	210 (92.9)
Body mass index (kg/m²)		29.68±5.14
Energy intake (kcal)		2188.02±667.90
Physical activity level (MET.h/week)		738.75 (0.0, 18900.0)***
Family history of hypertension	Yes	185 (81.9)
	No	41 (18.1)
Having other diseases	Yes	144 (63.7)
	No	82 (36.3)
Systolic blood pressure (mmHg)		127.82±15.87
Diastolic blood pressure (mmHg)		83.51±11.22
DASH Score		44.04±8.70†
Mediterranean Score		8.02±2.43††
Total-PDI Score		54.33±6.25†††
Healthy-PDI Score		54.10±7.12†††
Unhealthy-PDI Score		54.21±7.76†††

* Data are presented as mean±SD; ** Data are presented as N (%); Data are presented as median (Min, Max); † The score ranged from 8 to 80; †† The score ranged from 0 to 16; †††

The score ranged from 18 to 90; DASH, dietary approaches to stop hypertension; PDI, Plant-based dietary index.

Table 2. The characteristics of study participants, across quartiles of DASH score, Mediterranean score, total-PDI, healthy-PDI, and unhealthy PDI

		DASH Score				P	Mediterranean Score				P	Plant-based Dietary Index (PDI)														
												Total-PDI					Healthy-PDI					Unhealthy-PDI				
		Q1	Q2	Q3	Q4		Q1	Q2	Q3	Q4		Q1	Q2	Q3	Q4	P	Q1	Q2	Q3	Q4	P	Q1	Q2	Q3	Q4	P
Age (years)		45.94±7.41*	45.13±7.37	46.75±7.02	47.90±6.74	0.20	45.03±6.59	45.85±8.64	46.68±7.80	47.98±5.84	0.13	46.26±6.72	44.95±7.54	47.24±7.45	47.22±6.96	0.31	45.60±7.58[a]	45.09±7.52[a]	46.00±6.26[ab]	49.08±6.70[b]	0.01	45.44±6.12	46.34±7.39	47.05±7.64	47.00±7.43	0.60
Sex	Male	30 (27.0)**	21 (18.9)	31 (27.9)	29 (26.1)	0.52	30 (27.0)	19 (17.1)	28 (25.2)	34 (30.6)	0.48	24 (21.6)	25 (22.5)	25 (22.5)	37 (33.3)	0.20	41 (36.9)	30 (27.0)	18 (16.2)	22 (19.8)	<0.001	25 (22.5)	21 (18.9)	30 (27.0)	35 (31.5)	0.40
	Female	29 (25.2)	30 (26.1)	25 (21.7)	31 (27.0)		31 (27.0)	15 (13.0)	39 (33.9)	30 (26.1)		36 (31.3)	24 (20.9)	29 (25.2)	26 (22.6)		19 (16.5)	21 (18.3)	39 (33.9)	36 (31.3)		31 (27.0)	29 (25.2)	23 (20.0)	32 (27.8)	
Marital Status	Single	6 (30.0)	6 (30.0)	4 (20.0)	4 (20.0)		8 (40.0)	2 (10.0)	4 (20.0)	6 (30.0)		4 (20.0)	5 (25.0)	6 (30.0)	5 (25.0)		4 (20.0)	4 (20.0)	6 (30.0)	6 (30.0)		4 (20.0)	3 (15.0)	3 (15.0)	10 (50.0)	
	Married	45 (23.8)	42 (22.2)	48 (25.4)	54 (28.6)	0.38	48 (25.4)	30 (15.9)	59 (31.2)	52 (27.5)	0.37	51 (27.0)	41 (21.7)	43 (22.8)	54 (28.6)	0.89	53 (28.0)	46 (24.3)	46 (24.3)	44 (23.3)	0.28	51 (27.0)	43 (22.8)	48 (25.4)	47 (24.9)	0.12
	Widow	3 (42.9)	2 (28.6)	0 (0)	2 (28.6)		1 (14.3)	0 (0)	3 (42.9)	3 (42.9)		1 (14.3)	1 (14.3)	2 (28.6)	3 (42.9)		0 (0)	0 (0)	3 (42.9)	4 (57.1)		0 (0)	2 (28.6)	2 (28.6)	3 (42.9)	

Score	Quartile	Divorced	Other	Education (years)	Smoking: Yes	Smoking: No	Body Mass Index	Energy intake (kcal)
DASH Score	Q1	4 (44.4)	1 (100.0)	14.03±4.13	4 (25.0)	55 (26.2)	29.68±5.86	1957.74±63 6.38^{a}
	Q2	1 (11.1)	0 (0)	13.68±3.55	2 (12.5)	49 (23.3)	30.11±4.77	2149.29±69 8.10^{ab}
	Q3	4 (44.4)	0 (0)	14.76±3.66	6 (37.5)	50 (23.8)	29.05±5.21	2285.18±54 8.11^{b}
	Q4	0 (0)	0 (0)	14.88±3.17	4 (25.0)	56 (26.7)	29.91±4.68	2356.70±71 9.57^{b}
	P			0.25	0.59		0.72	0.006
Mediterranean Score	Q1	4 (44.4)	0 (0)	14.32±3.97	2 (12.5)	59 (28.1)	29.52±5.72	1933.49±62 3.53^{a}
	Q2	1 (11.1)	1 (100.0)	13.82±4.54	4 (25.0)	30 (14.3)	29.68±4.46	2022.93±76 3.59^{ab}
	Q3	1 (11.1)	0 (0)	14.28±3.03	5 (31.3)	62 (29.5)	29.20±4.98	2278.27±55 5.28^{bc}
	Q4	3 (33.3)	0 (0)	14.76±3.46	5 (31.3)	59 (28.1)	30.34±5.12	2423.85±67 2.20^{cd}
	P			0.67	0.46		0.64	<0.001
Plant-based Dietary Index (PDI): Total-PDI	Q1	3 (33.3)	1 (100.0)	14.20±4.05	1 (6.3)	59 (28.1)	30.32±5.63	1778.01±56 6.32^{a}
	Q2	2 (22.2)	0 (0)	14.95±3.55	4 (25.0)	45 (21.4)	29.03±4.83	2000.29±43 6.78^{a}
	Q3	3 (33.3)	0 (0)	14.31±3.71	1 (6.3)	53 (25.2)	29.41±4.03	2329.70±62 6.32^{b}
	Q4	1 (11.1)	0 (0)	14.09±3.32	10 (62.5)	53 (25.2)	29.81±5.75	2603.08±66 0.00^{b}
	P			0.62	0.006		0.59	<0.001
Healthy-PDI	Q1	3 (33.3)	0 (0)	14.00±4.21	7 (43.8)	53 (25.2)	29.36±5.76	2320.37±66 2.56^{a}
	Q2	1 (11.1)	0 (0)	14.37±3.83	2 (12.5)	49 (23.3)	30.33±5.28	2294.21±71 8.10^{a}
	Q3	1 (11.1)	1 (100.0)	14.96±2.65	5 (31.3)	52 (24.8)	30.07±5.04	2195.52±63 7.60^{ab}
	Q4	4 (44.4)	0 (0)	14.13±3.75	2 (12.5)	56 (26.7)	29.06±4.43	1950.36±60 7.10^{b}
	P			0.50	0.25		0.53	0.01
Unhealthy-PDI	Q1	1 (11.1)	0 (0)	16.03±3.40^{a}	5 (31.3)	51 (24.3)	31.12±5.23^{a}	2506.89±67 1.58^{a}
	Q2	2 (22.2)	0 (0)	14.64±2.73^{ab}	1 (6.3)	49 (23.3)	29.91±4.33^{ab}	2277.01±66 8.79^{ab}
	Q3	0 (0)	0 (0)	14.24±3.64^{bc}	3 (18.8)	50 (23.8)	29.38±5.54^{ab}	2178.29±60 4.64^{b}
	Q4	6 (66.7)	1 (100.0)	12.85±3.91^{c}	7 (43.8)	60 (28.6)	28.55±5.11^{b}	1862.79±57 0.16^{c}
	P			<0.001	0.31		0.04	<0.001

		DASH Score					Mediterranean Score					Plant-based Dietary Index (PDI)														
												Total-PDI					Healthy-PDI					Unhealthy-PDI				
		Q1	Q2	Q3	Q4	P	Q1	Q2	Q3	Q4	P	Q1	Q2	Q3	Q4	P	Q1	Q2	Q3	Q4	P	Q1	Q2	Q3	Q4	P
Physical activity level (MET.h/week)		2851.44±4296.90	3647.35±4890.17	2056.33±4018.20	2145.10±2859.10	0.15	2818.56±4216.83^{ab}	3309.76±4728.53^{ab}	3306.12±4620.94^{a}	1439.61±2429.48^{b}	0.03	2455.81±3831.04	2747.95±4206.01	2550.77±4278.10	2831.26±4084.12	0.95	2801.01±4035.03	2803.88±4562.46	2497.65±4213.53	2494.56±3563.10	0.95	1443.52±2342.57	3086.70±4141.82	2866.15±4551.90	3149.73±4597.35	0.08
Family history of hypertension	**Yes**	47 (25.4)	42 (22.7)	45 (24.3)	51 (27.6)	0.87	52 (28.1)	27 (14.6)	53 (28.6)	53 (28.6)	0.80	48 (25.9)	41 (22.2)	45 (24.3)	51 (27.6)	0.94	45 (24.3)	41 (22.2)	50 (27.0)	49 (26.5)	0.31	50 (27.0)	39 (21.1)	41 (22.2)	55 (29.7)	0.34
	No	12 (29.3)	9 (22.0)	11 (26.8)	9 (22.0)		9 (22.0)	7 (17.1)	14 (34.1)	11 (26.8)		12 (29.3)	8 (19.5)	9 (22.0)	12 (29.3)		15 (36.6)	10 (24.4)	7 (17.1)	9 (22.0)		6 (14.6)	11 (26.8)	12 (29.3)	12 (29.3)	
Having other diseases	**Yes**	38 (26.4)	32 (22.2)	36 (25.0)	38 (26.4)	0.99	41 (28.5)	24 (16.7)	42 (29.2)	37 (25.7)	0.57	40 (27.8)	29 (20.1)	38 (26.4)	37 (25.7)	0.49	38 (26.4)	32 (22.2)	39 (27.1)	35 (24.3)	0.83	40 (27.8)	30 (20.8)	34 (23.6)	40 (27.8)	0.53
	No	21 (25.6)	19 (23.2)	20 (24.4)	22 (26.8)		20 (24.4)	10 (12.2)	25 (30.5)	27 (32.9)		20 (24.4)	20 (24.4)	16 (19.5)	26 (31.7)		22 (26.8)	19 (23.2)	18 (22.0)	23 (28.0)		16 (19.5)	20 (24.4)	19 (23.2)	27 (32.9)	
Systolic Blood Pressure (mmHg)		128.98±16.84	124.15±13.38	128.26±16.23	129.39±16.39	0.30	128.44±17.16	126.44±12.82	127.27±15.41	128.54±16.80	0.90	130.49±17.50	125.89±14.11	127.68±15.44	126.0±15.85	0.45	129.45±13.88	128.62±15.23	128.13±17.67	125.13±16.54	0.48	130.32±18.08	125.17±13.56	124.01±14.83	130.73±15.67	0.04

	DASH Score					Mediterranean Score					Plant-based Dietary Index (PDI)														
											Total-PDI					Healthy-PDI					Unhealthy-PDI				
	Q1	Q2	Q3	Q4	P	Q1	Q2	Q3	Q4	P	Q1	Q2	Q3	Q4	P	Q1	Q2	Q3	Q4	P	Q1	Q2	Q3	Q4	P
Diastolic Blood Pressure (mmHg)	86.32±12.10^{a}	80.72±9.34^{b}	83.82±12.08^{ab}	82.85±10.53^{ab}	0.06	85.52±12.90	83.26±10.64	82.10±9.72	83.22±11.23	0.38	85.15±11.90	84.02±11.16	82.29±9.74	82.62±11.80	0.49	86.33±12.11^{a}	84.17±9.72^{ab}	82.92±11.60^{ab}	80.61±10.58^{b}	0.04	85.05±12.51	80.48±9.10	81.85±10.31	85.82±11.68	0.03
DASH score	33.23±3.90^{a}	40.84±1.46^{b}	46.64±1.87^{c}	54.98±3.93^{d}	<0.001	36.88±7.55^{a}	41.14±5.78^{b}	45.21±6.07^{c}	51.20±7.25^{d}	<0.001	41.36±8.67^{a}	42.46±8.83^{a}	45.18±8.99^{ab}	46.85±7.48^{b}	0.002	37.98±7.68^{a}	43.23±6.48^{b}	46.54±7.22^{bc}	48.58±9.14^{c}	<0.001	49.10±7.21^{a}	45.46±8.30^{ab}	44.79±7.86^{b}	38.17±7.52^{c}	<0.001
Mediterranean score	6.10±2.01^{a}	7.33±2.15^{b}	8.73±1.86^{c}	9.85±1.85^{d}	<0.001	4.96±1.01^{a}	7.00±0.00^{b}	8.47±0.50^{c}	11.01±0.98^{d}	<0.001	6.48±2.01^{a}	7.34±2.08^{a}	8.57±2.52^{b}	9.55±1.87^{c}	<0.001	6.35±2.08^{a}	8.01±2.11^{b}	8.73±2.06^{b}	9.06±2.49^{b}	<0.001	9.23±2.25^{a}	8.12±2.35^{a}	8.45±1.95^{a}	6.61±2.32^{b}	<0.001
Total-PDI score	51.35±5.52^{a}	54.13±6.25^{ab}	55.64±5.48^{b}	56.20±6.62^{b}	<0.001	50.39±5.42^{a}	51.79±5.00^{a}	55.77±5.68^{b}	57.92±5.56^{b}	<0.001	46.55±2.65^{a}	52.53±1.19^{b}	55.94±0.83^{c}	61.76±3.75^{d}	<0.001	51.25±5.24^{a}	55.21±6.56^{b}	54.78±5.62^{b}	56.29±6.51^{b}	<0.001	54.58±7.18	53.86±5.21	55.66±6.29	53.41±6.04	0.24
Healthy-PDI score	50.10±7.64^{a}	52.41±5.60^{ab}	54.92±5.52^{b}	58.70±6.37^{c}	<0.001	50.42±7.02^{a}	51.97±6.98^{ab}	54.97±5.69^{bc}	57.82±6.67^{c}	<0.001	52.18±6.71^{a}	52.69±6.34^{a}	54.53±8.20^{ab}	56.65±6.40^{b}	0.002	45.08±3.19^{a}	52.03±1.38^{b}	56.40±1.23^{c}	62.98±3.44^{d}	<0.001	55.62±6.42^{a}	54.46±8.28^{ab}	54.52±6.35^{ab}	52.22±7.08^{b}	0.05
Unhealthy-PDI score	59.25±7.35^{a}	56.33±6.28^{a}	51.85±7.10^{b}	49.66±6.36^{b}	<0.001	58.45±8.28^{a}	54.91±6.11^{ab}	54.13±6.61^{b}	49.89±6.91^{c}	<0.001	54.88±8.42	54.48±6.64	54.16±8.34	53.41±7.51	0.76	56.58±8.29^{a}	55.17±6.91^{ab}	51.56±7.09^{b}	53.53±7.81^{ab}	0.003	44.51±3.31^{a}	50.82±1.42^{b}	56.07±1.45^{c}	63.38±4.05^{d}	<0.001

*Data are presented as Mean±SD; **Data are presented as N (%), P: P value; DASH, dietary approaches to stop hypertension; PDI, Plant-based dietary index; Q, Quartile.

Table 3. Multivariate-adjusted linear regression analysis of systolic and diastolic blood pressure related to the scores of DASH, Mediterranean, total-PDI, healthy-PDI, and unhealthy-PDI

		DASH Score	Mediterranean Score	Plant-based Dietary Index		
				Total-PDI	Healthy-PDI	Unhealthy-PDI
Systolic blood pressure (mmHg)	Unadjusted Model	0.04 (-0.19,0.28)	-0.07 (-0.93, 0.78)	-0.22 (-0.56, 0.10)	-0.27 (-0.56, 0.02)	0.10 (-0.17, 0.37)
	Model 1	0.04 (-0.19, 0.28)	-0.09 (-0.97, 0.79)	-0.47 (-0.85, -0.09)	-0.10 (-0.40, 0.19)	0.02 (-0.26, 0.31)
	Model 2	0.07 (-0.16, 0.31)	-0.21 (-1.11, 0.68)	-0.56 (-0.94, -0.18)	-0.08 (-0.38, 0.22)	-0.10 (-0.40, 0.20)
	Model 3	0.07 (-0.16, 0.31)	-0.23 (-1.12, 0.66)	-0.53 (-0.91, -0.15)	-0.08 (-0.38, 0.22)	-0.06, (-0.37, 0.24)
Diastolic blood pressure (mmHg)	Unadjusted Model	-0.12 (-0.30, 0.04)	-0.43 (-1.00, 0.17)	-0.20 (-0.43, 0.03)	-0.35 (-0.55, -0.15)	0.09 (-0.09, 0.28)
	Model 1	-0.08 (-0.24, 0.07)	-0.28 (-0.87, 0.32)	-0.30 (-0.55, -0.04)	-0.17 (-0.37, 0.03)	0.01 (-0.18, 0.20)
	Model 2	-0.07 (-0.24, 0.08)	-0.31 (-0.92, 0.29)	-0.33 (-0.60, -0.07)	-0.15 (-0.35, 0.05)	-0.05 (-0.25, 0.16)
	Model 3	-0.07 (-0.23, 0.08)	-0.34 (-0.94, 0.25)	-0.30 (-0.54, -0.03)	-0.15 (-0.35, 0.05)	0.007 (-0.20, 0.21)

Data are presented as beta (95% CI); Model 1; adjusted for age, sex, energy intake; Model 2; additionally adjusted for physical activity, education, marital status, smoking, family history of hypertension, having other diseases; Model 3; further adjusted for body mass index; DASH, dietary approaches to stop hypertension; PDI, Plant-based dietary index

Discussion

This study revealed that neither DASH nor Mediterranean dietary scores were not associated with SBP and DBP. In addition, although t-PDI was inversely associated to both SBP and DBP, no significant association was seen for h-PDI and u-PDI. Linear regression analysis in the present study demonstrated that the DASH score was not significantly associated with SBP and DBP levels after controlling the confounders. Similar to our findings, results of a former multicenter cross-sectional study indicated that the DASH diet was not significantly related to hypertension in young subjects with type 2 diabetes mellitus after controlling for confounders. However, higher adherence to this diet showed an inverse association with hypertension among young subjects with type 1 diabetes mellitus (16). Another cross-sectional study that was conducted by Islami et al., assessed the diet quality of women in rural areas of Indonesia by a DASH-like diet score which composed of nine components including carbohydrate, protein, saturated fat, total fat, fiber, sodium, potassium, magnesium, calcium, and sodium to potassium ratio. Islami et al. reported no significant difference between the DASH diet quality and blood pressure status (17). Within a multi-national cohort study, a cross-sectional analysis was also performed in Malaysian and Philippines populations. In the Malaysian population, the DASH score was not significantly related to blood pressure. Nevertheless, in the Philippines population, a 5-unit elevation in the DASH score was negatively associated with SBP and DBP (18). Furthermore, results of multivariate regression analysis on baseline data of EPIC-Florence cohort study revealed that higher adherence to DASH score was inversely associated with SBP and DBP values in healthy adults of Central Italy (19). In terms of interventional studies, a meta-analysis of randomized controlled trials published in 2020 reported that following the DASH diet significantly decreased both SBP and DBP compared with control group in adults with and without hypertension (20).

Restriction of sodium intake is one of the features of the DASH diet with the purpose of lowering blood pressure. Moreover, high quantities of fruit and vegetables in DASH diet provide large amounts of potassium, magnesium and fiber, all have been reported to alleviate hypertension (21). Reducing the serum levels of angiotensin-converting enzyme may also occur in response to decreasing saturated fats intake that can control blood pressure (21, 22). The multiple health benefits attributed to following such a diet may be due to the integrated effects of DASH components exerted through several mechanisms such as modifying the antioxidant capacity, inflammatory status, natriuresis, and endothelial function (23). This study showed no significant relationship between the Mediterranean diet score and SBP and DBP. In agreement with our results, findings of a previous cross-sectional study in France on community dwellers aged above 65 years showed that higher Mediterranean diet adherence was not associated with hypertension (24). Additionally, in another cross-sectional study conducted on adults in Italy, although higher adherence to the Mediterranean diet was negatively associated with high blood pressure, this relationship did not remain significant after adjusting for sodium and potassium intakes (25).

On the other hand, in a cross-sectional study which was performed on non-hypertensive adults in Iran, higher Mediterranean diet score was inversely associated with lower SBP as well as pre-hypertension (26). Besides, a Spanish prospective cohort study evaluated the incidence of hypertension in educated adults. In this investigation, although moderate or high adherence to the Mediterranean diet was not associated with hypertension after adjusting for confounders, they showed significant inverse relationships with changes of SBP and DBP after 6 years of follow-up (27). Even a more conflicting result has been reported in a cross-sectional study that was carried out on non-diabetic patients in Saudi Arabia. Unexpectedly, in this investigation, those individuals with adequate adherence to Mediterranean diet had significantly higher DBP compared with those with inadequate adherence level (28). A recent meta-analysis of randomized controlled trials and observational studies published in 2021 has suggested that Mediterranean diet is an effective dietary approach to decrease blood pressure and to reduce the odds of developing hypertension (29).

The combined effects of all dietary aspects in the Mediterranean diet as well as presence of some specific foods in this diet play a role in conferring health benefits. Perhaps olive oil is the most important constituent of the Mediterranean diet. Based on recent studies, polyphenols that are found in olive oil have been attributed to increased synthesis of nitric oxide in the endothelium. Thus they exert vasoprotective effects and influence blood pressure (30). Moreover, high amounts of fiber and antioxidant compounds found in fruits, vegetables, legumes and whole-grain products in the Mediterranean diet may contribute to reducing the risk of hypertension (25). With regard to the plant-based diets in this study, significant inverse associations were found between t-PDI and both of SBP and DBP after adjusting for all the confounders. Nonetheless, these negative associations did not remain statistically significant for h-PDI as well as u-PDI. There are only limited studies that have investigated h-PDI or u-PDI on blood pressure levels. In a cross-sectional study conducted by Amini et al., overall-PDI, h-PDI and u-PDI were assessed among Iranian older adults. The authors have found that the tertiles of measured indices in crude or adjusted models are not significantly different for SBP and DBP (31). Besides, in a multi-center cross-sectional investigation, eight blood pressure assessments and four 24-h dietary recalls were collected for individuals aged 40–59 years. Modified PDI, h-PDI and u-PDI were subsequently calculated based on country-specific dietary guidelines. Contrary to our results, h-PDI was inversely related to SBP and DBP, u-PDI was directly associated with SBP and overall-PDI was not associated with blood pressure (32). A prospective cohort study in South Korea, explored similar associations in men and women who were not diagnosed with hypertension and related chronic disorders at baseline. After controlling for demographic and lifestyle factors, the incidence of hypertension among individuals in the top quintile of h-PDI was 35% lower compared with bottom quintile, while the incidence was 44% higher among those in the top quintile of u-PDI versus bottom quintile (33).

Multiple mechanisms have been suggested by which plant-based diets result in reduced blood pressure. For instance, vasodilatory effect, improved antioxidant and anti-inflammatory status, reduced blood viscosity, alterations in the renin-angiotensin and sympathetic nervous systems, and modifying the gut microbiota have been proposed in this regard (34). The healthfulness of such a diet has also a significant role in the development of hypertension (33). A healthful plant-based diet is rich in potassium, a nutrient which has been reported to lower blood pressure through influencing endothelial function and vascular homeostasis (32, 35, 36). Furthermore, plant-based diet is high in fiber, vitamins, polyphenols, and unsaturated fatty acids, which help maintain normal blood pressure (32). Conversely, sodium, nitrates, and nitrites that are used in preserved processed meats may compromise cardiovascular health by mechanisms like elevating blood pressure and impairing endothelial function (35). Failure to obtain significant results in the present study may be explained by some of the following reasons: First of all, hypertensive individuals in this research used medications for controlling their blood pressure. As a result, the efficacy of healthful diets might be attenuated._The relatively small sample size as well as the cross-sectional design of this investigation could be other justifications for our insignificant findings. In fact, in such a design interpretation of causal relationships is not possible since both the exposures and outcomes are measured simultaneously. Genetic variations of individuals in different geographic regions or countries may also account for another possible reason for coming to such a result. The strength of this study was comparing three of the most important and applicable dietary indices in relation to blood pressure levels. Additionally, unlike most of the previous studies, the present research evaluated the dietary factors and their associations with levels of blood pressure in those individuals who all had hypertension. On the other hand, this research had some limitations. Due to the cross-sectional design of this study, the causal relationship between dietary indices and blood pressure levels could not be well established. The relatively small sample size can be considered as another limitation of the current study. In conclusion, no significant associations could be found between various dietary scores including the DASH diet, Mediterranean diet, and healthy or unhealthy plant-based dietary index, and blood pressure levels among hypertensive individuals. Conducting more comprehensive studies in the future, especially with prospective or interventional designs are needed to make a more definite conclusion.

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Conflict of interests: There are no conflicts of interest.

Authors' contribution: ZH conceptualized the study, analyzed the data, and wrote the manuscript. MM and MR collaborated in writing the manuscript. SJM participated in all parts of the study. All authors have read and approved the final manuscript.

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