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Original Article

The Association of Diet Quality Indices with Metabolic Syndrome Components: A PERSIAN Cohort Study in Fasa, Iran

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ABSTRACT

Background: Metabolic syndrome (MetS) is a significant health concern both in developed and developing countries. This cohort Prospective Epidemiological Research Study in Iran (PERSIAN) aimed to determine the association of diet quality, assessed by the Healthy Eating Index-2015 (HEI-2015) and Mediterranean Diet Score (MDS), with MetS components among individuals with MetS in Fasa, southern Iran**.**

Methods: In this cross-sectional study, 907 individuals with MetS aged 35-65 years were recruited from the Fasa PERSIAN Cohort Study, Fasa, Iran. The National Cholesterol Education Program Adult Treatment Panel III (ATP III) and Iranian National Committee of Obesity criteria were used to define MetS. A 125-item food frequency questionnaire was employed to evaluate dietary intake. The association between the quartiles of dietary scores and MetS components analyzed by Multivariate linear regression with the backward method.

Results: The mean age of the individuals (67.3% female) was 48.75±8.22 years. After adjusting for covariates, the highest HEI-2015 quartile was positively correlated with fasting blood sugar (FBS, β=7.30, 95%CI=1.03, 13.58) and triglyceride levels (β=32.71, 95%CI=9.09, 56.33). The MDS had a significant negative association with the systolic blood pressure (SBP) in both crude and adjusted models (β=-3.14, 95%CI=-6.2, -0.019). The triglyceride (TG, β=26.008, 95%CI=4.32, 47.69) and FBS (β=5.77, 95%CI=0.057, 11.49) levels also were positively correlated with the highest MDS quartile.

Conclusion: The SBP was shown to be inversely associated with the MDS, wherease higher adherence to HEI-2015 and MDS values were also linked with increased FBS and TG levels.

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Introduction

Metabolic syndrome (MetS), also known as insulin resistance syndrome, syndrome X, hypertriglyceridemic waist, and deadly quartet, is one of the most important public health issues among the non-communicable diseases (NCDs) (1). Central obesity, raised triglyceride levels, low high-density lipoprotein (HDL) levels, hypertension, and elevated fasting blood sugar (FBS) levels are all risk factors for MetS (2). According to recent data, people with MetS have a 1.5 times greater mortality rate than healthy people (3). MetS affects almost a quarter of the world's population (4). According to a meta-analysis published in 2019, about a third of the adult Iranian population were affected by MetS, with an overall prevalence of 30.4% that is far greater than countries such as Japan (5.3%) and the United States (22.9%) (5). The development of MetS appears to be influenced by genetic, metabolic, and environmental factors, particularly by nutritional factors (6). According to data of several studies, healthy eating patterns are connected to a lower risk of insulin resistance and MetS, because they include more fruits, vegetables, whole grains, and fiber; whereas the western dietary pattern is linked to an elevated risk of both disorders (7, 8).

Dietary pattern assessment is a proper method to evaluate whether diet is linked to the risk of chronic diseases at the population level (9). It is comprised of posteriori and priori-defined methods (10). Among the priori-defined dietary pattern assessment tools, the Healthy Eating Index (HEI) and Mediterranean Diet Score (MDS) have been mentioned. The United States Department of Agricultural (USDA) established the HEI in 1995 to evaluate diet quality based on the Food Guide Pyramid and Dietary Guidelines (11, 12). The Mediterranean diet is an effective approach for preventing and treating MetS (13). Also, its protective effects against type 2 diabetes mellitus (T2DM) and MetS have been confirmed in previous studies (14).

Cross-sectional studies have shown a remarkable inverse relationship between the HEI and the risk of MetS components (11) and risk factors of cardiovascular disease (CVD) (15). However, a cross-sectional study on 230 women in Tehran, Iran, found no significant relation between HEI and risk factors of CVD (16). Higher modified MDS values were correlated with decreased prevalence rates of MetS, abdominal obesity, and hypertriglyceridemia in a study on Korean adults (17). Nevertheless, better adherence to the Mediterranean diet was correlated favorably with MetS components other than FBS level and diastolic blood pressure (DBP) in a cross-sectional analysis of people with MetS (18).

Previous meta-analysis studies have examined the effects of the HEI and MDS in lowering the risk of all-causes (19) and mortality of elderly population (20), respectively. However, no study has investigated the link between these two dietary patterns and MetS components among the Iranian MetS population. Given that MetS is highly prevalent in Iran and considering the effective role of diet in preventing it, this study aimed to evaluate the association of diet quality indices including Healthy Eating Index-2015 (HEI-2015) and MDS with MetS components among people with MetS who participated in cohort study of Prospective Epidemiological Research Study in Iran (PERSIAN) in Fasa City, Southern Iran.

Materials and Methods

Individuals with MetS aged 35-65 years from the Fasa Cohort Study (FACS), a branch of Prospective Epidemiological Research Study in Iran (PERSIAN) were recruited cross-sectionally (21). FACS is a 15-year population-based longitudinal study conducted on individuals aged 35-70 years living in rural areas of Sheshdeh, a suburb of Fasa, Iran. The FACS protocol has already been thoroughly explained before (22). The total number of the study population was 10118. participants older than 65 years (n=488) who received medication to control diabetes, hypertension, or dyslipidemia (n=1771) were excluded from the study. People with at least 3 MetS components (n=1216) were included among the remaining 7859 participants. Then, 309 individuals were excluded due to unusual daily energy intake (<800 and >4200 Kcal). A total of 907 participants with MetS were finally included in the present study. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Ethics Committee of Shiraz University of Medical Sciences, Shiraz, Iran (IR.SUMS.SEC.1399.1030). Written informed consent was obtained from each participant.

Height and weight were measured with an unstretched tape and digital scale, respectively, with accuracy of to 0.1 cm and 0.1 kg. The body mass index (BMI) was determined by dividing the weight (kg) by height squared (m^2). Waist circumference (WC) and hip circumference (HC) were determined with an unstretched tape at the midpoint between the iliac crest and the lower rib and the largest part of the buttocks, respectively. The waist to hip ratio (WHR) was calculated as the ratio of the WC (cm) to the HC (cm).

A validated, semi-quantitative Food Frequency Questionnaire (FFQ) (23) was employed by a nutritionist to evaluate dietary intake over the preceding year during an in-person interview with each participant. This 125-item FFQ was an adapted version of the Willette questionnaire based on Iranian food items. Participants were requested to describe the frequency of consumption of each food item (daily, weekly, monthly, or yearly). Subsequently, each food portion size was converted to grams/day. Finally, Nutritionist IV software (version 7.0) was utilized to determine the energy and nutrient content of the foods.

The HEI-2015 score was assessed by a method described before (24). The total score was computed using 13 components, including nine adequacy and four moderation constituents. Among the adequacy components, whole fruits, total fruits, total protein foods, total vegetables, seafood and plant proteins, greens, and beans were scored from 0 (lowest consumption) to 5 (highest consumption); whereas whole grains, dairy products, and fatty acids (poly-unsaturated fatty acids (PUFA) + mono-unsaturated fatty acids (MUFA)/saturated fatty acids (SFA)) were scored from 0 (lowest consumption) to 10 (highest consumption). Maximum intake of the moderation components (sodium, saturated fatty acids, refined grains, and added sugar) was scored as 0, whereas the minimum intake was scored as 10. Eventually, the scores of the 13 components were summed to arrive at the total HEI score, which ranged from 0 to 100.

Based on previous studies (25, 26), the MDS was calculated using a total of 9 components, including fruits, vegetables, fish, whole grains, legumes, nuts, MUFA to SFA ratio, meats (red meat, poultry, and processed meats), and dairies. The first seven components were assigned a score of 1 if they were consumed at or above the median intake and 0 if they were not. The other two components were scored

Table 1: General characteristics of participants among quartiles of the Healthy Eating Index-2015.

Variable	Healthy Eating Index-2015 score								
	Quartile 1 N=217		Quartile 2 N=204		Quartile 3 N=270		Quartile 4 N=216		*P* value
Age (year)[a]	49.53	7.90	48.35	8.11	48.40	8.41	48.80	8.41	0.40
Weight (kg)[a]	75.24	12.84	74.99	11.93	76.53	11.49	76.43	11.32	0.38
WC (cm)[a]	102.26	10.29	101.87	7.791	102.87	8.33	103.15	8.71	0.42
BMI (kg/m^2)[a]	29.48	4.62	28.80	3.84	29.64	4.05	29.92	3.99	0.04
WHR[a]	0.97	0.051	0.97	0.041	0.97	0.048	0.97	0.054	0.97
DBP (mmHg)[a]	80.66	11.61	79.63	12.76	80.27	11.68	81.45	12.82	0.48
SBP (mmHg)[a]	119.62	11.57	119.007	19.48	117.93	17.002	120.83	19.29	0.37
FBS (mg/dL)[a]	97.73	22.85	101.30	41.04	98.90	33.21	103.45	32.89	0.27
TG (mg/dL)[a]	195.40	96.91	203.75	97.11	208.50	128.66	224.62	161.84	0.09
HDL-C (mg/dL)[a]	44.82	13.35	42.93	10.97	43.96	13.02	44.84	13.63	0.37
PA (met.h/week)[a]	39.55	8.80	38.51	8.56	38.66	7.99	38.53	9.23	0.54
Sex (male)[b]	64	(7.1%)	65	(7.2%)	95	(10.5%)	73	(8%)	0.58
Ethnicity[b]									<0.0001
Fars	81	(8.9%)	99	(10.9%)	138	(15.2%)	126	(13.9%)	
Turkish	99	(10.9%)	74	(8.2%)	113	(12.5%)	72	(7.9%)	
Arab/others	37	(4.1%)	31	(3.4%)	19	(2.1%)	18	(2%)	
Education[b]									0.002
Illiterate/ Elementary	199	(21.9%)	169	(18.6%)	214	(23.6%)	168	(18.5%)	
Middle school/ Diploma	16	(1.8%)	33	(3.6%)	51	(5.6%)	41	(4.5%)	
University degree	2	(0.2%)	2	(2.6%)	5	(0.6%)	7	(0.8%)	
Marital status[b]									0.22
Single	6	(0.7%)	7	(0.8%)	11	(1.2%)	2	(0.2%)	
Married	194	(21.4%)	174	(19.2%)	238	(26.2%)	200	(22.1%)	
Widow /Divorced	17	(1.9%)	23	(2.5%)	21	(2.3%)	14	(1.5%)	
Current smoker[b]									0.40
Yes	25	(2.8%)	25	(2.8%)	33	(3.6%)	17	(1.9%)	
No	192	(21.2%)	179	(19.7%)	237	(26.1%)	199	(21.9%)	

Abbreviations: WC: Waist Circumference, BMI: Body Mass Index, WHR: Waist to Hip Ratio, DBP: Diastolic Blood Pressure, SBP: Systolic Blood Pressure, FBS: Fasting Blood Sugare, TG: Triglycerides, HDL-C: High-density Lipoproteins Cholesterol, PA: Physical Activity. a: Analyzed by one-way analysis of variance (ANOVA), b: Analyzed by Chi-squared test. Quantitative variables were presented as mean±standard deviation and qualitative variables were shown as frequency (percentage).

conversely to the former ones. By adding together the scores of all components, a final score between 0 (low adherence) and 9 (high adherence) was obtained. The residual method was used to adjust all food groups for energy intake before scoring.

Sociodemographic data, including age, gender, marital status, educational level, ethnicity, and current smoking status were evaluated using an electronic questionnaire filled by FACS experts. Physical activity was measured in metabolic equivalent hours per week (MET.h/W) using the International Physical Activity Questionnaire (IPAQ). To assess blood pressure and biochemical markers**,** participants were first asked to sit and rest for 15 minutes. Subsequently, blood pressure was evaluated twice across a 15-minute interval using a mercury sphygmomanometer. The average of the two measurements was taken as the final value. Blood samples of participants were collected after they had fasted for 12 hours. Biochemical markers, including FBS, triglycerides (TG), and high-density lipoprotein cholesterol (HDL-C), were measured by the enzymatic colorimetric method.

To define participants with MetS, the National Cholesterol Education Program Adult Treatment Panel III (ATP III) (27) and the Iranian National Committee of Obesity (28) (for defining abdominal obesity due to the study's Iranian population) criteria were employed. Individuals with at least three of the following criteria were considered to have MetS: (i) WC>95cm (in both sexes); (ii) high serum TG levels (≥150 mg/dL); (iii) high serum FBS levels (≥100 mg/dL); (iv) low serum HDL-C levels (<40 mg/dL in males and <50 mg/dL in females); (v) high blood pressure (systolic blood pressure (SBP)≥30 mmHg or DBP≥85 mmHg).

SPSS software (Version 26, Chicago,IL, USA) was used to conduct the statistical analysis.

Table 2: General characteristics of participants among quartiles of Mediterranean diet score.

Variable	Mediterranean Diet Score								
	Quartile 1 N=268		Quartile 2 N=187		Quartile 3 N=184		Quartile 4 N=268		*P* value
Age (year)[a]	49.79	8.14	48.87	7.99	47.72	8.003	48.33	8.54	0.047
Weight(kg)[a]	75.01	11.63	76.26	11.46	74.93	11.68	77.04	12.51	0.15
WC (cm)[a]	101.70	9.52	103.28	7.98	102.50	9.19	102.97	8.34	0.22
BMI (kg/m^2)[a]	29.04	4.29	29.59	4.04	29.47	4.29	29.85	3.95	0.15
WHR[a]	0.97	0.051	0.97	0.043	0.96	0.052	0.97	0.047	0.47
DBP (mmHg)[a]	81.77	12.36	79.44	11.59	80.83	12.11	79.74	12.41	0.14
SBP (mmHg)[a]	121.60	18.75	117.33	16.64	119.08	18.03	118.40	18.89	0.069
FBS (mg/dL)[a]	99.15	30.57	100.98	29.54	101.97	37.51	100.24	34.47	0.66
TG (mg/dL)[a]	199.54	117.41	197.87	76.58	214.21	124.67	219.71	155.16	0.15
HDL-C (mg/dL)[a]	44.50	12.60	43.74	12.58	43.32	11.85	44.64	13.85	0.67
PA (met.h/week)[a]	39.37	9.33	38.48	7.96	39.81	9.07	37.79	7.89	0.055
Sex (male)[b]	98	(10.8%)	58	(6.4%)	56	(6.2%)	85	(9.4%)	0.45
Ethnicity[b]									0.023
Fars	120	(13.2%)	96	(10.6%)	130	(11%)	128	(14.1%)	
Turkish	102	(11.2%)	72	(7.9%)	67	(7.4%)	117	(12.9%)	
Arab/others	46	(5.1%)	19	(2.1%)	17	(1.9%)	23	(2.5%)	
Education[b]									0.008
Illiterate/Elementary	233	(25.7%)	165	(18.2%)	148	(16.3%)	204	(22.5%)	
Middle school/ Diploma	32	(3.5%)	21	(2.3%)	32	(3.5%)	56	(6.2%)	
University degree	3	(0.3%)	1	(0.1%)	4	(0.4%)	8	(0.9%)	
Marital status[b]									0.136
Single	4	(0.4%)	6	(0.7%)	3	(0.3%)	13	(1.4%)	
Married	241	(26.6%)	165	(18.2%)	171	(18.9%)	229	(25.2%)	
Widow/Divorced	23	(2.5%)	16	(1.8%)	10	(1.1%)	26	(2.9%)	
Current smoker[b]									0.09
Yes	37	(4.1%)	19	(2.1%)	24	(2.6%)	20	(2.2%)	
No	231	(25.5%)	168	(18.5%)	160	(17.6%)	248	(27.3%)	

Abbreviations: WC: Waist Circumference, BMI: Body Mass Index, WHR: Waist to Hip Ratio, DBP: Diastolic Blood Pressure, SBP: Systolic Blood Pressure, FBS: Fasting Blood Sugare, TG: Triglycerides, HDL-C: High-density Lipoproteins Cholesterol, PA: Physical Activity. a: Analyzed by one-way analysis of variance (ANOVA), b: Analyzed by Chi-squared test. Quantitative variables were presented as mean±standard deviation and qualitative variables were shown as frequency (percentage).

Significance was indicated by P-values<0.05. Participants' general characteristics were analyzed by one-way analysis of variance (ANOVA) and the Chi-squared test across quartiles of dietary scores for quantitative and qualitative variables, which were reported as mean±standard deviation (SD) and frequency (percentage), respectively. A simple linear regression method was utilized to determine the relationship between dietary index quartiles and MetS components. Multivariate linear regression with the backward method was used to adjust for potential confounders. Model I was fully adjusted for age, sex, energy intake, ethnicity, education levels, marital status, current smoking status, physical activity, and BMI. For the second model, the backward method was followed, and the confounding variables with greater P-values were eliminated one by one. Model II was chosen as the one with a greater R-squared value or fewer confounding variables if the R-squared values were equal.

Results

The mean age of the participants was 48.75±8.22 years, and 32.7% of them were male. The mean HEI-2015 score and MDS were 43.41±7.55 and 4.50±1.68, respectively (data not shown). Participants' general characteristics among HEI-2015 quartile were summarized in Table 1. Individuals in the highest HEI-2015 quartile had a higher BMI (p=0.04), a higher frequency of Fars ethnicity (p<0.0001), and more school or university degrees (p=0.002) than individuals in the bottom quartile. Participants' general characteristics among MSD quartile were summarized in Table 2. Participants in the top MDS quartile were younger and were mainly of Fars or Turkish ethnic origin. There were also more subjects with school/diploma or university degrees in the top MDS quartile relative to the bottom MDS quartile (p=0.008).

The association between MetS components and HEI-2015 quartiles was demonstrated in Table 3. After controlling for potential confounders, individuals who were in the highest HEI-2015 quartile had higher FBS levels in model I (β=7.30, 95%CI=1.03, 13.58) and model II (β=7.93, 95%CI=1.75, 14.12). TG levels were also higher in the highest HEI-2015 quartile relative to the lowest quartile in model I (β=32.71, 95%CI=9.09, 56.33), in the crude model (β=29.22, 95%CI=5.71, 52.73), and in another adjusted model (β=31.90, 95%CI=8.38, 55.41). Other

Table 3: The association between HEI-2015 score and MetS components among participants with MetS[£].

Variable	HEI-2015 quartiles			
	Q_1 N=217	Q_2 N=204	Q_3 N=270	Q_4 N=216
	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)
WC (cm)				
Crude	Ref	-0.38 (-2.07,1.30)	0.61 (- 0.96, 2.19)	0.89 (-0.77, 2.56)
Model I	Ref	-0.23 (-1.89, 1.42)	1.05 (-0.51, 2.62)	1.18 (-0.48, 2.84)
Model II[a]	Ref	-0.27 (-1.92, 1.38)	0.93 (-0.62, 2.48)	1.18 (-0.46, 2.82)
DBP (mmHg)				
Crude	Ref	-1.03 (-3.37, 1.30)	-0.39 (-2.58, 1.78)	0.78 (-1.51, 3.08)
Model I	Ref	-0.79 (-3.12, 1.54)	-0.61 (-2.80, 1.60)	0.62 (-1.71, 2.95)
Model II[b]	Ref	-0.82 (-3.15, 1.49)	-0.62 (-2.80, 1.57)	0.53 (-1.79, 2.85)
SBP (mmHg)				
Crude	Ref	-0.61(-4.11, 2.88)	-1.68 (-4.95, 1.58)	1.21 (-2.23, 4.66)
Model I	Ref	0.11 (-3.27, 3.56)	-1.16 (-4.71, 1.70)	1.67 (-1.93, 4.89)
Model II[c]	Ref	0.09 (-3.30, 3.48)	-1.40 (-4.60, 1.78)	1.65 (-1.72, 5.02)
FBS (mg/dL)				
Crude	Ref	3.57 (-2.74, 9.89)	1.17 (-4.73, 7.08)	5.72 (-0.50, 11.94)
Model I	Ref	4.22 (-2.05, 10.50)	2.48 (-3.42, 8.38)	7.30 (1.03, 13.58)
Model II[d]	Ref	4.52 (-1.72, 10.77)	2.89 (-2.94, 8.73)	7.93 (1.75, 14.12)
TG (mg/dL)				
Crude	Ref	8.35 (-15.50, 32.20)	13.10 (-9.19, 35.40)	29.22 (5.71, 52.73)
Model I	Ref	5.48 (-18.15, 29.11)	14.47 (-7.74, 36.68)	32.71 (9.09, 56.33)
Model II[e]	Ref	4.32 (-19.18, 27.83)	13.48 (-8.32, 35.99)	31.90 (8.38, 55.41)
HDL-C (mg/dL)				
Crude	Ref	-1.88 (-4.34, 0.56)	-0.85 (-3.15, 1.43)	0.014 (-2.40, 2.43)
Model I	Ref	-0.71 (-3.04, 1.60)	0.05 (-2.13, 2.23)	1.08 (-1.24, 3.45)
Model II[f]	Ref	-0.83 (-3.14, 1.48)	0.045 (-2.21, 2.12)	1.05 (-1.24, 3.35)

Abbreviations: WC: Waist Circumference, BMI: Body Mass Index, WHR: Waist to Hip Ratio

MetS components showed no significant variations across the HEI-2015 quartiles.

Multivariate linear regression for the correlation of MetS components with MDS quartiles can be seen in Table 4. Ppeople in the top MDS quartiles had reduced SBPs in both crude and adjusted models (model I:β=-3.14, 95%CI=-6.27, -0.019). Unexpectedly, individuals with higher MDS showed higher TG levels in the adjusted models (model I: β=26.008, 95%CI=4.32, 47.69) as well as higher FBS levels in model II (β=5.77, 95%CI=0.057, 11.49). No significant correlations were found for the other components.

Discussion

In this cross-sectional investigation, SBP was inversely associated with the MDS. Increased FBS and TG levels were also linked with higher HEI-2015 and MDS values. Supporting the results of the current syudy, a cross-sectional study showed a reverse correlation between MDS and blood pressure (29). Another cross-sectional study based on Fasa Cohort Study data by Motamedi *et al.* reported a significant negative association between adherence to MDS and risk of hypertension (30). A meta-analysis of six clinical trials with over 7000 participants discovered that over the course of a year, the Mediterranean diet could lower both SBP and DBP (31). An umbrella study assessing the relationship between this diet and multiple health outcomes found no correlation for SBP and DBP in meta-analyses of cross-sectional studies, as opposed to meta-analyses of prospective studies, referring to the inability of cross-sectional studies

Table 4: The association between MDS and MetS components among participants with MetS[£].

Variable	MDS quartiles			
	Quartile 1 N=268	Quartile 2 N=187	Quartile 3 N=184	Quartile 4 N=268
	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)
WC (cm)				
Crude	Ref	1.58 (-0.064, 3.23)	0.80 (-0.85, 2.46)	1.27 (-0.22- 2.77)
Model I	Ref	1.32 (-0.30, 2.94)	0.80 (-0.83, 2.45)	1.24 (-0.28, 2.76)
Model II[a]	Ref	1.27 (-0.33, 2.88)	0.75 (-0.87, 2.38)	1.20 (-0.28, 2.67)
DBP (mmHg)				
Crude	Ref	-2.32 (-4.60, -0.05)	-0.94 (-3.23, 1.34)	-2.03 (-4.09, 0.034)
Model I	Ref	-2.20 (-4.48, 0.05)	-0.65 (-2.94, 1.64)	-2.13 (-4.26, 0.005)
Model II[b]	Ref	-2.18 (-4.44, 0.08)	-0.63 (-2.91, 1.66)	-2.07 (-4.20, 0.048)
SBP (mmHg)				
Crude	Ref	-4.27 (-7.68, -0.86)	-2.52 (-5.94, 0.90)	-3.20 (-6.29, -0.11)
Model I	Ref	-4.00 (-7.32, -0.68)	-1.42 (-4.78, 1.94)	-3.14 (-6.27, -0.019)
Model II[c]	Ref	-4.03 (-7.33, -0.73)	-1.35 (-4.69, 1.98)	-4.69 (-6.07, -0.041)
FBS (mg/dL)				
Crude	Ref	-0.56 (-6.74, 5.62)	1.83 (-4.38, 8.04)	2.82 (-2.78, 8.42)
Model I	Ref	0.33 (-5.79, 6.45)	3.68 (-2.51, 9.87)	5.64 (-0.11, 11.40)
Model II[d]	Ref	0.56 (-5.53, 6.66)	3.90 (-2.26, 10.06)	5.77 (0.057, 11.49)
TG (mg/dL)				
Crude	Ref	-1.67 (-25.00, 21.64)	14.67 (-8.76, 38.10)	20.16 (-0.97, 41.31)
Model I	Ref	2.85 (-20.18, 25.89)	18.69 (-4.62, 42.01)	26.008 (4.32, 47.69)
Model II[e]	Ref	2.64 (-20.27, 25.56)	19.52 (-3.63, 42.67)	26.70 (4.63, 46.77)
HDL-C (mg/dL)				
Crude	Ref	-0.75 (-3.15, 1.65)	-1.17 (-3.59, 1.23)	0.15 (-2.02, 2.32)
Model I	Ref	-1.10 (-3.37, 1.16)	-1.22 (-3.51, 1.07)	-0.034 (-2.16, 2.09)
Model II[f]	Ref	-1.06 (-3.32, 1.20)	-1.23 (-3.52, 1.05)	-0.063 (-2.17, 2.05)

Abbreviations: WC: Waist Circumference, FBS: Fasting Blood Sugar, TG: Triglyceride, HDL-C: High-Density Lipoprotein Cholesterol, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, Q: Quartile, MDS: Mediterranean Dietary Score, MetS: Metabolic Syndrome. Model I: Adjusted for age, sex, energy intake, ethnicity, marital status, education level, current smoking status, physical activity and BMI (except for WC). a: Adjusted for sex, education level, marital status, current smoking status, age and physical activity. b: Adjusted for sex, ethnicity, education level, current smoking status, age, energy intake and BMI. c: Adjusted for sex, ethnicity, marital status, current smoking status and age. d: Adjusted for sex, education level, marital status, age, energy intake, physical activity and BMI. e: Adjusted for sex, ethnicity, education level, current smoking status, age and BMI. f: Adjusted for sex, ethnicity, age, energy intake, physical activity and BMI. £: Analyzed by simple linear regression for crude model and multivariate linear regression was used for adjusted models.

to conclude any causal relationships (32).

The Mediterranean diet emphasizes intake of high fish consumption and a low intake of red and processed meat. A previous research (33) denoted to a linked high red meat intake and high blood pressure, while fish consumption reduced blood pressure because fish contains peptides that inhibit the angiotensin-converting enzyme (34). Increased consumption of fruits and vegetables is also suggested in the Mediterranean diet that are high in magnesium, potassium, and antioxidants such as phytochemicals and polyphenols, all of which contribute to the Mediterranean diet's anti-hypertension effects (30, 31).

Unfortunately, there is relatively little data to support this study's findings for the HEI in terms of FBS and TG levels. A study on 9568 Iranian participants in the Isfahan Healthy Heart Program (IHHP) by Haghighat Doost *et al.* found that those in the highest quintile of HEI had greater mean of FBS, which is consistent with the current study (35). Contrary to findings of the present study, some studies have found a negative relationship between HEI and the aforementioned biochemical markers. FBS level and HEI adherence were inversely correlated in a cross-sectional study on 107 elderly Iranian population (15). Saraf-bank *et al.* (11) discovered that increased adherence to HEI-2010 was inversely connected to TG level in Iranian female nurses aged above 30 years, but no significant relationship was detected for FBS level. After 6.7 years of follow-up, men in the highest HEI-2005 quartile had smaller changes in TG level according to a cohort study based on the Tehran Lipid and Glucose Study, while MDS had no association with changes in lipid profile (36).

Numerous studies have been conducted abroad in this field of research. A cross-sectional survey of 92 Hispanic first-year college students found that diet quality (according to the HEI-2015) was not significantly associated with blood glucose and lipid levels (37). Similar to the results of the present study, in a cross-sectional study on 6874 obese/overweight adults with MetS from the PREDIMED-plus trial, better adherence to an energy-restricted Mediterranean diet was associated with higher FBS level, whereas subjects with higher MDS values had lower TG level (18). A meta-analysis of 10 prospective studies showed a 23% reduction in T2DM risk with an increase in MDS adherence (38). Several previous studies (17, 39, 40) observed an inverse association between higher MDS and lower TG levels, differing from findings of this study. Due to the study's cross-sectional methodology, these findings may imply the presence of reverse causation bias. People with MetS were evaluated in the current study, and that they might have enhanced their adherence to healthy dietary plans to control their abnormal glycemic or lipid profiles. Almost half of the participants were assigned to the higher categories of dietary index scores (third and fourth quartiles). On the other hand, people with chronic diseases were more sensitive regarding their diet than healthy people, which may lead to under-reporting of dietary intake, especially for harmful food groups. Moreover, differences in sample sizes, applied methods to compute dietary scores, dietary intake assessment methods, genetic and ethnic population characteristics, disease patterns, and criteria used to define MetS may contribute to the conflicting results.

Among the strengths of the present study were its use of a local definition of abdominal obesity, the consideration of potential confounding variables in statistical analysis, and the collection of FFQ data through face-to-face interviews. However, some limitations should be noted. First, the study's cross-sectional design makes it impossible to deduce any causal associations. Second, there could have been other confounders that we have not identified. Third, even when employing a validated FFQ to assess dietary intake, recall bias is inescapable due to under or over-estimation of food intake and misclassification.

Conclusion

According to the study results, MDS was linked to lower SBP, while increased FBS and TG levels were associated with higher adherence to the HEI-2015 and MDS in this study; which demonstrates the inability of cross-sectional studies to conclude any causal relationship and the presence of reverse causation bias. To confirm our findings, we recommend studies on individuals with MetS with larger sample sizes and prospective or clinical trial designs.

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Authors' Contribution

RD: Data collection, Dietary scores consumption, Data analyses and interpretation, Writing the orginal draft, Reviewed and approved the manuscript. AA: Conceptualization, Methodology, Data analyses and interpretation, Writing, Review and Editing the manuscript. RH: Conceptualization, Methodology, Data analyses and interpretation, Writing, Review and Editing the manuscript. MZ: Sample size determination, consulting for Data analyses and interpretation, Reviewed and approved the manuscript. MF: Methodology, Investigation, Reviewed and approved the manuscript. NH: Advice on Dietary scores consumption, Investigation, Reviewed and approved the manuscript.

Conflict of Interest

None declared.

References

1 Saklayen MG. The global epidemic of the metabolic syndrome. *Curr Hypertens Rep*. 2018;20:1-8. DOI: 10.1007/s11906-018-0812-z. PMID: 29480368.

2 Zujko ME, Waśkiewicz A, Witkowska AM, et al. Dietary total antioxidant capacity and dietary polyphenol intake and prevalence of metabolic syndrome in polish adults: a nationwide study. *Oxid Med Cell Longev*. 2018;2018:7487816. DOI: 10.1155/2018/7487816, PMID: 29770169.

3 Finicelli M, Squillaro T, Di Cristo F, et al. Metabolic syndrome, Mediterranean diet, and polyphenols: Evidence and perspectives. *J Cell Physiol*. 2019;234:5807-26. DOI: 10.1002/jcp.27506. PMID: 30317573.

4 O'Neill S, O'Driscoll L. Metabolic syndrome: a closer look at the growing epidemic and its associated pathologies. *Obes Rev*. 2015;16:1-12. DOI: 10.1111/obr.12229. PMID: 25407540.

5 Farmanfarma KK, Kaykhaei MA, Adineh HA, et al. Prevalence of metabolic syndrome in Iran: A meta-analysis of 69 studies. *Diabetes Metab Syndr*. 2019;13:792-9. DOI: 10.1016/j.dsx.2018.11.055. PMID: 30641809.

6 Zaribaf F, Falahi E, Barak F, et al. Fish consumption is inversely associated with the metabolic syndrome. *Eur J Clin Nutr*. 2014;68:474-80. DOI: 10.1038/ejcn.2014.5. PMID: 24549028.

7 Esmaillzadeh A, Kimiagar M, Mehrabi Y, et al. Dietary patterns, insulin resistance, and prevalence of the metabolic syndrome in women. *Am J Clin Nutr*. 2007;85:910-8. DOI: 10.1093/ajcn/85.3.910. PMID: 17344515.

8 Rodriguez-Monforte M, Sánchez E, Barrio F, et al. Metabolic syndrome and dietary patterns: a systematic review and meta-analysis of observational studies. *Eur J Nutr*. 2017;56:925-47. DOI: 10.1007/s00394-016-1305-y. PMID: 27605002.

9 Neuhouser ML. The importance of healthy dietary patterns in chronic disease prevention. *Nutr Res*. 2019;70:3-6. DOI: 10.1016/j.nutres.2018.06.002. PMID: 30077352.

10 Kastorini CM, Papadakis G, Milionis HJ, et al. Comparative analysis of a-priori and a-posteriori dietary patterns using state-of-the-art classification algorithms: a case/case-control study. *Artif Intell Med*. 2013;59:175-83. DOI: 10.1016/j.artmed.2013.08.005. PMID: 24080079.

11 Saraf-Bank S, Haghighatdoost F, Esmaillzadeh A, et al. Adherence to Healthy Eating Index-2010 is inversely associated with metabolic syndrome and its features among Iranian adult women. *Eur J Nutr*. 2017;71:425-30. DOI: 10.1038/ejcn.2016.173. PMID: 27677367.

12 Yosaee S, Esteghamati A, Nasab MN, Khosravi A, Alinavaz M, Hosseini B, et al. Diet quality in obese/overweight individuals with/without metabolic syndrome compared to normal weight controls. *Med J Islamic Republic of Iran*. 2016;30:376. PMID: 27493920.

13 De la Iglesia R, Loria-Kohen V, Zulet MA, et al. Dietary strategies implicated in the prevention and treatment of metabolic syndrome. *Int J Mol Sci*. 2016;17:1877. DOI: 10.3390/ijms17111877. PMID: 27834920.

14 Tuttolomondo A, Simonetta I, Daidone M, et al. Metabolic and Vascular Effect of the Mediterranean Diet. *Int J Mol Sci*. 2019;20:4716. DOI: 10.3390/ijms20194716. PMID: 31547615.

15 Rashidipour-Fard N, Karimi M, Saraf-Bank S, et al. Healthy eating index and cardiovascular risk factors among Iranian elderly individuals. *ARYA Atheroscler*. 2017;13:56-65. PMID: 29026411.

16 Daneshzad E, Larijani B, Azadbakht L. Diet quality indices and cardiovascular diseases risk factors among diabetic women. *J Sci Food Agric*. 2019;99:5926-33. DOI: 10.1002/jsfa.9867. PMID: 31206677.

17 Kim Y, Je Y. A modified Mediterranean diet score is inversely associated with metabolic syndrome in Korean adults. *Eur J Clin Nutr* 2018;72:1682-9. DOI: 10.1038/s41430-018-0156-4. PMID: 29563642.

18 Álvarez-Álvarez I, Martínez-González M, Sánchez-Tainta A, et al. Adherence to an Energy-restricted Mediterranean Diet Score and Prevalence of Cardiovascular Risk Factors in the PREDIMED-Plus: A Cross-sectional Study. *Rev Esp Cardiol (Engl Ed)*. 2019;72:925-34. DOI: 10.1016/j.rec.2018.08.010. PMID: 30287240.

19 Onvani S, Haghighatdoost F, Surkan PJ, et

al. Adherence to the Healthy Eating Index and Alternative Healthy Eating Index dietary patterns and mortality from all causes, cardiovascular disease and cancer: a meta-analysis of observational studies. *J Hum Nutr Diet.* 2017;30:216-26. DOI: 10.1111/jhn.12415. PMID: 27620213.

20 Bonaccio M, Di Castelnuovo A, Costanzo S, et al. Mediterranean diet and mortality in the elderly: a prospective cohort study and a meta-analysis. *Br J Nutr*. 2018;120:841-54. DOI: 10.1017/S0007114518002179. PMID: 30157978.

21 Poustchi H, Eghtesad S, Kamangar F, et al. Prospective Epidemiological Research Studies in Iran (the PERSIAN Cohort Study): Rationale, Objectives, and Design. *Am J Epidemiol*. 2018;187:647-55. DOI: 10.1093/aje/kwx314. PMID: 29145581.

22 Farjam M, Bahrami H, Bahramali E, et al. A cohort study protocol to analyze the predisposing factors to common chronic non-communicable diseases in rural areas: Fasa Cohort Study. *BMC Public Health*. 2016;16:1090. DOI: 10.1186/s12889-016-3760-z. PMID: 27756262.

23 Willett WC, Sampson L, Stampfer MJ, et al. Reproducibility and validity of a semiquantitative food frequency questionnaire. Am J Epidemiol. 1985;122:51-65. DOI: 10.1093/oxfordjournals.aje.a114086. PMID: 4014201.

24 Krebs-Smith SM, Pannucci TE, Subar AF, et al. Update of the Healthy Eating Index: HEI-2015. *J Acad Nutr Diet.* 2018;118:1591-602. DOI: 10.1016/j.jand.2018.05.021. PMID: 30146071.

25 Hu FB, Bronner L, Willett WC, et al. Fish and omega-3 fatty acid intake and risk of coronary heart disease in women. *JAMA.* 2002;287:1815-21. DOI: 10.1001/jama.287.14.1815. PMID: 11939867.

26 Trichopoulou A, Kouris-Blazos A, Wahlqvist ML, et al. Diet and overall survival in elderly people. *BMJ.* 1995;311:1457-60. DOI: 10.1136/bmj.311.7018.1457. PMID: 8520331.

27 Alberti K. International Diabetes Federation Task Force on Epidemiology and Prevention; Hational Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; International Association for the Study of Obesity: Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. *Circulation*. 2009;120:1640-5. DOI: 10.1161/CIRCULATIONAHA.109.192644, PMID: 19805654

28 Azizi F, Hadaegh F, Khalili D, et al. Appropriate definition of metabolic syndrome among Iranian adults: report of the Iranian National Committee of Obesity. *Arch Iran Med*. 2010;13:426-8. PMID: 20804311.

29 La Verde M, Mule S, Zappala G, et al. Higher adherence to the Mediterranean diet is inversely associated with having hypertension: is low salt intake a mediating factor? *Int J Food Sci Nutr*. 2018;69:235-44. DOI: 10.1080/09637486.2017.1350941. PMID: 28705075.

30 Motamedi A, Ekramzadeh M, Bahramali E, et al. Diet quality in relation to the risk of hypertension among Iranian adults: cross-sectional analysis of Fasa PERSIAN cohort study. *Nutr J.* 2021;20:57. DOI: 10.1186/s12937-021-00717-1. PMID: 34174902.

31 Nissensohn M, Román-Viñas B, Sánchez-Villegas A, et al. The Effect of the Mediterranean Diet on Hypertension: A Systematic Review and Meta-Analysis. *J Nutr Educ Behav.* 2016;48:42-53.e1. DOI: 10.1016/j.jneb.2015.08.023. PMID: 26483006.

32 Dinu M, Pagliai G, Casini A, et al. Mediterranean diet and multiple health outcomes: an umbrella review of meta-analyses of observational studies and randomised trials. *Eur J Clin Nutr*. 2018;72:30-43. DOI: 10.1038/ejcn.2017.58. PMID: 28488692.

33 Zhang Y, Zhang DZ. Red meat, poultry, and egg consumption with the risk of hypertension: a meta-analysis of prospective cohort studies. *J Hum Hypertens*. 2018;32:507-17. DOI: 10.1038/s41371-018-0068-8. PMID: 29725070.

34 Lordan S, Ross RP, Stanton C. Marine bioactives as functional food ingredients: potential to reduce the incidence of chronic diseases. *Mar Drugs.* 2011;9:1056-100. DOI: 10.3390/md9061056. PMID: 21747748.

35 Haghighatdoost F, Sarrafzadegan N, Mohammadifard N, et al. Healthy eating index and cardiovascular risk factors among Iranians. *J Am Coll Nutr.* 2013;32:111-21. DOI: 10.1080/07315724.2013.767590. PMID: 24015718.

36 Asghari G, Mirmiran P, Hosseni-Esfahani F, et al. Dietary quality among Tehranian adults in relation to lipid profile: findings from the Tehran Lipid and Glucose Study. *J Health Popul Nutr.* 2013;31:37-48. DOI: 10.3329/jhpn.v31i1.14747. PMID: 23617203.

37 Landry MJ, Asigbee FM, Vandyousefi S, et al. Diet Quality Is an Indicator of Disease Risk

Factors in Hispanic College Freshmen. *J Acad Nutr Diet*. 2019;119:760-8. DOI: 10.1016/j.jand.2018.12.002. PMID: 30799284.

38 Koloverou E, Esposito K, Giugliano D, Panagiotakos D. The effect of Mediterranean diet on the development of type 2 diabetes mellitus: a meta-analysis of 10 prospective studies and 136,846 participants. *Metabolism*. 2014;63:903-11. DOI: 10.1016/j.metabol.2014.04.010. PMID: 24931280.

39 Bihuniak JD, Ramos A, Huedo-Medina T, et al. Adherence to a Mediterranean-Style Diet and Its Influence on Cardiovascular Risk Factors in Postmenopausal Women. *J Acad Nutr Diet*. 2016;116:1767-75. DOI: 10.1016/j.jand.2016.06.377. PMID: 27568885.

40 Grosso G, Stepaniak U, Micek A, et al. A Mediterranean-type diet is associated with better metabolic profile in urban Polish adults: Results from the HAPIEE study. *Metabolism*. 2015;64:738-46. DOI: 10.1016/j.metabol.2015.02.007. PMID: 25752843.