

Dietary diversity score and cardiovascular risk factors in Tehranian adults

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Abstract

Aim: To evaluate the relationship between dietary diversity score (DDS) and cardiovascular risk factors in Tehranian adults.

Methods: In this population-based cross-sectional study, a representative sample of 581 subjects (295 males and 286 females) aged over 18 years, residents of Tehran, participated. Hypercholesterolaemia, hypertriglyceridaemia and low high-density lipoprotein cholesterol were defined according to the Adult Treatment Panel III guidelines of the National Cholesterol Education Program. Diabetes was defined as fasting plasma glucose concentration ≥ 126 mg dl⁻¹ or 2-h post challenge glucose concentration ≥ 200 mg dl⁻¹. Hypertension was defined on the basis of the sixth report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure. Dietary diversity was defined according to the Diet Quality Index revised.

Results: Mean (\pm standard deviation) DDS was 6.15 ± 1.02 . The probability of having diabetes (odds ratio (OR) among quartiles: 1.45, 1.26, 1.11 and 1.00, respectively; *P* for trend = 0.04) and hypertriglyceridaemia (OR = 1.41, 1.23, 1.05 and 1.00, respectively; *P* for trend = 0.04) decreased with increasing quartile of the diversity score for whole grains. The probability of having obesity (OR among quartiles: 1.39, 1.06, 1.03 and 1.00, respectively; *P* for trend = 0.03), hypercholesterolaemia (OR = 1.46, 1.28, 1.11 and 1.00, respectively; *P* for trend = 0.03), hypertension (OR = 1.32, 1.17, 1.13 and 1.00, respectively; *P* for trend = 0.03) and high low-density lipoprotein cholesterol (LDL-C) (OR = 1.25, 1.12, 1.07 and 1.00, respectively; *P* for trend = 0.04) decreased with increasing quartile of the diversity score for vegetables. The probability of having hypercholesterolaemia, high LDL-C, hypertension and diabetes decreased with quartile of the DDS. But the probability of being obese increased with quartile of the DDS (*P* for trend = 0.03).

Conclusion: DDS was inversely associated with cardiovascular risk factors in this cross-sectional study. Increased diversity scores of diets, to increase the variety score for vegetables, may be emphasised in programmes attempting to bring about changes in lifestyle.

Keywords
Dietary diversity score
Cardiovascular risks
Variety

In contrast to trends observed in northern Europe and the USA¹, recent data show that mortality from cardiovascular diseases (CVD) is increasing in Iran². Further progress in prevention may depend on identifying the population at increased risk for CVD. Previous studies in this population showed that 22% of men and 24% of women aged 20 years and above had hypertension. Fourteen per cent of men and 29% of women in this population were obese, while 23% of the total population had high levels of total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C). Hypertriglyceridaemia was seen in 4% of people³. Although CVD have heterogeneous aetiologies, environmental factors, including diet, play a major role in their development⁴. The role of nutrients in preventing CVD risk is known^{5,6}, but there is little emphasis on overall

diet characteristics. Dietary diversity score (DDS), which is an indicator of overall diet, is associated with some nutrient adequacy ratios after adjusting for the effect of energy intake^{7–9}. Studies suggest that diets with higher variety score are also associated with increased intakes of fibre, vitamin C and calcium^{7,8}, all of which protect against CVD^{10–12}. On the other hand, it is reported that increased variety in the food supply may contribute to the development and maintenance of obesity^{13–15}. Therefore evaluating the association between DDS and obesity would be interesting; a relationship may exist between central obesity and DDS. Diverse diets have been shown to protect against chronic diseases such as cancer¹⁶ while also being associated with prolonged longevity¹⁷ and improved health status¹⁸. A significant correlation

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between total food variety and arterial wall index has been shown¹⁹, as well as a significant association between a poorly diversified diet and hypertension²⁰.

Nowadays, nutritional epidemiology has moved away from investigating the effects of a single nutrient to examining the effect of overall diet quality on diet–disease relationships. The Tehran Lipid and Glucose Study (TLGS)²¹ provides the opportunity to assess diet–disease relationships from an epidemiological perspective. Our previous study showed that DDS is a good indicator of nutritional adequacy of the diet⁷ and so the present study was undertaken to assess the relationship between DDS and CVD risk factors in an urban population of Tehran.

Subjects and methods

Subjects

This study was conducted within the framework of the TLGS, a prospective study performed on residents of district 13 of Tehran, with the aims of determining the prevalence of non-communicable disease risk factors and developing a healthy lifestyle to improve these risk factors²¹. A representative sample of 1476 people aged ≥ 3 years was randomly selected for dietary assessment; among this population, 862 subjects aged ≥ 18 years were enrolled. Subjects with a prior history of CVD, diabetes and stroke (23 subjects) were excluded because of possible changes in diet. We also excluded subjects whose reported daily energy intake was not between 800 and 4200 kcal (3347–17 537 kJ)²² to identify under- and overreporters of food intake (11 subjects). Among the remaining population (828 subjects), there were 581 subjects (286 women and 295 men) for whom we had all the relevant data on nutrient adequacy and variety. The proposal of this study was approved by the research council of the Endocrine Research Center of Shaheed Beheshti University of Medical Sciences and informed written consent was obtained from each subject.

Assessment of dietary intake

Usual dietary intake was assessed using a semi-quantitative food-frequency questionnaire (FFQ). All questionnaires were completed by trained dietitians with at least 5 years of experience in the Nationwide Food Consumption Survey project^{23,24}. The FFQ consisted of a list of 168 items and a standard serving size for each (Willett format²⁵). Participants were asked to report their frequency of consumption of each food item during the previous year on a daily (e.g. bread), weekly (e.g. rice, meat) or monthly (e.g. fish) basis. The reliability of the FFQ in this cohort was evaluated in a randomly chosen subgroup of 132 subjects by comparing the nutrient intakes ascertained from their responses to the FFQ on two occasions (one per year); the FFQ had high reliability²⁶. Portion sizes of consumed foods were converted to grams using household measures²⁷. Each food and beverage was then coded

according to the prescribed protocol and was analysed for content of energy and other nutrients using Nutritionist III software, version 7.0 (N-Squared Computing, Salem, OR, USA), which was designed for evaluation of Iranian foods.

Dietary diversity score

To score dietary diversity, five main groups – bread/grains, vegetables, fruits, meats and meat substitutes and dairy foods – according to the Food Guide Pyramid were used²⁸. These main groups were divided into 23 subgroups according to Haines *et al.*²⁹. The categories show the dietary diversity across the main groups. We expanded the number of bread/grain group categories into seven subgroups (refined bread, biscuits, macaroni, whole bread, cornflakes, rice, refined meal) to reflect the diversity and importance of plant-based foods. Two subgroups of fruits were considered (fruit and fruit juice, berries and citrus) and vegetables were divided into seven subgroups (vegetables, potatoes, tomatoes, starchy vegetables, legumes, yellow vegetables, green vegetables). Four subgroups of meat (red meat, poultry, fish, egg) and three subgroups for dairy (milk, yoghurt, cheese) were considered.

To be counted as a ‘consumer’ for any of the food group categories, a respondent had to consume at least one-half serving, as defined by the Food Guide Pyramid quantity criteria, during one day. It did not need to be eaten all at once. Each of the five broad food categories received a maximum diversity score of 2 out of the 10 possible score points. For calculation of the score of each group, we divided the number of subgroups consumed by the total number of subgroups in each main group and then we multiplied this by 2. For example, if a person consumed at least one-half serving from two of seven possible grain categories, he/she would receive a subgroup score of $(2/7) \times 2 = 0.57$ and if a person consumed at least one-half serving from two of the four possible meat categories, he/she would receive a subgroup score of $(2/4) \times 2 = 1$. Within each of the food groups, the score reflects the percentage of the possible maximum score²⁹. Total score was the sum of the scores of the five main groups.

Assessment of other variables

While the subjects were minimally clothed and without shoes, weight was measured using digital scales and recorded to the nearest 100 g. Height was measured using a measuring tape with the subject in standing position, without shoes, while the shoulders were in a normal state. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in metres. Waist circumference (WC) was measured at the narrowest level and hip circumference at the maximum level, over light clothing, using an inelastic measuring tape and without any pressure applied to the body surface; measurements were recorded to the nearest 0.1 cm. Waist-to-hip ratio (WHR) was calculated as WC divided by hip

circumference. To avoid subjective error, all measurements were taken by the same person³⁰.

Fasting blood samples for the measurement of glucose and lipid concentrations were drawn after an overnight fast of 12 h³¹. A 75-g oral glucose tolerance test was administered according to World Health Organization standards³² and 2-h post challenge glucose concentration was measured. Blood glucose was measured on the day of blood collection by an enzymatic colorimetric method using glucose oxidase³². Serum TC and triglyceride (TG) concentrations were measured using commercially available enzymatic reagents (Pars Azmoon, Iran) adapted to a Selecta autoanalyser³¹. High-density lipoprotein cholesterol (HDL-C) was measured after precipitation of the apolipoprotein B-containing lipoproteins with phosphotungstic acid. LDL-C was calculated according to the Friedewald method³³. It was not calculated when serum TG concentration was greater than 400 mg dl⁻¹. All samples were analysed when internal quality control checks met acceptable criteria. Inter- and intra-assay coefficients of variation were respectively 2.0 and 0.5% for TC, and 1.6 and 0.6% for TG. Blood pressure was measured twice after the participants had been sitting for 15 min³. Additional information on covariates – age, smoking habits³⁴, physical activity³⁵, medical history and current use of medications³⁴ – was obtained using validated questionnaires, as reported earlier.

Definition of terms

Obesity was defined³⁶ as BMI ≥ 30 kg m⁻². According to the Adult Treatment Panel III guidelines of the National Cholesterol Education Program³⁷, hypercholesterolaemia was considered as TC ≥ 240 mg dl⁻¹, hypertriglyceridaemia as TG ≥ 200 mg dl⁻¹, low HDL-C as < 40 mg dl⁻¹ and high LDL-C as ≥ 160 mg dl⁻¹. Previously undiagnosed diabetes was defined³⁸ as fasting plasma glucose concentration ≥ 126 mg dl⁻¹ or 2-h post challenge glucose concentration ≥ 200 mg dl⁻¹. Hypertension was defined as systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg or current use of antihypertensive medication on the basis of the sixth report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure³⁹.

Statistical methods

The Statistical Package for the Social Sciences, version 9.05 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. In separate models, there were no significant interactions by sex on the association of DDS and CVD risk factors. Subjects were categorised based on quartile cut points of the DDS: Q1, < 3.5 ; Q2, 3.5 to < 6 ; Q3, 6 to < 8 ; Q4, ≥ 8 . The numbers of subjects in the quartiles are different because we used quartile cut points for categorising subjects, not the distribution of subjects based on quartiles. Cut points for quartiles of the diversity score for whole grains were as follows: Q1, < 0.6 ; Q2, 0.6

to < 1.0 ; Q3, 1.0 to < 1.4 ; Q4, ≥ 1.4 . Cut points for quartiles of the diversity score for vegetables also were calculated: Q1, < 0.8 ; Q2, 0.8 to < 1.3 ; Q3, 1.3 to < 1.6 ; Q4, ≥ 1.6 . Of course, we calculated all cut points for quartiles of the diversity score for each food group. Significant differences in general characteristics across quartile categories of DDS were searched using one-way analysis of variance and Tukey's test. We determined multivariate-adjusted means (age, sex, physical activity, smoking, BMI, WHR, total energy intake, percentage of energy from fat, current use of antihypertensive medication and oestrogen replacement therapy) for CVD risk factors and age-, sex- and energy-adjusted means for dietary variables across quartiles of DDS using the GLM procedure. Analysis of covariance with the correction of Tukey's test was used to compare these means. Logistic regression models controlled for age (years), energy intake (kcal day⁻¹), percentage of energy from fat, carbohydrate and other food group intake, use of blood pressure medication (yes or no), cigarette smoking (categorical: daily smoker, current smoker, ex-smoker, non-smoker), physical activity level (light, moderate, heavy) and current oestrogen replacement therapy among women (yes or no) were used. In all multivariate models, Q4 of the DDS was considered as reference. The Mantel–Haenszel extension test was performed to assess the overall trend of increasing quartile categories of DDS associated with an increasing prevalence of risk factors.

Results

Mean (\pm standard deviation (SD)) DDS was 6.15 ± 1.02 . The maximum and minimum scores for diversity respectively were related to fruit (1.48 ± 0.60) and grain (0.85 ± 0.24) groups. Mean (\pm SD) age, anthropometric measures and cardiovascular risks, as well as the distribution of subjects with regard to obesity, smoking, physical activity status and current oestrogen use, are shown in Table 1 across quartile categories of DDS. Those in the lower category of DDS were younger and had lower BMI. There was no significant difference regarding WC and WHR across DDS quartiles. Most subjects had light physical activity in all quartile groups of DDS. There was no regular trend across the quartiles of DDS to be a daily smoker. The prevalence of obesity was higher among those in the upper category of DDS, compared with the lower one. Multivariate-adjusted means for metabolic risk factors showed that higher DDS was associated with lower levels of LDL-C, systolic and diastolic blood pressure.

Age-, sex- and energy-adjusted means for dietary variables across DDS quartile categories are presented in Table 2. A higher DDS was associated with a healthier diet. Those in the upper category also consumed less cholesterol and meat, and more dietary fibre, fruit, vegetables and vegetable oil. The higher DDS was

Table 1 Characteristics* of Tehran Lipid and Glucose Study participants by quartile of dietary diversity score (DDS)

	DDS quartile†			
	Q1 [<3.5] ($n = 88$)	Q2 [3.5 to <6] ($n = 131$)	Q3 [6 to <8] ($n = 182$)	Q4 [≥ 8] ($n = 180$)
Women (%)	53	63	52	51
Age (years)	37 \pm 11	37 \pm 12	38 \pm 11	41 \pm 13‡
BMI (kg m^{-2})	24.9 \pm 4.3	25.7 \pm 4.3	25.2 \pm 4.6	26.9 \pm 4.7§
WHR	0.88 \pm 0.07	0.87 \pm 0.08	0.87 \pm 0.07	0.87 \pm 0.07
WC (cm)	86 \pm 16	86 \pm 15	85 \pm 15	85 \pm 15
Physical activity (%)				
Light	59	56	57	58
Moderate	20	32	28	28
Heavy	11	12	15	14
Current daily smokers (%)	10	6	8	10¶
BMI $\geq 30 \text{ kg m}^{-2}$ (%)	18	19	21	23¶
TC (mg dl^{-1})	200 \pm 2	199 \pm 3	199 \pm 3	198 \pm 3
LDL-C (mg dl^{-1})	128 \pm 2	127 \pm 3	124 \pm 3	120 \pm 2§
TG (mg dl^{-1})	161 \pm 11	160 \pm 10	160 \pm 11	159 \pm 11
HDL-C (mg dl^{-1})	42 \pm 6	43 \pm 5	43 \pm 4	43 \pm 5
FBG (mg dl^{-1})	91 \pm 5	91 \pm 6	90 \pm 5	88 \pm 5
2HPG (mg dl^{-1})	118 \pm 5	117 \pm 4	115 \pm 4	113 \pm 4
SBP (mmHg)	126 \pm 6	114 \pm 6	111 \pm 6	101 \pm 6‡
DBP (mmHg)	87 \pm 5	82 \pm 5	79 \pm 5	78 \pm 5‡

BMI – body mass index; WHR – waist-to-hip ratio; WC – waist circumference; TC – total cholesterol; LDL-C – low-density lipoprotein cholesterol; TG – triglycerides; HDL-C – high-density lipoprotein cholesterol; FBG – fasting blood glucose; 2HPG – 2-h postprandial glucose; SBP – systolic blood pressure; DBP – diastolic blood pressure.

* Data are expressed as mean \pm standard deviation unless indicated otherwise.

† Quartile cut points in square brackets.

‡ $P < 0.01$ (analysis of variance (ANOVA) with Tukey's test).

§ $P < 0.05$ (ANOVA with Tukey's test).

¶ $P < 0.05$ (chi-square test).

Table 2 Dietary intakes* of Tehran Lipid and Glucose Study participants by quartile of dietary diversity score (DDS)

Dietary intake	DDS quartile†			
	Q1 [<3.5] ($n = 88$)	Q2 [3.5 to <6] ($n = 131$)	Q3 [6 to <8] ($n = 182$)	Q4 [≥ 8] ($n = 180$)
Nutrients				
Total energy (kcal day^{-1})	2236‡‡	2318	2456	2523
Carbohydrate (% of total energy)	60	58	58	58
Protein (% of total energy)	12	11	12	11
Fat (% of total energy)	28	31	30	31
Cholesterol (mg day^{-1})	183	177	169§§	162§§
Dietary fibre (g day^{-1})	10	14	17	21§§
Vitamin C (mg day^{-1})	112	156	189	210§§
Calcium (mg day^{-1})	817	850	910	960§§
Foods (g day^{-1})				
Fruit‡	171	189	196	220§§
Vegetables§	230‡‡	291	310	319
Meat¶	111	109	108	107
Whole grains	19‡‡	38‡‡	49‡‡	61‡‡
Refined grains**	81‡‡	61‡‡	50	45
Dairy††	201	212	218	230§§
Vegetable oils	91	117	126	131§§
Animal oils	110	88	80	76§§

* Reported nutrient and food intakes were adjusted for age, sex and total energy intake.

† Quartile cut points in square brackets.

‡ Includes apples, oranges, bananas, peaches, grapes, strawberries, pears, watermelon, grapefruit, prunes, pomegranates, kiwi, persimmons, raisins, figs, coconuts, apricots and sweet lemons.

§ Includes onions, cucumbers, lettuces, carrots, cauliflower, Brussels sprouts, kale, cabbage, spinach, mixed vegetables, corn, green beans, green peas, peppers, beets, potatoes, tomatoes, broccoli and celery.

¶ Includes beef, liver, chicken hearts and kidneys, hamburger, sausages, processed meats, meat in a sandwich, tuna and other fish.

|| Includes dark breads (*sangak*, *barbari*, *taftoon*), barley bread, cornflakes, bulgur and germs.

** Includes white breads (*lavash*, *baguette*), noodles, pasta, rice, toasted bread, milled barley, sweet bread, white flour, starch and biscuits.

†† Includes milk, yoghurt and cheeses.

‡‡ $P < 0.05$ compared with other quartiles (Mantel–Haenszel extension test).

§§ $P < 0.05$ compared with first quartile (Mantel–Haenszel extension test).

Table 3 Odds ratio (95% confidence interval)* of having cardiovascular risk factors by quartile of the diversity score for whole grains

Risk factor	Quartile of diversity score for whole grains†				P for trend
	Q1 [<0.6] (<i>n</i> = 88)	Q2 [0.6 to <1.0] (<i>n</i> = 131)	Q3 [1.0 to <1.4] (<i>n</i> = 182)	Q4 [≥ 1.4] (<i>n</i> = 180)	
Hypercholesterolaemia (TC ≥ 240 mg dl ⁻¹)	1.36 (0.96–1.61)	1.26 (0.63–1.41)	1.21 (0.78–1.61)	1.00	NS
Low HDL-C (<40 mg dl ⁻¹)	1.13 (0.81–1.61)	1.08 (0.80–1.56)	1.06 (0.88–1.31)	1.00	NS
Hypertriglyceridaemia (TG ≥ 200 mg dl ⁻¹)	1.41 (1.09–1.78)‡	1.23 (1.01–1.56)‡	1.05 (0.87–1.23)	1.00	<0.04
Diabetes (FBG ≥ 126 mg dl ⁻¹ or 2HPG ≥ 200 mg dl ⁻¹)	1.45 (1.09–1.88)‡	1.26 (1.05–1.55)‡	1.11 (0.89–1.44)	1.00	<0.04
Hypertension (SBP ≥ 140 mmHg or DBP ≥ 90 mmHg)	1.22 (0.88–1.51)	1.18 (0.84–1.36)	1.15 (0.55–1.43)	1.00	NS

TC – total cholesterol; HDL-C – high-density lipoprotein cholesterol; TG – triglycerides; FBG – fasting blood glucose; 2HPG – 2-h postprandial glucose; SBP – systolic blood pressure; DBP – diastolic blood pressure; NS – not significant.

*Odds ratios are adjusted for age, sex, smoking, physical activity, body mass index (BMI), waist-to-hip ratio (WHR), total energy intake, percentage energy from fat, carbohydrate and other food group intake, use of blood pressure medication and use of oestrogen. BMI and WHR were not adjusted when testing the association between obesity and dietary diversity score.

† Quartile cut points in square brackets.

‡ $P < 0.05$ compared with the fourth quartile.

positively associated with total intakes of dietary fibre ($r = 0.43$), calcium ($r = 0.51$) and vitamin C ($r = 0.48$).

Table 3 shows the odds ratio (OR) and 95% confidence interval (CI) for the incidence of CVD risk factors across quartile categories of the diversity score for whole grains. As can be seen, the probability of having diabetes (OR among quartiles, Q1–Q4: 1.45, 1.26, 1.11 and 1.00, respectively; P for trend = 0.04) and hypertriglyceridaemia (OR, Q1–Q4: 1.41, 1.23, 1.05 and 1.00, respectively; P for trend = 0.04) decreased with increasing quartile of the diversity score for whole grains.

The OR and 95% CI for CVD risk factors across quartile categories of the diversity score for vegetables are shown in Table 4. The probability of having obesity (OR, Q1–Q4: 1.39, 1.06, 1.03 and 1.00, respectively; P for trend = 0.03), hypercholesterolaemia (OR, Q1–Q4: 1.46, 1.28, 1.11 and 1.00, respectively; P for trend = 0.03), hypertension (OR, Q1–Q4: 1.32, 1.17, 1.13 and 1.00, respectively; P for trend = 0.03) and high LDL-C (OR, Q1–Q4: 1.25, 1.12, 1.07 and 1.00, respectively; P for trend = 0.04) decreased with increasing quartile of the diversity score for vegetables.

Analysis of data according to diversity score for dairy also showed that the odds of having hypertension

decreased with increasing quartile of the dairy diversity score (OR, Q1–Q4: 1.42, 1.19, 1.13 and 1.00, respectively; P for trend = 0.03).

Figure 1 shows the OR and 95% CI of having hypercholesterolaemia, high LDL-C and hypertriglyceridaemia across quartiles of the DDS. OR are adjusted for age, sex, smoking, physical activity, BMI, WHR, total energy intake, percentage energy from fat, carbohydrate and other food group intake, use of blood pressure medication and use of oestrogen. The probability of having hypercholesterolaemia and high LDL-C decreased with increasing quartile of DDS (P for trend = 0.02 and 0.04, respectively).

Figure 2 shows the OR and 95% CI for having hypertension, diabetes and obesity across the quartiles of DDS. OR are adjusted for age, sex, smoking, physical activity, BMI, WHR, total energy intake, percentage energy from fat, carbohydrate and other food group intake, use of blood pressure medication and use of oestrogen. The probability of having hypertension and diabetes decreased with increasing quartile of DDS (P for trend = 0.03 for both), but the probability of being obese increased across DDS quartiles (P for trend = 0.03).

Table 4 Odds ratio (95% confidence interval)* of having cardiovascular risk factors by quartile of the diversity score for vegetables

Risk factor	Quartile of diversity score for vegetables†				P for trend
	Q1 [<0.8] (<i>n</i> = 88)	Q2 [0.8 to <1.3] (<i>n</i> = 131)	Q3 [1.3 to <1.6] (<i>n</i> = 182)	Q4 [≥ 1.6] (<i>n</i> = 180)	
Obesity (BMI ≥ 30 kg m ⁻²)	1.39 (1.01–1.51)‡	1.06 (0.91–1.28)	1.03 (0.71–1.36)	1.00	<0.03
Hypercholesterolaemia (TC ≥ 240 mg dl ⁻¹)	1.46 (1.20–1.69)‡	1.28 (1.08–1.73)‡	1.11 (1.01–1.49)‡	1.00	<0.03
Low HDL-C (<40 mg dl ⁻¹)	1.06 (0.83–1.51)	1.03 (0.60–1.56)	1.02 (0.81–1.41)	1.00	NS
Hypertriglyceridaemia (TG ≥ 200 mg dl ⁻¹)	1.21 (0.91–1.78)	1.17 (0.89–1.46)	1.15 (0.77–1.25)	1.00	NS
Diabetes (FBG ≥ 126 mg dl ⁻¹ or 2HPG ≥ 200 mg dl ⁻¹)	1.12 (0.54–1.88)	1.06 (0.51–1.55)	1.05 (0.89–1.34)	1.00	NS
Hypertension (SBP ≥ 140 mmHg or DBP ≥ 90 mmHg)	1.32 (0.86–1.61)	1.17 (0.85–1.36)	1.13 (0.55–1.43)	1.00	<0.03
High LDL-C (≥ 160 mg dl ⁻¹)	1.25 (0.76–1.51)	1.12 (0.86–1.50)	1.07 (0.61–1.31)	1.00	<0.04

BMI, body mass index; TC – total cholesterol; HDL-C – high-density lipoprotein cholesterol; TG – triglycerides; FBG – fasting blood glucose; 2HPG – 2-h postprandial glucose; SBP – systolic blood pressure; DBP – diastolic blood pressure; LDL-C low-density lipoprotein cholesterol; NS – not significant.

*Odds ratios are adjusted for age, sex, smoking, physical activity, body mass index, waist-to-hip ratio, total energy intake, percentage energy from fat, carbohydrate and other food group intake, use of blood pressure medication and use of oestrogen.

† Quartile cut points in square brackets.

‡ $P < 0.05$ compared with the fourth quartile.

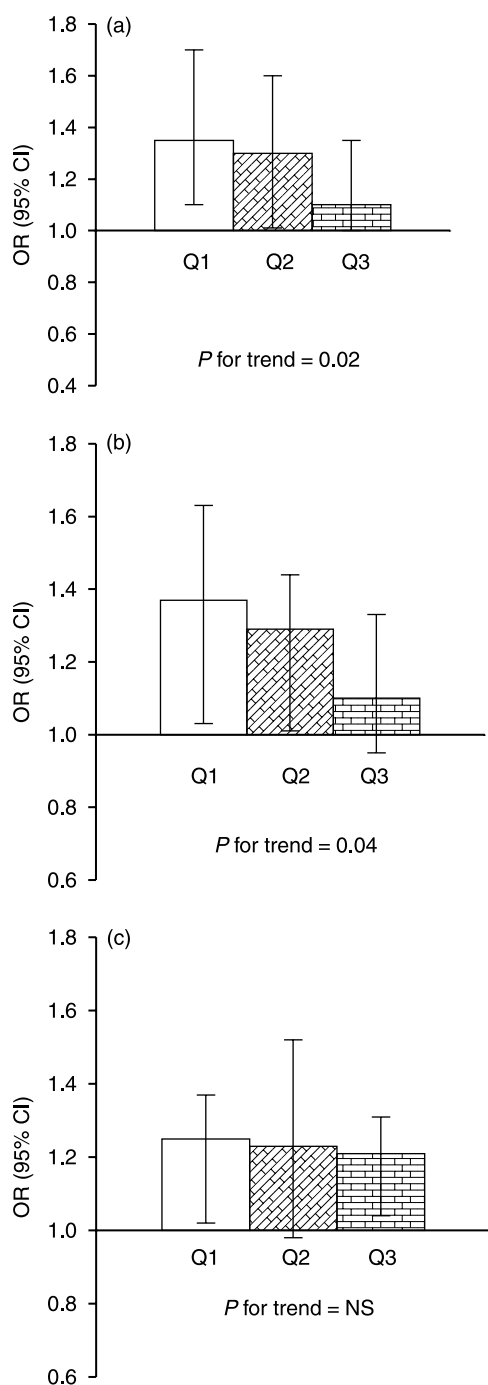


Fig. 1 Multivariate-adjusted odds ratio (OR) and 95% confidence interval (CI; shown by vertical bars) of having hypercholesterolaemia (a), high low-density lipoprotein cholesterol (LDL-C) (b) and hypertriglyceridaemia (c) across quartiles of dietary diversity score (DDS). The probability of having hypercholesterolaemia and high LDL-C decreased with increasing quartile of DDS. OR are adjusted for age, sex, smoking, physical activity, body mass index, waist-to-hip ratio, total energy intake, percentage energy from fat, carbohydrate and other food group intake, use of blood pressure medication and use of oestrogen. Q1–Q3 – quartiles 1 to 3 of DDS, quartile 4 (Q4) was the reference (OR = 1.00); NS – not significant. Quartile cut points of DDS are as follows: Q1, <3.5; Q2, 3.5 to <6, Q3, 6 to <8; Q4, ≥ 8 . Hypercholesterolaemia is defined as total cholesterol ≥ 240 mg dl⁻¹, high LDL-C as ≥ 160 mg dl⁻¹ and hypertriglyceridaemia as triglycerides ≥ 200 mg dl⁻¹

Discussion

The present study, conducted among a representative sample of Tehranian adults, showed an inverse association between DDS and some CVD risk factors like hypertension, hypercholesterolaemia, high LDL-C and diabetes. To the best of our knowledge, this is one of the first studies reporting the association of overall diversity score and the diversity score of different food groups with CVD risk factors. Bernstein *et al.*⁴⁰ mentioned the association between DDS and serum lipid level, but there are no data specific to the diversity score for individual food groups. As previous research in the field of DDS–chronic disease relationships has focused mostly on cancer^{41,42}, the present study offers the opportunity of studying other chronic diseases.

The favourable association between DDS and metabolic risks may be attributed to the healthier lifestyle (higher consumption of fibre, fruit, vegetables and vegetable oil, lower consumption of meat and cholesterol) associated with higher DDS. Of course, changing the dietary pattern among patients with diabetes and hypercholesterolaemia may confound the association between DDS and metabolic risks. Although people in the higher categories of DDS had higher energy intake and were more obese, this higher amount of energy could be attributed to the increased consumption of vegetables, fruit, vegetable oil and dairy, i.e. healthy nutrition patterns. Therefore, it seems that it is better to suggest increasing the diversity scores for vegetables and fruit and not to increase the diversity scores for fat and sugar, which are related to being more obese.

A previous study in this area of Tehran showed DDS to be correlated with nutrient adequacy ratio of vitamin C and calcium¹¹. As mentioned in previous studies^{11,12,43}, these two nutrients have a negative association with CVD such as hypertension. Osborne *et al.*⁴⁴ found that calcium had an important role in blood pressure regulation and that adequate intake of calcium might reduce the risk of hypertension. Some mechanisms responsible for this effect of calcium may be the natriuretic effect, regulation of the sympathetic nervous system, and prevention of vessel constriction. In Azizi *et al.*'s study¹¹ an inverse correlation between blood pressure and calcium intake was seen. On the other hand, calcium could bind to fatty acids and inhibit the absorption of fats¹². Recently, it has been demonstrated that dairy consumption is inversely associated with BMI and that calcium plays an essential role in this issue⁴³. On the whole, higher DDS is associated with higher intake of calcium and perhaps better cardiovascular status. In the present study, a higher diversity score for dairy products was associated with lower odds of having hypertension. Therefore, consumption of various low-fat dairy products might be a good way for preventing hypertension. Of course, consideration of the fat content of dairy products is an important issue, and if it is not paid sufficient attention, may result in an inverse outcome. Regarding vitamin

C, Azizi *et al.*¹¹ showed that high vitamin C intake is a predictor of high HDL-C in the TLGS population and also found an inverse relationship between vitamin C intake and hypertension.

Previous studies showed that DDS is a good indicator of diet quality and our study has shown that it may be

correlated with some CVD risks – higher DDS was associated with lower odds of having hypercholesterolaemia, hypertension and diabetes. Therefore, public education to improve within- and between-group dietary variety as well as to control energy intake may be beneficial. The results of the present study also show that the variety score of individual food groups might be related to particular metabolic risk factors. Our study demonstrates that not only the amount of food group intake but also the variety contributes to health and disease, e.g. the odds of having diabetes and hypertriglyceridaemia decreased with increasing quartile of the diversity score for whole grains. Fung *et al.*²² showed that higher consumption of whole grains is associated with better glycaemic control. A crossover intervention study also supports the hypothesis that diets rich in whole-grain foods are associated with lower insulin concentrations⁴⁵. In the Framingham offspring cohort, intake of whole grains was favourably associated with several metabolic risk factors of this syndrome, including central obesity, insulin sensitivity and dyslipidaemia⁴⁶. The variety score for vegetables in the present study was related to the most cardiovascular risks. It seems that emphasis on the variety score for the vegetables group might be related to a lower chance of having metabolic risks. Moreover, increasing the variety of vegetables might not be associated with high energy intake and increasing chance of obesity.

The favourable association between higher DDS and variety scores for food groups and CVD risks may be attributed to the healthier lifestyle associated with greater variety in food intakes. However, the higher odds of having cardiovascular risks persisted in multivariate models accounting for known coronary risk factors.

As higher DDS is associated with higher energy intake⁴⁷ and therefore may be associated with obesity¹³, it is obviously important to emphasise that the recommendation to increase dietary diversity be associated with the consideration of energy intake. It is better to increase the diversity score for healthy food

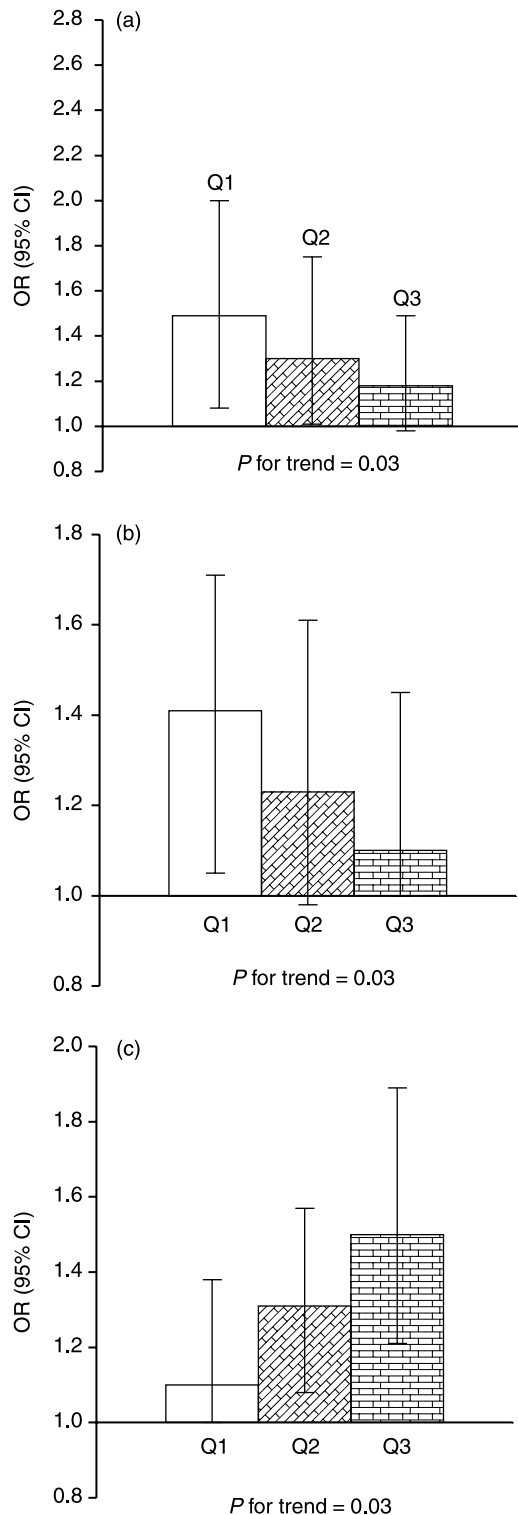


Fig. 2 Multivariate-adjusted odds ratio (OR) and 95% confidence interval (CI; shown by vertical bars) of having hypertension (a), diabetes (b) and obesity (c) across quartiles of dietary diversity score (DDS). The probability of having hypertension and diabetes decreased with increasing quartile of DDS, but the probability of having obesity increased with increasing DDS quartile. OR are adjusted for age, sex, smoking, physical activity, body mass index (BMI), waist-to-hip ratio, total energy intake, percentage energy from fat, carbohydrate and other food group intake, use of blood pressure medication and use of oestrogen. Q1–Q3 – quartiles 1 to 3 of DDS, quartile 4 (Q4) was the reference (OR = 1.00). Quartile cut points of DDS are as follows: Q1, <3.5; Q2, 3.5 to <6; Q3, 6 to <8; Q4, ≥8. Hypertension is defined as systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg or current use of antihypertensive medication; diabetes as fasting plasma glucose concentration ≥126 mg dl⁻¹ or 2-h post challenge glucose concentration ≥200 mg dl⁻¹; and obesity as BMI ≥30 kg m⁻².

groups such as vegetables and whole grains. Unfortunately, there is no study explaining the association of CVD risks with DDS and variety scores for various food groups with which we can compare our results.

We used categorical variables in this study, which has several advantages. First, the investigator can visualise directly how the actual numbers of cases and non-cases vary by level of intake. Second, the use of multiple categories makes no assumptions about the dose–response relationship, and it is therefore possible to visualise whether this is most compatible with a linear trend or some non-linear alternative. Third, the use of categories constrains any undue influence of outlying data points, which are the observations most likely to be affected by errors in data collection or processing. However, this categorisation of the variables may cause data loss⁴⁸.

There are several limitations that should be considered when examining the results of this study. First, we used cross-sectional data to identify the association of DDS with CVD risks, which does not allow us to make causal inferences. However, it must be kept in mind that appropriate analysis of cross-sectional data represents a valuable initial step in identifying diet–disease relationships. Moreover, prospective cohort studies and clinical trials have their own weaknesses. Future studies using longitudinal data will provide stronger evidence on this association. Second, high scores on dietary diversity appear to reflect an overall healthier lifestyle that may not have been accurately captured and controlled in our analysis, resulting in residual confounding. Third, subjects with known coronary artery disease, diabetes and stroke were excluded from the study. These exclusions may have reduced the likelihood of finding significant trends in odds of having metabolic risks across quartile categories of DDS. Chronic diseases are heterogeneous and besides dietary pattern, other factors such as hereditary factors may need to be considered. Additionally, most of the risk factors are interrelated and this could confound the relationship between DDS and CVD risk factors. However, our study has several strengths. Use of a population-representative sample of Tehran, logistic regression models and simultaneous adjustment of confounding variables in the association of DDS with the metabolic syndrome allowed us to find a cross-sectional relationship between DDS and CVD risks and some of its features such as hypertension, hypercholesterolaemia, high LDL-C, obesity and diabetes.

In conclusion, DDS is inversely associated with CVD risks. Therefore, efforts to increase the diversity score of diets by emphasising the diversity scores for vegetable and fruit groups and controlling total energy intake may be beneficial. Besides following the recommendations of dietary guidelines, this procedure might be associated with reductions in the incidence of metabolic risks.

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