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Comparison of diet quality indices for predicting metabolic syndrome in Iran: cross-sectional findings from the persian cohort study

Kimia Haji Ali Pashaei[1], Zahra Namkhah[1] and Seyyed Reza Sobhani[1*]

Abstract

Background The metabolic syndrome (MetS) comprises metabolic irregularities, including hypertension and central obesity, which are influenced by genetic, metabolic, environmental, and dietary factors. As diet and lifestyle are risk factors for MetS, it is important to know which diet quality index better predicts MetS. The aim of this study is to compare the ability of different diet quality indices in predicting MetS and to identify the most effective one.

Methods This cross-sectional study involved 5,206 participants aged 35 to 70 engaged in the Prospective Epidemiological Research Study in Iran (PERSIAN) cohort. Assessment of one year's food intake via a validated 134-item semi-quantitative food frequency questionnaire (FFQ) facilitated the calculation of adherence to five diet quality indices: Dietary Approaches to Stop Hypertension (DASH), Mediterranean, Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND), Dietary Inflammatory Index (DII), and Diet Quality Indices (DQI). While bivariate Pearson correlation and binary logistic regression aided in identifying the strongest correlation and predictor for MetS among the indices.

Results This study showed a significant association between adhering to the DASH diet score, Mediterranean diet score, MIND diet score, DII score, and DQI score, and the odds of developing MetS (OR: 0.94, (95% CI: 0.93–0.95), OR: 0.85, (95% CI: 0.81–0.89), OR: 0.84, (95% CI: 0.80–0.89), OR: 1.22, (95%CI: 1.11–1.34), OR: 0.95, (95%CI 0.94–0.96) respectively). Therefore, with each unit increase in DASH diet score, Mediterranean diet score, MIND diet score, DII score, and DQI score, the odds of MetS was reduced by 5.4%, 14.5%, 15.6%, 22%, 5%, respectively. All the indices were correlated with the intake of most of the micronutrients, with the strongest correlations being observed in the DII. DASH diet score aligned with the most favourable MetS biomarker risk, while DII score primarily associated with MetS and could be considered as a predictor for MetS.

Conclusion The present study's findings reveal that between all these five diet quality indices, the DASH diet score correlates strongly with a favourable biomarker risk profile, while the DII score is predominantly linked to MetS.

Keywords Metabolic syndrome, DASH diet, Mediterranean diet, Healthy diet

*Correspondence:
Seyyed Reza Sobhani
Seyyedrezasobhani@gmail.com
[1]Department of Nutrition, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran

Introduction

The metabolic syndrome (MetS) is a common metabolic disorder that representing a spectrum of metabolic abnormalities including hypertension, central obesity, and insulin resistance [1]. Several factors, including genetics, metabolism and environment, and diet, can influence MetS risk [2, 3]. The global prevalence of MetS is 12.5 to 31.4 [4–7]. However, in people with type 2 diabetes, the percentage can reach almost 80% [8]. In Iran, the prevalence rate of MetS based on the National Cholesterol Education Program Adult Treatment Panel criteria (NCEP ATP III) was 38.3% [9].

MetS is strongly associated with an almost 2-fold and a 5-fold increased risk of cardiovascular disease and new-onset type 2 diabetes mellitus [10–12] and also other comorbidities including the prothrombotic, proinflammatory, non-alcoholic steatosis, polycystic ovary syndrome (PCOS), obstructive sleep apnea, lipodystrophy, reproductive disfunction, and all-cause mortality multiply [11]. In a study by Gami et al. [13] it was shown that after adjusting for conventional cardiovascular risk factors, there was a significant association between the MetS and cardiovascular events.

Therapeutic options for managing the MetS range from expensive and invasive methods (surgery and drug therapy), to cheap and publicly available methods (lifestyle modification). Lifestyle recommendations are the primary way to control the earliest levels of MetS. These recommendations include smoking cessation, physical activity, weight loss, limiting saturated and trans fats, reducing sugar and salt intake, and eating a healthy diet [11]. Among dietary factors, high intakes of fruits, vegetables, legumes and nuts and also low intakes of high-fat dairy products, red meat, and processed meat reduce the risk of MetS and its components [3].

The Diet Quality Indices (DQIs) provides an overall picture of a person's dietary intake by assessing food and/or nutrient intake and lifestyle factors based on how well they align with dietary guidelines [14]. Indices reflecting overall diet quality are used in research worldwide to predict the risk for metabolic disorders such as MetS. These indices are created to measure adherence to dietary guidelines or to optimally evaluate diet–illness association [15]. Below are some of the dietary quality indices that have these qualities presented.

The first score is the DASH (Dietary Approaches to Stop Hypertension) diet which was designed to reduce the incidence of hypertension [16, 17]. The second score represents dietary aspects of Mediterranean lifestyle consisting of plant-based dishes [18]. Another score is Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) diet, initially designed for brain health [19]. The fourth score is the Dietary Inflammatory Index (DII) which is a nutritional index designed to measure the potential effect of a diet on inflammatory status of people [20]. At last but not the least, the Diet Quality Indices (DQIs) are tools to assess the quality of dietary intake, and lifestyle factors, depending on how close they are to dietary guidelines [14]. The DQI was devised with the objective of incorporating the various elements of a diet that contribute to its overall quality. These include diversity, adequacy, moderation and balance [21].

Although all the diet quality indices assess the quality of dietary intake but they differ not only in the items that represents healthy and unhealthy diet, but also in the way they are calculated; for instance, the DASH diet emphasizes on high potassium low sodium foods which lowers BP [22], the Mediterranean diet focuses on beneficial effects of olive oil like its anti-inflammatory effect [23], brain healthy foods are in MIND diet, micronutrients are much more focused on in DII score [24] and the DQI fully concentrated on the overall quality of diet, therefore all of these diet quality indices measure a MetS related diet.

The present study attempts to distinguish the effectiveness of various diet quality indices for consideration of MetS, and to determine the most effective diet quality index. Although there are studies that investigated the association between each of these indices and MetS, according to our knowledge, this is the first study to compare these dietary indices to predict MetS.

Methods

Subjects and study design

The present cross-sectional study was derived from Prospective Epidemiological Research Study in Iran (PERSIAN) cohort study involving 5,206 Mashhad University of Medical Sciences (MUMS) employees [25, 26].

The inclusion criteria of the study were possessing Iranian nationality, being residents of Mashhad, aging between 35 and 70 years old, being employed by Mashhad University of Medical Sciences, and participating in the Persian cohort. Individuals who were pregnant and those with physical or mental disabilities that prevented them from participating fully in the study were excluded the research. All participants provided written informed consent before participating in this study. Further information on PERSIAN cohort methods and strategies can be found in a study by Poustchi. et al. [27]. Information on age, sex, education, smoking (including those who have smoked at least 100 cigarettes during lifetime), marital status, BMI, waist circumference, Wealth Score Index (WSI), physical activity (MET-h/week), muscle mass, fat mass were collected for each individual in this study by self-reported questionnaire [28].

In the present study, MetS was defined by the guidelines of the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III). MetS is diagnosed when three or more of the following criteria are met: obesity, high blood sugar, low fasting high-density lipoprotein (HDL), high fasting triglyceride (TG), and high blood pressure [29]. Therefore, according to this definition, 895 of the total 5206 participants of the study had MetS.

Study measures

Dietary intakes

Each participant's food and nutrient intake was assessed using food-frequency questionnaire (FFQ). People's food intake over the past year was assessed using a validated 134-item semi-quantitative food frequency questionnaire [30]. FFQ classifies food items into groups of bread and cereals, legumes, meat and meat products, milk and dairy products, vegetables, fruits, sugars, oil and oilseeds, spices and miscellaneous. This questionnaire has been completed by trained nutritionists in the Persian cohort based on face-to-face interviews. The frequency of consumption of each food over the past year by day, week, month, and year were rated based on participants' self-report. Then, the measured food portions were converted to grams by using the Iranian Food Composition Tables and the United States Department of Agriculture (USDA) [31, 32]. Nutritionist IV software (version 7.0) was used to determine the nutrient contents and energy of foods [30].

Dietary quality indices

FFQ-based dietary intakes were used to calculate adherence to the five diet quality indices.

DASH score

Numerous approaches exist for computing the DASH diet score [33]. Evaluating a person's compliance with the DASH diet could be achieved by basing the DASH diet score on eight dietary elements, such as fruits, vegetables, nuts and legumes, dairy products, whole grains, sugar-sweetened beverages and sweets, sodium, and red and processed meats. Initially, energy-adjusted consumptions of these foods and nutrients were computed by using residual method [34]. Afterwards, people were classified into deciles based on their energy-adjusted consumption of various foods. Those in the top decile of fruits, vegetables, dairy products, legumes, and nuts were given the score of 10, while those in the lowest decile were given the score of 1. Conversely, for red and processed meat, sugar-sweetened beverages, sweets, and sodium, the highest decile received a score of 1 and the lowest, a score of 10. The participant's DASH diet score was then determined by totalling the scores for all foods and nutrients. Consequently, the smallest and greatest scores for the DASH diet for an individual was between 8 and 80 [3].

Mediterranean dietary score (MDS)

To evaluate adherence to the traditional Mediterranean diet, the modified version of the Mediterranean Diet Score (MDS), as developed by Trichopoulou et al. [35], was chosen as the region-specific diet quality index. It is characterized by nine food and nutritional components: high consumption of vegetables, fruits, nuts, legumes, grains, and fish, as well as high ratio of monounsaturated fat: saturated fat; low intake of meat and dairy products; moderate alcohol consumption. For Healthy components (vegetables, legumes, fruits and nuts, grains, and fish), intake above-average was assigned a value of 1; otherwise, the value 0 was assigned. For components deemed unhealthy (meat, poultry, and dairy products), equal to or above the average consumption was assigned a value of 0; otherwise, the value 1 was assigned. Overall MDS was between 0 and 8 (representing minimum to maximum adherence to this index) [36]. Alcohol intake is unusual or is perhaps less commonly reported in the Iranian population because of religious reasons, therefore the alcohol component was excluded from calculations [37].

MIND diet (Mediterranean-DASH Diet intervention for neurodegenerative Delay)

The MIND diet, which is based on the Mediterranean and DASH diets, emphasizes on consumption of natural, plant foods and limits foods with animal origin and high in saturated fat. However, while the MIND diet specifically mentions intake of berries and green leafy vegetables, and does not specify high fruit consumption (as seen both DASH and Mediterranean), high dairy intake (DASH), high potato or higher than one fish meal per week (Mediterranean). The MIND revisions focus on the foods and nutrients that have been scientifically linked to dementia prevention [38–40]. The MIND diet comprises of 9 food groups that are healthy for brain (green leafy vegetables, other vegetables, nuts, berries, beans, whole grains, seafood, poultry, olive oil, wine) and 5 unhealthy food groups (red meats, butter and stick margarine, cheese, pastries and sweets, and fried/fast food). In this research, the modified MIND diet scoring was applied to align with Iranian dietary habits [41]. Alcohol consumption is not included as consumption is prohibited. Therefore, another 14 food groups were used in the MIND scoring. Olive oil consumption was scored as 1 if the participants identified it as the most commonly used oil at their homes, and as 0 otherwise [42]. For all components of this dietary score, the frequency of consumption of each food item portion was summed associated with that component and then assigned a concordance score of 0, 0.5, or 1. The total MIND diet score was calculated by summing over all 14 of the component scores [43].

Dietary inflammatory index (DII)

The DII is a new non-recommendation-based index selected for comparison purposes, focusing on the pro-inflammatory aspects of the diet. The effects of 45 food parameters on 6 inflammatory biomarkers (IL-1β, IL-4, IL-6, IL-10, TNF-α and C-reactive protein) are calculated. The scores were based on whether the dietary parameter increased [1], decreased (-1) or had no effect (0) on each of the six inflammatory biomarkers [18] Unlike the other nutritional quality indices, higher DII score demonstrate a pro-inflammatory unhealthy nutritional status, while lower score demonstrates an anti-inflammatory healthy dietary condition. The DII score was calculated based on 30 groups of food including energy, fat, trans fat, cholesterol, caffeine, carbohydrate, protein, saturated fat, vitamin B12, iron, MUFA, PUFA, n-3 Fatty acids, n-6 Fatty acids, vitamin D, vitamin B6, fiber, vitamin B9, vitamin C, niacin, thiamin, riboflavin, vitamin A, magnesium, vitamin E, β-carotene, onion, garlic, green/black tea, selenium, and zinc. Consumption of groups such as alcohol, eugenol, turmeric, saffron, ginger, pepper, rosemary, thyme/oregano, isoflavones, anthocyanidins, flavonones, flavonols, flavones, and flavan-3-ol were not available for to calculate this index. First, the participants' energy intake of the participants was adjusted based on a 1000 kcal basis. Therefore, to calculate the DII, we subtracted the nutritional parameters from the global mean and divided it by the "global standard deviation" to obtain a Z score. The Z-score values were converted to percentiles. The percentile values were then multiplied by 2 minus 1. Lastly, the scores obtained for each of the parameters were multiplied by the overall inflammatory score; then, we added up all food items to calculate the total DII score [44].

Diet quality index (DQI)

The original DQI had 4 aspects representing variety, adequacy, moderation, and balance [21]. The main article discussing DQI from Kim et al. [21] has explained the calculation of this index thoroughly but here is a brief explanation of calculating DQI. Variety includes 2 elements assessing variety in food group and protein source (score between from 0 to 20). Food group variety encompasses meat, poultry, fish, eggs, dairy products, legumes, grains, fruits and vegetables. Protein source variety comprises meat, poultry, fish, dairy products, legumes and eggs.

Adequacy includes vegetables, fruits, grains, fiber, protein, iron, calcium, and vitamin C (score ranging from 0 to 40). The requirement for adequate protein intake is fulfilled when the percentage of total energy intake derived from protein is >10%. Moderation incorporates total fat, Saturated fatty acid (SFA), cholesterol, sodium, empty calorie foods (score ranging from 0 to 30). One of the unique components of the DQI is the "empty calorie foods" like sugar, alcohol and oils. Balance refers to the score ranging from 0 to 10 that represents the ratio of macronutrient ratio and fatty acid ratio. The cut off points used in this study were obtained from the DQI from Kim et al. [21] and have been utilized in previous studies conducted in Iran [45]. Total DQI score, could be ranged from 0 to 100 (0 is the minimum and 100 is the maximum score) [21].

Data analysis

For descriptive objectives, all the diet quality indices included in this study were separated into quartiles (Q). The Kolmogorov-Smirnov test was employed to evaluate the normality of the data. To compare the participants' demographic, socioeconomic, and lifestyle characteristics, the data on the first and fourth quartiles of each index were presented. Except for the DII, which exhibited a reverse pattern (i.e., ranging from a more anti-inflammatory profile to a more pro-inflammatory profile), Q1 and Q4 represented the minimum and maximum adherence to each nutritional score respectively. The number and percentage of participants are reported for categorical variables and means and standard errors are reported for continuous distributed variables. One-way ANOVA test and Chi-square test were employed to compare quantitative variables across groups, and compare frequency distribution of qualitative variables for Table 1 respectively.

To assess the correlation between the dietary quality indices and various micronutrients and vitamins, we utilized the bivariate Pearson's correlation method. According to the research conducted by Alkerwi et al. [36], the higher the absolute value of the Pearson's correlation coefficient (r), the stronger the correlation becomes. Therefore, the diet quality index could be considered a better index to assess the correlation between food intake and MetS. Binary logistic regression is a method used to predict the values of outcome therefore, we utilized it to predict MetS [46].

This research utilized binary logistic regression in both crude and adjusted models. The initial model involved controlling for age and sex. The second model included additional adjustment for physical activity. Furthermore, energy, WSI and smoking cigarettes were additionally controlled in the final model. Variables with p-values less than 0.05 were deemed significant, also odds ratio (OR) can help in understanding whether that variable increased or decreased the risk of MetS. The statistical analysis was conducted by utilizing SPSS version 16 (SPSS Inc., Chicago, IL, USA).

Table 1 Demographic characteristics of the participants across quartiles (Q) of five different diet quality indices

Participant characteristics		DASH Diet score ($n=5206$)			MDS ($n=5206$)			MIND score ($n=5206$)			DII score ($n=5206$)			DQI score ($n=5206$)		
		Q1	Q4	$p^{£}$	Q1	Q4	$p^{£}$	Q1	Q4	$p^{£}$	Q1	Q4	$p^{£}$	Q1	Q4	$p^{£}$
Age (years)		42.89 ± 7.14	47.68 ± 9.75	**< 0.001**	44.76± 8.48	45.98 ± 9.02	**< 0.001**	43.16 ± 7.37	47.58 ± 9.57	**< 0.001**	45.50 ± 8.78	44.84 ± 8.78	0.13	43.69 ± 7.96	46.78 ± 9.36	**< 0.001**
Sex	Male (%)	600 (50.8%)	656 (39.4%)	**< 0.00**	701 (45.9%)	853 (43.7%)	0.45	515 (46.9%)	753 (41.4%)	**< 0.001**	844 (47.8%)	605 (42.8%)	**< 0.001**	576 (46.5%)	778 (45.7%)	0.08
Education	Diploma and under Diploma	188 (15.9%)	416 (25.0%)	**< 0.001**	357 (23.4%)	337 (17.3%)	**< 0.001**	182 (16.6%)	394 (21.7%)	**0.02**	321 (18.2%)	340 (24.1%)	**< 0.001**	268 (21.6%)	358 (21.0%)	**0.02**
	Bachelor and associated	627 (53.0%)	853 (51.2%)		808 (52.9%)	1030 (52.8%)		615 (56.1%)	925 (50.9%)		937 (53.0%)	727 (51.5%)		654 (52.8%)	869 (51.1%)	
	MSc and PhD	367 (31.0%)	397 (23.8%)		363 (23.8%)	583 (29.9%)		300 (27.3%)	498 (27.4%)		509 (28.8%)	346 (24.5%)		317 (25.6%)	475 (27.9%)	
Non smokers		1113 (94.2%)	1606 (96.4%)	**0.02**	1458 (95.4%)	1851 (94.9%)	0.29	1042 (95.0%)	1736 (95.5%)	0.57	1657 (93.8%)	1376 (97.4%)	**< 0.001**	1170 (94.4%)	1636 (96.1%)	0.12
Marital Status	Single	95 (8.0%)	132 (7.9%)	0.42	123 (8.0%)	167 (8.6%)	0.96	89 (8.1%)	159)8.8%(	0.11	133 (7.5%)	135 (9.6%)	0.14	102 (8.2%)	141 (8.3%)	0.82
	Married	1034 (78.5%)	1428 (85.7%)		1319 (86.3%)	1671 (85.7%)		935 (85.2%)	1543 (84.9%)		1543 (87.3%)	1185 (83.9%)		1069 (86.3%)	1454 (85.4%)	
	Divorced	53 (4.5%)	106 (6.4%)		86 (5.6%)	112 (5.7%)		73 (6.7%)	115 (6.3%)		91 (5.1%)	93 (6.6%)		68 (5.5%)	107 (6.3%)	
BMI (Kg/M^2)		26.74 ± 4.02	27.32 ± 4.12	**< 0.001**	26.61 ± 3.96	27.10 ± 4.11	**< 0.001**	26.53 ± 3.92	27.32 ± 4.24	**< 0.001**	27.51 ± 4.19	26.28 ± 3.98	**< 0.001**	27.27 ± 4.09	26.70 ± 3.96	**< 0.001**
Waist Circumference (Cm)		96.98 ± 9.61	97.28 ± 9.98	**0.02**	96.29 ± 9.90	96.98 ± 9.86	0.10	96.07 ± 9.95	97.28 ± 10.26	**< 0.001**	97.83 ± 9.98	95.47 ± 10.24	**< 0.001**	97.54 ± 9.87	96.23 ± 9.70	**< 0.001**
WSI		0.11 ± 0.95	- 0.054 ± 1.02	**< 0.001**	-0.12 ± 0.99	0.10 ± 0.98	**< 0.001**	-0.05 ± 0.97	0.07 ± 1.01	**< 0.001**	0.14 ± 1.00	-0.19 ± 1.00	**< 0.001**	-0.09 ± 1.02	-0.05 ± 1.01	**< 0.001**
Physical activity (MET-h/week)		38.00 ± 5.93	38.70 ± 5.21	**0.00**	38.47 ± 5.92	38.57 ± 5.40	0.62	38.33 ± 5.66	38.61 ± 5.55	0.45	38.83 ± 5.34	38.71 ± 5.45	**0.01**	38.58 ± 5.73	38.64 ± 5.58	0.96
Muscle mass (%)		49.50 ± 10.68	46.97 ± 9.58	**< 0.001**	47.53 ± 9.92	47.99 ± 10.03	0.16	48.49 ± 10.41	47.49 ± 10.00	0.11	49.49 ± 10.32	46.55 ± 9.73	**< 0.001**	48.78 ± 9.87	47.55 ± 9.69	**0.03**
Fat mass (%)		24.95 ± 7.42	25.32 ± 7.84	**< 0.001**	24.40 ± 7.40	25.09 ± 7.80	0.19	24.37 ± 7.54	25.53 ± 7.83	**< 0.001**	25.55 ± 7.80	24.07 ± 7.29	**< 0.001**	25.34 ± 7.66	24.07 ± 7.62	**< 0.001**

BMI, Body Mass Index; DASH, Dietary Approaches to Stop Hypertension; DII, Dietary Inflammatory Index; DQI, Diet Quality Index; MDS, Mediterranean Diet Score; MIND, Mediterranean-DASH Intervention for Neurodegenerative Delay; WSI, Wealth Score Index. Data presented as mean ± SD or frequency (%). One-way ANOVA test was used to compare quantitative variables between groups like age, BMI, Waist circumference, WSI, physical activity, muscle mass, fat mass, and Chi-square test was used to compare frequency distribution of qualitative variables like sex, education category, nonsmokers, and marital status

£ : P value lower than 0.05 is considered to be significant

Results

Characteristics of participants according to diet quality indices

Table 1 presented an overview of the attributes of the participants, categorized into quartiles based on each diet quality index. There was a notable distinction across age, education level, BMI, WSI among different quartiles of all five diet scores. A meaningful difference was seen across sex and waist circumference across quartiles of all dietary scores, except for the MDS. Smoking demonstrated a significant difference across quartiles of DASH diet and DII score. The quartiles of the DASH and DII scores revealed a considerable dissimilarity in terms of physical activity and muscle mass. Also, there was a noteworthy difference between muscle mass and quartiles of the DQI score. The difference of fat mass was noticeable across quartiles of the DASH, MIND, DII and DQI scores.

Correlations between diet quality indices and food groups

Table 2 displays the associations between the five diet quality indices and their correlation with food groups. All of the indices were significantly correlated with each other (r ranged between −0.378 and 0.644 and all $P=0.01$). As anticipated, the DII had negative correlations with the other four indices due to its inverse scoring method. Additionally, all the indices showed strong correlations with the consumption of food groups except that the intake of poultry and dairy were not significantly correlated with adherence to the DASH diet score and DQI score at the 0.05 level (-0.005, 0.020) respectively. DII score showed the maximum correlation with food groups like vegetables, fruits, nuts, legumes, meat, fish, poultry and fiber which makes DII a great score for evaluating dietary intake. As the Pearson's correlation coefficient (r) for DII score was highly significant (fiber= -0.78, vegetable=0.62, fruits=0.49) the correlations were much more remarkable. DASH diet score had the strongest correlation with dairy and sugar-sweetened beverages and sweets group. MIND diet score was highly correlated with olive oil. For most of the food groups, DQI showed the lowest correlation except for fruits and sugar-sweetened beverages.

Correlations between diet quality indices and calorie, essential macronutrients and micronutrients

Table 3 presents the associations between the micronutrients and the five diet quality indices. Individuals who had higher scores on the diet quality indices reported consuming lower amounts of total energy, except for those following the Mediterranean dietary pattern. As the scores increased, the percentage of daily fat derived energy intake decreased, while the carbohydrates derived energy increased (except for the DII). All the indices showed notable correlations with the intake of the three types of fatty acids and most of the vitamins and

Table 2 Pearson's correlation coefficients (r) across the diet quality indices and food groups

		DASH Diet score	MDS	MIND score	DII score	DQI score
DASH Diet score		1	0.43**	0.64**	-0.40**	0.54**
Mediterranean Diet score		0.43**	1	0.52**	-0.52**	0.38**
MIND score		0.64**	0.52**	1	-0.50**	0.46*
DII score		-0.40**	-0.52**	-0.50**	1	-0.37**
DQI score	Variety	0.04**	0.02	0.13**	-0.47**	0.21**
	Adequacy	0.44**	0.47**	0.40**	-0.71**	0.65**
	Moderation	0.28**	0.05**	0.16**	0.33**	0.54**
	Balance	0.03**	0.16**	0.06**	-0.02*	0.25**
	Total	0.54**	0.38**	0.46**	-0.37**	1
Vegetables		0.47**	0.35**	0.46**	-0.62**	0.25**
Fruits		0.44**	0.36**	0.29**	-0.49**	0.39**
Nuts		0.17**	0.36**	0.24**	-0.38**	0.10**
Legumes		0.28**	0.28**	0.26**	-0.32**	0.18**
Dairy		0.30**	-0.12**	0.15**	-0.28**	0.02
Poultry		-0.01	-0.03**	0.19**	-0.27**	0.03*
Fish		0.07**	0.26**	0.25**	-0.31**	0.06**
Meat		-0.21**	0.01	0.03*	-0.35**	-0.01**
Sugar-sweetened beverages and sweets		-0.32**	0.06**	-0.13**	-0.23**	-0.15**
Fiber		0.52**	0.55**	0.48**	-0.78**	0.52**
Olive oil		0.13**	0.20**	0.22**	-0.18**	0.07**

DASH, Dietary Approaches to Stop Hypertension; DII, Dietary Inflammatory Index; DQI, Diet Quality Index; MDS, Mediterranean Diet Score; MIND, Mediterranean-DASH Intervention for Neurodegenerative Delay

*. Correlation is significant at the 0.05 level (2-tailed)

**. Correlation is significant at the 0.01 level (2-tailed)

Table 3 Pearson's correlation coefficients (r) across the diet quality indices and essential macronutrients and micronutrients

	DASH Diet score	MDS	MIND score	DII score	DQI score
Energy (Kcal/day)	0.14**	0.31**	0.16**	-0.69**	0.26**
Carbohydrates (%E)	0.25**	0.19**	0.15**	-0.00	0.50**
Protein (%E)	0.05**	-0.08**	0.25**	-0.15**	0.04**
Fats (%E)	-0.19**	-0.11**	-0.19**	-0.01	-0.50**
SFA	-0.01	0.01	-0.07**	-0.43**	-0.19**
MUFA	-0.05**	0.22**	0.02*	-0.52**	-0.11**
PUFA	0.06**	0.37**	0.14**	-0.55**	0.06**
Retinol	-0.02*	0.01	-0.03**	-0.36**	-0.13**
Vitamin B1	0.25**	0.36**	0.29**	-0.64**	0.41**
Vitamin B2	0.21**	0.24**	0.25**	-0.73**	0.22**
Vitamin B3	0.08**	0.30**	0.25**	-0.64**	0.31**
Vitamin B5	0.32**	0.31**	0.34**	-0.77**	0.34**
Vitamin B6	0.19**	0.16**	0.18**	-0.40**	0.12**
Vitamin B9	0.34**	0.42**	0.38**	-0.76**	0.38**
Vitamin B12	0.05**	0.14**	0.12**	-0.49**	0.04**
Vitamin C	0.36**	0.34**	0.32**	-0.59**	0.31**
Vitamin D	0.03**	0.21**	0.19**	-0.51**	-0.03**
Vitamin E	0.18**	0.40**	0.23**	-0.62**	0.12**
Ca	0.36**	0.14**	0.28**	-0.59**	0.24**
Selenium	0.03**	0.23**	0.15**	-0.57**	0.21**
Iron	0.26**	0.41**	0.34**	-0.71**	0.39**
Mg	0.38**	0.44**	0.40**	-0.82**	0.39**
Na	-0.10**	0.15**	0.03**	-0.37**	-0.01
K	0.44**	0.41**	0.42**	-0.84**	0.37**
P	0.29**	0.30**	0.33**	-0.76**	0.29**
Zn	0.10**	0.25**	0.20**	-0.70**	0.20**

Ca, Calcium; DASH, Dietary Approaches to Stop Hypertension; DII, Dietary Inflammatory Index; DQI, Diet Quality Index; K, Potassium; MDS, Mediterranean Diet Score; Mg, Magnesium; MIND, Mediterranean-DASH Intervention for Neurodegenerative Delay; MUFA, Mono Unsaturated Fatty Acid; Na, Sodium; P, Phosphorous; PUFA, Poly Unsaturated Fatty Acid; SFA, Saturated Fatty Acid; Zn, Zinc

**. Correlation is significant at the 0.01 level (2-tailed)

minerals. The strongest correlations were discovered between nutrient consumption and the DII. Same as Table 2, DII had the strongest correlation with most of the items and the absolute numbers were significant (K= -0.84, Mg= -0.82, Vitamin B5= -0.77) except for carbohydrate and fat which were correlated with DQI score and protein which was correlated with MIND score. Therefore, DII seems to be able to demonstrate intake of calorie, essential macronutrients and micronutrients much better.

Associations between diet quality indices and risk biomarkers of metabolic syndrome

Table 4 provided a summary of the connections between the chosen diet quality indices and the biomarkers linked to risk of MetS. Despite considering possible factors that could affect the results, all the diet quality indices showed a significant association with MetS. Furthermore, the connection between the DASH diet score and MetS remained significant even after accounting for other variables. In fact, each increment in the DASH score resulted in a 5.4% decrease in the risk of MetS in the thoroughly modified model (OR=0.946, CI 95%=0.935–0.956, $P<0.001$). Similarly, the link between the Mediterranean diet score and MetS was found to be significant, suggesting that a one-unit increase in the score led to a 14.5% reduction in the risk of metabolic syndrome in model 3 (OR=0.855, CI 95%=0.813–0.899, $P<0.001$). The MIND score also demonstrated a significant association with metabolic syndrome, with each unit increase in the score resulting in a 15.6% decrease in the risk of MetS in the third model (OR=0.848, CI 95%=0.808–0.890, $P<0.001$). The DII score exhibited a significant association with metabolic syndrome, indicating that as the score increased by one, the risk of MetS incremented by 22% in model 3 (OR=1.222, CI 95%=1.111–1.345, $P=0.001$). Lastly, the DQI score was also significantly associated with metabolic syndrome, with one-unit increase in the score potentially lowering the risk of MetS by 5% in model 3 (OR=0.955, 0.945–0.966, $P<0.001$).

Metabolic markers

The DASH score was associated with TG, HDL (OR=0.980, CI 95%=0.972–0.988, $P<0.001$; OR=0.980, CI 95%=0.971–0.989, $P<0.001$ respectively), and Mediterranean diet displayed a significant relationship with glucose level (OR=0.921, CI 95%=0.888–0.955, $P<0.001$), indicating that higher compliance to this dietary pattern was linked with a decreased likelihood of elevated glucose levels. Waist circumference was found to be significantly related with DII score, indicating that increased DII scores were associated with larger waist circumferences (OR=0.948, CI 95%=0.907–0.992, P value=0.020). Moreover, the Mediterranean diet, MIND, and DQI score demonstrated significant associations with HDL levels, implying that individuals with higher scores in these dietary patterns were less likely to have low HDL levels (OR=0.951 (CI 95%=0.912–0.992) P value=0.020, OR=0.954 (CI 95%= 0.916–0.994) P value=0.025 and OR=0.985 (CI 95%= 0.976–0.994) P value=0.02 respectively). Both the DASH diet and MIND diet score demonstrated an association with systolic blood pressure (SBP), although the association between the DASH diet and SBP was only marginally significant, the MIND diet had a significant association with SBP (OR=1.012 (CI 95%=1.000- 1.025) P value=0.048, and OR=1.097 (CI 95%=1.037–1.159) P value=0.001 respectively). Further association was not observed with diet scores.

Table 4 Binary logistic regression of the associations between diet quality indices and risk markers

		DASH Diet score (n = 5206)		MDS(n = 5206)		MIND score (n = 5206)		DII score(n = 5206)		DQI score(n = 5206)	
		OR (CI 95%)	P	OR (CI 95%)	P	OR (CI 95%)	P	OR (CI 95%)	P	OR (CI 95%)	P
Metabolic syndrome	Crude	0.96 (0.95–0.97)	**< 0.001**	0.88 (0.84–0.92)	**< 0.001**	0.90 (0.86–0.94)	**< 0.001**	1.07 (1.00- 1.14)	**0.03**	0.96 (0.95–0.97)	**< 0.001**
	Model 1	0.94 (0.93–0.95)	**< 0.001**	0.87 (0.83–0.91)	**< 0.001**	0.85 (0.81–0.89)	**< 0.001**	1.09 (1.02–1.16)	0.01	0.96 (0.95–0.97)	**< 0.001**
	Model 2	0.94 (0.93–0.95)	**< 0.001**	0.85 (0.81–0.89)	**< 0.001**	0.84 (0.80–0.88)	**< 0.001**	1.23 (1.12–1.35)	**< 0.001**	0.95 (0.94–0.96)	**< 0.001**
	Model 3	0.94 (0.93–0.95)	**< 0.001**	0.85 (0.81–0.89)	**< 0.001**	0.84 (0.80–0.89)	**< 0.001**	1.22 (1.11–1.34)	**< 0.001**	0.95 (0.94–0.96)	**< 0.001**
Metabolic markers	TG (mg/dl)	0.98 (0.97–0.98)	**< 0.001**	0.96 (0.93–1.07)	0.11	0.99 (0.95–1.03)	0.66	0.98 (0.93–1.03)	0.54	0.99 (0.98- 1.00)	0.09
	Glucose (mg/dl)	1.00 (0.99–1.01)	0.34	0.92 (0.88–0.95)	**< 0.001**	1.01 (0.97–1.04)	0.53	1.00 (0.95–1.05)	0.99	0.99 (0.98- 1.00)	0.07
	Waist Circumference (Cm)	1.00 (1.00- 1.01)	**0.02**	1.00 (0.97–1.03)	0.66	1.02 (0.99–1.06)	0.07	0.94 (0.90–0.99)	**0.02**	0.99 (0.98–0.99)	**< 0.001**
	HDL-cholesterol (mg/dl)	0.98 (0.97–0.98)	**< 0.001**	0.95 (0.91–0.99)	**0.02**	0.95 (0.91–0.99)	**0.02**	1.01 (0.95–1.07)	0.69	0.98 (0.97–0.99)	**< 0.001**
	SBP (mmHg)	1.01 (1.00- 1.02)	**0.04**	1.00 (0.94–1.06)	0.85	1.09 (1.03–1.15)	**< 0.001**	1.01 (0.93–1.10)	0.70	1.00 (0.99–1.02)	0.25
	DBP (mmHg)	0.98 (0.97- 1.00)	0.09	0.98 (0.91–1.05)	0.62	0.95 (0.88–1.01)	0.15	1.05 (0.95–1.16)	0.29	0.99 (0.98–1.01)	0.68

DASH, Dietary Approaches to Stop Hypertension; DBP, Diastolic Blood Pressure; DII, Dietary Inflammatory Index; DQI, Diet Quality Index; HDL-cholesterol: High Density Lipoprotein Cholesterol; LDL-cholesterol: Low-Density Lipoprotein Cholesterol; MDS, Mediterranean Diet Score; MIND, Mediterranean-DASH Intervention for Neurodegenerative Delay; SBP, Systolic Blood Pressure; TG, Triglyceride; WC, Waist Circumference

Model 1: adjusted for age and sex

Model 2: additionally adjusted for physical activity

Model 3: further adjustment was made for energy, WSI and smoking cigarettes

Discussion

This cross-sectional study aimed to assess the predictive capability of five different diet quality indices for metabolic syndrome and metabolic markers. The research found that all five dietary scores were significantly associated with the odds of MetS, even after accounting for potential confounding factors. Among the five indices, the DII score demonstrated the strongest association with Mets. Additionally, the DASH score was more likely to be associated with multiple components of MetS. Recent studies suggest that the quality of dietary macronutrients may predict the risk of metabolic disorders [47]. The relationship between MetS, sleep disorders, nutrient consumption, and social development factors, with a focus on gender differences, has been investigated [48].

Our study compares and finds the best diet quality score, and similar studies have been conducted. there are studies similar to ours. However, their findings differ from ours. For instance, Alkerwi et al. [36], conducted a cross-comparison research to assess the predictive ability of various diet quality indices for chronic disease risk. They determined that the Mediterranean diet score was the most optimal among the DII, DQI, MDS, RCI, and DASH indices. Another study by Golzarand et al. [49] demonstrated that high adherence to the DASH, MDS and MIND scores was linked with a reduced risk of metabolically unhealthy normal weight phenotypes. So as another research by Vahid et al. [50] demonstrated that DASH, DQI and Alternative Healthy Eating Index (AHEI), which are food-group-based indices, proved to be effective in predicting metabolic parameters.

As previously mentioned, our findings revealed that the DII score has the strongest association with MetS compared to other selected indices. Consistent with our findings, a systematic review and meta-analysis study consisting of eighteen cross-sectional and cohort studies showed that except for low HDL-cholesterol, an elevated DII, representing an inflammation promoting diet, was linked to greater likelihood of MetS and its various factors [51]. Same as the findings of a previous study, our research also indicates that a diet that promotes inflammation may increase the risk of developing MetS [52]. In another study conducted on Koreans, after adjusting for various confounders, the DII was significantly associated with the odds of MetS. DII was also positively correlated with the occurrence of hyperglycemia and obesity in men and postmenopausal women respectively [53]. Consistent with another study, our findings suggest that the DII may be a valuable clinical tool for identifying dietary sources of inflammation that should be minimized to decrease the risk of metabolic diseases, including MetS [54]. Similar to a research showing that an inflammation promoting diet was linked to increased C-reactive protein (CRP) and hyperglycemia, both of which are aspect of MetS [55].

The potential reason for the effectiveness of DII's strength may stem from the fact that individuals adhering closely to the DII tend to have a healthier overall diet characterized by consuming more vegetables, fruits, nuts, legumes, fish, poultry, while consuming less meat. This correlation between the DII and a healthy diet was also detected in a research by Vahid et al. [50], which supports our findings related to food groups such as vegetables, fruits, and non-caloric beverages. Therefore, a high compliance to DII, which involves consuming a high amount of vegetables and fruits, ensures a high intake of vitamins C, E, and fiber [56]. Additionally, consuming nuts leads to an increased intake of potassium, magnesium, calcium, MUFA, PUFA, and vitamin E [57, 58]. Legumes provide fiber, B vitamins, iron, magnesium, zinc, and phosphorus [59].

Our results, which revealed a strong association between the DII score and the consumption of various nutrients such as retinol, MUFA, PUFA, vitamins D, E, C, B1, B2, B3, B5, B6, B9, B12, calcium, selenium, iron, magnesium, sodium, potassium, phosphorus, and zinc. Same correlation is supported by another study [50]. A study discovered that women who consumed twice the recommended daily amounts of vitamin B2, B3, total vitamin A, retinol, monounsaturated fatty acids, polyunsaturated fatty acids, potassium, phosphorus, calcium, protein, n-3 fatty acids, and n-6 fatty acids had a reduced occurrence of MetS. Additionally, individuals with underlying health conditions who raised their consumption of vitamin B2, retinol, fruits, and white and red vegetables also experienced a lessened risk of MetS [60]. Another research demonstrated the beneficial impact of calcium in preventing the accumulation of fat, likely due to the presence of uncoupled protein (UCP2) in white adipose tissue that promotes thermogenesis and diminishes waist circumference [61, 62]. These findings support our results, which suggest a significant relationship between the DII score and waist circumference. Another study showed that elevated DII scores may contribute to abnormal characteristics, which could result in elevated WC and TG levels among overweight and obese women [63].

Based on our findings, it was evident that the DASH diet score exhibited a stronger correlation with various aspects of the MetS. This was demonstrated by the opposite relationship between alignment with the DASH diet and elevated blood pressure and TG, along with decreased levels of HDL-C. Similar to our findings, research also found that higher diet quality, according to alignment with the DASH score, was linked with reduced odds of MetS, and also correlated with higher HDL-c and lower TG [64]. In women, there was evidence of a significant protective relation between the DASH diet and MetS and its components [65, 66]. One research found that compliance with the DASH diet score was oppositely associated with the likelihood of MetS and its certain components, such as increased blood pressure, decreased HDL-C and elevated TG [3]. Therefore, promoting healthy dietary patterns such as the DASH diet can effectively lower the risk of MetS [67].

One proposed mechanism is that DASH diet is high in fruits and vegetables, low-fat dairy, and unsaturated vegetable oils, with reduced sugar-sweetened products and red and processed meat [68]. Our findings suggest that sugar-sweetened beverages, sweets, and dairy group were found to have the strongest correlation with adherence to the DASH diet in our findings. To be precise, there was a direct relation between consuming added sugar and having higher LDL and triglycerides levels, while having lower levels of mean HDL cholesterol because of their high glycemic load [69, 70]. Regularly consuming dairy products has been found to be linked with a lower occurrence of hypertriglyceridemia [71].

Our study revealed that MDS was linked with lowered blood glucose and levels of HDL-C. Researchers found that compliance with Mediterranean diet can affect MetS and all its parameters oxidative and inflammatory status [72–74]. The Mediterranean diet's unique characteristics lies in its ability to maintain diabetes balance, through promoting anti-inflammatory and antioxidant effects and enhancing insulin sensitivity [75].

The usefulness of the Mediterranean diet in regulating blood glucose and promoting healthy HDL cholesterol levels can be attributed to several mechanisms. Our findings showed that MDS had the strongest correlation with nut intake and fiber which may affect blood glucose and HDL levels. Consuming more nuts was linked to significantly decreased levels of all biomarkers related to diabetes, including blood glucose [76]. Furthermore, a diet rich in fiber slows down the emptying of the stomach, resulting in reduced indicators of metabolic abnormalities [64, 66, 77].

This study presented that the MIND diet was related to incremented SBP also lowered HDL-c. A research found that greater compliance with the MIND diet was associated with the reduced HDL-c [62]. A cross-sectional study by Aminifar et al. [78] on Iranian adults showed that the MIND diet score was contrarily correlated with decreased HDL and obesity [79]. Tsartsou et al. [80] reported that the main effect of polyphenol-rich olive oil was to increase circulating HDL-C. A recent study has claimed that, for the first time, uncovered a relationship between stronger adherence to the MIND diet and a reduction in SBP [81].

The mechanism of the effectiveness of the MIND diet on HDL and SBP can be attributed to its emphasis on specific nutrient-rich foods like vegetables and healthy fats especially olive oil which has the strongest correlation with MIND diet. These foods have been shown to have favourable effects on HDL levels and BP because of their high antioxidant and polyphenol content which relieves inflammation [62, 82, 83]. Additionally, the MIND diet restricts the consumption of red meat, butter, and high-fat dairy products, which are recognised contributors to elevated BP and decreased HDL levels [42].

The findings of this research indicated that there was an association between the DQI score and reduced levels of HDL-c and waist circumference. A related prospective study conducted by Funtikova et al. [84] revealed that, a higher DQI score at the beginning of the study was linked to a decrease in waist circumference during a 10-year follow-up. Similarly, the study by Alkerwi et al. [36] found a negative relationship between DQI and HDL. Another research indicated a link between DQI and factors contributing to cardiometabolic risk. It also suggested that changes in diet could potentially forecast a reduction in Waist-Hip Ratio (WHR) [85].

Our results have shown that DQI had the strongest correlation with vegetables, fruits and fiber intake. These elements, along with vitamin C, are commonly found in this diet score and serve as primary sources of dietary antioxidants [86]. Higher fruit and vegetable consumption was associated with increased HDL-C levels [87]. Furthermore, increased total antioxidant capacity, specially vitamin C was linked to higher HDL-C [86]. Increased HDL-C levels may also be attributed to increased consumption of fiber [88, 89], which is consistent with the findings of our study. Fiber could also have beneficial role in prevention of waist circumference gain which supports our findings [90].

As a result, these five diet quality indices were significantly associated with MetS due to their high content of fruits, vegetables, legumes, and unsaturated vegetable oils, as well as their low content of saturated fat, red and processed meat. Among the study population, the DASH diet score was found to have the most favourable MetS biomarker risk profile, while the DII score was mainly linked to MetS. The research's primary strength was its use of all five of these diet quality indices. These indices were derived from existing literature, based on population data, and standardized to allow quantitative comparisons within the same study [36]. As far as we know, this is one of the initial population-based studies to examine the predictive ability of diet quality indices for MetS. Moreover, the study's strength also lies in its significant sample size.

As with the majority of dietary studies conducted on populations, there are certain constraints involved in this research that prevent us from drawing causal conclusions due to its cross-sectional design. Furthermore, this study has limitations because it did not take into account certain components of the Dietary Inflammatory Index (DII), namely saffron, eugenol, ginger, turmeric, pepper, rosemary, and thyme, when conducting calculations. Alcohol and red wine, on the other hand, were not included in calculation of this study's diet quality scores because there was no information about wine in the used FFQ and also due to religious reasons, alcohol consumption is unusual or less commonly reported in the Iranian population.

Conclusion

In conclusion, our study provides compelling evidence that the DASH diet score is correlated with a highly favourable risk biomarker profile. Also, the DII score is primarily linked to MetS within the study population. These findings underscore the importance of dietary patterns in influencing overall health and accentuate the possible advantages of choosing the DASH diet to improve biomarker profiles and reduce the risk of MetS. This research revealed that the DII is a valuable tool for predicting the risk of MetS. The strong link between the DII score and MetS observed in our study suggests that dietary inflammation plays a crucial role in the development of MetS. By considering the intake of various pro-inflammatory and anti-inflammatory nutrients, the DII provides a comprehensive assessment of dietary patterns and their effect on metabolic health. Incorporating the DII into clinical practice and public health interventions may enable targeted interventions to prevent or manage MetS more effectively. Further RCT and clinical studies are needed to be done in the future on a more diverse population to conclude cause and effect outcomes.

Abbreviations

BMI	Body Mass Index
BP	Blood Pressure
DASH	Dietary Approaches to Stop Hypertension
DII	Dietary Inflammatory Index
DM	Diabetes Mellitus
DQIs	Diet Quality Indices
FFQ	Food-Frequency Questionnaire
HDL-C	High Density Lipoprotein Cholesterol
MDS	Mediterranean Dietary Score
MET	Metabolic Equivalent of Task
MetS	Metabolic syndrome
MIND	Mediterranean-DASH Intervention for Neurodegenerative Delay
MUFA	Monounsaturated Fatty Acids
NCEP ATP III	National Cholesterol Education Program Adult Treatment Panel
PCOS	Polycystic Ovarian Syndrome
PUFA	Polyunsaturated Fatty Acids

SBP	Systolic Blood Pressure
TC	Total Cholesterol
TG	Triglyceride
UC2	Uncoupled Protein
WSI	Wealth Score Index

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Author contributions
KHAP and SRS designed the study. KHAP and SRS performed all statistical analyses and wrote the first draft of the manuscript. ZN contributed to draft editing and revisions. All authors read and approved the final manuscript.

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Declarations

Competing interests
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