Interaction between major dietary patterns and cardiorespiratory fitness on metabolic syndrome in Iranian adults: a cross-sectional study

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Research

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Abstract

Background

Several researches have been conducted on the associations between diet and cardiorespiratory fitness (CRF) and major cardiovascular risk factors. However, there is no report about the interaction between major dietary patterns and CRF on metabolic syndrome (MetS)and its components. To investigate the combined association of major dietary patterns and CRF on MetS and its components.

Methods

This cross-sectional study was conducted in 270 adults living in Tehran, Iran. Dietary intake was evaluated using a validated food frequency questionnaire (FFQ). CRF was assessed using a graded exercise treadmill test. Socio-economic status, anthropometric measures, biochemical parameters, and blood pressure were evaluated according to standard methods. Major dietary patterns were identified by factor analysis.

Results

Three major identified dietary patterns were (healthy, mixed, and western dietary patterns). Adherence to mixed pattern showed a significant decrease for blood glucose ($P < 0.01$). There was a significant increase in triglycerides level among tertiles of western pattern ($P = 0.03$). However, there was no significant difference for MetS and its components between tertiles of CRF. Also we found that there was no interaction of any of dietary patterns (healthy ($P = 0.69$), mixed ($P = 0.80$), and western pattern ($P = 0.60$)) and CRF on odds of MetS.

Conclusions

we showed that the combination of dietary patterns and CRF is not associated with odds of MetS among Iranian adults. More studies are needed to clarify these associations.

Introduction

Metabolic syndrome (Mets) is a cluster of conditions that occur together, including excess fat accumulation around the waist, impaired metabolism of glucose due to insulin resistance, dyslipidemia such as increased blood triglycerides (TG), decreased high-density lipoprotein cholesterol (HDL-C) [1, 2]. The Mets also increases the risk for development of cardiovascular disease (CVD), type 2 diabetes, and hypertension [3, 4]. According to world health organization (WHO) reports CVDs are the number 1 cause of death globally, taking an estimated 17.9 million lives each year [5]. Cardiorespiratory fitness (CRF) is also identified as a key predictor of premature death and cardiovascular disease [6–8]. CRF is defined as the maximum cardiovascular capacity and respiratory systems to supply oxygen to the skeletal muscles during exercise [4]. As a result, it enables the person to maintain physical activity for longer. This ability relates to the three respiratory, cardiovascular, and muscular systems that work together to increase respiratory capacity but the cardiovascular system is more important than other systems [9–11]. Lifestyle changes are an important step in preventing the complications of MetS and the progression of CVD. There are several studies on the association between individual's food intake such as fruit, vegetable and legume intake or dietary fiber with cardiovascular risk factors among Iranian adults other population [12, 13]. Some researchers have also studied the association of processed foods or animal proteins with the risk of cardiovascular disease [14, 15]. Then, the current approach of nutritional epidemiology is to research the effects of dietary patterns instead of food groups on different disease [16, 17]. The results of recent studies on Iranian population showed that the Western dietary pattern causes higher levels of Lp-PLA2 in individuals. Which is directly related to vascular inflammation and cardiovascular disease [17]. Also, a prospective study in Mashhad showed that a balanced diet has no significant relationship with the risk of cardiovascular disease, but the Western diet significantly increases this risk [18]. Despite related studies, limited data are available on the study of CVD-related dietary patterns in the Middle East [19]. However, the data are contradictory in this regard. Numerous studies have been performed, Showed that following the West or unhealthy dietary pattern was no significant relationship With mortality from CVD [20, 21]. So, previous studies have suggested the importance of poor cardiorespiratory fitness in adulthood as a risk factor for developing cardiovascular disease in middle age [22]. Because of cardiorespiratory fitness is a powerful predictor of CVD mortality [23], we have examined the combined association of dietary patterns and CRF on MetS among Iranian population.

Methods

Study design

270 adults contain118 men and 152 women were participated in this cross-sectional study. Participants were recruited exploiting advertisement. Subjects were chosen by convenience sampling. The research criteria included age range of 18–45, participant who apparently healthy, having desire to take part in study, subjects who reside in Tehran. We excluded those who have extreme values of dietary intake (less than 800 kcal/d or more than 4200 kcal/d, respectively), suffering from kidney, liver and lung diseases and other conditions affecting the body composition status or infectious and

active inflammatory diseases, pregnancy, lactation, routine supplement or drug use, such as weight loss, hormonal, sedative drugs, thermogenic supplements like caffeine and green tea, conjugated linoleic acid (CLA) etc. This study was conducted according to the guidelines laid down in the Declaration of Helsinki. All necessary explanations about the project were given to the participants. All procedures were in accord with the ethical standards of the Tehran University of Medical Sciences (Ethic Number: IR.TUMS.VCR.REC.1396.4085), who approved the protocol and informed consent form. All participants signed a written informed consent prior to the start of the study.

Assessment of other variables

Participants completed a questionnaire designed to assess the participants' demographic including age, gender (male/female), marital status (single/married), smoking (non-smoker/former smoker/current smoker), diabetes (yes/no), cardiovascular disease (yes/no) and menopause status (yes/no). Physical activity was assessed using the international physical activity questionnaire (IPAQ)[24]. Subjects were grouped into three categories including very low (< 600 MET-minute/week), low (600–3000 MET-minute/week), moderate and high (> 3000 MET-minute/week) calculated based on Metabolic Equivalents (METs)[25].

Dietary intakes

The dietary intake of participants was assessed by a valid and reliable semi-quantitative Food Frequency Questionnaire (FFQ), which contained 168 food items [26]. FFQ was administered by trained dietitians via face-to-face interviews, asking participants to report their frequency of consumption of each food item, during the past year on a daily, weekly or monthly basis. To convert the portion sizes of the consumed foods to grams, household measures were used. Mean energy and nutrient intakes from the FFQs were calculated using a modified version of NUTRITIONIST IV software for Iranian foods (version 7.0; N-Squared Computing, Salem, OR, USA).

Anthropometric measures

Body weight was determined using a standard body weight scale (seca 707; Seca GmbH & Co. KG., Hamburg, Germany). Height was measured with a tape measure mounted on the wall. Patient's height was measured without shoes by a Stadiometer (Seca, Germany). We measured waist circumference (WC) based on the middle of bottom ribs and pelvic bones after a normal exhale using an inelastic tape. To calculate waist-hip ratio (WHR), WC in centimeter divided by hip circumference in centimeter. Body mass index (BMI) calculated as weight in kilogram divided by height in meters squared. Body composition was measured using body composition analyzer (InBody 720, Biospace, Tokyo, Japan). For this analysis, all patients were asked to follow these conditions before measurement: no food ingestion for at least 4 hours, minimal intake of 2 L of water the day before, no physical activity for at least 8 h, no coffee or alcoholic beverage consumption during at least 12 hours, and no diuretic use for at least 24 hours. Patients were required to empty their bladder immediately before the body composition test [27]. To assess blood pressure, first we asked participants to sit for 10 min. Blood pressure was then measured using a standard mercury sphygmomanometer, twice with a 5 min interval, while participants were sitting. The mean of the two measurements was recorded as the participant's blood pressure.

Laboratory investigations

All participants donated 10 ml of blood between the hours of 7–10 am, in a fasted status. Following this, blood samples were collected in acid-washed test tubes without anticoagulant. Then, after being stored at room temperature for 30 minutes and clot formation, blood samples were centrifuged at 1500 g for 20 minutes. Serums were stored in − 80 ° C until future testing. Fasting blood sugar (FBS) was assayed by the enzymatic (glucose oxidase) colorimetric method using a commercial kit (Pars Azmun, Tehran, Iran). Serum total cholesterol (TC) and high-density lipoprotein cholesterol (HDL-C) were measured using a cholesterol oxidase phenol aminoantipyrine method, and triglyceride (TG) was measured using a glycerol-3 phosphate oxidase phenol aminoantipyrine enzymatic method. Serum low-density lipoprotein cholesterol (LDL-C) was calculated using the Fried Ewald formula.

Definition of terms

MetS was defined according to the National Cholesterol Education Program (NCEP) Adult Treatment Panel-III (ATP III) classification as three or more of WC > 102 cm in males and WC > 88 cm in females, fasting plasma glucose ≥ 110 mg/dl in both gender, or a known diagnosis diabetes, fasting serum triglyceride ≥ 150 mg/dl in both gender, fasting high-density lipoprotein (HDL) cholesterol < 40 mg/dl in males and HDL < 50 mg/dl in females, or blood pressure ≥ 130/85 mmHg in both gender[28].

Cardiorespiratory fitness testing

To assess CRF, the maximum rate of oxygen consumed (VO2 max) by the treadmill and the respiratory gas analyzer (Cortex Metabolizer 3B) was measured. Accordingly, the participants warmed up for 5 minutes on the treadmill at a speed of 5 km / h, and then the Bruce test was used to determine the VO2max [29]. After completing the Bruce test, the participants walked at a speed of 4 km / h in order to cool down for 3 minutes and perform 10 to 5 minutes of stretching. The conditions for the end of the test were: the patient's heart rate reaches more than 90% of the maximum heart rate, the ratio of respiratory rate of up to 1.1 and having the plateau rate of oxygen intake, despite the increase in exercise intensity.

Dietary patterns

Foods and beverages from the FFQ were categorized into 17 food groups based on the similarity of nutrients. Factor loadings for each of the 25 food groups was estimated using principle component analysis (PCA) method. Orthogonal transformation was used to keep identified factors uncorrelated and to improve the interpretation. Eigenvalues, the scree plot test, and interpretability were evaluated to retain factors (> 1.5) for further analysis. An absolute factor loading ≥ 0.3 was used to define a subset of at least 6 food groups in each factor. The identified factors were labeled based on our

interpretation of the data and based on previous studies that found similar dietary patterns in adults [30–32]. Factor scores for each pattern was obtained by summing intakes of food groups weighted by their factor loadings[33]. Each participant received a factor score for each identified pattern. Participants were categorized based on tertiles of dietary pattern scores.

Statistical analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS version 25; SPSS Inc.). We considered $p < 0.05$ as significance level. Participants were divided based on the tertiles of major dietary patterns and CRF. To compare general characteristics among tertiles, we used one-way ANOVA and chi-square tests for quantitative and qualitative variables, respectively. Multivariate adjusted means test was performed to evaluate the association between major dietary patterns, CRF and MetS components and each its components after adjusting for potential confounders. Two-way ANOVA was used to investigate the combined association of major dietary patterns and CRF on MetS components. Multivariate adjusted odds ratios test was done for indicating the interaction between CRF and dietary pattern with MetS.

Results

General characteristics of study participants by tertiles of CRF are shown in Table 1. A total of 270 participants (117 men and 153 women) were included in this study. Mean age of participants was 36.71 ± 13.18. The mean BMI was 25.61 ± 4.67 for them. There were no significant differences in mean weight and having history of CVD and smoking across tertiles CRF. In the third tertile of CRF the mean height (174.01 ± 7.93) and FFM (56.38 ± 11.49) were higher ($p < 0.001$). The number of males ($p < 0.001$) and single ($p < 0.001$) participants were higher in the third compared to the first tertile. With increasing the tertiles of CRF the number of women with menopause ($p < 0.001$) and diabetes ($p = 0.01$) history and the mean of age ($p < 0.001$), FM ($p < 0.001$), WC ($p < 0.001$), BMI ($p < 0.001$), and WHR ($p < 0.001$) significantly reduced. Moreover, participants in the highest tertile of CRF were more active (p-value < 0.001) and more smoker (p-value = 0.33).

Table 1
General characteristics of study participants by tertiles of CRF

	All = 270	Tertiles of CRF			P_{value}
	Mean ± SD or%	T1	T2	T3	
n	270	90	88	92	
Height(cm)	168 ± 9.96	163 ± 9.57	166 ± 49	174 ± 7.93	< 0.001
Age(year)	36.7 ± 13.18	42.8 ± 13.78	35.2 ± 12.36	32.1 ± 11.02	< 0.001
FFM(kg)	50.1 ± 12.65	46.6 ± 11.40	47.2 ± 12.68	56.3 ± 11.49	< 0.001
FM(kg)	22.4 ± 9.39	27.9 ± 10.23	23.2 ± 7.27	16.3 ± 6.34	< 0.001
Weight (kg)	72.7 ± 16.06	74.5 ± 17.82	71.0 ± 16.34	72.6 ± 13.82	0.34
WC (cm)	89.6 ± 12.57	93.4 ± 13.48	89.6 ± 12.74	85.9 ± 10.30	< 0.001
WHR	0.90 ± 0.06	0.92 ± 0.05	0.91 ± 0.06	0.87 ± 0.06	< 0.001
BMI (kg/m2)	25.6 ± 4.67	27.6 ± 5.36	25.3 ± 4.12	23.8 ± 3.62	< 0.001
Sex, male, n(%)	117(43.5%)	16(5.9%)	32(11.9%)	69(25.7)	< 0.001
Marital status ,n(%)					< 0.001
Single	115(43.3)	23(8.6)	36(13.5)	57(21.3)	
Married	152(56.7)	66(24.6)	51(19.0)	35(13.0)	
Smoking, n(%)					0.33
Non-smoker	233(86.9)	83(31.0)	75(28.0)	75(28.0)	
Former and current smoker	35(13.1)	6(2.20)	12(4.50)	17(6.30)	
Physical activity ,n(%)					< 0.001
Low	103(38.4)	43(16.0)	39(14.6)	21(7.80)	
Medium	110(41.0)	37(13.8)	34(12.7)	39(14.6)	
high	55(20.5)	9(3.40)	14(5.20)	32(11.9)	
Diabetes, yes, n(%)	9(3.40)	7(2.60)	2(0.70)	0(0.0)	0.01
CVD, yes, n(%)	5(1.90)	3(1.10)	1(0.40)	1(0.40)	0.43
Menopause status, yes, n (%)	36(13.5)	34(12.7)	2(0.70)	0(0.0)	< 0.001

P value less than 0.05 was considered significant.

Values are based on average ± standard deviation or reported number (percentage).

One-way anova for quantitative data and Chi-2 test for qualitative data have been used.

BMI:Body Mass Index; WC: Waist Circumference; FFM: fat free mass; FM: fat mass; WHR: waist to hip ratio; CRF: cardiorespiratory fitness

General characteristics of participants across the tertiles of three major dietary patterns are indicated in Table 2. Participants in the highest tertile of Healthy dietary pattern (HDP) had highest BMI (p-value = 0.01), WC (p-value = 0.01), FFM (p-value < 0.01), height (p-value = 0.04), weight (p-value < 0.01), and age (p-value < 0.001). The number of males (p = 0.03) and women with menopause status (p-value = 0.03) increased significantly by increasing the tertiles of this pattern. Adherence to mixed dietary pattern showed a significant increase for FM(p-value = 0.02), WC(p-value = 0.04), WHR(p-value < 0.01), and menopause status(p-value = 0.02). Participants in the highest tertile of Western dietary pattern (WDP) had highest FFM(p-value = 0.03), BMI (p-value < 0.001), and less menopause status(p-value < 0.001) (Table 2).

Table 2
General characteristics of participants across the tertiles of three major dietary patterns

	Healthy pattern				Mixed pattern				Western pattern			
Characteristics	T1	T2	T3	P	T1	T2	T3	p	T1	T2	T3	p
n	89	90	89		89	90	89		89	90	89	
Height(cm)	166 ± 10.0	168 ± 9.04	169 ± 10.6	0.04	169 ± 11.0	167 ± 9.43	167 ± 9.35	0.13	165 ± 10.3	168 ± 9.70	171 ± 9.04	< 0.001
Age(year)	33.4 ± 12.1	35.4 ± 12.7	40.9 ± 13.1	< 0.001	32.7 ± 11.6	36.6 ± 12.5	40.3 ± 14.0	< 0.001	41.7 ± 14.4	34.0 ± 11.6	34.1 ± 11.7	< 0.001
FFM(kg)	47.6 ± 12.4	50.1 ± 11.6	52.7 ± 13.4	< 0.01	51.3 ± 15.0	49.3 ± 11.4	49.8 ± 11.2	0.44	48.5 ± 12.3	49.3 ± 12.2	52.6 ± 13.1	0.03
FM(kg)	21.6 ± 8.12	22.3 ± 9.57	23.3 ± 10.4	0.22	20.8 ± 8.17	22.4 ± 10.2	24.1 ± 9.56	0.02	22.9 ± 8.97	22.4 ± 10.5	21.9 ± 8.70	0.50
Weight (kg)	69.2 ± 15.8	72.5 ± 16.4	76.4 ± 15.3	< 0.01	72.6 ± 16.5	71.6 ± 16.0	73.9 ± 15.8	0.57	71.4 ± 14.0	71.7 ± 17.8	75.1 ± 16.1	0.12
WC (cm)	87.3 ± 12.2	89.4 ± 12.9	92.0 ± 12.3	0.01	88.0 ± 12.1	88.9 ± 12.5	91.8 ± 12.9	0.04	88.9 ± 10.9	88.7 ± 14.2	91.1 ± 12.3	0.24
WHR	0.89 ± 0.06	0.90 ± 0.06	0.91 ± 0.06	0.08	0.89 ± 0.06	0.90 ± 0.06	0.91 ± 0.07	< 0.01	0.89 ± 0.05	0.90 ± 0.07	0.91 ± 0.06	0.05
BMI (kg/m2)	24.8 ± 4.38	25.4 ± 4.68	26.5 ± 4.85	0.01	25.0 ± 4.12	25.5 ± 4.98	26.2 ± 4.87	0.08	26.0 ± 25.2	25.2 ± 5.35	25.5 ± 4.29	0.38
Sex, male, n(%)	30 (11.2)	40 (14.9)	47 (17.5)	0.03	42 (15.7)	33 (12.3)	42 (15.7)	0.26	42 (10.4)	33 (13.1)	42 (20.1)	< 0.001
Marital status ,n(%)				0.40				0.27				0.14
Single	51 (19.0)	39 (14.6)	36 (13.4)		46 (17.2)	38 (14.2)	32 (11.9)		32 (11.9)	42 (15.7)	42 (15.7)	
Married	38 (14.2)	51 (19.0)	53 (19.8)		43 (16.0)	52 (19.4)	57 (21.3)		57 (21.3)	48 (17.9)	48 (17.9)	
Smoking, n(%)				0.31				0.13				0.24
Non-smoker	81 (30.2)	78 (29.1)	73 (27.2)		77 (28.7)	81 (30.2)	74 (27.6)		77 (28.7)	84 (31.3)	71 (26.5)	
Former and current smoker	8 (3.2)	12 (4.8)	16 (6.4)		12 (4.5)	9 (3.4)	15 (5.6)		12 (4.5)	6 (2.3)	18 (6.7)	
Physical activity ,n(%)				0.10				0.19				0.92
Low	40 (14.9)	35 (13.1)	27 (10.1)		33 (12.3)	40 (14.9)	29 (10.8)		31 (11.6)	35 (13.1)	36 (13.4)	
Medium	36 (13.4)	39 (14.6)	36 (13.4)		33 (12.3)	38 (14.2)	40 (14.9)		40 (14.9)	37 (13.8)	34 (12.7)	
high	13 (4.9)	16 (6.0)	26 (9.7)		23 (8.6)	12 (4.5)	20 (7.5)		18 (6.7)	18 (6.7)	19 (7.1)	
Diabetes, yes, n(%)	3 (1.1)	2 (0.7)	4 (1.5)	0.70	1 (0.4)	3 (1.1)	5 (1.9)	0.25	5 (1.9)	2 (0.7)	2 (0.7)	0.35
CVD, yes, n(%)	2 (0.7)	2 (0.7)	2 (0.7)	0.90	0 (0.0)	3 (1.1)	3 (1.1)	0.22	2 (0.7)	1 (0.4)	3 (1.1)	0.60
Menopause status, yes, n (%)	11 (4.1)	10 (3.7)	15 (5.6)	0.03	6 (2.2)	12 (4.5)	18 (6.7)	0.02	21 (7.9)	10 (3.7)	5 (1.9)	< 0.001

P value less than 0.05 was considered significant.

Values are based on average ± standard deviation or reported number (percentage).

One-way ANOVA for quantitative data and Chi-2 test for qualitative data have been used.

BMI: body mass index; CVD: cardiovascular disease; WC: waist circumference; WHR: waist to hip ratio; FFM: fat free mass; FM: fat mass;

Table 3 shows food groups and their loading factors for three major identified dietary patterns. Positive loading demonstrated strong associations between the food groups and dietary patterns, while negative loading demonstrated negative associations. Healthy dietary pattern was characterized by high positive loading for the consumption of legumes, vegetables, poultry, fruits and fruits juices, nuts, fish, egg, low fat dairy product, olive and

olive oil. The mixed dietary pattern showed positive loading for the consumption of non-refined cereals, vegetables, vegetable oils, mayonnaise, high fat dairy product, and pickles. The western dietary pattern was represented mainly by positive loading for refined cereals, red or processed meat, soft drinks, sweets and desserts, tea and coffee, salty snacks, and french fries. (Table 3).

Table 3
Food groups and their loading factors for three identified dietary patterns.

		Dietary Patterns		
	Group details	Healthy pattern	Mixed pattern	Western pattern
Refined cereals	Lavash bread, baguette bread, rice, pasta, others			0.456
Non refined cereals	Dark breads (e.g., *barbari*, *sangak*, *taftun*), bran breads, others		0.468	
Legumes	Lentils, split pea, beans, chick pea, fava bean, soy, others	0.623		
Red or processed meat	Beef and veal, lamb, minced meat, sausage, deli meat, hamburger			0.401
Vegetables	Cauliflower, carrot, tomato and its products, spinach, lettuce, cucumber, eggplant, onion, greens, green bean, green pea, squash, mushroom, pepper, corn, garlic, turnip, others	0.538	0.467	
Vegetable oils	Vegetable oils (except for olive oils)		0.428	
Poultry	Chicken	0.727		
Organ meats	Heart, kidney, liver, tongue, brain, offal, rennet			
Soft drinks	Soft drinks			0.699
Sweets and desserts	Cookies, cakes, biscuits, muffins, pies, chocolates, honey, jam, sugar cubes, sugar,candies, sweet tahini, others			0.469
Salt	Salt			
Mayonnaise	Mayonnaise		0.767	
Tea and coffee	Tea and coffee			0.313
Salty snacks	Corn puffs, crackers, potato chips, others			0.547
High fat dairy product	High-fat milk, high-fat yogurt, cream cheese, cream, dairy fat, ice cream, others		0.543	
French fries	French fries			0.621
Potatoes	Potatoes			
Fruits and fruits juices	Melon, watermelon, honeydew melon, plums, prunes, apples, cherries, sour cherries,peaches, nectarine, pear, fig, date, grapes, kiwi, pomegranate, strawberry, banana,persimmon, berry, pineapple, oranges, dried fruits, all juices, others	0.582		
Nuts	Almonds, peanut, walnut, pistachio, hazelnut, seeds, others	0.485		
Fish	All fish types	0.581		
Pickles	Pickles, sauerkraut		0.718	
Egg	Eggs	0.648		
Low fat dairy product	Low-fat milk, skim milk, low-fat yogurt, cheese, *Kashk*, yogurt drink, others	0.451		
Hydrogenated fats	Hydrogenated vegetable oils, solid fats (animal origin), animal butter, margarine			
Olive and olive oil	Olive and olive oil	0.453		
Factor loadings < 0.30 for all three patterns were excluded.				

Multivariate adjusted means for FBS, TG, WC, HDL, SBP and DBP across tertiles of major dietary patterns are indicated in Table 4. Adherence to HDP showed a significant increase for WC ($p = 0.04$) and SBP (p-value < 0.01). Adjustment for confounding factors including age, sex, education, physical activity, smoking, income, total energy and, BMI attenuated the significance of the results. Adherence to MDP showed a significant increase for WC ($p = 0.04$) and DBP (p-value = 0.04). Adjustment for confounding factors attenuated these results. However, after adjustment for confounding factors, participants in highest tertile of this pattern had lowest FBS (< 0.001). The results showed that, participants in the highest tertile of WDP had highest TG ($p = 0.03$) and WC ($p = 0.05$) after adjustment for potential confounders. A significant decrease was showed for WC across the tertiles of CRF (p-value < 0.001). Results remained significant after adjustment for confounding factors (p-value < 0.01). Also Participants in the highest tertile of CRF had highest SBP (p-value = 0.04). This finding remained significant after adjustment for confounding factors, too (p-value < 0.001).

Table 4
Multivariate adjusted means for FBS, TG, WC, HDL, SBP, and DBP across tertiles of major dietary patterns and CRF

	Tertiles of major dietary patterns					
	Healthy Dietary Pattern					
	T1	T2	T3	P*	P_{Trend}	P$
n	90	88	92			
FBS (mg/dl)	98.5 ± 12.0	96.7 ± 10.5	99.9 ± 28.6	0.53	0.63	0.72
TG (mg/dl)	117 ± 65.5	132 ± 80.5	109 ± 59.8	0.08	0.46	0.10
WC (cm)	87.3 ± 12.2	89.4 ± 12.9	92.0 ± 12.3	0.04	0.01	0.86
HDL (mg/dl)	49.1 ± 10.5	50.8 ± 11.7	189 ± 40.2	0.47	0.98	0.50
SBP (mmHg)	106 ± 26.9	110 ± 10.8	116 ± 14.5	0.01	< 0.001	0.15
DBP (mmHg)	69.9 ± 11.7	69.7 ± 10.4	72.2 ± 9.75	0.22	0.15	0.72
	Mixed Dietary Pattern					
	T1	T2	T3	P	P_{Trend}	P_{ANCOVA}
FBS (mg/dl)	101 ± 28.6	97.98 ± 10.29	96.2 ± 11.5	0.23	0.09	0.01
TG (mg/dl)	116 ± 69.7	124.90 ± 72.44	117 ± 67.1	0.70	0.92	0.81
WC (cm)	88.0 ± 12.1	88.94 ± 12.59	91.8 ± 12.9	0.11	0.04	0.24
HDL (mg/dl)	49.5 ± 9.81	50.54 ± 11.97	49.1 ± 10.2	0.67	0.82	0.55
SBP (mmHg)	109 ± 18.6	110.75 ± 20.74	114 ± 17.8	0.22	0.09	0.94
DBP (mmHg)	69.7 ± 8.31	69.23 ± 12.38	72.9 ± 10.7	0.04	0.04	0.63
	Western Dietary Pattern					
	T1	T2	T3	P	P_{Trend}	P_{ANCOVA}
FBS (mg/dl)	97.9 ± 8.81	97.2 ± 12.6	100 ± 28.8	0.56	0.46	0.80
TG (mg/dl)	108 ± 54.90	129 ± 75.1	122 ± 75.9	0.10	0.17	0.03
WC (cm)	88.9 ± 10.96	88.7 ± 14.2	91.1 ± 12.3	0.35	0.24	0.053
HDL (mg/dl)	49.5 ± 9.84	50.3 ± 11.5	49.3 ± 10.7	0.80	0.52	0.86
SBP (mmHg)	114 ± 18.04	110 ± 19.7	109 ± 19.5	0.24	0.13	0.25
DBP (mmHg)	70.0 ± 13.11	70.2 ± 8.81	71.5 ± 9.80	0.59	0.35	0.17
	Cardiorespiratory fitness (ml/kg/min)					
	T1	T2	T3	P	P_{Trend}	P_{ANCOVA}
FBS (mg/dl)	97.5 ± 9.76	100 ± 27.5	97.5 ± 14.9	0.58	0.98	0.59
TG (mg/dl)	123 ± 60.7	125 ± 80.2	110 ± 66.4	0.27	0.20	0.61
WC (cm)	93.4 ± 13.4	89.6 ± 12.7	85.9 ± 10.3	< 0.001	< 0.001	0.01
HDL (mg/dl)	49.8 ± 9.16	49.5 ± 12.0	49.9 ± 10.7	0.95	0.93	0.96
SBP (mmHg)	108 ± 27.9	111 ± 13.76	114 ± 11.1	0.12	0.04	< 0.001
DBP (mmHg)	71.1 ± 12.2	70.2 ± 11.7	70.3 ± 7.69	0.81	0.59	0.62

Values are presented as mean ± SD.

* obtained using one-way ANOVA test.

$ obtained using analysis of covariance (ANCOVA) test (adjusted for age, sex, marital status, physical activity, smoking, total energy, diabetes, cardiovascular disease history, menopause status, and body mass index.

Abbreviations: FBS: Fasting Blood Sugar; CRF: cardiorespiratory fitness; TG: Triglyceride; HDL: High Density Lipoprotein; SBP: Systolic Blood Pressure; DBP: Diastolic Blood; WC = Waist Circumference

Table 5 shows multivariate adjusted odds ratios and 95% confidence intervals for metabolic syndrome and its components across tertiles of CRF. Multiple logistic regression models showed that CRF had significantly negative association (highest vs lowest terile) with abdominal obesity in the crude model (OR = 0.09, 95% CI (0.04–0.20)) and model 1 (OR = 0.12, 95% CI (0.04–0.32)). Our results also showed that being in the third compared to the first category of CRF was inversely associated with metabolic syndrome (OR = 0.43, 95% CI (0.20–0.94)) and low HDL-C levels (OR = 0.44, 95% CI (0.24–0.82)) in crude model.

Table 5
Multivariate adjusted odds ratios and 95% confidence intervals for metabolic syndrome and its components across tertiles of CRF

	Tertiles of CRF			P for trend
	T1	T2	T3	
Metabolic Syndrome				
Crude	1.00	0.64(0.31,1.32)	0.43(0.20,0.94)	0.10
Model 1*	1.00	0.81(0.35,1.86)	0.66(0.23,1.84)	0.73
Model 2 §	1.00	1.16(0.50,2.71)	1.22(0.41,3.65)	0.91
Hypertriglyceridemia				
Crude	1.00	0.85(0.43,1.70)	0.80(0.40,1.60)	0.82
Model 1	1.00	0.85(0.40,1.83)	0.83(0.34,2.05)	0.90
Model 2	1.00	0.92(0.42,2.01)	0.97(0.37,2.54)	0.97
Hypertension				
Crude	1.00	1.02(0.28,3.66)	0.37(0.07,2.00)	0.45
Model 1	1.00	1.01(0.21,4.91)	0.35(0.04,2.91)	0.53
Model 2	1.00	1.33(0.22,8.04)	0.66(0.06,7.23)	0.75
Hyperglycemia				
Crude	1.00	0.76(0.41,1.42)	0.87(0.48,1.60)	0.70
Model 1	1.00	1.02(0.50,2.06)	1.43(0.62,3.29)	0.62
Model 2	1.00	1.09(0.53,2.27)	1.68(0.68,4.11)	0.46
Low HDL-C				
Crude	1.00	1.11(0.61,2.01)	0.44(0.24,0.82)	0.01
Model 1	1.00	1.54(0.77,3.06)	1.04(0.45,2.39)	0.36
Model 2	1.00	1.59(0.79,3.20)	1.11(0.46,2.68)	0.35
Abdominal obesity				
Crude	1.00	0.38(0.20,0.70)	0.09(0.04,0.20)	< 0.001
Model 1	1.00	0.40(0.20,0.79)	0.12(0.04,0.32)	< 0.001
Model 2	1.00	0.67(0.23,1.93)	0.30(0.06,1.56)	0.36
Data are presented as OR (95%CI)				
*Adjusted for age and sex, smoking, physical activity, socioeconomic status				
§ Adjusted for age, sex, smoking, physical activity, socioeconomic status, body mass index and energy.				
HDL-C: high density lipoprotein-cholesterol; CRF: cardiorespiratory fittness				

Multivariate adjusted odds ratios and 95% confidence intervals for metabolic syndrome and its components across tertiles of identified dietary patterns are summarized in Table 6. Accordingly, the results showed that greater adherence to the HDP (third vs first tertile) was significantly associated with lower odds of low HDL-C levels (OR = 0.54, 95% CI (0.29– 0.99)) in crude model. However, after adjustment for potential confounders was attenuated. Also, our results indicated positive association (highest vs lowest tertile) between MDP and metabolic syndrome in crude model (OR = 2.57, 95% CI (1.10– 6.02)) and model 1 (OR = 2.66, 95% CI (1.06–6.62)). This association changed to non-significant results after additional

adjustment for body mass index and energy intakes. Moreover, we did not find any significant association between the WDP and odds of metabolic syndrome and its components in crude and adjusted models.

Table 6
Multivariate adjusted odds ratios and 95% confidence intervals for metabolic syndrome and its components across tertiles of dietary patterns

	Healthy pattern				Mixed pattern				Western pattern			
	T1	T2	T3	P	T1	T2	T3	p	T1	T2	T3	p
Metabolic Syndrome												
Crude	1.00	1.30 (0.62,2.71)	0.92 (0.42,2.00)	0.62	1.00	2.87 (1.24,6.66)	2.57 (1.10,6.02)	0.03	1.00	1.30 (0.62,2.71)	0.92 (0.42,2.00)	0.62
Model 1*	1.00	1.31 (0.61,2.81)	0.95 (0.41,2.17)	0.67	1.00	2.88 (1.17,7.04)	2.66 (1.06,6.62)	0.05	1.00	1.42 (0.63,3.20)	1.25 (0.53,2.94)	0.68
Model 2 §	1.00	1.24 (0.56,2.75)	0.68 (0.27,1.71)	0.40	1.00	3.06 (1.21,7.77)	2.68 (0.92,7.78)	0.05	1.00	1.38 (0.60,3.18)	1.02 (0.39,2.63)	0.67
Hypertriglyceridemia												
Crude	1.00	2.22 (1.09,4.54)	1.43 (0.67,3.01)	0.08	1.00	1.54 (0.76,3.11)	1.39 (0.68,2.84)	0.46	1.00	1.72 (0.85,3.45)	1.22 (0.59,2.53)	0.29
Model 1	1.00	2.02 (0.89,4.19)	1.23 (0.56,2.69)	0.12	1.00	1.79 (0.84,3.78)	1.59 (0.73,3.44)	0.29	1.00	2.06 (0.95,4.46)	1.49 (0.66,3.34)	0.19
Model 2	1.00	1.96 (0.94,4.08)	1.04 (0.45,2.39)	0.10	1.00	1.78 (0.84,3.79)	1.49 (0.64,3.49)	0.31	1.00	2.03 (0.94,4.41)	1.38 (0.58,3.27)	0.18
Hypertension												
Crude	1.00	031 (0.06,1.60)	0.65 (0.17,2.39)	0.37	1.00	1.33 (0.29,6.13)	1.70 (0.39,7.36)	0.77	1.00	0.73 (0.15,3.37)	1.26 (0.32,4.87)	0.76
Model 1	1.00	0.25 (0.04,1.38)	0.33 (0.08,1.41)	0.17	1.00	1.23 (0.25,6.09)	1.05 (0.21,5.08)	0.96	1.00	1.32 (0.23,7.40)	2.32 (0.49,10.9)	0.53
Model 2	1.00	0.18 (0.03,1.17)	0.28 (0.05,1.41)	0.13	1.00	1.62 (0.29,8.82)	2.73 (0.37,19.9)	0.61	1.00	1.24 (0.20,7.54)	3.88 (0.60,24.9)	0.27
Hyperglycemia												
Crude	1.00	0.49 (0.26,0.92)	0.59 (0.32,1.08)	0.07	1.00	1.66 (0.90,3.07)	1.01 (0.53,1.88)	0.16	1.00	0.89 (0.48,1.63)	0.78 (0.42,1.44)	0.73
Model 1	1.00	0.47 (0.25,0.90)	0.58 (0.29,1.13)	0.06	1.00	1.42 (0.74,2.70)	0.85 (0.43,1.67)	0.27	1.00	0.94 (0.48,1.82)	0.91 (0.46,1.82)	0.96
Model 2	1.00	0.46 (0.24,0.89)	0.54 (0.26,1.12)	0.05	1.00	1.41 (0.74,2.70)	0.81 (0.38,1.74)	0.27	1.00	0.94 (0.48,1.83)	0.95 (0.45,1.98)	0.98
Low HDL-C												
Crude	1.00	0.78 (0.43,1.41)	0.54 (0.29,0.99)	0.13	1.00	1.48 (0.81,2.69)	1.01 (0.54,1.83)	0.32	1.00	1.23 (0.68,2.24)	1.04 (0.57,1.91)	0.76
Model 1	1.00	0.83 (0.44,1.56)	0.65 (0.33,1.29)	0.47	1.00	1.37 (0.71,2.64)	1.11 (0.56,2.18)	0.61	1.00	1.41 (0.72,2.79)	1.70 (0.84,3.44)	0.32
Model 2	1.00	0.80 (0.42,1.52)	0.57 (0.27,1.19)	0.33	1.00	1.36 (0.70,2.62)	1.03 (0.48,2.19)	0.59	1.00	1.42 (0.72,2.81)	1.77 (0.82,3.83)	0.32
Abdominal obesity												
Crude	1.00	1.28 (0.67,2.42)	1.58 (0.84,2.97)	0.36	1.00	1.42 (0.75,2.69)	1.67 (0.88,3.15)	0.27	1.00	0.84 (0.45,1.57)	0.81 (0.43,1.52)	0.79
Model 1	1.00	1.35 (0.68,2.69)	1.79 (0.87,3.66)	0.28	1.00	1.16 (0.58,2.33)	1.41 (0.70,2.86)	0.61	1.00	1.09 (0.53,2.22)	1.33 (0.64,2.75)	0.72
Model 2	1.00	1.23 (0.41,3.74)	2.19 (0.58,8.21)	0.48	1.00	1.62 (0.53,4.95)	1.29 (0.35,4.64)	0.69	1.00	2.49 (0.71,8.67)	1.78 (0.49,6.39)	0.35

Data are OR (95%CI)

*Adjusted for age and sex, smoking, physical activity, socioeconomic status

§ Adjusted for age, sex, smoking, physical activity, socioeconomic status, body mass index, and energy intake.

HDL-C: high density lipoprotein-cholesterol

Multivariate adjusted odds ratios and 95% confidence intervals for interaction between CRF and identified dietary patterns with metabolic syndrome are indicated in Table 7. The results showed that there was not significant interaction between CRF and HDP (p = 0.69), MDP (p = 0.80), and WDP (p = 0.60) with odds of metabolic syndrome after adjustment for potential confounders.

Table 7
Multivariate adjusted odds ratios and 95% confidence intervals for interaction between CRF and dietary pattern with metabolic syndrome

CRF	Tertiles of healthy dietary pattern			
	T1	T2	T3	$P_{value\ for\ interaction}$
	90	88	92	
T1	1.00	1.00	1.00	0.69
T2	1.00	0.85(0.14,5.06)	1.85(0.29,11.70)	
T3	1.00	0.57(0.09,3.53)	0.43(0.05,3.22)	
CRF	Tertiles of mixed dietary pattern			
	T1	T2	T3	P_{value}
T1	1.00	1.00	1.00	0.80
T2	1.00	1.54(0.19,12.07)	1.32(0.16,10.48)	
T3	1.00	1.36(0.17,10.91)	0.47(0.05,4.28)	
CRF	Tertiles of western dietary pattern			
	T1	T2	T3	P_{value}
T1	1.00	1.00	1.00	0.60
T2	1.00	0.58(0.09,3.54)	1.60(0.25,10.21)	
T3	1.00	1.36(0.21,8.72)	0.76(0.09,6.23)	
Data are presented as OR (95%CI)				
CRF:cardiorespiratory fitness				

Multivariate adjusted means for interaction between CRF and dietary patterns with metabolic syndrome components are shown in Table 8. Adherence to WDP showed a significant decrease for HDL across tertiles of CRF(p-value = 0.03). Also, adherence to HDP indicated a significant increase for SBP across tertiles of CRF (p = 0.03). Moreover, adherence to MDP showed a significant decrease for WC (p-value = 0.05) and DBP (p-value < 0.01) across tertiles of CRF (Table 8).

Table 8
Multivariate adjusted means for interaction between CRF and dietary patterns with metabolic syndrome components

FBS (mg/dl)	**CRF (ml/kg/min)**			
Tertiles of healthy pattern	T1	T2	T3	P_{value}
	90	88	92	
T1	98.0 ± 11.8	100 ± 14.0	96.4 ± 9.63	0.45
T2	97.6 ± 7.25	94.6 ± 8.09	98.1 ± 14.5	
T3	96.8 ± 9.58	106 ± 48.1	97.6 ± 18.1	
FBS (mg/dl)	CRF (ml/kg/min)			
Tertiles of mixed pattern	T1	T2	T3	P_{value}
T1	97.5 ± 13.4	104.5 ± 42.0	99.3 ± 16.8	0.86
T2	98.3 ± 9.85	97.8 ± 10.3	97.7 ± 11.0	
T3	96.6 ± 7.41	96.6 ± 10.7	95.1 ± 15.9	
FBS (mg/dl)	CRF (ml/kg/min)			
Tertiles of western pattern	T1	T2	T3	P_{value}
T1	98.7 ± 7.94	97.9 ± 8.05	96.7 ± 10.6	0.22
T2	97.1 ± 9.72	95.5 ± 13.0	99.1 ± 14.7	
T3	96.0 ± 12.8	106 ± 44.0	96.8 ± 17.8	
TG (mg/dl)	CRF (ml/kg/min)			
Tertiles of healthy pattern	T1	T2	T3	P_{value}
T1	110 ± 47.2	127 ± 80.6	114 ± 70.8	0.66
T2	138 ± 65.7	133 ± 90.5	125 ± 83.3	
T3	126 ± 70.7	115 ± 66.2	94.1 ± 41.4	
TG (mg/dl)	CRF (ml/kg/min)			
Tertiles of mixed pattern	T1	T2	T3	P_{value}
T1	129 ± 87.9	109 ± 64.0	117 ± 64.0	0.27
T2	118 ± 46.0	146 ± 86.4	110 ± 79.1	
T3	125 ± 56.4	126 ± 90.8	101 ± 56.4	
TG (mg/dl)	CRF (ml/kg/min)			
Tertiles of western pattern	T1	T2	T3	P_{value}
T1	109 ± 45.6	121 ± 63.5	93.9 ± 57.3	0.84
T2	135 ± 63.4	136.6 ± 91.4	115 ± 65.3	
T3	133 ± 77.5	119 ± 81.0	117 ± 73.1	
HDL (mg/dl)	CRF (ml/kg/min)			
Tertiles of healthy pattern	T1	T2	T3	P_{value}
T1	49.5 ± 8.56	47.1 ± 11.0	50.9 ± 12.6	0.39
T2	51.5 ± 10.0	49.7 ± 13.4	51.5 ± 11.4	
T3	48.3 ± 9.38	51.7 ± 11.5	48.0 ± 8.66	
HDL (mg/dl)	CRF (ml/kg/min)			
Tertiles of mixed pattern	T1	T2	T3	P_{value}
T1	50.3 ± 9.26	49.1 ± 10.0	49.4 ± 10.1	0.65

FBS (mg/dl)	CRF (ml/kg/min)			
T2	51.6 ± 9.55	48.7 ± 13.9	51.1 ± 12.5	
T3	47.7 ± 8.80	50.8 ± 12.7	49.5 ± 9.99	
HDL (mg/dl)	CRF (ml/kg/min)			
Tertiles of western pattern	T1	T2	T3	P_{value}
T1	51.9 ± 9.73	47.6 ± 11.2	48.0 ± 8.19	0.03
T2	47.8 ± 7.80	49.0 ± 13.2	54.2 ± 11.8	
T3	48.6 ± 9.76	51.3 ± 11.6	48.0 ± 10.8	
WC (cm)	CRF (ml/kg/min)			
Tertiles of healthy pattern	T1	T2	T3	P_{value}
T1	90.3 ± 13.8	86.0 ± 11.0	84.1 ± 10.4	0.78
T2	94.5 ± 13.6	88.9 ± 12.9	85.5 ± 11.2	
T3	96.3 ± 12.9	94.5 ± 13.4	87.3 ± 9.47	
WC (cm)	CRF (ml/kg/min)			
Tertiles of mixed pattern	T1	T2	T3	P_{value}
T1	92.0 ± 15.2	88.7 ± 12.3	85.1 ± 9.35	0.05
T2	89.2 ± 13.8	88.7 ± 13.6	88.7 ± 10.0	
T3	98.0 ± 11.2	91.9 ± 12.6	84.1 ± 11.3	
WC (cm)	CRF (ml/kg/min)			
Tertiles of western pattern	T1	T2	T3	P_{value}
T1	91.8 ± 11.7	86.4 ± 10.7	87.0 ± 9.26	0.32
T2	91.6 ± 15.6	90.7 ± 15.0	83.5 ± 10.4	
T3	98.3 ± 13.2	90.9 ± 11.6	86.9 ± 10.8	
SBP (mmHg)	CRF (ml/kg/min)			
Tertiles of healthy pattern	T1	T2	T3	P_{value}
T1	99.0 ± 39.0	108 ± 11.9	115 ± 13.4	0.03
T2	113.0 ± 13.4	108 ± 9.23	111 ± 9.71	
T3	115.7 ± 16.9	119 ± 17.1	115 ± 10.4	
SBP (mmHg)	CRF (ml/kg/min)			
Tertiles of mixed pattern	T1	T2	T3	P_{value}
T1	99.3 ± 32.6	111 ± 9.88	113 ± 11.6	0.12
T2	108 ± 28.7	107 ± 15.6	117 ± 11.3	
T3	113 ± 24.0	117 ± 14.8	112 ± 10.1	
SBP (mmHg)	CRF (ml/kg/min)			
Tertiles of western pattern	T1	T2	T3	P_{value}
T1	114 ± 24.2	110 ± 11.7	117 ± 10.9	0.26
T2	106 ± 29.7	112 ± 14.9	111 ± 10.3	
T3	100 ± 31.2	111 ± 14.2	114 ± 11.3	
DBP (mmHg)	CRF (ml/kg/min)			
Tertiles of healthy pattern	T1	T2	T3	P_{value}

FBS (mg/dl)	CRF (ml/kg/min)			
T1	69.8 ± 14.1	69.8 ± 10.9	69.7 ± 9.06	0.78
T2	70.2 ± 10.1	68.5 ± 13.3	70.5 ± 6.84	
T3	74.0 ± 11.6	72.7 ± 10.4	70.5 ± 7.59	
DBP (mmHg)	CRF (ml/kg/min)			
Tertiles of mixed pattern	T1	T2	T3	P_{value}
T1	69.0 ± 9.13	69.4 ± 9.60	70.5 ± 6.46	0.01
T2	68.0 ± 13.6	66.8 ± 14.5	73.1 ± 6.43	
T3	75.4 ± 11.5	75.5 ± 9.09	67.4 ± 9.21	
DBP (mmHg)	CRF (ml/kg/min)			
Tertiles of western pattern	T1	T2	T3	P_{value}
T1	70.9 ± 15.1	66.0 ± 14.7	72.5 ± 6.56	0.13
T2	71.5 ± 9.16	71.1 ± 9.75	67.9 ± 6.98	
T3	71.2 ± 10.8	72.6 ± 10.5	70.6 ± 8.62	

P value less than 0.05 was considered significant.

Data are presented as mean ± standard deviation

P_{value} derived from two-way analysis of variances

CRF: cardiorespiratory fitness; FBS, Fasting Blood Sugar; TG, Triglyceride; HDL, High Density Lipoprotein; SBP: Systolic Blood Pressure; DBP: Diastolic Blood; WC = Waist Circumference

mg/dl:miligram per deciliter; cm^2:centimeter^2 mmHg: millimetre of mercury; ml/kg/min: milliliter per kilogram per minute

Discussion

In this cross-sectional study we identified three major dietary patterns including healthy, mixed, and western patterns. None of these patterns were associated with odds of metabolic syndrome or its components. In addition, we found that there was no interaction of any of dietary patterns (healthy, mixed and western pattern) and CRF on odds of MetS. However, Adherence to WDP showed a significant decrease for HDL across tertiles of CRF. Adherence to HDP indicated a significant increase for SBP across tertiles of CRF and adherence to MDP showed a significant decrease for WC and DBP across tertiles of CRF.

To date, several epidemiological studies have been performed on the impact of dietary pattern on MetS. The results of previous studies showed that HDP (rich in vegetables, fruits, and whole grains) was inversely related to metabolic syndrome and its component [34–36]. Evidence from a cross-sectional study of 4984 women aged 30–79 years indicated that HDP (high in green-yellow vegetables, healthy-protein foods, seaweeds, and bonefish) is associated with a decreased risk for MetS [37]. In another study by Esmaillzadeh et al., in 486 Tehrani female teachers the HDP (high in fruits, poultry and vegetables) was associated with less prevalence of the MetS [38]. Williams et al., in a cross sectional study of 802 UK-population aged 40–65 years reported that a HDP (high in fruits, raw and salad vegetables, fish and low in fried foods) is associated with decreased central obesity and fasting glucose concentration [39]. In addition, a previous prospective study of 15972 white and black men and women 45 to 64 years of age revealed adherence to prudent dietary pattern that described by intakes of cruciferous and carotenoid vegetables, fruit, fish, and poultry, was not correlated with an increase in the prevalence of MetS [40]. One of the reasons for the decrease in the prevalence of metabolic syndrome with more adherence to a HDP can be ascribed to its healthy ingredients, such as vegetables, fruits, whole grains, fiber, high quality protein, monounsaturated fatty acids, magnesium, phytochemicals and phytoestrogen [41–45]. In the current study, it seems that a HDP (high in legumes, vegetables, poultry, fruits and fruits juices, nuts, fish, egg, low fat dairy product, olive and olive oil) is neither associated with a reduction in the prevalence of metabolic syndrome nor its components. In the present study, other factors such as weight control in people who have a HDP may affect the desired effects. For example, in our study, participants in the highest tertile of HDP had highest BMI, weight and WC. In addition, participants in the highest tertile of HDP are older than those in the lowest tertile. The prevalence of metabolic syndrome increases with age, so this may be influential. Generally, although the HDP identified in our study is rich in foods that have the potential to reduce the risk of metabolic syndrome but it cannot be propounded exclusively a health-promoting diet. This pattern is more a reflection of the effort to choose healthy foods.

WDP that is determined by excessive consumption of fat, sweets, and refined grains showed inconsistent results with metabolic syndrome and its components [46–48]. In research by Cho et al., the WDP (high in fast foods, animal fat-rich foods, fried foods, grilled meat and seafoods, and sweet foods) indicated no association with MetS [49]. However, WDP in 486 Tehrani female teachers in the study of Esmaillzadeh et al .,was related with

greater risks of MetS [31]. Adherence to a WDP that determined by high consumption of refined grains, processed meat, fried foods, and red meat, was correlated with a 18% higher risk of occurrence MetS [50]. One of the reasons we can rely on it to justify the positive relationship between the WDP and the metabolic syndrome is the high amounts of saturated fats [51], red meat [52, 53] and refined grains [54] in this pattern. In our study, Dietary consumption of a WDP (including refined cereals, red or processed meat, soft drinks, sweets and desserts, tea and coffee, salty snacks, and french fries) was not correlated with an increased risk of metabolic syndrome and its components. This maybe because people who follow the WDP also consume great amounts of food from healthy dietary pattern. Finally, it can be concluded that beneficial foods and nutrients in a HDP can reduce the negative effects of foods in the WDP.

In relation to the MDP, which has a combination of healthy (non-refined cereals, vegetables, vegetable oils) and unhealthy (mayonnaise, high fat dairy product) foods in present study is almost identical to the pattern described in Esmaillzadeh and colleagues study as the traditional food pattern [31]. It has been suggested that healthy combinations of this pattern can have a protective effect on the syndrome, while unhealthy foods can have a negative effect on the prevalence of the syndrome. As well as, the synergistic effect of other food compounds on HDP may be a factor in reducing the risk of metabolic syndrome [31]. The result of our analysis showed, Dietary consumption of a MDP (high consumption of non-refined cereals, vegetable oils, mayonnaise, high fat dairy product, and pickles) was not associated with odds of metabolic syndrome or its components. Anthropometric characteristics and menopause status may influence the relationship between the MDP and the metabolic syndrome. In this pattern subjects in the highest tertile of MDP had highest FM, WC, WHR, and menopause status. Several studies have reported an opposite association between metabolic syndrome and the amount of body fat [55–57] and menopausal status [58, 59].

Our results indicated that having a higher score on the CRF compared with a lower score was associated with decreased odds of MetS, however, were not statistically significant. Also, higher CRF levels were associated with lower measures of abdominal obesity. Several studies have investigated the associations of CRF and MetS. Shaibi et al., indicated that CRF was not associated with any individual risk factor of the metabolic syndrome [60]. In addition, in a population-based cohort on 605 middle-aged men and women found no independent association between CRF and the development of MetS [61]. In contrast, Ekelund et al., reported significant reverse association between CRF and with indicators of insulin resistance, hyperglycemia, hyperlipidemia, and clustered metabolic risk in children [62]. Others studies have shown that CRF is linked to insulin sensitivity as a risk factor for MetS [63, 64]. Hassinen et al., in 1226 men and women aged 57–78 years, reported that higher levels of CRF protect against MetS[65]. Increased muscle insulin sensitivity, lipoprotein lipase activity in active musculoskeletal, transport of lipids and lipoproteins from the peripheral blood circulation and tissues to the liver and reduction abdominal obesity [66] are mechanisms by which MetS may improve with fitness [67, 68]. The differences between the results of the association between CRF and MetS in different studies may be related to different sample sizes, group characteristics, and differences in study methods. In addition, genetic, age, body composition and most importantly, physical activity determines CRF [69]. In this study, subjects who have top levels of CRF have more physical activity, have greater FFM, lower BMI, WC and WHR than those who have lower level of CRF. Indeed, CRF moderates the link between obesity and metabolic status [70]; considering that the risk of metabolic disorders, including MetS, increases with obesity.

All of these articles separately evaluated the association between dietary pattern and cardiorespiratory fitness on metabolic syndrome. Food selection are closely linked to lifestyle [71]. Recently, it has been reported that following more healthy dietary patterns is related with a better selection of foods, increase physical activity and thus reducing the incidence of obesity [72, 73]. In this regard, some studies have evaluated that the association between CRF and dietary patterns [74, 75]. For example; in a cross-sectional study in 279 students aged 14–18 years, the result indicated CRF was associated with a healthier dietary pattern include higher intake of fruit, vegetables, whole grain and lower intake of sweets, chocolates, fries and sugar-sweetened drinks [74]. In another study, in 2632 participants aged 38–50 years, meat dietary pattern was negatively correlated with CRF [76]. Accordingly, we considered the combined effect of these two related factors on metabolic syndrome. However, we did not find significant interaction between dietary patterns and CRF on MetS.

In this study, follow to HDP showed a significant increase for systolic blood pressure across tertiles of CRF. Interestingly, some people develop high blood pressure notwithstanding an active physical lifestyle or a healthy diet, while some sedentary people with unhealthy dietary patterns may have optimal blood pressure. A number of studies have shown that higher cardiorespiratory fitness and physical activity are associated with lower blood pressure [77, 78]. However some studies did not find a connection [79] and in some cases it is even accompanied by a scant increase [80]. The two chief factors that can lead to these differences are the level of primary phenotype and familial aggregation [69]. In general, information on the contribution of genetic diversity to the antihypertensive effect associated with cardiorespiratory fitness is low. In this study, more adherence to the mixed dietary pattern was associated with an increase in waist circumference and blood pressure. But in people who have a mixed dietary pattern, waist circumference and diastolic blood pressure decreased with increasing physical activity and cardiorespiratory fitness. Physical activity decreased the effect of genetic factors like FTO genotype to cause high BMI and WC [81]. Eventually high cardiorespiratory fitness overcame the harmful effects of a mixed dietary pattern on WC and DBP. In relation to the interaction of western dietary pattern and cardiovascular fitness with the components of MetS it is notable that, despite have reported that HDL-C is highly responsive in exercise and have ascertained that exercise and high level of cardiorespiratory fitness increases HDL-cholesterol [82] adherence to WDP showed a significant decrease for HDL across tertiles of CRF. many studies the western dietary pattern was inversely associated with HDL-C [83, 84]. One mechanism clarifying the association between the WDP and lower HDL-C could be higher intake of refined carbohydrates among participants who follow the WDP [84]. Finally, western dietary pattern dominates the detrimental effects of a cardiorespiratory fitness on HDL-C.

Our study had some strengths. According to our knowledge, that interaction between major dietary patterns and cardiorespiratory fitness on metabolic syndrome is reported for the first time in our study. However, it should be mentioned that present study had some limitations owing to the cross-sectional design prevent any causal conclusion between diet, CRF and metabolic syndrome being distinguished. Also Residual disruptors that are unmeasurable and possible in observational studies could affect the study.

Conclusion

We showed that the combination of dietary patterns and CRF is not associated with risk of MetS among Iranian adults. More studies should be conducted to clarify the association.

Abbreviations

HDP: Healthy Dietary Pattern; MDP: Mixed Dietary Pattern; WDP: Western Dietary Pattern; CRF: Cardiorespiratory Fitness; FBS: Fasting Blood Sugar; TC: Total Cholesterol; TG: Triglyceride; HDL-C: High Density Lipoprotein; LDL-C: Low Density Lipoprotein; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; FFM: Fat Free Mass; FM: Fat Mass; WC: Waist Circumference; CVD: cardiovascular disease; WHR: waist to hip ratio; BMI: Body Mass Index

Declarations

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Authors contributions

SSb contributed to conception/design of the research; MGH, MSH and NP contributed to acquisition, analysis, or interpretation of the data; HSH and CC drafted the manuscript; KD and SSb critically revised the manuscript, and SS-b agrees to be fully accountable for ensuring the integrity and accuracy of the work. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the ethics committee of Tehran University of Medical Sciences (TUMS.VCR.REC.1396.4085). Written informed consent was obtained from all subjects/patients.

Consent for publication

Participants were provided a study overview and verbal consent was attained.

Competing interests

The authors declare that they have no competing interests.

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