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Adherence to dietary recommendations and risk of metabolic syndrome: Tehran Lipid and Glucose Study

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Abstract

The “Dietary Guidelines for Americans Adherence Index (DGAI) 2005” was developed based on the latest dietary recommendations to assess the contribution of dietary patterns to chronic diseases. The objective of the study was to evaluate the association of dietary patterns as measured by the modified DGAI 2005 with both the prevalence of metabolic syndrome (MetS) and the MetS risk factors. In this population-based cross-sectional study, 2504 adults (1120 men and 1384 women), aged 19 to 70 years, were randomly selected from the third phase of the Tehran Lipid and Glucose Study. Usual dietary intake was assessed using a food frequency questionnaire, and the DGAI score was calculated for all participants. *Metabolic syndrome* was defined according to Adult Treatment Panel III diagnostic criteria. Generally, mean values for waist circumference, triglyceride, and blood pressure were significantly higher among male compared with female participants ($P < .05$). Low high-density lipoprotein cholesterol was the most prevalent MetS risk factor among both men (65.4%) and women (72.5%). After mutual adjustment for confounding variables, those in the highest quartile category of DGAI had a 21% lower prevalence of MetS risk factors clustering than those in the lowest quartile (odds ratio [OR], 0.79; confidence interval [CI], 0.63-0.92; P for trend = .02). Being in the highest quartile category of DGAI score was shown to significantly reduce the prevalence of hyperglycemia (OR, 0.64; CI, 0.47-0.86; P for trend < .001), hypertension (OR, 0.76; CI, 0.70-0.93; P for trend = .05), and low high-density lipoprotein cholesterol (OR, 0.69; CI, 0.54-0.94; P for trend < .001). Consuming a diet consistent with new dietary guidelines was associated with lower risk of MetS prevalence and some of its risk factors. Preventive interventions for MetS risk reduction should focus on the overall dietary pattern.

1. Introduction

Metabolic syndrome (MetS) represents a cluster of metabolic abnormalities characterized by central obesity, hypertension, insulin resistance, prothrombotic state, and atherogenic dyslipidemia. According to the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III), each abnormality of this syndrome can independently increase the atherosclerosis risk; and the clustering of these abnormalities is a risk factor for type 2 diabetes mellitus and cardiovascular disease (CVD) morbidity and mortality [1]. These metabolic abnormalities can also enhance the risk of developing colorectal [2], pancreatic [3], and female breast cancers [4]. Prevalence of MetS is increasing worldwide especially in non-Western Asian countries [5]; and in Iran, the prevalence rate of this disease has increased from 30.1% [6] in 2003 to 34.7% in 2009 [7].

Among several contributing factors that influence the prevalence of MetS, dietary habits play an essential role [8,9]; and accordingly, several studies have assessed the impact of dietary habits on the risk of MetS [10,11].

In 2004, the American Heart Association recommended adherence to the Dietary Guidelines for Americans (DGA) as a dietary approach to decrease the risk of Mets [12]. The DGA 2005 is a departure from earlier versions of DGA in

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introducing updated recommendations and including the concept of discretionary calorie and energy density [13]. The “Dietary Guidelines for Americans Adherence Index (DGAI) 2005” [14] was developed with the aim of measuring the dietary alignment to the DGA 2005 and is reported to be associated with insulin resistance and MetS [15,16]. In Iran, although attempts have been made to assess the relationship between dietary patterns and MetS prevalence [17,18], adherence to latest dietary guidelines and its association with MetS have not yet been assessed. The aims of the present study were therefore to evaluate the association of adherence to DGA 2005 as measured by the modified DGAI 2005 and both the prevalence and clustering of MetS risk factors.

2. Materials and method

2.1. Population and sampling

The Tehran Lipid and Glucose Study (TLGS) [19,20] is a community-based prospective ongoing investigation aimed at preventing noncommunicable diseases by development of a program to promote healthy lifestyle and reduce the noncommunicable disease risk factors. This study is being conducted on a sample of residents under the coverage of 3 medical health centers in District No. 13 of Tehran, the capital city of Iran. These health centers were considered together for analyses, being similar in participants' characteristics including the prevalence of MetS risk factors. During the third phase of the TLGS (2006-2008), a total of 12 523 subjects completed the examinations, of which 4920 were randomly selected for completing the dietary assessment based on their age and sex. The randomization was performed because of cost and complexity of dietary data collection in large populations and also the fact that this process is time consuming. Finally, the dietary data for 3462 subjects who agreed to participate and completed the food frequency questionnaire (FFQ) were available. The characteristics of participants who completed the validated FFQ were similar to those of the total population in the third phase of TLGS. Of participants who completed the FFQ, 45.4% were male compared with 44.1% in the third phase of TLGS. The percentages of the 19- to 70-year-old subjects who completed the FFQs vs the total population of the third phase were 76.7% and 82.3%, respectively. In the third phase of TLGS, 20.1% had academic education and 11.6% were smokers compared with the 25.3% and 12.8% in subjects who completed the FFQ. For the purpose of the present study, only subjects aged 19 to 70 years were selected, making up a population of 2881 adults who were not following a specific diet. We excluded individuals for whom physical activity, anthropometric, and biochemical data were missing (n = 103). The reported energy intake was then divided by the predicted energy intake, and the reports that did not qualify for ±2 SD range were excluded (n = 274). Finally, the data for 2504 adults (1120 men and 1384 women) were analyzed. Informed written consents were obtained from all participants; and the study protocol was approved by the research council of the Research Institute for Endocrine Sciences, Shahid Beheshti University of Medical Sciences.

2.2. Assessment of energy requirement

To obtain various measurements of energy expenditure and physical activity, the physical activity questionnaire of Krishka et al [21] was used. Participants were asked to identify the frequency and time spent during the previous year on activities of light, moderate, hard, and very hard intensity according to a list of common activities of daily life. Metabolic equivalent was calculated according to the compendium of physical activity [22], and it was then used for estimating the energy requirements. Using the dietary reference intake equations, [23] estimated energy requirement was determined according to participants' age, sex, height, weight, and physical activity level.

2.3. Dietary intake assessment

Dietary data were collected by means of a validated semiquantitative FFQ, which contained 168 food items [24]. Trained dietitians with at least 5 years of experience in TLGS survey [20] asked participants to designate their consumption frequency for each food item consumed during the previous year on a daily, weekly, or monthly basis. Portion sizes of consumed foods that were reported in household measures were then converted to grams [25].

Because the Iranian Food Composition Table (FCT) is incomplete, and with limited data on nutrient content of raw foods and beverages [26], foods and beverages were analyzed for their energy and nutrient content using the US Department of Agriculture (USDA) FCT [27]. However, the Iranian FCT was used for some dairy products (like *Kashk*) that are not listed in the USDA FCT [26]. McCance and Widdowson's composition of foods [28] was used to calculate transfat content of foods (not included in USDA FCT). Moreover, the nutrient content of mixed food items (eg, pizza) was calculated according to usual restaurant recipes.

2.4. Dietary Guidelines for American Adherence Intake

To score the prevailing dietary habits of Tehranian adults, the DGAI 2005 was used [14]. This index is composed of 20 dietary item scores and evaluates 16 key recommendations of the DGA 2005 specific to dietary intakes of the general public [14]. Eleven items are related to the calorie-specific “food group recommendation,” and 9 assess the “healthy choice recommendation” [14]. In the present study, only 19 items were attainable; and a component of “healthy choice subscore” (ie, alcohol consumption) was not calculated because most Iranians do not drink because of their religious beliefs. Items of this index have a maximum value of 1.0; and for most items, there is a partial credit of 0.5 for those who did not meet the recommendations fully [14]. Zero point refers to total dietary nonadherence [14]. This index also considers a penalty for overconsumption of energy-dense foods (meat, dairy, grains, and starchy vegetables groups) to limit the likelihood of one obtaining maximum score solely by energy overconsumption [14].

2.4.1. Food group subscore

Each of the 5 vegetable groups (orange, dark green, starchy, and other vegetables and legumes) is scored separately on a weekly basis [14]. We evaluated the consumption pattern of fruit, grain, milk products, and meat group as well as the variety of fruit and vegetables for each participant based on their daily energy intake. *Discretionary calorie* is a concept introduced in the 2005 DGA and is defined as either absolute energy intake or the energy derived from solid fat and added sugar [13]. Because solid fat is included as a score item in the healthy choice recommendation subscore, only the percentage of energy derived from added sugar is considered in the food group subscore [14].

2.4.2. Healthy choice subscore

These dietary recommendations are independent of energy needs and are the same at all energy levels [14]. The percentages of grains consumed as whole grains, fiber intake, sodium intake, and 5 items on fat and cholesterol intake, including total percentage of fat and saturated fatty acid, cholesterol, and transfatty acid intakes and low fat (milk and meat choices) [14], were analyzed as items of this subscore.

2.5. Clinical and biological measurements

Face-to-face private interviews were conducted by trained interviewers for completion of the pretested questionnaires [19]. Initially, age and smoking habits of individuals were obtained. Afterward, weight was measured and recorded to the nearest 100 g with subjects minimally clothed and without shoes while standing on digital scales (Seca, Hamburg, Germany).

Height was measured and recorded to the nearest 0.5 cm using tape meter fixed to a wall while subjects were standing without shoes and with their shoulders in a normal position. Dividing weight in kilograms by square of height in meters, body mass index (BMI) was calculated. Waist circumference (WC) was measured at the umbilical site using an outstretched tape meter and without pressure to body surfaces and was recorded to the nearest 0.1 cm. All measurements were carried out by one examiner for women and one for men to avoid subjective errors.

For blood pressure measurement, participants initially rested for 15 minutes. Before being examined, subjects were asked about drinking tea or coffee, physical activity, smoking, and a full bladder. A qualified physician then measured blood pressure twice in a sitting position, with one initial measurement for peak inflation level using a standard mercury sphygmomanometer. Based on subjects' arm circumference, either an adult or a large cuff was chosen. Cuff was placed on participants' right hand, at heart level, and was inflated until the cuff pressure reached 30 mm Hg above the level of radial pulse disappearance. Between 2 measurements, an at least 30-second interval was considered; and finally, the mean blood pressure recorded in the 2 measurements was reported as the subjects' blood pressure. Deflation of the cuff was performed at 2- to 3-mm/s decrement rate of the mercury column; and *systolic blood pressure* was defined as the appearance of the first sound (Korotkoff phase 1), whereas *diastolic blood pressure* was defined as the disappearance of the first sound (Korotkoff phase 5).

Between 7:00 and 9:00 AM, after 12 to 14 hours of overnight fasting, blood samples were drawn into Vacutainer tubes in a sitting position from all study participants [20]. Samples were centrifuged within 30 to 45 minutes of collection according to the standard protocols. All biochemical analyses were performed at the TLGS research laboratory on the same day of blood collection, and analyses were conducted using Selectra 2 autoanalyzer (Vital Scientific, Spankeren, the Netherlands). Fasting blood glucose (FBG) was measured by the enzymatic colorimetric method using glucose oxidase. Triglyceride (TG) was measured using TG kits (Pars Azmoon, Tehran, Iran) by enzymatic colorimetric tests and with glycerol phosphate oxidase. High-density lipoprotein cholesterol (HDL-C) was measured after precipitation of the apolipoprotein B containing lipoproteins with phosphotungstic acid. Monitoring of assay performance was performed once every 20 tests using lipid control serum, Percinorm (reference range), and Percipath (pathologic range) wherever applicable (Boehringer Mannheim, Mannheim, Germany; catalog no. 1446070 for Percinorm and 171778 for Percipath). Lipid standard (Cfas, Boehringer Mannheim; catalog no. 759350) was used to calibrate the Selectra 2 autoanalyzer for each day of laboratory analyses, and all samples were analyzed when internal quality control met the acceptable criteria. Inter- and intraassay coefficients of variation were 1.6% and 0.6% for TG, respectively [19].

2.6. Definition of terms

Metabolic syndrome was identified according to the diagnostic criteria proposed by NCEP ATP III [29] and was characterized as co-occurrence of at least 3 of the 5 metabolic abnormalities: WC of at least 88 cm for women or at least 102 cm for men, HDL-C less than 40 mg/dL (<1.04 mmol/L) for men and less than 50 mg/dL (1.29 mmol/L) for women or drug treatment, TG of at least 150 mg/dL (1.69 mmol/L) or drug treatment, fasting plasma glucose of at least 100 mg/dL (5.6 mmol/L)or drug treatment of hyperglycemia, and hypertension (systolic blood pressure ≥130 mm Hg or diastolic blood pressure ≥85 mm Hg) or drug treatment for a previous diagnosis of hypertension [29]. We also coded WC according to the newly introduced cutoff points for Iranian adults (94.5 cm for both sexes) but did not consider this coding in calculating the final MetS risk factor clustering because of a lack of relevant information [30].

Table 1
Mean (SD)/median and percentage of participants with abnormal values for each component of the MetS in a group of TLGS participants[a]

	FBG (mmol/L)		TG[b] (mmol/L)		HDL-C (mmol/L)		SBP (mm Hg)		DBP (mm Hg)		WC (cm)		
	Mean (SD)	%	Median (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%[c]	%[d]
Men (n = 1120)	5.15 (1.17)	7.9 (NS)	1.52 (1.09)	45.2	0.98 (0.22)	65.4	116.0 (16.2)	18.7	76.2(10.8)	20.4	94.2(11.1)	22.8	50.2
Women (n = 1384)	5.04 (1.41)	7.9	1.22 (0.97)	31.5	1.16 (0.26)	72.5	108.1 (16.0)	12.6	71.6 (10.1)	11.3	85.3 (13.7)	43.0	25.4

SBP indicates systolic blood pressure; DBP, diastolic blood pressure; NS, not statistically significant among sexes.

[a] *P* value was measured using Student *t* test.

[b] Ln (TG) was used to normalize the distribution of this risk factor's distribution, and the median TG is presented in this table.

[c] According to the ATP III cutoff (88 cm for women and 102 for men).

[d] According to the Iranian cutoff (94.5 cm for both sexes).

2.7. Statistical analysis

All statistical analyses were performed using the Statistical Package for Social Sciences (Version 16.0; SPSS, Chicago, IL). A 2-sided *P* value < .05 was considered significant. Mean (SD) of each MetS risk factors in sex categories was calculated and compared using the Student *t* test. The DGAI was distributed normally and was divided into quartile categories (2.50-7.00 in the first quartile, 7.25-8.25 in the second quartile, 8.50-9.50 in the third quartile, and 9.75-15.00 in the fourth quartile). All MetS component risk factors were shown to have a normal distribution except for TG where Ln was used to normalize the data. After adjustment for age and sex, analysis of covariance was used to compare the characteristics of participants across quartile categories of DGAI; and χ^2 test was used to determine the percentage of low-active participants in 2 different age groups. To determine the *P* value for trend across the DGAI quartiles, linear regression coefficient was used for continuous variables; and logistic regression was used for dichotomous dependent variables.

The association between nutrients and food groups within quartile categories of DGAI was assessed using the covariance analysis adjusted for age, sex, and energy intake. Linear regression was used to calculate the *P* value for trend. Analyses performed for determining mean values of each risk factor of MetS across DGAI quartiles were adjusted for age, sex, energy intake, smoking status, and physical activity; and variables were entered as continuous.

To assess the independency of the relationship between clustering of MetS risk factors and DGAI, odds ratios (ORs) were calculated using logistic regression with the lowest DGAI quartile being considered as the reference category. In the analysis for mean values of MetS risk factors across DGAI quartiles and also in the logistic regression test, participants receiving treatment for any of MetS component risk factors (hypoglycemic agents or insulin, lipid-lowering medication, or antihypertensive medication) were excluded,

Table 2
Characteristics of TLGS participants across DGAI 2005 quartiles[a]

	DGAI 2005 quartile category				
	1	2	3	4	*P* trend[b]
DGAI range[c]	2.50-7.00	7.25-8.25	8.50-9.50	9.75-15.00	
Participants, n	699	626	579	600	
DGAI score, median	6.25	7.75	9.00	10.50	
Healthy choice subscore,[d] median	2.25	3.50	4.00	4.75	
Food group subscore,[e] median	3.50	4.50	5.00	6.00	
Age,[f] y	35.0	37.7	40.9	45.1	<.001
BMI, kg/m^2	26.7	26.9	27.2	26.9	.27
WC, cm	89.22	89.43	89.55	89.07	.90
Light activities participants,[g] %					
19-50 y	47.7	45.8	43.3	40.3	<.001
50-70 y	53.4	41.8	46.0	45.4	.49
Current smokers,[h] %	15.9	14.0	11.1	8.6	<.001

[a] Values are reported as mean or percentages and are adjusted for age and sex unless otherwise noted.

[b] The *P* value for trend was determined using the linear regression coefficient for DGAI score for continuous variables (age, BMI, and WC) and regression coefficient for the dichotomous variables (current smoker and physical activity).

[c] Possible points range from 0 to 19.

[d] Possible points range from 0 to 8 and are assessed at the same level for all subjects.

[e] Possible points range from 0 to 11 and are assessed at 10 different energy levels.

[f] Adjusted for sex only.

[g] The metabolic equivalent values were categorized according to intensity using American College of Sports Medicine/Centers for Disease Control and Prevention (ACSM/CDC) guidelines. Only percentage of light active participants is reported in this table.

[h] Smoking status was classified according to the World Health Organization guidelines.

leaving 2401 subjects for the analysis of blood glucose, 2385 for the analysis of HDL-C and TG, and 2392 for the analysis of blood pressure.

3. Results

Of 2504 study participants, 44.7% were men and 55.3% were women, with a mean age of 40.5 ± 13.8 and 38.6 ± 12.9 years for each, respectively. Mean/median values for each of the MetS risk factors and the percentage of individuals with abnormal parameters (vs cutoff) are presented in Table 1. There was a pronounced difference in mean values of MetS risk factors among sexes. Men had a significantly higher mean value for 3 of the 5 MetS risk factors and lower mean value for HDL concentration. Low HDL-C concentration was the most prevalent MetS risk factor among both men and women (65.4% and 72.5%, respectively; $P < .001$).

The mean DGAI score in this study was 8.3 ± 1.9 (range, 2.5-15.0). This score was associated with several healthful lifestyle behaviors (Table 2). After adjustment for age and sex, those in the highest quartile category of DGAI were found to be more nonsmokers ($P < .001$) and physically active in the 19- to 50-year age group (47.7% vs 40.3%; $P < .001$). Older subjects were more likely to obtain a higher DGAI score (45.1 vs 35.0; $P < .001$). Waist circumference and BMI did not differ significantly across the DGAI score quartiles.

Fig. 1 presents the distribution of the total DGAI score and the food group and healthy choice subscores in TLGS participants. More women compared with men scored between 10 and 15 (22.2% vs 11.8%); while comprising a lower proportion in scores 5 to 10 (74.7% vs 83.1%). Women obtained significantly higher scores in both food group subscore and healthy choice subscore ($P < .001$).

Table 3 shows the dietary intake of participants across the DGAI quartile categories. Energy consumption was higher in the highest quartile category of DGAI (2374 vs 2220; $P < .001$); and significantly higher percentage of energy was obtained from carbohydrate and protein ($P < .001$), leaving a lower percentage of energy to be taken from fat in higher quartile categories ($P < .001$). Consumption of both vegetable oil and animal fat dropped significantly moving from the first to the last quartile of DGAI ($P < .001$). In addition, total calorie intake derived from discretionary energy was lower in the highest quartile category of DGAI (22.4% vs 37.9%; $P < .001$).

Figs. 2 and 3 present the means for the risk factors of MetS in their continuous form, according to the quartile categories of DGAI score, healthy choice subscore, and food group subscore. Data are only presented for the risk factors that showed a significant association with DGAI subscores. After adjustment for age, sex, smoking status, and physical activity, FBG was inversely associated with DGAI score and both its subscores ($P < .05$). On the other hand, larger WC was only associated with food group subscore ($P < .001$).

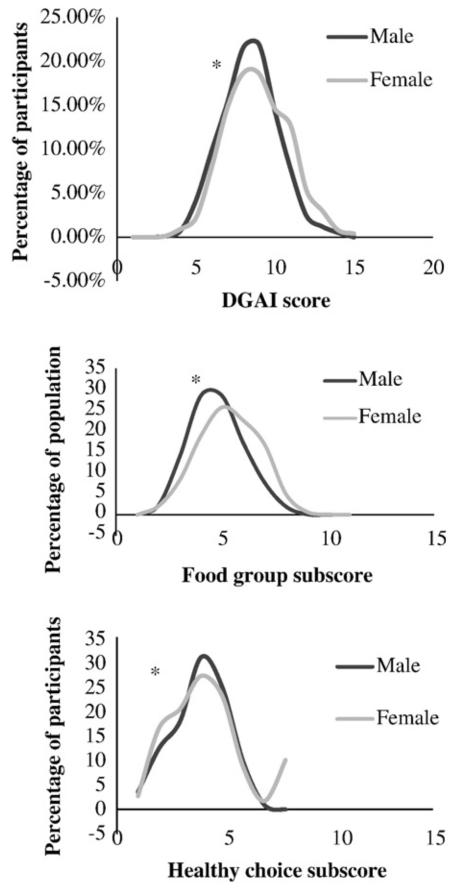

Fig. 1. Distribution of total DGAI 2005 score and its subscores in the TLGS participants. In the present study, DGAI had a maximum score of 19. Food group subscore and healthy choice subscore consisted of 11 and 8 items, respectively. *Statistically significant between sexes ($P < .05$). The proportion of female participants in higher score categories was higher ($P < .001$). As can be seen, the highest percentage of male participants scored between 8 and 9; and women comprised a higher proportion in scores 10 to 15 compared with men. Women scored significantly higher in both subscores ($P < .001$).

Table 4 shows the ORs for the MetS risk factors as dichotomous variables based on the ATP III definition. Those in the highest quartile category of DGAI had an independent lower risk of MetS risk factors clustering (OR, 0.79; confidence interval [CI], 0.63-0.92; P trend = .0.2). Being in the highest quartile category of DGAI reduced the risk of hyperglycemia by 36% (OR, 0.64; CI, 0.47-0.86; P trend < .001) and hypertension by 24% (OR, 0.76; CI, 0.70-0.93; P trend < .05). The risk of having low HDL-C risk also decreased significantly (OR, 0.69; CI: 0.54-0.94; P trend < .001) in the upper quartile category of DGAI.

4. Discussion

The findings of the present study show that the mean values for BP and WC and the median for TG in men were higher compared with women, whereas mean HDL-C

Table 3
Dietary intake of participants of the TLGS by DGAI 2005 quartiles[a]

	DGAI 2005 quartile category				
	1	2	3	4	*P* trend[b]
DGA score, range	2.50-7.00	7.25-8.25	8.50-9.50	9.75-15.00	
Total reported energy, kcal/d	2220	2194	2251	2374	<.001
Carbohydrate, % of energy intake	53.8	57.3	58.7	60.9	<.001
Protein, % of energy intake	12.8	13.4	14.1	14.8	<.001
Fat, % of energy intake	35.2	31.5	29.9	27.8	<.001
Cholesterol, mg	258	223	220	203	<.001
Total fiber, g	26.2	28.3	32.0	32.9	<.001
Fruit, cup equi/d	1.4	1.7	2.3	3.2	<.001
Vegetables, cup equi/d	1.7	2.0	2.5	3.5	<.001
Meat,[c] oz equi/d	3.5	3.5	3.7	4.3	<.001
Whole grain, oz equi/d	1.9	2.9	3.1	3.9	<.001
Refined grain, oz equi/d	9.8	6.0	6.1	5.8	.44
Dairy products, cup equi/d	2.4	2.4	2.6	2.9	<.001
Vegetable oil,[d] g	57.8	51.4	51.0	50.3	<.001
Animal fat, g	76.6	61.9	57.5	49.3	<.001
Discretionary calorie, %	37.9	31.7	27.6	22.4	<.001

[a] Values are adjusted for age, sex, and energy intake.
[b] *P* value for trend was calculated using the linear regression coefficient for the DGAI score for each subject.
[c] Taking into account the DGA recommendations, legumes were assigned to the meat group for those who needed to meet the 1.0-point criterion for meat intake; and the extra was counted toward the vegetable group.
[d] Described as fat from either a plant source (including vegetable oil, nuts, and seeds) or a fish source.

concentration was higher in women. Participants whose dietary patterns were in close concordance with 2005 DGA had a lower risk of overall MetS prevalence and some of its risk factors, independent of age, sex, energy intake, physical activity, and smoking status.

Studies concerning the prevalence of MetS in TLGS [6,31,32] found an upward trend in MetS prevalence with age advancement. In 2003, 30.1% of adults aged at least 20 years had MetS ;and later studies showed a prevalence rate of 24% in male adults and 40.5% in female adults. In subjects aged at least 65 years, the prevalence rate of MetS was reported to be 50.8% in 2009.

Regarding the impact of dietary intake on MetS risk factors, several studies have been conducted. McCullough and colleagues [33,34] have evaluated the impact of adherence to earlier versions of DGA [35] on risk of major chronic diseases. They concluded that being in the highest quintile category of the Healthy Eating Index (HEI) was associated with a nonsignificant (14%) reduction in CVD risk in women and a significant (28%) risk reduction in men. They suggest that adherence to earlier versions of DGA assessed by means of HEI may have a modest impact on CVD prevention. The HEI has also been evaluated in predicting other intermediate CVD risk factors and was found to have an inverse association with C-reactive protein in women [36]. The DGAI 2005 was developed by Fogli-Cawley et al [15,16] as an index of adherence to the latest DGA and has been shown to be associated with insulin resistance and MetS in the Framingham Heart Study.

In the present study, we aimed at finding the relationship between a diet consistent with the 2005 DGA and MetS prevalence in a group of Tehranian adults. After mutual adjustment in logistic regression, the modified DGAI used in the present study was shown to be significantly associated with 3 of 5 MetS risk factors (hypertension, hyperglycemia, and low HDL-C); however, in the Framingham Heart Study, DGAI was shown to be significantly associated with WC risk and hyperglycemia [15]. Although WC emerged significant in relation to food score subscore in the present study, it failed to be significantly associated with total DGAI score. However, higher energy consumption in the upper quartile categories of DGAI in an Iranian population could have contributed to lack of significant association between WC and DGAI, although higher energy consumption could have been the result of being more physically active in upper quartile categories. Hypertriglyceridemia failed to show any significant association with the DGAI quartile categories, a finding in line with those of other studies evaluating the association of DGAI [15], Dietary Approaches to Stop Hypertension diet, and HEI with hypertriglyceridemia [37,38]. Unlike the findings of Fogli-Cawley et al [15,16], a strong relationship between HDL-C and DGAI (total score and healthy choice subscore) was observed. These discrepancies could be due to the difference in genetic predisposition in the different ethnicities evaluated in addition to the environmental factors like diet and disease patterns [39,40]. Moreover, it highlights the need for development and promotion of country-based dietary indices to address the specific characteristics of dietary patterns in relation to the disease [41], considering refined grains as a staple food in Middle-East region [42].

A large body of evidence suggests that adherence to dietary patterns rich in fruit, legumes, vegetables, whole grain, and fish could decrease the risk of all-cause mortality,

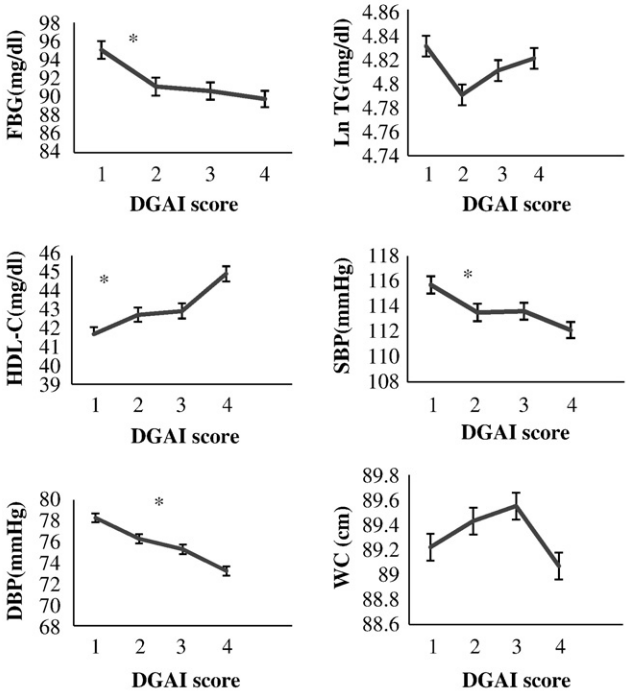

Fig. 2. Means for each of the MetS risk factors according to quartile categories of the DGAI 2005 score. *P < .05. Values are adjusted for sex, age, energy intake, smoking status, and physical activity. SBP indicates systolic blood pressure; DBP, diastolic blood pressure. Quartile categories of DGAI (first quartile: 2.50-7:00, second quartile: 7:25-8.25, third quartile: 8.50-9.50, and fourth quartile: 9.75-15:00). Participants receiving treatment for any of the MetS component risk factors (receiving hypoglycemic agents or insulin, lipid-lowering medication, or antihypertensive medication) were excluded from analysis, leaving 2401 subjects for the analysis of blood glucose, 2385 for the analysis of HDL-C and TG, and 2392 for the analysis of blood pressure. Fasting blood glucose and SBP were inversely associated with DGAI score, whereas low HDL-C risk was found to be inversely associated with the DGAI score.

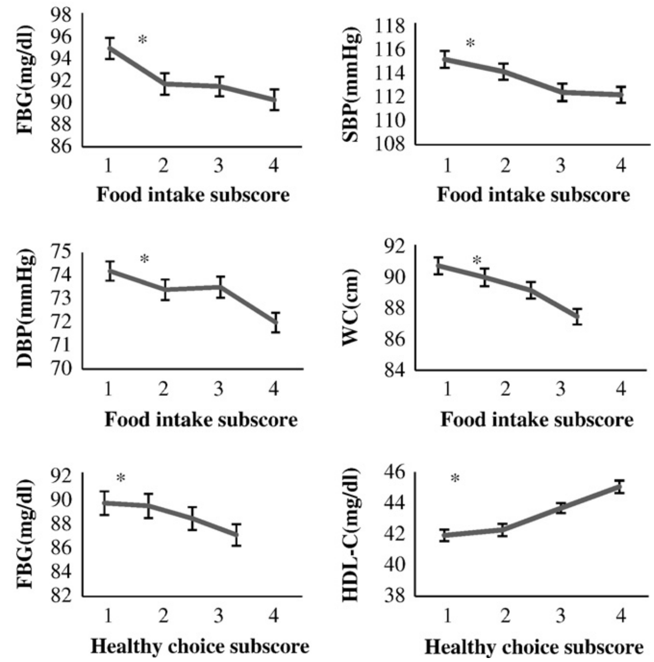

Fig. 3. Means for each of the MetS risk factors according to quartile categories the food group and healthy choice subscores. *P < .05. Values are adjusted for sex, age, energy intake, smoking status, and physical activity. Quartile categories of food group subscore (first quartile: −1.00 to 4.00, second quartile: 4.25-4.50, third quartile: 4.75-6.00, and fourth quartile: 6.25-9.50) and healthy choice subscore (first quartile: 0.00-2.50, second quartile: 2.50-3.50, third quartile 3: 3.75-4.50, and fourth quartile: 4.75-7.25). Participants receiving treatment for any of the MetS component risk factors (receiving hypoglycemic agents or insulin, lipid-lowering medication, or antihypertensive medication) were excluded from analysis, leaving 2401 subjects for the analysis of blood glucose, 2385 for the analysis of HDL-C and TG, and 2392 for the analysis of blood pressure. Fasting blood glucose was inversely associated with both subscores, whereas low HDL-C risk was found to be inversely associated with the healthy choice subscore, and SBP was found to be inversely associated with the food group subscore.

various types of cancer, dyslipidemia, large WC, hyperglycemia, and coronary heart disease [18,43,44].The high content of β-carotene, vitamins C and E, polyphenols, and various minerals; the high intake of monounsaturated fat, complex carbohydrate, and fiber; and the low intake of saturated fat in these dietary habits all contribute to the beneficial effect of diet on the health of human beings [45]. These dietary habits improve lipid profiles, endothelial function, and insulin resistance and decrease the risk of thrombosis, inflammatory marker concentrations, and ventricular irritability [46]. The DGA 2005 consists of dietary goals that reflect a healthy dietary pattern and could promote health. In the present study, a healthier lifestyle pattern was observed in terms of smoking and physical activity in the higher quartile categories of DGAI; in addition, significantly higher intakes of fruit, vegetables, whole grains, and dairy products along with lower intakes of oil (both vegetable and solid), discretionary calorie, refined grains, cholesterol, and total fat were noticed in the higher quartile categories of DGAI score.

The findings of the present investigation are subject to several potential limitations. Firstly, because a standard quantitative dietary guideline for Iranian population [47] is not available, we assessed the dietary habits of adults among DGA 2005, which was developed for the American population. To compensate for this limitation, we assessed the face validity of this tool in our population and found that this index was associated with certain participant characteristics. In fact, by using DGAI, we aimed to introduce a modified index for assessing the dietary pattern of Iranian adults; and our results showed that the modified DGAI was associated with several health outcomes, findings that are consistent with results of previous investigations using DGAI, HEI, and Harnack scores [14-34] because dietary indices are created on the basis of previous knowledge of a "healthy diet" and are generally applicable to different ethnic groups [37,48,49]. Dietary scores derived from diet quality tools (HEI, DGAI) have been calculated based on different dietary intake assessment methods (FFQ, dietary recalls, dietary records) [15,50], and the relationship between these

Table 4
Multivariate ORs (95% CI) for the MetS components according to the quartile categories of the DGAI 2005 in participants of TLGS[a,b]

	DGAI 2005 quartile category				
	1	2	3	4	P trend[c]
DGA score, range	2.50-7.00	7.25-8.25	8.50-9.50	9.75-15.00	
Mean no. of risk factors	1.99	1.74	1.62	1.49	
Component risk factors[d]					
Large WC[e]	1[f]	0.89 (0.65-1.00)	1.06 (0.89-1.31)	0.88 (0.61-1.19)	.29
Large WC[g]	1	0.74 (0.52-1.07)	1.03 (0.82-1.25)	0.72 (0.69-1.04)	.52
Hyperglycemia	1	0.74 (0.49-0.89)	0.67 (0.59-0.81)	0.64 (0.47-0.86)	<.001
Hypertriglyceridemia	1	0.98 (0.82-1.09)	0.97 (0.72-1.13)	1.14 (1.01-1.26)	.41
Low HDL	1	0.84 (0.62-0.90)	0.85 (0.73-0.95)	0.69 (0.54-0.94)	<.001
Hypertension	1	0.95 (0.71-1.01)	0.92 (0.56-0.97)	0.76 (0.70-0.93)	.05
MetS[h]	1	0.94 (0.89-1.08)	0.91 (0.78-1.03)	0.79 (0.63-0.92)	. 02

[a] Values are adjusted for age, sex, energy intake, physical activity, and smoking status.
[b] Participants receiving treatments for any risk factors of MetS were excluded from the analysis, leaving 2401 subjects for analysis of hyperglycemia, 2392 for hypertension, and 2385 for hypertriglyceridemia or low HDL-C.
[c] *P* value was calculated based on the logistic regression coefficient.
[d] Diagnostic criteria of NCEP ATP Ш.
[e] Based on NCEP ATP Ш diagnosis criteria (88 cm for women and 102 cm for men).
[f] Reference category.
[g] Based on Iranian WC cutoff (94.5 cm for both sexes).
[h] Having at least 3 component of MetS risk factors according to NCEP ATP Ш.

indices and disease outcomes has been shown in several studies [15,16]. In addition, using data collected in a cross-sectional study cannot truly reveal the adherence to dietary recommendations and also the effect of dietary pattern on the development of MetS. Furthermore, we were unable to measure the alcoholic beverage intake as a DGAI component; and thus, the modified DGAI we used had a maximum score of 19 instead of 20. There were 2 barriers restricting data collection on alcohol consumption in the present study. Firstly, because alcohol consumption is prohibited in Iran, it was assumed that participants would refrain from reporting their consumption. Secondly, because of the ban that exists in Iran on import of alcoholic beverage of any kind, the contents of alcohol in beverages that Iranian consume may differ from that consumed in other countries; and also, the Iranian FCT does not have data on any type of alcohol [26].

Moreover, high variation of the DGAI score in the present study could be due to the fact that DGAI considers partial score cutoffs (0.5 and 0.25) and also penalizes individuals on some items. In contrast, the majority of dietary indices use only few cutoff points (eg, 1 or 2 cutoff values) for each component, which results in a small scale index and leads to loss of information [15,16]. In addition, considering both sexes and the large age group of 19- to 70-year subjects together could be the reason for the large variability in the present study.

An important limitation to consider in interpretation of our results is the use of FFQ for collecting the dietary data, although the FFQ used has previously been shown to be valid [24]. Moreover, DGAI does not include the recommendations on body weight and physical activity components of DGA, which can overpower the association between dietary patterns and chronic diseases [51]. The final limitation is neglecting the role of genetics in risk of MetS due to lack of relevant information.

However, the strength of the present study is being a population-based analysis conducted in a developing country under nutrition transition. Epidemiologic studies of dietary patterns are mostly conducted in Westernized countries; and so, the results are representative for specific developed countries. To our knowledge, this is the first study to assess the impact of dietary pattern on MetS prevalence and its risk factors in an Iranian population. Moreover, assessing the impact of DGAI subscores on MetS risk factors separately is another strength of this study.

In conclusion, elucidation of how dietary pattern is associated with MetS risk factors is valuable; and dietary strategies aimed at this multicomponent syndrome are more beneficial for the public compared with strategies pointing at individual risk factors. Taken collectively, the findings of this research confirm that following a dietary pattern in line with DGA 2005 presents a healthy eating pattern and reduces the risk of MetS clustering and its risk factors in Tehranian adults.

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References

[1] Third report of the National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. Circulation 2002;106:3143-421.

[2] Giovannucci E. Metabolic syndrome, hyperinsulinemia, and colon cancer: a review. Am J Clin Nutr 2007;86(suppl):S836-42.

[3] Russo A, Autelitano M, Bisanti L. Metabolic syndrome and cancer risk. Eur J Cancer 2008;44:293-7.

[4] Xue F, Michels KB. Diabetes, metabolic syndrome, and breast cancer: a review of the current evidence. Am J Clin Nutr 2007;86(suppl): S823-35.

[5] Cheung BM. The cardiovascular continuum in Asia—a new paradigm for the metabolic syndrome. J Cardiovasc Pharmacol 2005;46:125-9.

[6] Azizi F, Salehi P, Etemadi A, et al. Prevalence of metabolic syndrome in an urban population: Tehran Lipid and Glucose Study. Diabetes Res Clin Pract 2003;61:29-37.

[7] Delavari A, Forouzanfar MH, Alikhani S, et al. First nationwide study of the prevalence of the metabolic syndrome and optimal cutoff points of waist circumference in the Middle East: the national survey of risk factors for noncommunicable diseases of Iran. Diabetes Care 2009;32: 1092-7.

[8] Willet WC. Is dietary fat a major determinant of body fat? Am J Clin Nutr 1998;67(suppl):556S-62S.

[9] Meydani M. A Mediterranean-style diet and metabolic syndrome. Nutr Rev 2005;63:312-4.

[10] Lerman RH, Minich DM, Darland G, et al. Enhancement of a modified Mediterranean-style, low glycemic load diet with specific phytochemicals improves cardiometabolic risk factors in subjects with metabolic syndrome and hypercholesterolemia in a randomized trial. Nutr Metab (Lond) 2008;5:29.

[11] Baxter AJ, Coyne T, McClintock C. Dietary patterns and metabolic syndrome-a review of epidemiologic evidence. Asia Pac J Clin Nutr 2006;15:134-42.

[12] Grundy SM, Hansen B, Smith Jr SC, et al. Clinical management of metabolic syndrome: report of the American Heart Association/ National Heart, Lung, and Blood Institute/American Diabetes Association conference on scientific issues related to management. Arterioscler Thromb Vasc Biol 2004;24:e19-e24.

[13] USDA. Dietary Guidelines for Americans, 2005. 6th ed. Washington, DC: US Department of Agriculture and Department of Health and Human Services; 2005.

[14] Fogli-Cawley JJ, Dwyer JT, Saltzman E, et al. The 2005 Dietary Guidelines for Americans Adherence Index: development and application. J Nutr 2006;136:2908-15.

[15] Fogli-Cawley JJ, Dwyer JT, Saltzman E, et al. The 2005 Dietary Guidelines for Americans and risk of the metabolic syndrome. Am J Clin Nutr 2007;86:1193-201.

[16] Fogli-Cawley JJ, Dwyer JT, Saltzman E, et al. The 2005 Dietary Guidelines for Americans and insulin resistance in the Framingham Offspring Cohort. Diabetes Care 2007;30:817-22.

[17] Esmaillzadeh A, Kimiagar M, Mehrabi Y, et al. Dietary patterns, insulin resistance, and prevalence of the metabolic syndrome in women. Am J Clin Nutr 2007;85:910-8.

[18] Esmaillzadeh A, Kimiagar M, Mehrabi Y, et al. Fruit and vegetable intakes, C-reactive protein, and the metabolic syndrome. Am J Clin Nutr 2006;84:1489-97.

[19] Azizi F, Ghanbarian A, Momenan AA, et al. Prevention of non-communicable disease in a population in nutrition transition: Tehran Lipid and Glucose Study phase II. Trials 2009;10:5.

[20] Azizi F, Rahmani M, Emami H, Madjid M. Tehran Lipid and Glucose Study: rationale and design. CVD Prevention 2000;3:242-7.

[21] Krishka AM, Knowler WC, Laporte RE, et al. Development of questionnaire to examine relationship of physical activity and diabetes in Prima Indians. Diabetes Care 1999;13:401-11 Reprinted in: Modifiable activity questionnaire. Med J Sports Exerc 1997; 29: S73-8.

[22] Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc 2000;32(9 Suppl):S498-S504.

[23] A Report of the Panel on Macronutrients, Subcommittees on Upper Reference Levels of Nutrients and Interpretation and Uses of Dietary Reference Intakes, and the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. Dietary reference intake for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids (macronutrients). Washington, DC: The national Academic Press; 2005.

[24] Mirmiran P, Hosseini Esfahani F, Mehrabi Y, et al. Reliability and relative validity of a food frequency questionnaire for nutrients in the Tehran Lipid and Glucose Study. Public Health Nutr 2009;13:654-62.

[25] Ghaffarpour M, Houshiar-Rad A, Kianfar H. The manual for household measures, cooking yields factors and edible portion of food. Tehran: Keshaverzi press; 1999.

[26] Azar M, Sarkisian E. Food Composition Table of Iran. Tehran: National Nutrition and Food Research Institute. Shahid Beheshti University Press; 1980.

[27] The Nutrient Data Laboratory. Food Composition Table (FCT), food and nutrition information center, United States Department of Agriculture (USDA). www.nal.usda.gov/fnic/foodcomp.

[28] Robertson CE. McCance and Widdowson's the composition of foods-sixth edition; 2002.

[29] Grundy SM, Cleeman JI, Daniels SR, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute scientific statement. Circulation 2005; 112:2735-52.

[30] Hadaegh F, Zabetian A, Sarbakhsh P, et al. Appropriate cut off value of anthropometric variables to predict cardiovascular outcomes: 7.6 years of follow-up in an Iranian population. Int J Obes 2009;33:1437-45.

[31] Zabetian A, Hadaegh F, Azizi F. Prevalence of metabolic syndrome in Iranian adult population, concordance between the IDF with the ATPIII and the WHO definitions. Diabetes Res Clin Pract 2007;77:251-7.

[32] Hadaegh F, Zabetian A, Tohidi M, et al. Prevalence of metabolic syndrome by the Adult Treatment Panel III, International Diabetes Federation, and World Health Organization definitions and their association with coronary heart disease in an elderly Iranian population. Ann Acad Med Singapore 2009;38:142-9.

[33] McCullough ML, Feskanich D, Rimm EB, et al. Adherence to the Dietary Guidelines for Americans and risk of major chronic disease in men. Am J Clin Nutr 2000;72:1223-31.

[34] McCullough ML, Feskanich D, Stampfer MJ, et al. Adherence to the Dietary Guidelines for Americans and risk of major chronic disease in women. Am J Clin Nutr 2000;72:1214-22.

[35] Kennedy ET, Ohls J, Carlson S, et al. The Healthy Eating Index: design and applications. J Am Diet Assoc 1995;95:1103-8.

[36] Ford ES, Mokdad AH, Liu S. Healthy Eating Index and C-reactive protein concentration: findings from the National Health and Nutrition Examination Survey III, 1988-1994. Eur J Clin Nutr 2005;59:278-83.

[37] Drewnowski A, Fiddler EC, Dauchet L, et al. Diet quality measures and cardiovascular risk factors in France: applying the Healthy Eating Index to the SU.VI.MAX study. J Am Coll Nutr 2009;28:22-9.

[38] Obarzanek E, Sacks FM, Vollmer WM, et al. Effects on blood lipids of a blood pressure-lowering diet: the Dietary Approaches to Stop Hypertension (DASH) Trial. Am J Clin Nutr 2001;74:80-9.

[39] Esmaillzadeh A, Azadbakht L. Major dietary patterns in relation to general obesity and central adiposity among Iranian women. J Nutr 2008;138:358-63.

[40] Gao SK, Beresford SA, Frank LL, et al. Modifications to the Healthy Eating Index and its ability to predict obesity: the Multi-Ethnic Study of Atherosclerosis. Am J Clin Nutr 2008;88:64-9.

[41] Freeland-Graves J, Nitzke S. Position of the American Dietetic Association: total diet approach to communicating food and nutrition information. J Am Diet Assoc 2002;102:100-8.

[42] Atinmo T, Mirmiran P, Oyewole OE, et al. Breaking the poverty/malnutrition cycle in Africa and the Middle East. Nutr Rev 2009;67 (Suppl 1):S40-6.
[43] Schaefer EJ, Lamon-Fava S, Ordovas JM, et al. Factors associated with low and elevated plasma high density lipoprotein cholesterol and apolipoprotein A-I levels in the Framingham Offspring Study. J Lipid Res 1994;35:871-82.
[44] Panagiotakos DB, Chrysohoou C, Pitsavos C, et al. The association of Mediterranean diet with lower risk of acute coronary syndromes in hypertensive subjects. Int J Cardiol 2002;82:141-7.
[45] Trichopolous S, Lagiou P. Dietary patterns and mortality. Br J Nutr 2001;85:133-4.
[46] Knapp HR. Dietary fatty acids in human thrombosis and hemostasis. Am J Clin Nutr 1997;65(5 Suppl):1687S-98S.
[47] Safavi SM, Omidvar N, Djazayery A, et al. Development of food-based dietary guideline for Iran: a preliminary Report. Ann Nutr Metab 2007;51(suppl 2):32-5.
[48] Azadbakht L, Mirmiran P, Hosseini F, et al. Diet quality status of most Tehranian adults needs improvement. Asia Pac J Clin Nutr 2005;14: 163-8.
[49] Fisberg RM, Morimoto JM, Slater B, et al. Dietary quality and associated factors among adults living in the state of São Paulo, Brazil. J Am Diet Assoc 2006;106:2067-72.
[50] Guo X, Warden BA, Paeratakul S, Bray GA. Healthy Eating Index and obesity. Eur J Clin Nutr 2004;58:1580-6.
[51] Harnack L, Nicodemus K, Jacobs Jr DR, et al. An evaluation of the Dietary Guidelines for Americans in relation to cancer occurrence. Am J Clin Nutr 2002;76:889-96.