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Dietary variety score and risk of metabolic syndrome incidence: Tehran Lipid and Glucose Study

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ABSTRACT

Purpose There are contradictions in the association between dietary variety and metabolic syndrome (MetS). The concept of dietary variety should be merged with other dietary recommendations including diet quality and proportion. We aimed to investigate the association of the healthy food diversity index with MetS and its components in Iranian adults.

Design/methodology/approach In this prospective study, 4654 subjects (62.0% women) were chosen from participants of the Tehran Lipid and Glucose Study. Diet was assessed based on a valid and reliable semi-quantitative Food Frequency Questionnaire. The healthy food diversity index was based on 26 food groups extracted from the 2020 dietary guideline. MetS was defined based on the Iranian-modified National Cholesterol Education Programme and Adult Treatment Panel III.

Findings The mean±SD ages of men and women were, respectively, 39.3±14.7 and 36.1±12.1 years. The incident cases of MetS were 1129 during a median follow-up of 3.31 years. Participants in the top quartiles of diversity score had higher educational levels, also they were likely to be older, female and were less likely to be current smokers in comparison to those in the lower quartiles ($p<0.05$). After adjustment of potential confounders, participants in the top quartile of the healthy food diversity score had lower risk of hypertriglyceridaemia (HR 0.14; 95% CI 0.05 to 0.25) and high fasting blood glucose (FBG) (HR 0.11; 95% CI 0.02 to 0.21, P trend=0.004) in comparison to those in the lowest quartile. There was no significant association between the healthy food diversity score and risk of MetS and the other components of MetS after adjustment of confounding factors.

Originality Increasing diversity score may be sufficient to reduce the risk of hypertriglyceridaemia and high FBG, but the healthy food diversity score is not associated with the risk of MetS incidence in the Tehranian population.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Variety in food consumption as recommended in dietary guidelines contributes to nutrient adequacy. There are contradictions about the effect of healthy and unhealthy food varieties on the prevention of cardiovascular risk factors.

WHAT THIS STUDY ADDS

⇒ Higher healthy food diversity scores reduce the risk of hypertriglyceridaemia and high fasting blood glucose.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The healthy food diversity index regards three aspects of dietary guidelines; variety (the number of foods), quality (similarity with dietary guidelines) and proportion (balance of food group intakes). So this index better considers a healthy diet than traditional measures.

INTRODUCTION

Non-communicable diseases (NCDs) were accountable for 41 million death each year, equal to 74% of all mortality worldwide, twofold the number of deaths from acute and infectious diseases.[1] The percentage of people with more than one chronic disease has been evaluated to be 25%–50%.[2] Cardiovascular diseases (CVDs), diabetes and metabolic syndrome (MetS) are the most frequent and high-cost chronic diseases.[3]

Previous studies indicated that diet modifications can prevent most NCDs.[4] During the last three decades, different dietary recommendations have been developed to prevent and manage NCDs. At first, most dietary recommendations for controlling NCDs were based on data about nutrient intakes and distinct foods; however, foods are not consumed separately and the quality effect of a whole diet such as dietary patterns on chronic diseases has been progressively studied in epidemiological studies.[5] For most people, high exposure to energy-dense foods makes it difficult to expand and sustain healthful dietary patterns[6] so novel strategies to assist healthy food choices should be promoted. People have natural preferences for eating a wider variety of foods,[7] also variety in food consumption as recommended in dietary guidelines contributes to nutrient adequacy.[6] On the other hand, variety can induce an increase in calorie intake and

general and abdominal obesity.[8 9] Higher dietary diversity was certainly related to being overweight in Chinese men.[10] High diversity within the fruit, vegetable and dairy food groups reduced the risk of diabetes in the EPIC-Norfolk study and MetS in Korean adults.,[11 12] In cross-sectional studies, inverse relationships were observed between dietary variety score and the risk of MetS[13 14] so there are contradictions in the association between food variety and cardiovascular risk factors. Variety within excess consumption of unhealthy food groups may only be harmful. Also, variety within healthy food groups may only be favourable when consumed in suitable amounts.[15] So the concept of dietary variety in dietary guidelines should be merged with other dietary recommendations including diet quality and proportion; previous dietary variety indices did not consider dietary variety along with these dietary recommendations; therefore, the healthy food diversity index regards three aspects of dietary guidelines; variety (the number of foods), quality (similarity with dietary guidelines) and proportion (balance of food group intakes).[15] This index acknowledges a greater number of healthy food groups consumption with the proper amount recommended in the dietary guidelines. In this study, we aimed to look over the association of the healthy food diversity index with MetS and its components in a group of Tehranian adults.

METHODS

Subjects of this cohort study were chosen from participants of the Tehran Lipid and Glucose Study (TLGS),[16 17] a population-based ongoing study performed to determine risk factors for NCDs in a group of residents of District 13 of Tehran, the capital of Iran. The first survey was done from 1999 to 2001 on 15 005 individuals aged ≥3 years, using the multistage stratified cluster random sampling technique, and follow-up surveys were performed every 3 years; 2002–2005 (survey 2), 2005–2008 (survey 3), 2008–2011 (survey 4) and 2012–2015 (survey 5) to find out recently developed diseases.

Of individuals entered in surveys 3 (42%) and 4 (58%), the baseline of our study, respectively, 3682 and 7897 subjects were chosen based on age-stratified and sex-stratified random sampling for dietary assessment.

To investigate prospectively the association between the healthy food diversity index with MetS and its components, participants aged ≥18 years with accessible dietary, anthropometric and biochemical data were selected (n=8177) as the baseline population and followed until survey 5 for MetS measurements. Pregnant or lactating women were excluded from these subjects. Also, those with MetS recognition at baseline (n=2325), under-reporting or over-reporting of energy intake (<800 or ≥4200 kcal/day) (n=547) and participants with missing any follow-up data (n=632) were kept out. Finally, 4654 subjects stayed and entered in the analysis, 42% and 58% were from surveys 3 and 4, respectively. For MetS components including high triglyceride (TG), low high-density lipoprotein cholesterol (HDL-C), abdominal obesity, high fasting blood glucose (FBG) and high blood pressure (BP), the same study selection outlines were done (figure 1).

Measurements

Data on age, sex, education, smoking status, medical history and medication were obtained at baseline and next surveys using a standardised questionnaire through a personal interview.

Dietary intake measurements

A valid and reliable 168-item semiquantitative Food Frequency Questionnaire was applied for dietary assessment[18]; skilled nutritionists questioned the intake of food items with standard serving sizes through face-to-face interviews. The frequency intake of each food item was changed to intake per day (gram/day) using local household measures. Since the Iranian food composition table (FCT) is not complete, the US Department of Agriculture FCT was used to analyse the nutrients of foods.

The food groups and subgroups were chosen based on the 2020 dietary guideline,[15 19 20] as well as 'emphasis' groups (whole grain, low-fat milk, vegetables, nuts, seeds, and soya products, seafood, oils and fruits), four food groups belong to 'include' (meat, poultry, eggs and refined grains) and 'limit' groups (discretionary solid fats and added sugar). Uniformed cup measurements were estimated to better manage the proportion of food groups. The overall food intake of each individual was aggregated to compute total food volume. The healthy dietary diversity index measures dietary quality, dietary variety (the number of foods) and proportionality as the spreading of food groups in the diet based on the Vadiveloo *et al* study.[15] For calculating the proportion of total food volume, food groups to 'emphasise' equate to 78% of the total food volume including 9.49 cups, and food groups to 'include' and 'limit', respectively, equate to 20% including 2.43 cups and 2% of the total food volume including 0.23 cups, the total recommended cup is 12.15 based on 2000 Kcal intake pattern. Health factor (hf) for each food group was developed by the recommended proportion of food groups multiplied by the proportion of food subgroups; for example, 3 cups of 9.49 cups in the emphasis food groups should derive from low-fat milk (share of low-fat milk: 3/9.49= 0.32), then hf for low-fat milk was equivalent to multiplying share of food subgroup (0.32) by the broad food share (0.78) (0.32×0.78=0.25). For all food groups, hf was computed.

Food share for each food group was calculated by dividing the amount of each food group intake by the total amount of food intake of each individual's diet. Health values of foods were defined by multiplying the food shares of each food group by the hf of that food group.

To measure the health value of the diet, the health values for each individual were summed.

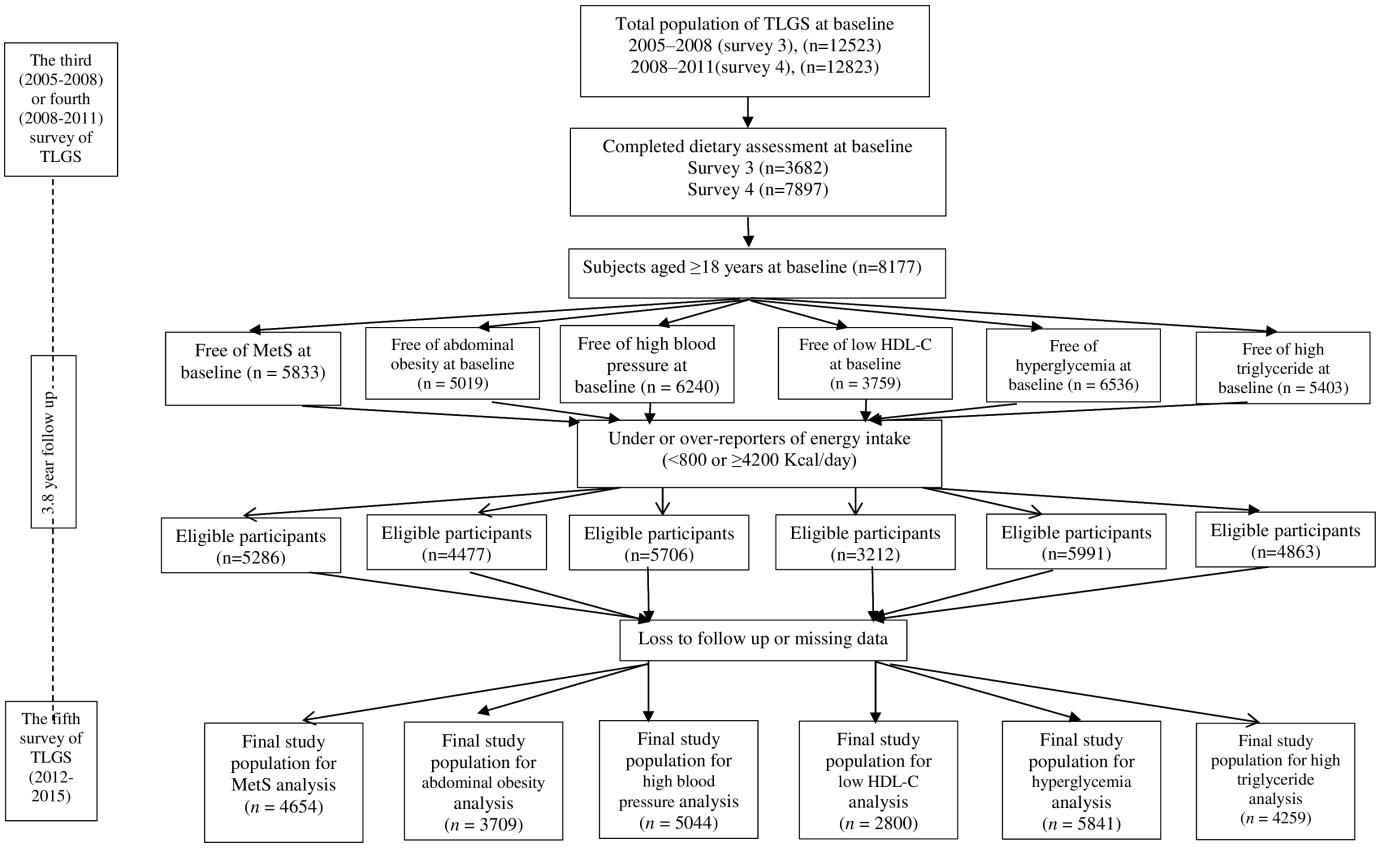

Figure 1 Outline of study participants' selection. HDL-C, high-density lipoprotein cholesterol; MeTS, metabolic syndrome; TLGS, Tehran Lipid and Glucose Study.

Finally, the following equivalent was applied to calculate the healthy dietary diversity index.

$(1-\sum \text{food shares}_i^{\,2}) \times \text{health value of the diet.}$

The score ranged from 0 (belongs to a diet with a single food) to 1 (belongs to a balanced diet with many high-quality foods).[15]

Anthropometric measurement

A trained technician measured the body weight of participants with minimal clothing. A calibrated digital scale (model 707, Seca, Hamburg, Germany) was used and the weights were rounded to the nearest 0.1 kg. Heights were measured by a stadiometer (model 208 Portable Body Meter Measuring Device; Seca) and rounded to the nearest 0.5 cm; the subjects stood in a normal position without shoes. Waist circumference (WC) was measured using an unstretched tape metre without exerting any pressure on the umbilicus and with light clothing.

Physical activity assessment

The trained interviewer questioned physical activity with the Persian-translated Modifiable Activity Questionnaire (MAQ). MAQ has high reliability and moderate validity.[21] Data on the time and frequency of light, moderate, hard and very hard intensity typical activities over the last year were collected. The physical activity levels were estimated based on metabolic equivalent (MET)-hours/week (MET/hour/week).

Laboratory assays

Blood samples were collected into vacutainer tubes between 7:00 and 9:00 hours after a overnight fasting of 12–14 hours while the participants were in a sitting position. The samples were centrifuged within 30–45 min of collection. At the TLGS research laboratory, all biochemical analyses were done on the day of blood collection using a Selectra 2 autoanalyser. The enzymatic colorimetric method and the glucose oxidase technique were used for the measurement of FBG concentration. HDL-C concentration was estimated after condensation of apolipoprotein B-containing lipoproteins with phosphotungstic acid. The evaluation of execution was fixed once in every 20 tests, using lipid control serum, Percinorm (normal range) and Percipath (pathological range), where relevant (Boehringer Mannheim; catalogue no. 1 446 070 for Percinorm and 171 778 for Percipath). On each day of laboratory analysis, a lipid standard (Cfas, Boehringer Mannheim; catalogue no. 759350) was used to calibrate the Selectra 2 autoanalyser. All samples were analysed after controlling the internal quality according to the standard criteria. Both interassay and intra-assay coefficients of variation of all analyses were <5%.

Definitions

The Iranian-modified National Cholesterol Education Programme and Adult Treatment Panel III were

used for MetS definition. Individuals with ≥3 of the following criteria were regarded as MetS phenotype.[22] (1) Abdominal obesity (WC≥95 cm in men and women); (2) BP≥130/85 mm Hg or antihypertensive drug treatment; (3) HDL-C<1.30 mmol/L (<50 mg/dL) in women and <1.04 mmol/L (<40 mg/dL) in men or taking drug treatment; (4) FBG≥6.11 mmol/L (≥110 mg/dL) or taking drug treatment for hyperglycaemia and (5) TG≥1.70 mmol/L (≥150 mg/dL) or taking drug treatment.

Statistical analysis

Statistical analyses were performed by applying the SPSS (V.21.0). A two-tailed p<0.05 was used to resolve statistical significance. The characteristics of participants across quartiles of the healthy dietary diversity score were compared through the χ^2 test for qualitative variables and the one-way analysis of variance for quantitative variables. Log-transformed values were used in statistical analysis for non-normal nutritional and biochemical variables (TG concentration). The multivariable Cox proportional hazard regression models were applied to estimate the HR and 95% CI of incident MetS and its components. The incidence of CVD, MetS or its components during the follow-up period was considered as dichotomous variables (yes/no) in the models. The Healthy dietary diversity score was classified into quartiles and the first quartile was considered as the reference. The survival time for censored individuals was determined as the period between the first and the last examination dates. The mid-time between the date of the follow-up visit at which the events were diagnosed for the first time, and the most recent follow-up visit preceding the diagnosis was determined as the event date for the incidence of MetS and its components.

Study participants were censored due to the end of the surveillance period, death or loss of follow-up. The median of each quartile was used as a continuous variable to assess the overall trends of HRs across quartiles of healthy dietary diversity score in the Cox proportional hazard regression models. Schoenfeld's global test of residuals was applied to assess the proportional hazard assumption of multivariate Cox models.

The Cox regression models for the incidence of MetS and its components concerning healthy dietary diversity score were considered into three models: crude model, without adjustment, model 1 was adjusted for sex and age, model 2 was adjusted for model 1 plus education levels (>14 and ≤14 years), smoking (never smoked, ex-smoker and current smoker), physical activity (continuous), baseline body mass index (BMI) and energy intake. The confounders were selected based on the literature; also, each confounder was entered in the univariable Cox regression model. A two-tailed p<0.20 was used for determining inclusion in the model.

RESULT

Of 4654 participants, 62.0% were women. The mean±SD ages of participants at baseline were, respectively, 39.3±14.7 and 36.1±12.1 years in men and women. The incident cases of MetS were 1129 (543 in men and 586 in women) during a median follow-up of 3.31 years (IQR 2.79–5.05).

The characteristics of study participants based on quartiles of the healthy food diversity score are reported in table 1. Participants in the top quartile of diversity score had higher educational levels, also they were likely to be older, female and were less likely to be current smokers in comparison to those in the lowest quartile (p<0.05). There were no other significant differences in terms of physical activity level and MetS components across quartiles of diversity score. Participants had higher BMI and HDL-C levels in the top quartile, in comparison to the lowest quartile. The percentage of obesity was increased with increasing diversity score (p<0.01).

The food group and nutrient intakes of participants across the healthy food diversity score are shown in table 2. In terms of nutrient intakes, those in the highest category had higher consumption of energy, fat, protein and fibre and lower intakes of carbohydrates in comparison to those in the lowest category of diversity score. In terms of food group intakes, participants in the highest quartile had higher consumption of whole grain, green vegetables, fruit, nuts, and dairy products and lower intakes of sugar, chicken, refined grain, starchy vegetables, fish and egg.

Multivariable-adjusted HR and 95% CIs for Mets and its components based on categories of diversity score are shown in table 3. Although there was a significant relationship between diversity score and MetS in the crude model (HR 1.09; 95% CI 1.01 to 1.19), this relationship did not remain significant after multivariable adjustment in model 1 (HR 1.06; 95% CI 0.98 to 1.16) and model 2 (HR 1.03; 95% CI 0.94 to 1.13).

The HR of general obesity was higher in the top quartile of variety score in the crude model compared with those in the lowest quartile (HR 1.10; 95% CI 1.01 to 1.20), but this relationship did not remain significant after multivariable adjustment. In the last quartile of all three models, crude (HR 1.07; 95% CI 0.98 to 1.17), model 1 (HR 1.04; 95% CI 0.95 to 1.14) and model 2 (HR 0.98; 95% CI 0.93 to 1.69), greater diversity score had no significant relationship with the risk of abdominal obesity.

Participants in the highest quartile of diversity score had lower HR of hypertriglyceridaemia compared with those in the lowest quartile (HR 0.14; 95% CI 0.05 to 0.25) after controlling for potential confounders. Participants in the highest quartiles of diversity score had lower HR of high FBG compared with those in the lowest quartiles (HR 0.11; 95% CI 0.02 to 0.21). HR of high FBG decreased significantly across quartiles of diversity score (P trend=0.004).

There was no significant association between the healthy food diversity score and risk of hypertension (HR

Table 1 Characteristics of the study population, according to the healthy dietary diversity score: the Tehran Lipid and Glucose Study

	Quartiles of the healthy dietary diversity score*				
	Q1	Q2	Q3	Q4	
	<0.08	≥0.08, <0.09	≥0.09, <0.1	≥0.10	P value
Sex (female %)	50.6	59.8	63.7	71.2	<0.001
Age (years)	34.6±12.6	36.8±13.1	38.4±13.9	38.1±13.4	<0.001
Current smoker (%)	5.6	5.8	6.4	4.9	<0.001
Physical activity (MET/min/week)	454±881	604±956	627±882	633±846	0.06
Education level (%)†	65.0	60.4	56.6	60.7	0.005
Baseline BMI (kg/m^2)	22.8±3.3	23.0±3.2	23.8±3.1	24.4±3.3	0.01
Obesity (%)*	11.9	13.2	15.8	16.4	0.001
Baseline WC (cm)	85.9±11.8	86.2±11.7	86.9±111	86.6±11.5	0.19
Abdominal obesity (%)	20.6	22.4	21.6	21.8	0.15
Baseline systolic BP (mm Hg)	107±13.4	108±13.1	108±13.7	107±14.0	0.05
Baseline diastolic BP (mm Hg)	71.9±9.4	72.2±9.5	71.7±9.5	71.4±9.6	0.13
Elevated BP (%)	9.0	10.7	10.8	11.5	0.51
Baseline HDL-C (mg/dL)	43.6±10.8	47.9±10.6	48.6±11.2	49.6±11.2	<0.001
Low HDL-C (%)	47.5	46.0	45.5	43.6	0.31
Baseline TG (mg/dL)	113±61.9	110±56.9	110±63.7	109±52.1	0.24
High TG (%)	18.3	15.3	15.0	15.7	0.08
Baseline FBG (mg/dL)	89.3±15.4	89.6±14.3	89.9±14.5	89.1±13.7	0.48
High FBG (%)	6.8	7.8	7.9	6.8	0.55

The healthy dietary diversity index was designed to measure dietary quality using the 2010 dietary guideline, dietary variety (the number of foods) and proportionality as distributing of food groups in the diet.
*Values are mean±SD unless otherwise listed.
†Educational level ≤14 years.
BMI, body mass index; BP, blood pressure; FBG, fasting blood glucose; HDL-C, high density lipoprotein cholesterol; MET, metabolic equivalent; TG, triglyceride; WC, waist circumference.

in the top quartile of diversity score: 0.99; 95% CI 0.91 to 1.08) and low HDL-C (HR in the top quartile of diversity score: 0.99; 95% CI 0.88 to 1.12).

DISCUSSION

Our study found that participants in the higher quartiles of the healthy food diversity score had significantly lower risk of hypertriglyceridaemia and high FBG incidence compared with those in the lowest quartile in a group of Tehranian adults. Also, the healthy food diversity score was not related to obesity and other components of MetS. Additionally, in our study, the risk of MetS did not change significantly with increasing or decreasing healthy food diversity score.

Previous studies evaluated the relationship between variety score and MetS in a cross-sectional design[13 23]; however, our study evaluated this relationship in a cohort design.

In our study, the risk of high TG and abnormal glucose homoeostasis decreased with increasing diversity score. These results are plausible since people with higher diversity scores consumed more fibre, whole grain, fruit and green vegetables and consumed lower carbohydrate, starchy vegetables and refined grains. Previous studies reported that the risk of high TG increased with higher intakes of refined grains and the risk of high TG decreased with higher consumption of fibre and whole grains.[24] In another study, as whole grain intake increased, FBG levels decreased.[25] The possible mechanism that explains this result is that the fibre of whole grains, which remains as larger particles after mastication, can challenge mechanical and enzymatic degradation and lead to less and longer release of glucose into the bloodstream, which in turn leads to more gradual release of insulin.[26 27]

Although in our study, fat and calorie intake increased with the rise in the dietary diversity score, this increase did not lead to obesity. Previous meta-analysis of cross-sectional studies reported no association between diversity score and overweight/obesity.[28] Findings of the Chinese Health and Nutrition Survey revealed that a higher dietary diversity score was associated with a higher risk of overweight in this population.[10] In US women, an inverse linear association was reported between the

Table 2 Energy, nutrient and food group intakes of study participants across quartiles of the healthy dietary diversity score: the Tehran Lipid and Glucose Study

Nutrients or food groups	Quartiles of the healthy dietary diversity score*				P value
	Q1	Q2	Q3	Q4	
Energy intake (kcal)	2319±769	2346±713	2366±706	2350±720	0.01
CHO intake (% of energy)	60.5±9.5	58.9±8.2	58.7±9.7	57.1±9.5	<0.001
Protein intake (% of energy)	14.1±4.78	14.5±3.0	15.1±3.7	15.6±4.7	<0.001
Total fat (% of energy)	29.3±7.7	31.3±6.7	32.1±6.5	33.5±8.0	<0.001
SFA (% of energy)	9.17±2.8	10.3±5.5	10.7±3.0	12.3±4.1	<0.001
MUFA (% of energy)	10.0±3.0	10.6±2.9	10.6±2.6	11.0±3.2	<0.001
Whole grain†	0.65±2.82	0.78±1.37	0.93±1.42	0.99±1.38	<0.001
Refined grains†	10.51±7.2	7.40±3.24	6.23±2.75	4.92±2.41	<0.001
Dairy†	1.34±0.88	1.76±0.92	2.25±1.15	3.23±1.75	<0.001
Green vegetables†	0.38±0.48	0.48±0.47	0.52±0.44	0.45±0.35	<0.001
Starchy vegetables†	0.72±1.15	0.76±0.82	0.69±0.69	0.58±0.60	0.005
Red and orange vegetables†	0.93±1.35	1.03±2.96	1.08±0.87	0.98±0.83	0.01
Other vegetables†	1.35±1.47	1.56±1.21	1.62±1.02	1.43±0.92	0.001
Fruits†	1.89±3.62	2.39±2.24	3.32±3.08	3.50±2.48	0.19
Nuts and seeds†	0.03±0.08	0.04±0.16	0.04±0.07	0.04±1.06	0.002
Red meat†	0.15±0.20	0.15±0.17	0.15±0.21	0.14±0.15	0.05
Chicken†	0.19±0.30	0.20±0.29	0.21±0.27	0.18±0.21	0.016
Seafood†	0.17±3.23	0.09±0.14	0.10±0.11	0.09±0.13	0.38
Eggs†	0.13±0.17	0.13±0.17	0.13±0.14	0.12±0.15	<0.001
Legumes†	0.38±0.76	0.40±0.48	0.39±0.40	0.32±0.36	<0.001
Discretionary solid fats†	0.19±0.13	0.19±0.12	0.20±0.13	0.21±0.13	<0.001
Oils†	0.03±0.04	0.03±0.03	0.04±0.04	0.04±0.03	0.07
Added sugar†	0.17±0.24	0.16±0.13	0.16±0.13	0.15±0.12	<0.001

*Data are mean ±SD obtained from ANOVA.
†Cup or cup equivalents/day.
ANOVA, analysis of variance; CHO, carbohydrate; MUFA, mono-unsaturated fatty acid; SFA, saturated fatty acid.

dietary diversity score that considers dietary quality and proportionality, and most indicators of body adiposity.[19]

In justifying this finding, several points should be noted while consuming more varied foods, the intakes of total carbohydrates, refined grains, added sugar and starchy vegetables have decreased, which can neutralise the effects of fats[29 30]; also, high-calorie intakes of this subjects could be due to consuming more vegetables, fruits, whole grains and dairy products, that is healthy nutrition pattern. Moreover, in our study, there was a small difference in calorie intake across quartiles of diversity score; however, due to the large sample size of this study, this small difference has become significant. The healthy food diversity score did not evaluate only the number and quantitative amount of foods but also considered proportionality in consumption of 26 food groups; individuals, who had higher scores, consumed a high proportion of healthy food groups and low unhealthy food groups so this index better classifies individuals for understanding the association of dietary variety and obesity.[15]

In our study, the association between variety score and MetS risks became non-significant after adjustment of BMI, and increasing the healthy food diversity score is incapable of reducing the risk of MetS. These findings were consistent with a previous meta-analysis by Qorbani *et al* which reported no significant association between variety score and cardiometabolic risk factors.[31] In contrast to our results, inverse relationships between variety score and MetS risk were also reported by several cross-sectional studies.[12 13 32 33] Vadiveloo *et al* reported that greater dietary variety along with dietary guideline recommendations favourably affects MetS and some of its components.[32] These studies measure prevalent rather than incident cases and the associations identified may be difficult to compare with our study.[34] Furthermore, awareness of disease may induce changes in diet, confound the association and attenuate the protective effect of variety score; however, in our study, only data from newly developed diseases were analysed to reduce the possibility of any dietary behaviour changes. One prospective study has

Table 3 HRs (95% CI) of general obesity, MetS and its components according to quartiles of the healthy dietary diversity score in adult participants: the Tehran Lipid and Glucose Study

	Crude model					Model 1*					Model 2†				
	Q1	Q2	Q3	Q4	P trend	Q1	Q2	Q3	Q4	P trend	Q1	Q2	Q3	Q4	P trend
General Obesity	1	1.06 0.97±1.16	1.13 1.03±1.24	1.10 1.01±1.20	0.01	1	1.04 0.95±1.14	1.09 0.99±1.19	1.08 0.99±1.19	0.04	1	1.03 0.93±1.69	1.09 0.99±1.13	1.04 0.95±1.15	0.19
MetS	1	1.07 0.98±1.16	1.14 1.05±1.24	1.09 1.01±1.19	0.008	1	1.04 0.95±1.12	1.09 1.01±1.19	1.06 0.98±1.16	0.06	1	1.04 0.95±1.13	1.08 0.98±1.18	1.03 0.94±1.13	0.35
Abdominal obesity	1	1.04 0.95±1.14	1.09 1.00±1.19	1.07 0.98±1.17	0.06	1	1.02 0.93±1.12	1.05 0.96±1.15	1.04 0.95±1.14	0.31	1	1.03 0.93±1.13	1.03 0.93±1.14	0.98 0.93±1.69	0.80
High FBG	1	0.24 0.14±0.34	0.17 0.08±0.27	0.12 0.03±0.21	<0.001	1	0.14 0.05±0.23	0.19 0.10±0.29	0.09 0.09±0.18	<0.001	1	1.01 0.99±1.11	0.17 0.08±0.28	0.11 0.02±0.21	0.004
High TG	1	0.14 0.04±0.24	0.11 0.02±0.21	0.10 0.00±0.19	0.01	1	0.09 0.00±0.19	0.10 0.01±0.20	0.07 0.00±1.17	<0.001	1	0.19 0.09±0.29	0.19 0.09±0.30	0.14 0.05±0.25	0.001
High BP	1	1.07 0.99±1.16	1.07 0.99±1.16	1.04 0.97±1.13	0.22	1	1.06 0.98±1.14	1.04 0.96±1.12	1.02 0.94±1.11	0.58	1	1.05 0.96±1.14	1.03 0.94±1.20	0.99 0.91±1.08	0.83
Low HDL-C	1	1.02 0.92±1.14	1.10 0.99±1.22	1.12 1.00±1.24	0.01	1	0.99 0.89±1.10	1.05 0.94±1.17	1.04 0.94±1.16	0.28	1	0.95 0.84±1.07	1.03 0.91±1.15	0.99 0.88±1.12	0.74

Crude model: without adjustment.
*Model 1: adjusted for age, sex.
†Model 2 for general obesity, MetS, abdominal obesity, high FBG, high TG, high BP, low HDL-C: adjusted as model 1 plus education levels (>14 and ≤14 years), smoking (never smoked, ex-smoker and current smoker), physical activity, baseline body mass index and energy intake.
BP, blood pressure; FBG, fasting blood glucose; HDL-C, high density lipoprotein cholesterol; MetS, metabolic syndrome; TG, triglyceride.

also investigated the association between dietary variety score and MetS risk but the variety score was created by factor analysis; however, dietary patterns identified using factor analysis are specific to a particular study population, and such patterns may not be generalisable for other populations, therefore, it cannot be extended to other communities.[12] In our study, people in higher quartiles of variety score had higher amounts of total fat intake, which can neutralise the possible beneficial effects of diversity.

Previous studies reported that variety score is a good index of diet quality and micronutrient adequacy.[35–37] Consistent with this finding, our study showed that dietary intake of nutrient-dense food groups such as vegetables, fruits, whole grains and nuts increased across quartiles of variety score.

As far as we know, there was no cohort study regarding the association between the MetS and variety score. The use of prospective studies with long-term follow-up, large numbers of samples and adjustment of confounding variables are the strengths of our study. In our study, to evaluate food diversity, the healthy food diversity index was used; this index evaluates the quality and proportion of foods in addition to the amount of food diversity so better to consider a healthy diet than traditional measures.

This study has several limitations that should be regarded in the interpretation of the results. In this study, a high variety score seems to reflect an overall healthier lifestyle that may not have been accurately controlled. Also, MetS like other chronic diseases is heterogeneous, and other factors such as hereditary factors may need to be considered in addition to dietary patterns. Furthermore, the inter-relationship of metabolic risk factors could confound the association between variety scores and outcomes.

In conclusion, a higher dietary diversity score is sufficient to reduce the risk of hypertriglyceridaemia and high FBG, but dietary diversity is not associated with the risk of MetS incidence in the Tehranian population; therefore, efforts should be led to expand the healthy dietary diversity score to prevent hypertriglyceridaemia and abnormal glucose homoeostasis.

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