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Original article

Association between dietary habits and changes in cardiometabolic risk factors in patients with metabolic syndrome: a 10-year follow-up study

Mohammadtaghi Sarebanhassanabadi[1], *Seyed Jalil Mirhosseini*[1], *Masoud Mirzaei*[1], *Seyedeh Mahdieh Namayandeh*[1], *Mohammad Hossein Soltani*[1], *Ali Pedarzadeh*[1], *Zahra Baramesipour*[1], *Reza Faraji*[1], *Nastaran Ahmadi*[1], *Amin Salehi-Abargouei*[2,3]

[1]Yazd Cardiovascular Research Center, Shahid Sadoughi University of Medical Sciences, Yazd, Iran - E-mail: mhsoltane@gmail.com ; [2]Nutrition and Food Security Research Center, Shahid Sadoughi University of Medical Sciences, Yazd, Iran; [3]Department of Nutrition, School of Public Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran.
Corresponding author: Mohammad Hossein Soltani
E-mail: mhsoltane@gmail.com

Summary. *Background:* Dietary habits are important in managing the cardiometabolic risk factors. The present study aimed to investigate the association between dietary habits and changes in components of metabolic syndrome (MetS) and other cardiometabolic factors in a sample of the Iranian adult population who had MetS based on a 10-year follow-up study. *Materials and Methods:* In this cohort study, 1979 urban adults aged 20-74 years were selected using a cluster sampling method in the context of the Yazd Healthy Heart Project (YHHP) during 2005-2006 and the data on demographics, education, physical activity, smoking, economic status, and dietary habits were collected. Biochemical tests, anthropometric and blood pressure measurements were also conducted. The same data were also collected during 2015-2016 for participants who had MetS at the first phase of the study. *Results:* Our analysis revealed that consumption of high-fat dairy significantly increased fasting blood glucose levels, and the participants who regularly consumed fast foods had a significantly higher waist circumference before and after adjustment for age and sex. However, the association disappeared in fully adjusted model in total population, yet, it remained significant only in males after subgroup analysis for fast food consumption (P<0.05). There was a significant association between "adding mayonnaise and salt to food" and "changes in waist circumference" in total population. The association remained significant only among women after the subgroup analysis (P<0.05). *Conclusion:* Dietary habits are associated with the cardiometabolic changes in patients with Mets, therefore lifestyle changes, especially improving the dietary habits are recommended.

Key words: dietary habits, metabolic syndrome, cardiometabolic risk factor, waist circumference, fasting blood glucose

Introduction

Metabolic syndrome (MetS) refers to a complex group of risk factors for cardiovascular disease and diabetes and is becoming a major problem in the world which imposes high socioeconomic costs (1). These cardiometabolic risk factors include central obesity, high fasting blood glucose, elevated blood pressure, raised triglyceride and decreased high-density lipoprotein (HDL) cholesterol levels (2). However, MetS is rapidly developing, worldwide (3). Prevalence of MetS and its components might change over time. In the United States, prevalence of abnormal waist circumference (45.4% to 56.1%) and fasting blood glucose

(12.9% to 19.9%) increased and high triglyceride level (33.5% to 24.3%) and blood pressure decreased (32.3% to 24%) during 10 years from 2000 to 2010 (4). Also, in a 9-year follow-up study performed in China, some cardiometabolic factors such as fasting blood glucose and triglyceride level increased from 2005 to 2014 in both genders, but systolic and diastolic blood pressure decreased during this time. Also, HDL cholesterol and waist circumference increased significantly in females, but not in males (2). However, some risk factors including age, sex, smoking (5), genetics (6), physical activity, socioeconomic status, and education are effective risk factors for MetS and its components (7, 8). Diet is one of the important risk factors that might be associated with disappearance or remission of MetS and its cardiometabolic factors (7). Koh-Banerjee *et al.* after 8 years of follow-up reported that high-fiber diet might decrease total body weight among US men (9). Another study reported that saturated fatty acids in dairy could decrease triglyceride and increase HDL cholesterol (10) while high-salt diet might increase insulin resistance and waist circumference (11). Furthermore, high-fatty acids diet is associated with high blood lipid and increased waist circumference (12). Dietary habits and nutrition have an effect on the cardiometabolic risk factors, especially on weight change and obesity (13). It has been proposed that even poor breakfast habits are associated with high fasting blood sugar and central obesity (14). Some studies reported the association between eating fast food (15), soft drink, high-fat diet and salt and obesity while low-fat milk, fruits, and legumes is inversely associated with obesity (16). Other studies emphasize the effect of dietary habits on diabetes (17), hypertension (18) and serum lipid profiles (19). Therefore, dietary habits might affect MetS and its cardiometabolic components; therefore, studying such associations might provide a good insight into the management of the cardiometabolic factors. To the best of our knowledge, no study exists regarding the association between dietary habits and changes in the components of MetS. Therefore, the main objective of the current study was to identify the association between dietary habits and changes in the cardiometabolic risk factors in a sample of Iranian adult population with MetS in the framework of a 10-year follow-up study.

Materials and methods

Study population

At the start of a cohort study (phase I) in the Yazd Healthy Heart Project (YHHP) during 2005-2006, 1979 participants aged 20-74 years were selected using the cluster sampling method. The selected population came from the Yazd city, Iran. Based on the responses to an oral questionnaire, some data included demographics, education, physical activity, smoking habits, economic status, and dietary habits were collected. Also, another set of data including biochemical tests (fasting blood sugar, triglyceride, and HDL cholesterol), anthropometric measurements (weight, height, waist circumference), and blood pressure for estimating the prevalence of MetS was gleaned by trained staff. At the baseline, 887 out of 1979 participants had MetS and these participants were again invited to Yazd Cardiovascular Research Center (YCRC) to be assessed for MetS during 2015-2016 and the same data as in phase I were collected again. The process of invitation of participants in phase II was done via phone by a trained clinical psychologist. To reduce loss to follow-up (subject attrition), the Yazd Telecom databank was used to make contact with some of the participants who could not be found via their old phone numbers provided during 2005-2006.

Ethical approval

The present study was ethically approved by Shahid Sadoughi University of Medical Sciences' ethics committee, (ethics code: IR.SSU.MEDICINE.REC.1395.287). Also, informed consents were obtained from all subjects at both phases of the study.

Biochemical tests and measurements

To measure biochemical tests, venous blood samples were taken from subjects by a skilled nurse after 9-12 hours of fasting. To separate serum and plasma from the whole blood, centrifugation was used. Fasting blood glucose as well as triglyceride levels were measured by a biochemical auto-analyzer (model BT 3000, Italy) and Pars Azmoon Kits (Pars Azmoon Kit, Pars Azmoon Inc., Tehran, Iran). Also, HDL-cholesterol levels were assessed by Bionic kits (Bionic Company, Tehran, Iran).

Anthropometric and blood pressure measurements

A stadiometer was used for accurate measurement of height and participants were assessed barefoot. To measure the exact body weight of participants, a digital scale (Omron Karada Body Scan and Scale, Model BF511, Omron Co. Osaka, Japan) was used and the participants were dressed with minimal clothing. Waist circumference was measured by a tape measure at the superior border of iliac crest. Blood pressure was assessed twice with five minute intervals in the seated position with back support after at least five minutes at rest by an automatic digital monitor model M6 Comfort, (Omron Co. Osaka, Japan). All of the above measurements were performed by a trained nurse and the instruments were calibrated before using for participants.

Definition of metabolic syndrome

In this study, a modified version of National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) criteria was used to define the MetS (20, 21). According to the definition, having three out of five components of MetS was considered as MetS. In this study, abdominal obesity was considered as waist circumference ≥ 91.5 cm for men and ≥85.5 cm for women which are adopted for the Iranian population (22). Other components were fasting blood sugar (FBS) ≥100 mg/dL or current treatment for diabetes, elevated blood pressure (systolic blood pressure ≥130 mmHg and/or diastolic blood pressure ≥ 85 mmHg or taking drugs for hypertension), hypertriglyceridemia (triglyceride level ≥150 mg/dL), and finally low HDL cholesterol levels (<40 mg/dL in men and <50 mg/dL in women) or current treatment for dyslipidemia.

Assessment of dietary habits

Dietary habits were defined based on the habitual decisions of participants about food choices (23, 24). Dietary habits data were collected according to the oral responses to a questionnaire during 2005-2006 that were designed by expert nutritionists. The content validity of the researcher-made questionnaire for dietary habits was assessed by experts in nutrition and the reliability of the questionnaire was tested using Cronbach's alpha (α=0.63). The questionnaire items were as follows: being on any special diet, eating salad, adding mayonnaise as condiment to food, adding salt to food when eating, cutting the poultry's skin off before cooking, the fat content of dairy usually eaten (low/high fat) dairy, eating fast foods, dining out, choosing frying and boiling as the main cooking method, eating fried and roasted foods, removing fat from meat when eating, and finally adding oil and salt by special measuring cups when cooking. All variables were responded as Yes/ No.

Assessment of other covariates

Economic status was considered based on the three variables including home area, income level, and owning a private car during 2005-2006. The three variables were scored and its scores were summed together. According to the tertile of the summed score, economic status was classified into three groups of low, moderate, and high.

Physical activity was another covariate in the study that was assessed based on the International Physical Activity Questionnaires (IPAQ) (25). In the study, according to the cut-off point of 600 and 1200 kilocalories/week, participants were categorized into three groups of low (< 600 kilocalories/week), moderate (600-1200 kilocalories/week), and vigorous (> 1200 kilocalories/week).

According to the levels of education including primary school, high school diploma, and academic degree, the participants were classified into three groups of low, moderate, and high. Also, regarding smoking status, the participants were divided into two groups of smokers and non-smokers.

Statistical analysis

Statistical package for Social Sciences (SPSS) version 19 (IBM Corporation, New York, USA) was used to analyze all data in the present study. Student's t-test was used to find the significant differences in quantitative variables (such as age, weight, BMI, systolic/diastolic blood pressure, triglyceride, HDL-cholesterol and waist circumference) between two groups of follow-up and loss to follow-up in the participants who had MetS at the first phase of the study. Also, Student's t-test was used to examine the quantitative variables in the participants with persistent MetS compared with participants who their MetS disappeared after about 10 years in the second follow-up. The results of Student's t-test were represented as means ± standard deviation (SD). Chi-square test was used to compare the participants according to the categorized variables including sex, smoking, economic status, physical activity and education.

The analysis of covariance (ANCOVA) in crude and multivariable adjusted models was used to find the difference in mean change in components of MetS including fasting blood sugar, systolic blood pressure, diastolic blood pressure, waist circumference, hypertriglyceridemia, low HDL-cholesterol, Weight and also body mass index (BMI) based on the participants' dietary habits at baseline.

In model I, the association between dietary habits and components of MetS was adjusted for age and sex and in model II, in addition to sex and age, other potential covariates such as smoking habits, economic status, physical activity, and educational level were adjusted. The results for ANCOVA are displayed as means ± standard error of mean. In this study, statistical significance level was considered as P-values less than 0.05.

Results

In the current study, 1979 participants were recruited for the study during 2005-2006. According to the modified NCEP-ATP III criteria, 887 (44.8%) of the subjects with a mean age of 54.7±12.5 years had MetS at the first phase. After a 10-year follow-up, 648 (73%) participants were followed up and 239 (27%) were lost to follow-up. Table 1 presents the comparison of the participants' characteristics based on follow-up and lost to follow-up groups in those who had MetS at the first phase of the study. There were statistically significant differences for age, weight, systolic blood pressure, fasting blood glucose, economic status, and education between those who completed the study ant participants who were lost to follow-up. The participants that completed the study were significantly younger, had more weight, and had lower systolic blood pressure and fasting blood glucose compared to lost to follow-up group. There were no statistically significant differences in BMI, diastolic blood pressure, triglyceride and HDL-cholesterol levels, waist circumference, sex, smoking status, and physical activity between the follow-up and lost to follow-up groups. After a 10-year follow-up, 565 (87.2%) participants showed still had MetS and in 83(12.8%) participants the MetS was disappeared.

The comparison of the participants' characteristics based on the existence of MetS and the absence of MetS in phase II is displayed in Table 2. There were statistically significant differences in baseline weight, BMI, triglyceride levels, and waist circumference. In other words, the participants in whom the MetS was disappeared had less weight, BMI, waist circumference, and serum triglyceride levels compared to those with remaining MetS in the second visit. There were no statistically significant differences in age, systolic and diastolic blood pressure, fasting serum blood glucose, HDL-cholesterol levels, sex, smoking and economic status, physical activity, and education between the two groups.

Association between baseline dietary habits and the mean changes of fasting blood sugar, weight, BMI and waist circumference after a 10-year follow-up in the participants who had MetS at the first phase of the study is shown in Table 3. There were statistically significant differences between consuming high-fat dairy and increased mean change in fasting blood glucose in the crude analysis (P= 0.03) and the model I (P= 0.03), but the difference was disappeared in the model II in the total population. This result was similar in men (P= 0.03) in the crude analysis after subgroup analysis based on gender. The participants who reported that they usually eat fast food experienced more increase in waist circumference in the crude analysis and (P= 0.003) and the model I (P= 0.01), but not in model II in total population. After subgroup analysis based on gender, this difference was found in men in crude (P= 0.001), model I (P= 0.003) and even in model II (P= 0.047), but not in women (P=0.474).

There was a statistically significant difference between adding mayonnaise (P= 0.01) and salt to food when eating (P= 0.04) and decreased mean changes of waist circumference in model II in the total popula-

Table 1. Comparison of the participants' characteristics based on follow-up and loss to follow-up in participants who had MetS at the first phase of the study

Variable		Follow-up	Loss to follow-up	Total	P value
Age (year)		53.4±12	58±13.2	54.7±12.5	0.001
Weight (Kg)		75.4±12.3	71.7±12.9	74.4±12.5	0.001
BMI (Kg/m²)		27.9±4	27.6±4.4	27.8±4.1	0.39
Systolic blood pressure (mmHg)		134.4±14.7	137.7±17.1	135.3±15.4	0.009
Diastolic blood pressure (mmHg)		85.6±9	86.3±9.8	85.8±9.2	0.33
Fasting blood glucose (mg/dL)		118.3±52.3	133.8±68.5	122.5±57.5	0.002
Triglyceride (mg/dL)		234.6±119.3	229.8±109.4	233.3±116.7	0.58
HDL-cholesterol(mg/dL)		50.8±13.8	49.8±12.8	50.5±13.5	0.3
Waist circumference (cm)		100±9.7	99.2±10.2	99.8±9.9	0.25
Sex					
Male		305(47.1%)	98(41%)	403	0.1
Female		343(52.9%)	141(59%)	484	
Current smokers (%)		108(16.7%)	33(13.8%)	141	0.48
Economic Status (%)					
	Low	93(31.8%)	43(49.4%)	136	0.003
	Moderate	118(40.4%)	20(23%)	138	
	High	81(27.7%)	24(27.6%)	105	
Physical activity (%)					
	Low	331(73.6%)	138(80.7%)	469	0.057
	Moderate	104(23.1%)	25(14.6%)	129	
	Vigorous	15(3.3%)	8(4.7%)	23	
Education (%)					
	Low	458(71.8%)	194(81.2%)	652	0.017
	Moderate	138(21.6%)	33(13.8%)	171	
	High	42(6.6%)	12(5%)	54	

[1] Values are mean± standard deviation, otherwise indicated.

tion. The significant association was stable in women for consuming mayonnaise (P= 0.021), but it was not stable in men after subgroup analysis. There was no significant association between adding salt to food and decreased mean changes of waist circumference in both genders after subgroup analysis. Moreover, there was no significant association between other dietary habits behaviors and mean changes of components of MetS after a 10-year follow-up.

Table 4 illustrates the association between baseline dietary habits and mean changes of hypertriglyceridemia, low HDL-cholesterol, and systolic/diastolic blood pressure after a 10-year follow-up in the participants who had MetS at the first phase of the study. There was no statistically significant difference between dietary habits and the mean changes after adjusting for potential cofounders including age, sex, smoking, economic status, physical activity, and educational level.

Discussion

In the present follow-up study conducted in Yazd, central Iran, there was a statistically significant difference between consuming high-fat dairy and increased mean changes of high fasting blood glucose in crude and after adjusting based on age and sex (model I) in the total population. Also, this result was similar in men in crude status after subgroup analysis after a 10-year

Table 2. Comparison of the participants' characteristics based on existence of MetS and absence of MetS in phase II in participants who had MetS at the first phase of the study

Variable		Remained MetS	Disappeared MetS	Total	P value
Age (year)		53.8±11.5	50.7±14.5	54.7±12.5	0.06
Weight (Kg)		75.8±12.2	72.6±12.3	74.4±12.5	0.03
BMI (Kg/m²)		28±4	26.9±3.6	27.8±4.1	0.01
Systolic blood pressure (mmHg)		134.8±14.8	131.6±13	135.3±15.4	0.06
Diastolic blood pressure (mmHg)		85.7±9	85.1±8.9	85.8±9.2	0.59
Fasting blood glucose (mg/dL)		119.7±53.2	109.2±45.2	122.5±57.5	0.08
Triglyceride (mg/dL)		240.1±121.1	196.7±98.8	233.3±116.7	0.001
HDL-cholesterol(mg/dL)		50.9±13.9	50.1±12.8	50.5±13.5	0.62
Waist circumference (cm)		100.5±9.6	96.8±10.1	99.8±9.9	0.001
Sex					
	Male	263(46.5%)	42(50.6%)	305	0.49
	Female	302(53.5&)	41(49.4%)	343	
Current smokers (%)		91(16.1%)	17(20.5%)	108	0.57
Economic Status (%)					
	Low	86(33.7%)	7(18.9%)	93	0.07
	Moderate	97(38%)	21(56.8%)	118	
	High	72(28.2%)	9(24.3%)	81	
Physical activity (%)					
	Low	291(74.2%)	40(69%)	331	0.12
	Moderate	86(21.9%)	18(31%)	104	
	Vigorous	15(3.8%)	0	15	
Education (%)					
	Low	405(72.5%)	53(67.1%)	458	0.52
	Moderate	117(20.9%)	21(26.6%)	138	
	High	37(6.6%)	5(6.3%)	42	

[1] Values are mean± standard deviation, otherwise indicated.

follow-up. It should be noted that after adjusting for potential cofounders including age, sex, smoking, economic status, physical activity, and educational level in model II, the significant association disappeared. The current result was similar to the cross-sectional study performed in Iran (3). Also, the researchers in a cohort study did not find any significant association between milk consumption and relative risk of diabetes (26). The results of a study by van Meijl *et al*. showed that consuming low-fat dairy for 8 weeks could not change fasting blood glucose in obese participants (27). Also, our current study has shown that high fasting blood glucose decreased significantly in the participants who consumed low-fat dairy compared to high-fat dairy in crude and model I, but not in model II. In our study, there were no statistically significant differences between low-fat dairy diet and other components of MetS that was similar to van Meijl *et al*. (27) study, but in systolic blood pressure. It should be noted that the design of the two studies were different. However, high-fat diet can increase the receptors of insulin, but affinity of the receptors will remain without changes and this mechanism is activated by saturated and polyunsaturated fatty acid. Also, saturated fat can activate oxidative stress mechanism and this process has inverse effects on the glucose-insulin system. As a result, saturated fatty acid can increase fasting blood glucose levels. (28).

Our study showed that there was a significant association between eating fast food and increased mean

Table 3. Association between baseline dietary habits and changes in high fasting blood sugar, systolic /diastolic blood pressure and waist circumference in participants who had MetS at the first phase of the study

Dietary	Fasting blood glucose (mg/dl)			Weight (Kg)			Body mass index (kg/m^2)			Waist circumference (cm)		
habits	Crude	Model I[1]	Model II[2]	Crude	Model I[1]	Model II[2]	Crude	Model I[1]	Model II[2]	Crude	Model I[1]	Model II[2]
Being on special diet												
Yes	20±3.4	20±3.5	24±5.9	0.18±0.5	0.36±0.5	0.8±0.9	1.1±0.2	1.2±0.2	1.3±0.3	5.5±0.6	5.6±0.6	4.1±1
No	17.4±3	17.3±3	19.3±4.5	0.5±0.46	0.37±0.5	-0.5±0.7	0.8±0.5	0.8±0.2	0.8±0.3	4.8±0.5	4.8±0.5	4.4±0.8
P value	0.57	0.56	0.54	0.6	0.98	0.78	0.34	0.18	0.23	0.38	0.29	0.82
Add mayonnaise as condiments												
No	20.6±3.7	20.5±3.8	23.8±6.4	1.2±0.59	1.45±0.58	0.4±0.9	1.4±0.2	1.5±0.2	1.2±0.3	5.6±0.7	5.8±0.7	6.1±1
Yes	15.4±3.3	15.5±3.3	18.6±5.5	-.38±0.5	-0.6±0.5	-1.7±0.8	0.68±0.2	0.6±0.2	0.7±3	4.7±0.6	4.5±0.6	2.7±0.9
P value	0.3	0.3	o.5	0.06	0.008	0.1	0.02	0.004	0.3	0.35	0.15	0.01
Eating salad												
Yes	16.8±2.6	16.8±2.6	21.1±3.9	0.27±0.4	0.19±0.39	-0.8±0.6	1±0.16	0.99±0.2	0.96±0.2	5.1±0.4	5.1±0.4	4.3±0.6
No	23.4±4.5	23.6±4.6	19.9±8	0.68±0.7	0.9±0.7	0.04±1.3	0.9±0.3	1±0.3	1.1±0.5	5.3±0.8	5.3±0.8	3.8±1.4
P value	0.2	0.2	0.89	0.6	0.36	0.56	0.8	0.9	0.83	0.8	0.83	0.76
Add salt to food when eating												
No	19.3±2.5	19.4±2.5	20.1±4	0.4±0.4	0.5±0.38	-0.1±0.6	1.1±0.2	1±0.16	1.1±0.2	5.2±0.4	5.2±0.4	4.9±0.7
Yes	15.3±4.8	15.2±4.8	23.2±7.2	0.06±0.7	-0.3±0.7	-2.2±1.1	0.57±0.4	0.8±0.3	0.5±0.4	5.1±0.8	4.9±0.8	2±1.2
P value	0.45	0.45	0.7	0.65	0.3	0.12	0.28	0.46	0.2	0.92	0.73	0.04
Cut poultry skin off												
Yes	18.7±2.3	18.7±2.3	20.8±3.6	0.44±0.3	0.39±-0.3	-0.58±0.5	1±0.1	1±0.14	1±0.2	5.3±0.4	5.2±0.4	4.3±0.6
No	13.5±9.5	13.4±9.6	20.9±14.1	-0.7±1.4	-0.09±1.4	-1.5±2.3	0.8±0.6	1.1±0.6	0.03±0.8	2.3±1.7	3.2±1.7	2.2±2.4
P value	0.59	0.59	0.99	0.4	0.74	0.69	0.76	0.86	0.2	0.08	0.25	0.41
Dairy consumption												
Low-fat	13.2±2.7	13.1±2.7	18±3.5	0.2±0.4	0.3±0.4	-.4±0.7	1±0.1	1±0.1	1±0.2	5.1±0.5	5±0.5	4.6±0.7
High-fat	23.9±4.2	24±4.3	20.5±7.3	0.7±0.7	0.6±0.7	0.005±1.5	0.89±0.3	0.8±0.3	1±0.5	4.8±0.8	4.9±0.7	4.1±1.4
P value	0.03	0.03	0.75	0.5	0.7	0.8	0.69	0.57	0.98	0.78	0.82	0.79
Dining out												
No	17.7±3.1	17.6±3.2	18.3±5	0.2±0.5	0.47±0.48	-1.1±0.82	0.92±0.2	1±0.2	0.93±0.3	4.9±0.5	5.1±0.5	3.4±0.85
Yes	19.3±3.2	19.3±3.3	23.4±4.9	0.54±0.5	0.26±0.49	-0.2±0.8	1.1±0.2	1±0.2	1±0.3	5.3±0.57	5.1±0.6	5±0.8
P value	0.73	0.71	0.48	0.64	0.76	0.4	0.57	0.98	0.78	0.64	0.98	0.17
Eating fast food												
No	19.3±5.3	18.4±5.5	29.7±8.9	-0.3±0.6	-0.04±0.6	-0.5±1.1	0.9±0.25	0.9±0.3	0.68±0.39	4.1±0.68	4.3±0.68	3.3±1.1
Yes	22.7±5.7	23.6±6	18.1±9	0.7±0.6	0.33±0.6	-1.7±1.1	1.2±0.3	1.1±0.3	0.8±0.4	7±0.73	6.7±0.73	5.4±1.1
P value	0.67	0.5	0.37	0.2	0.69	0.44	0.43	0.76	0.8	0.003	0.01	0.21
Low-fat meat												
Yes	18.6±2.5	18.6±2.5	20.5±4	0.4±0.4	0.45±0.38	-0.4±0.6	1±0.16	1.1±0.2	1.2±0.2	5.4±0.4	5.4±0.44	4.2±0.6
No	19.1±5	19±5.3	23.2±7.7	0.18±0.8	-0.06±0.8	-1.3±1.3	0.7±0.3	0.67±0.3	0.3±0.4	4.3±0.9	4.2±0.9	4.4±1.3
	0.93	0.9	0.77	0.8	0.55	0.5	0.4	0.29	0.12	0.3	0.25	0.89
Using measuring cup for oil												
Yes	19.7±2.7	19.9±2.7	20.4±4	0.3±0.4	0.4±0.4	-0.6±0.6	0.9±0.2	1±0.2	0.9±0.2	5.2±0.5	5.3±0.5	4.6±0.7
No	15.4±4.2	15.4±4.2	23.5±7.3	0.5±0.6	0.2±0.6	-0.6±1.2	1±0.3	0.9±0.3	1±0.4	5.2±0.7	4.9±0.7	3.4±1.2
P value	0.36	0.36	0.7	0.7	0.8	0.9	0.8	0.8	0.9	0.99	0.6	0.4
Using measuring cup for salt												
Yes	19.5±2.6	19.5±2.6	19.7±3.9	0.3±0.4	0.4±0.4	-0.6±0.6	1±0.2	1±1	1±0.2	5±0.5	5±0.4	4±0.7
No	16.1±4.5	16±4.5	20±4.5	0.6±0.7	0.4±0.7	-0.4±1.2	0.9±0.4	0.9±0.3	0.9±0.4	5.8±0.8	5.5±0.78	4.9±1.2
P value	0.5	0.5	0.46	0.7	0.9	0.9	0.9	0.9	0.9	0.4	0.59	0.56
Boiling as the main cooking method												
Yes	18.8±2.7	18.8±2.8	22.9±4.4	0.7±0.4	0.8±0.4	-0.2±0.7	1.1±0.1	1.1±0.17	0.8±0.2	5.5±0.48	5.5±0.48	4.2±0.75
No	18.4±3.9	18.4±4.1	17.7±6.4	-0.3±0.6	-0.6±0.6	-1.2±1	0.7±0.2	0.7±0.2	1.2±0.4	4.5±0.7	4.4±0.7	4.4±1.1
P value	0.93	0.93	0.5	0.1	0.04	0.4	0.2	0.1	0.5	0.23	0.18	0.9
Frying as the main cooking method												
No	18.8±2.8	18.9±2.8	28.8±4.5	0.7±0.4	0.9±0.4	-0.1±0.7	1.1±0.1	1.1±0.1	0.9±0.2	5.5±0.5	5.6±0.49	4.3±0.77
Yes	18.2±3.8	18.2±3.9	16.4±6.1	-0.3±0.5	-0.70.5	-1.4±0.9	0.7±0.2	0.6±0.2	1.1±0.3	4.5±0.7	4.3±0.7	4.2±1
P value	0.89	0.88	0.35	0.1	0.02	0.3	0.2	0.08	0.6	0.2	0.13	0.94

1) Model I: Adjusted for age and sex; 2) Model II: Adjusted for age, sex, smoking, economic status, physical activity and education; 3) Values are mean± standard error, otherwise indicated.

Table 4. Association between baseline dietary habits and changes in hypertriglyceridemia, low HDL-cholesterol and body mass index in participants who had MetS at the first phase of the study

Dietary habits	Triglyceride (mg/dl)			HDL-cholesterol (mg/dl)			Systolic blood pressure (mmHg)			Diastolic blood pressure (mmHg)		
	Crude	Model I[1]	Model II[2]	Crude	Model I[1]	Model II[2]	Crude	Model I[1]	Model II[2]	Crude	Model I[1]	Model II[2]
Being on special diet												
Yes	-45.6±8	-46.5±8.3	-67.2±14.2	-9.1±1	-8.7±1	-7±2	7±4.3	6.9±4.3	3.3±3.4	-1.9±3.1	-1.1±3.1	-2.5±2.3
No	-51.3±7	-50.6±7.3	-46.2±11	-7.3±0.8	-7.5±0.89	-5.6±1.5	6±3.9	6±3.9	2.5±2.7	2.6±2.8	1.9±2.8	-3.2±1.8
P value	0.6	0.7	0.26	0.17	0.38	0.6	0.86	0.87	0.85	0.28	0.49	0.83
Add mayonnaise as condiments												
No	-42.2±9.5	-42.4±9.6	-55.4±14.6	-9.5±1.2	-9±1.2	-7.4±2	8.8±4.5	7.7±4.5	1.8±3.8	7±4.1	8.3±4.1	-2.3±2.6
Yes	-60.5±8.5	-60.3±8.5	-58±12.6	-6.4±1	-6.8±1	-6±1.8	3.6±4	4.4±4	2.4±3.2	-2±3.7	-3.1±3.7	-3.4±2.2
P value	0.15	0.17	0.89	0.05	0.16	0.6	0.39	0.56	0.9	0.1	0.04	0.74
Eating salad												
Yes	-52.6±6	-52±6	-55.9±9.5	-7.8±0.7	-8±0.76	-6.4±1.3	5.8±3.3	5.5±3.3	2±2.3	1.8±2.4	1.5±2.4	-3.1±1.6
No	-36±10.9	-37±11	-44±19	-8.9±1.3	-8.3±1.4	-5.5±2.7	8.4±5.7	9±5.8	6±4.6	-2.9±4.1	-2±4.1	-1.7±3.1
P value	0.18	0.2	0.58	0.48	0.8	0.76	0.69	0.6	0.44	0.3	0.46	0.7
Add salt to food when eating												
No	-43±6	-43±6	-51±9.7	-8±0.7	-8±0.7	-5.5±1.3	8±3.2	7.8±3.2	3±2.4	1.7±2.3	2±2.3	-2.3±1.6
Yes	-68.7±11	-68±11	-61±17	-7.8±1	-8±1.4	-8.5±2.4	0.6±6.2	1.2±6.2	2.5±4.3	-.3.5±4.5	-4.6±4.5	-4.2±2.9
P value	0.04	0.05	0.6	0.8	0.8	0.29	0.29	0.34	0.92	0.3	0.19	0.57
Cut poultry skin off												
Yes	-47.7±5.5	-47.8±5.5	-52±8.7	-8±0.69	-8±0.68	-6±1.2	6.8±3	7.1±2.9	3±2.1	1±2.1	0.99±2.1	-.2.5±1.4
No	-63±22.8	-62±23	-73±34	-9.7±2.8	-8.9±2.8	-8.2±4.8	-0.5±12	-4.7±12.1	0.6±8.6	-7.2±8.8	-5.8±8.8	-7.2±5.7
P value	0.5	0.55	0.55	0.54	0.76	0.67	0.55	0.35	0.78	0.36	0.45	0.43
Dairy consumption												
Low-fat	-45±0.6	-45±6.9	-48±10	-8.5±0.8	-8.4±0.8	-7.2±1.4	8.5±3.8	8.6±3.7	4.1±2.5	-2±2.2	-1.9±2.2	-.1.7±1.6
High-fat	-45.8±11	-45±11	-56±21	-7.7±1.3	-8±1.3	-2.5±3	4.7±6.4	4.5±6.4	3.2±5.6	5.6±3.7	5.3±3.8	-3.5±3.7
P value	0.99	0.96	0.74	0.6	0.87	0.16	0.6	0.57	0.88	0.08	0.1	0.66
Dining out												
No	-56±7.5	-57±7.6	-51.7±12	-8.5±0.9	-8±0.9	-5.6±1.7	8.2±3.9	7.7±4	3.5±3	0.92±2.9	2.1±2.9	-1.9±2
Yes	-40.6±7.7	-39±7.8	-55±12	-7.6±0.9	-8±0.96	-6.8±1.7	4.5±4.2	5±4.2	2.2±3	0.26±3	-1±3	-3.7±2
P value	0.15	0.11	0.83	0.5	0.96	0.61	0.52	0.64	0.77	0.87	0.47	0.54
Eating fast food												
No	-43±11	-42±11	-75±18.9	-8±1.3	-7.3±1.3	-8.7±2.6	17.3±7.8	15.5±7.9	1.2±4	-1.6±4.6	-.66±4.7	-3.2±2.8
Yes	-37±12	-37±12	-37±19	-7±1.4	-8.3±1.4	-6.7±2.7	0.17±8.9	2.4±9.1	4.9±4.2	3.2±5.3	1.9±5.4	-.3.8±2.9
P value	0.7	0.7	0.17	0.59	0.62	0.6	0.15	0.28	0.54	0.49	0.49	0.87
Consuming low-fat meat												
Yes	-54±6	-45±6	-55±9.8	-8.5±0.7	-8±0.7	-6±1.3	7.9±3.2	8±3.2	4.2±2.4	0.49±2.3	0.8±2.3	-1.2±1.6
No	-60±12	-59±12	-48±18.8	-6±1.5	-7±1.5	-6±2.6	-0.3±6.6	-0.4±6.7	-1.5±4.5	1.5±4.8	0.2±4.8	-7.7±2.9
	0.29	0.35	0.74	0.2	0.4	0.93	0.26	0.25	0.27	0.85	0.9	0.06
Using measuring cup for oil												
Yes	-49±6	-49±6	-58±9	-8±0.8	-7.8±0.8	-5±1.4	7.3±3.4	6.8±3.4	2.4±2.4	1.3±2.4	1.6±2.4	-2.7±1.6
No	-45±10	-45±10	-36±17	-8±1.3	-0.8±1.2	-9±2.5	3.7±5.5	5.2±5.5	4.5±4.4	-1±4	-2±3.9	-2.7±2.9
P value	0.7	0.7	0.28	0.9	0.6	0.2	0.57	0.8	0.68	0.6	0.44	0.98
Using measuring cup for salt												
Yes	-50±6	-50±6	-60±9	-8±0.7	-7.8±0.7	-5.6±1.3	7.3±3.5	6.9±3.3	2.5±2.4	-0.4±2.4	-0.1±2.4	-2.9±1.6
No	-42±10	-42±11	-29±18	-8±1.3	-8.7±1.3	-8±2.5	3.5±5.8	4.5±5.8	4.2±4.4	3.8±4.2	3±4.2	-2±2.9
P value	0.5	0.5	0.14	0.8	0.6	0.4	0.5	0.7	0.75	0.38	0.5	0.78
Boiling as the main cooking method												
Yes	-43±6.5	-43±6	-44±10	-8±0.8	-7.9±0.8	-6.5±1.5	9±3.4	9.2±3.5	3.6±2.6	1.4±2.5	2.1±2.5	-0.7±1.7
No	-59±9	-58±9.7	-70±15	-7.8±1.2	-8±1.2	-5±2.2	0.6±5	0.1±5.2	1.6±3.9	-1±3.7	-2.5±3.8	-6.8±2.5
P value	0.16	0.2	0.2	0.7	0.7	0.6	0.17	0.15	0.69	0.59	0.32	0.6
Frying as the main cooking method												
No	-44±6.6	-44±6.8	-44±11	-8±0.8	-8±0.8	-6±1.5	9.1±3.5	9.2±3.6	3.1±2.7	1.2±2.6	2±2.6	-1.1±1.7
Yes	-55±9	-54±9	-69±15	-7±1.1	-8±1.1	-6±2	1.1±4.9	0.9±5	2.6±3.7	-0.5±3.6	-2.1±3.7	-5.6±2.5
P value	0.3	0.3	0.1	0.5	0.9	0.9	0.19	0.18	0.9	0.7	0.36	0.15

Model I: Adjusted for age and sex; 2) Model II: Adjusted for age, sex, smoking, economic status, physical activity and education; 3) Values are mean± standard error, otherwise indicated.

changes of waist circumference in crude and after adjustment for age and sex in model I, but not in model II in the total population. After subgroup analysis based on gender, these significance differences were found in men in crude, model I, and even in model II after adjusting for potential confounders, but these results were not found in women. However, consumption of fast food is rapidly spreading among Iranians (29), and the results from the Tehran Lipid and Glucose Study has shown that there was a significant association between eating fast food and increased waist circumference in Iranian adults (29). Also, there was a direct correlation between increased BMI and fast food consumption (29-31). After reviewing the seven cohort studies by Rosenheck in a systematic review study, six of these cohort studies revealed a positive association between eating fast food and increased BMI (32). Fast foods contain much less micronutrients (32), a lot of fat, sugar and salt, high energy density, and larger portion sizes with lower fiber that increase weight, waist circumference, and BMI (30, 33).

There was no significantly association between dining out and mean changes of diastolic/systolic blood pressure after potential confounders (model II) in total population. Anyway, the desire for dining out is developing in Iran and other countries. It is difficult to control salt intake and consequently, blood pressure (29, 34). However, studies have reported that salt intake in restaurant is more than salt intake at home in other countries (35, 36).

Some unexpected statistically significant differences were found between adding mayonnaise (high-fat condiments) and salt to food when eating and decreased mean changes of waist circumference in model II in total population. These associations were stable in women for consuming mayonnaise, but not in men. Management and treatment of high waist circumference by participants during these 10 years might be the reason of the unexpected results of our study (9). Also, there was no association between adding salt to food when eating and decreased/increased mean changes of waist circumference in men and women after subgroup analysis. None of other dietary habits in our study were associated with cardiometabolic risk factors either in crude or fully adjusted models that was similar to another follow-up study reporting the lack of association between some dietary intake such as fiber, sugar, fruit, vegetable, and changes of cardiometabolic risk factors (37).

The current study is the first study about the effect of dietary habits on mean changes of components of MetS in the Iranian population based on a 10-year follow-up study. This might be the strengths and novelty of the present study. Also, the population representative of Yazd city with adjusting for maximum potential confounders is strength of the study.

Several limitations should be considered before using the results of the study: 1) dietary habits were considered based on oral responses to a questionnaire as yes/no. It would be better to consider the frequency of food consumption, 2) we could not check the stability of dietary habits during 10 years of the study, and also dietary intake was not assessed in the study, 3) it was better to perform the follow-up assessment in a shorter period of time, 4) despite the investigators' attempts in the study, 30% of participants who had MetS at the baseline were lost to follow-up in phase II; however, loss to follow-up is common in cohort studies, 5) to know the exact time of disappearance and remission of MetS and dietary habits behaviors, the study should be repeated each year because of possible treatment or managements of MetS by participants.

In conclusion, the results of the current study indicated that there are some expected and unexpected associations between dietary habits behaviors and changes in cardiometabolic risk factors in the patients with metabolic syndrome after a 10-year follow-up. Consumption of high-fat dairy increased fasting blood glucose significantly. Also, eating fast food had a significant association with higher waist circumference in crude status and model I in the total population under study. Furthermore, consumption of fast food was associated with higher waist circumference in men after adjustment for all potential confounders. Adding mayonnaise and salt to food when eating were associated with decreased mean changes of waist circumference and the association remains in women for consuming mayonnaise after adjustment for all potential confounders.

To confirm these findings, further cohort studies especially longitudinal studies are required. However, to reduce cardiometabolic risk factors, management and treatment of MetS and its components by changing the lifestyle especially in the field of dietary habits behaviors are recommended.

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Correspondence:
Mohammad Hossein Soltani
Yazd Cardiovascular Research Center, Shahid Sadoughi University of Medical Sciences, Yazd, Iran
E-mail: mhsoltane@gmail.com