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Research Report

Dietary diversity score is associated with cardiometabolic risk factors in patients with hypertension (Hoveyzeh Cohort Study)

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Abstract.
BACKGROUND: Dietary diversity score (DDS) is recognized as an essential factor of a high-quality diet.
OBJECTIVE: To evaluate the relationship between DDS and cardiometabolic risk factors in hypertensive patients.
METHODS: In this cross-sectional study, 972 hypertensive patients (322 males and 650 females) aged 35–70y participated were recruited. Dietary intake was evaluated using a semi-quantitative food frequency questionnaire and DDS was calculated. Metabolic syndrome was defined according to the IDF/AHA criteria. The anthropometric parameters, fasting blood sugar, lipid profile, and liver enzymes were measured.
RESULTS: Male subjects who assigned to the top DDS tertile had 51% lower risk of having low serum HDL-C (OR: 0.49; 95% CI: 0.24–0.96) in the crude model. A similar association was observed for men in the second tertile of DDS after adjusting for covariates (OR: 0.47; 95% CI: 0.23–0.97). A significant inverse association was found between vegetable diversity score and odds of hyperglycemia in the male group in the adjusted model (OR: 0.44; 95% CI: 0.22–0.91). The vegetable diversity score was inversely associated with 67% decreased metabolic syndrome risk in the adjusted model (OR: 0.33; 95% CI: 0.15–0.70).
CONCLUSION: These findings clarify the possible preventive role of higher DDS against metabolic syndrome.

Keywords: Cardiometabolic risk factors, dietary diversity score, hypertension, metabolic syndrome

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1. Introduction

Hypertension (HTN) is one of the most serious disorders worldwide [1]. HTN defined as systolic blood pressure (SBP) ≥140 mmHg and/or diastolic blood pressure (DBP) ≥ 90 mmHg [2]. The number of people with HTN rose from 1 million in 2008 to nearly 1.13 billion in 2015 and HTN is responsible for nearly half of deaths due to heart disease and stroke [3, 4]. According to data from a meta-analysis, the prevalence of hypertension among adults was 24% in men and 25% in women in Iran [3]. HTN is a main risk factor of cardiovascular disease (CVD) [5]. Lifestyle/environmental factors such as smoking, unhealthy diet and physical inactivity that are associated with HTN account for approximately 80% of CVD [6]. Hypertensive patients are at increased risk of developing obesity, dyslipidemia, high blood glucose, and metabolic syndrome (MetS) [7], which multiplies the risk for CVD [8]. Life style and diet modification may have an important role in reducing the burden of chronic diseases [9, 10].

Recently it has been suggested that assessing overall diet instead of the effects of a single nutrient on diet-disease associations may be more informative [11]. Dietary diversity score (DDS) is considered an indicator of overall diet quality and correlates positively with nutritional adequacy [12]. Previous studies have demonstrated that higher DDS is associated with higher intake of fiber [11, 13] as well as vitamin C [13] and calcium [11], all which are protective factors against hypertension, metabolic syndrome, and cardiovascular disease [14–17]. The relationship between DDS and cardiovascular risk factors among patients with non-alcoholic fatty liver disease has been evaluated in several previous studies [18, 19]. A cross-sectional study found that higher DDS may be associated with lower incidence of some metabolic disorders [20]. Furthermore, another study showed that there is a significant association between a poorly diversified diet and hypertension [21].

To the best of our knowledge, no previous study has evaluated associations between DDS and cardiometabolic risk factors among hypertensive patients. Considering the importance of HTN in public health, the current study was designed to investigate the relationship between DDS and some cardiometabolic risk factors among hypertensive patients.

2. Materials and methods

2.1. Study participants

This cross-sectional study was conducted as the enrolment phase of the Hoveyzeh cohort study (HCS), a prospective population-based cohort study of 10,009 adults (aged 35–70 years) recruited from May 2016 to August 2018 that has the aim of estimating the prevalence of non-communicable diseases (NCDs), and discovering the risk and protective factors of NCDs in the Arab community [22]. HCS is a part of the Prospective Epidemiological Research Studies (PERSIAN Cohort Study) in Iran [23]. Based on the 2016 door-to-door census, there were 12,103 eligible individuals living in Hoveyzeh County (2 cities of Hoveyzeh and Rofayyeh and 27 villages) and 7 villages and 2 urban areas of Susangerd bordering Hoveyzeh. Overall, 10,009 individuals were recruited [22].

The inclusion criteria were as follows: hypertensive individuals with and without anti-hypertension medication use between 35 to 70 years of age. The criteria for hypertension are defined as systolic and diastolic blood pressures greater than 140 and/or 90 mmHg, respectively. Subjects with secondary hypertension (i.e., chronic kidney injury, reno-vascular disease, and endocrine disease), history of cancer, Type 2 diabetes mellitus, renal, autoimmune, inflammatory systemic and cardiovascular diseases, being pregnant, taking medications other than antihypertensive drugs, smoking, and alcohol consumption were excluded from the study. From a total of 2,643 hypertensive patients, 972 patients (322 males and 650 females) were entered into the study based on inclusion and exclusion criteria.

The study was conducted according to the principles of the Declaration of Helsinki, and the Ethical Committee of the Ahvaz Jundishapur University of Medical Sciences confirmed the study and the approval of the Ethics Committee was obtained (IR.AJUMS.REC.1398.492). Signed informed consent was obtained from all participants.

2.2. Dietary diversity score

Usual dietary intake was assessed using a 130-item semi-quantitative food-frequency questionnaire (FFQ) [23]. The FFQ consists of a list of foods with standard serving size for each. Subjects report frequency of consumption of a given food item during the previous year on a daily, weekly or monthly basis. Portion sizes of foods were converted to grams using household measures [24]. To determine DDS, we used a method first developed by Kant et al. [12, 25]. Five food groups consisting of bread-grains, vegetables, fruits, meats, and dairy are considered for scoring dietary diversity. The main food groups are divided into 23 subgroups. These subgroups show dietary diversity across the food groups introduced by US Department of Agriculture (USDA) food guide pyramid. The bread-grain group is divided into seven subgroups (refined bread, biscuits, macaroni, whole bread, corn flakes, rice, and refined flour), the fruit group is divided into two subgroups (fruits and fruit juice, and berries and citrus), and vegetables into seven subgroups (vegetables, potato, tomato, starchy vegetables, legumes, yellow vegetables, and green vegetables). There are four subgroups for the meat group (red meat, poultry, fish, and eggs) and three subgroups for the dairy group (milk, yogurt and cheese). To be counted as a consumer of one food group, a respondent should consume at least one-half serving in one day as defined by the food guide pyramid quantity criteria. A maximum diversity score of 2 out of the 10 was considered for each food group. Therefore, the range of total DDS was 0 to 10 [20].

2.3. Wealth index

Wealth index as an individual level of socioeconomic status was calculated by means of information on households' possession, including freezer, TV, motorbike, cell phone, car, vacuum cleaner, access to internet, washing machine, computer and household utilities including house ownership, and number of rooms per capita were entered to into a principal component analysis and finally the score of wealth index was converted to 5-ordered categories from poorest to richest [26].

2.4. Assessment of anthropometric variables

Weight (kg) was measured using a standing scale (Seca 755); height (cm) was measured using a stadiometer (Seca 206) while the subjects were in a relaxed position and not wearing shoes. Waist circumference (WC) and hip circumference (HC) (cm) were measured using Seca locked tape meters. Body mass index (BMI) and waist to hip ratio (WHR) were calculated as weight (kg)/height (m^2) and waist circumference divided by hip circumference, respectively.

2.5. Laboratory analysis

Systolic and diastolic blood pressure (SBP, DBP) was measured in a sitting position by mercury sphygmomanometer and then the average of the two measurements was considered as the blood pressure (mmHg) measurement. Blood samples were collected from individuals after fasting 12 h. Samples were centrifuged at 3000 rpm for 10 minutes to separate serum. Serum levels of FBS, total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C) were determined by enzymatic methods. Serum glutamic-oxaloacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT) levels were measured using the kinetic method.

Table 1
Demographic, anthropometric, biochemical and dietary variables of study population according to tertiles of DDS

Variable	DDS			
	1st tertile (N = 350)	2nd tertile (N = 344)	3rd tertile (N = 278)	P^*
Sex, n (%)				< 0.001
Male	73 (20.9)	124 (36)	126 (45.3)	
Female	277 (79.1)	220 (64)	152 (54.7)	
Marital status, n (%)				< 0.001
Married	279 (79.7)	304 (88.4)	247 (88.8)	
others	71 (20.3)	40 (11.6)	31 (11.2)	
Education Level, n (%)				< 0.001
Illiterate	284 (81.1)	253 (73.5)	155 (55.8)	
Less than high school	42 (12.0)	61 (17.7)	71 (25.5)	
Higher	24 (6.9)	30 (8.7)	52 (18.7)	
Smoking, n (%)				< 0.001
Yes	42 (12.0)	42 (12.2)	35 (12.6)	
No	308 (88.0)	302 (87.8)	243 (87.4)	
Alcohol, n (%)				–
Yes	0 (0)	0 (0)	0 (0)	
No	350 (100.0)	344 (100.0)	278 (100.0)	
Wealth Index, n (%)				0.912
Poorest	57 (16.3)	77 (22.4)	58 (20.9)	
Poor	76 (21.7)	64 (18.6)	63 (22.7)	
Moderate	69 (19.7)	61 (17.7)	55 (19.8)	
Rich	78 (22.3)	69 (20.1)	52 (18.7)	
Richest	70 (20.0)	73 (21.2)	50 (18.0)	
Age (y)	$53.85 \pm 8.98^{b,c}$	$52.14 \pm 9.18^{a,c}$	$49.91 \pm 8.71^{a,b}$	< 0.001
Weight (kg)	79.17 ± 16.16	80.77 ± 16.90	80.18 ± 16.14	0.433
BMI (kg/m^2)	29.97 ± 5.49	30.20 ± 5.54	30.09 ± 5.56	0.857
WC (cm)	101.35 ± 11.63	103.30 ± 12.36	103.10 ± 11.17	0.060
HC (cm)	106.32 ± 10.31	80.77 ± 16.90	105.66 ± 10.22	0.706
WHR	0.96 ± 0.06	0.97 ± 0.06	0.96 ± 0.06	0.553
FBS (mg/dl)	96.91 ± 11.29	96.33 ± 10.96	97.20 ± 11.04	0.605
DBP (mmHg)	79.05 ± 13.37	80.40 ± 13.95	81.72 ± 13.70	0.052
SBP (mmHg)	129.68 ± 20.24	131.22 ± 20.95	131.33 ± 22.52	0.532
TG (mg/dl)	164.38 ± 89.95	160.97 ± 89.50	163.18 ± 102.03	0.888
TC (mg/dl)	198.92 ± 38.23	197.98 ± 41.47	194.27 ± 38.60	0.313
HDL (mg/dl)	52.20 ± 12.43	52.10 ± 12.06	51.58 ± 11.99	0.798
SGOT (U/L)	18.92 ± 8.83	18.81 ± 7.96	20.11 ± 11.44	0.171
SGPT (U/L)	19.47 ± 13.36^{c}	20.96 ± 15.87	23.76 ± 19.32^{a}	0.004
Dietary energy intake (kcal)	$2437.9 \pm 748.07^{b,c}$	$3036.4 \pm 845.9^{a,c}$	$3539.6 \pm 1024.3^{a,b}$	< 0.001
Dairy diversity	$0.02 \pm 0.15^{b,c}$	$0.18 \pm 0.38^{a,c}$	$0.56 \pm 0.49^{a,b}$	< 0.001
Vegetable diversity	$0.37 \pm 0.28^{b,c}$	$0.59 \pm 0.26^{a,c}$	$0.76 \pm 0.26^{a,b}$	< 0.001
Fruits diversity	$0.55 \pm 0.50^{b,c}$	$0.97 \pm 0.29^{a,c}$	$1.21 \pm 0.42^{a,b}$	< 0.001
Grain diversity	$0.79 \pm 0.16^{b,c}$	$0.83 \pm 0.14^{a,c}$	$0.90 \pm 0.20^{a,b}$	< 0.001
Meat diversity	$0.54 \pm 0.38^{b,c}$	$0.97 \pm 0.41^{a,c}$	$1.37 \pm 0.44^{a,b}$	< 0.001

Discrete and continuous variables data were presented based on number (percent) and mean ± SD, respectively. *P-value obtained using one-way ANOVA for continuous variables; follow up by Tukey's *post-hoc* test, and Chi-square test for categorical variables. Indicates statistically significant values as $P < 0.05$. DDS, Dietary Diversity Score; BMI, Body Mass Index; WC, Waist Circumference; HC, Hip Circumference; WHR, waist-hip ratio; FBS, Fasting Blood Sugar; DBP, Diastolic Blood Pressure; SBP, Systolic Blood Pressure; TG, Triglyceride; TC, Total Cholesterol; HDL, High-Density Lipoprotein; SGOT, Serum Glutamic Oxalacetic Transaminase; SGPT, Serum Glutamate Pyruvate Transaminase. a: P-value less than 0.05 vs. T1 group. b: P-value less than 0.05 vs. T2 group. c: P-value less than 0.05 vs. T3 group.

2.6. Definition of terms

Metabolic syndrome was defined as the presence of ≥ 3 of the following components according to IDF/AHA criteria; 1) abdominal adiposity (WC ≥ 94 cm in men and ≥ 80 cm in women); 2) low serum HDL cholesterol (< 40 mg/dl for men and < 50 mg/dl for women); 3) high serum triacylglycerol (≥ 150 mg/dl); 4) elevated blood pressure (≥ 130/85 mm Hg); 5) abnormal glucose homeostasis (fasting blood sugar (FBS) ≥ 100 mg/dl) [8, 27].

2.7. Statistical analysis

The data were analyzed using SPSS version 22 (SPSS Inc., Chicago, IL) and the results are expressed as mean ± SD or frequency (percent). *P*-values of less than 0.05 are considered significant. Cut-points for DDS scores were defined by tertile categories. Subjects were categorized based on tertile cut points of the DDS: to T1, < 2.966; T2, 2.966–3.966; T3, ≥3.966. The comparison of quantitative variables between different DDS tertiles was performed using one-way analysis of variance (ANOVA) and Tukey's test. For comparison of qualitative variables across the tertiles of DDS, χ^2 test was performed. To determine the association between DDS and several risk factors of cardiometabolic, binary logistic regression was used in different models.

Table 2
Odd's ratio (OR) and confidence interval (CI) for dietary diversity tertiles and cardiometabolic risk factors of participants

	Male			Female		
	1st tertile (N = 73)	2nd tertile (N = 124)	3rd tertile (N = 126)	1st tertile (N = 277)	2nd tertile (N = 220)	3rd tertile (N = 152)
Obesity						
Crude	1 (Ref.)	0.77 (0.38–1.56)	1.29 (0.61–2.70)	1 (Ref.)	1.02 (0.37–2.78)	2.51 (0.53–11.80)
Model 1	1 (Ref.)	0.81 (0.39–1.68)	1.24 (0.55–2.79)	1 (Ref.)	1.07 (0.37–3.12)	2.45 (0.46–12.98)
MetS[b]						
Crude	1 (Ref.)	0.76 (0.42–1.39)	1.10 (0.60–2.02)	1 (Ref.)	1.09 (0.73–1.61)	0.89 (0.58–1.37)
Model 1	1 (Ref.)	0.84 (0.43–1.63)	1.24 (0.61–2.52)	1 (Ref.)	1.10 (0.72–1.68)	0.95 (0.58–1.55)
Low HDL-C						
Crude	1 (Ref.)	**0.44 (0.22–0.89)**	**0.49 (0.24–0.96)**	1 (Ref.)	0.88 (0.61–1.27)	1.04 (0.69–1.56)
Model 1	1 (Ref.)	**0.47 (0.23–0.97)**	0.58 (0.27–1.24)	1 (Ref.)	0.84 (0.56–1.24)	1.05 (0.66–1.67)
High TG						
Crude	1 (Ref.)	0.57 (0.32–1.04)	0.63 (0.35–1.14)	1 (Ref.)	1.14 (0.80–1.64)	0.88 (0.58–1.32)
Model 1	1 (Ref.)	0.62 (0.32–1.16)	0.58 (0.30–1.13)	1 (Ref.)	1.20 (0.82–1.76)	0.98 (0.62–1.55)
High FBS						
Crude	1 (Ref.)	1.32 (0.71–2.45)	1.11 (0.59–2.08)	1 (Ref.)	0.83 (0.58–1.21)	1.06 (0.71–1.59)
Model 1	1 (Ref.)	1.39 (0.72–2.67)	1.28 (0.64–2.57)	1 (Ref.)	0.81 (0.54–1.20)	1.06 (0.66–1.68)

The binary logistic regression across tertiles of dietary diversity was used for estimation of ORs and confidence interval (CI). Model1: Crude model. Model 2: Adjusted for age, energy intake, waist circumference, wealth index and smoking. Indicates statistically significant values as $P < 0.05$. [b]Defined as the presence of ≥ 3 of the following components: 1) abdominal adiposity (WC ≥ 94 cm in men and ≥ 80 cm in women); 2) low serum HDL cholesterol (< 40 mg/dl for men and < 50 mg/dl for women); 3) high serum triacylglycerol (≥150 mg/dl); 4) elevated blood pressure (≥ 130/85 mm Hg); 5) abnormal glucose homeostasis (fasting blood sugar ≥ 100 mg/dl). MetS, Metabolic Syndrome; HDL, High-Density Lipoprotein; TG, Triglyceride; FBS, Fasting Blood Sugar.

3. Results

General characteristics of the participants studied according to DDS tertiles are presented in Table 1. In comparison with the upper tertile, those who were placed to the lowest tertile of DDS were significantly older

Table 3
Odd's ratio (OR) and confidence interval (CI) for meat diversity and vegetable diversity and cardiometabolic risk factors of participants

		Meat diversity			Vegetable diversity		
		1st tertile (N = 382)	2nd tertile (N = 323)	3rd tertile (N = 267)	1st tertile (N = 372)	2nd tertile (N = 424)	3rd tertile (N = 176)
Male	Obesity						
	Crude	1 (Ref.)	1.36 (0.66–2.81)	1.02 (0.52–2.01)	1 (Ref.)	1.03 (0.55–1.93)	1.04 (0.50–2.14)
	Model 1	1 (Ref.)	1.30 (0.61–2.73)	1.03 (0.50–2.10)	1 (Ref.)	0.96 (0.49–1.86)	0.91 (0.41–2.01)
	MetS[b]						
	Crude	1 (Ref.)	1.34 (0.73–2.48)	0.91 (0.51–1.63)	1 (Ref.)	**0.51 (0.29–0.88)**	**0.50 (0.26–0.93)**
	Model 1	1 (Ref.)	1.30 (0.66–2.56)	0.99 (0.51–1.91)	1 (Ref.)	**0.40 (0.21–0.76)**	**0.33 (0.15–0.70)**
	Low HDL-C						
	Crude	1 (Ref.)	1.12 (0.56–2.23)	0.55 (0.27–1.15)	1 (Ref.)	0.64 (0.34–1.20)	0.60 (0.28–1.26)
	Model 1	1 (Ref.)	1.20 (0.59–2.47)	0.61 (0.28–1.33)	1 (Ref.)	0.74 (0.38–1.44)	0.66 (0.29–1.52)
	High TG						
	Crude	1 (Ref.)	0.80 (0.44–1.43)	0.73 (0.41–1.28)	1 (Ref.)	1.03 (0.62–1.71)	0.91 (0.50–1.64)
	Model 1	1 (Ref.)	0.78 (0.41–1.47)	0.79 (0.43–1.48)	1 (Ref.)	0.98 (0.56–1.73)	0.82 (0.42–1.61)
	High FBS						
	Crude	1 (Ref.)	1.10 (0.58–2.06)	1.24 (0.68–2.28)	1 (Ref.)	0.61 (0.36–1.04)	**0.47 (0.24–0.89)**
	Model 1	1 (Ref.)	1.01 (0.52–1.94)	1.35 (0.71–2.58)	1 (Ref.)	0.63 (0.36–1.12)	**0.44 (0.22–0.91)**
Female	Obesity						
	Crude	1 (Ref.)	2.80 (0.78–10.07)	1.74 (0.48–6.30)	1 (Ref.)	1.37 (0.50–3.73)	1.66 (0.35–7.85)
	Model 1	1 (Ref.)	2.83 (0.76–10.45)	1.68 (0.43–6.53)	1 (Ref.)	1.26 (0.44–3.60)	1.62 (0.30–8.53)
	MetS[b]						
	Crude	1 (Ref.)	0.96 (0.65–1.42)	0.92 (0.59–1.43)	1 (Ref.)	0.97 (0.67–1.40)	1.20 (0.71–2.01)
	Model 1	1 (Ref.)	0.94 (0.63–1.41)	1.04 (0.64–1.68)	1 (Ref.)	1.01 (0.68–1.50)	1.28 (0.72–2.27)
	Low HDL-C						
	Crude	1 (Ref.)	1.29 (0.90–1.86)	1.18 (0.77–1.80)	1 (Ref.)	0.92 (0.65–1.30)	0.95 (0.59–1.53)
	Model 1	1 (Ref.)	1.28 (0.88–1.87)	1.30 (0.82–2.05)	1 (Ref.)	0.87 (0.60–1.26)	0.89 (0.53–1.51)
	High TG						
	Crude	1 (Ref.)	0.92 (0.64–1.32)	0.79 (0.52–1.21)	1 (Ref.)	1.01 (0.72–1.42)	1.23 (0.77–1.97)
	Model 1	1 (Ref.)	0.92 (0.63–1.33)	0.86 (0.55–1.35)	1 (Ref.)	1.09 (0.76–1.57)	1.42 (0.85–2.37)
	High FBS						
	Crude	1 (Ref.)	1.03 (0.72–1.48)	1.11 (0.73–1.69)	1 (Ref.)	0.99 (0.70–1.40)	1.22 (0.76–1.96)
	Model 1	1 (Ref.)	0.99 (0.68–1.44)	1.15 (0.73–1.81)	1 (Ref.)	1.05 (0.72–1.52)	1.28 (0.76–2.16)

The binary logistic regression across tertiles of meat diversity and vegetable diversity was used for estimation of ORs and confidence interval (CI). Model1: Crude model. Model 2: Adjusted for age, energy intake, waist circumference, wealth index and smoking. Indicates statistically significant values as $P < 0.05$. [b]Defined as the presence of ≥ 3 of the following components: 1) abdominal adiposity (WC ≥ 94 cm in men and ≥ 80 cm in women); 2) low serum HDL cholesterol (< 40 mg/dl for men and < 50 mg/dl for women); 3) high serum triacylglycerol (≥ 150 mg/dl); 4) elevated blood pressure (≥130/85 mm Hg); 5) abnormal glucose homeostasis (fasting blood sugar ≥ 100 mg/dl). MetS, Metabolic Syndrome; HDL, High-Density Lipoprotein; TG, Triglyceride; FBS, Fasting Blood Sugar.

($P < 0.001$). Participants with lower DDS were significantly more likely to be female, have low educational attainment, and to be nonsmoking ($P < 0.001$). Additionally, subjects in the top category of DDS in comparison with those in the lowest had a significantly higher mean of serum SGPT level ($P = 0.004$). Moreover, there was a significant difference regarding marital status across tertile categories of DDS ($P < 0.001$). Distribution of participants regarding the scores of all the food groups across tertile categories of DDS was significantly different; DDS of all of food groups increased significantly from the first to the third tertile ($P < 0.001$). There was a significant positive association between dietary energy intake and DDS score ($P = 0.04$).

Table 2 shows the sex-stratified crude and multivariable-adjusted odds ratios and 95% confidence intervals (95% CI) for MetS and its components across different categories of DDS. We found that male subjects who were assigned to the top DDS tertile had 51% lower risk of having low serum HDL-C (OR: 0.49; 95% CI: 0.24–0.96). However, these results changed substantially after controlling the effects of covariates (age, WC, energy intake, wealth index and smoking) (OR: 0.58; 95% CI: 0.27–1.24). A similar association was observed for men in the second tertile of DDS, in both the crude (OR: 0.44; 95% CI: 0.22–0.89) and adjusted (OR: 0.47; 95% CI: 0.23–0.97) model, taking into account different confounders. No statistically significant association was observed between odds of other variables and DDS; neither in the crude nor in the multi-adjusted model.

Table 3 shows the results of multivariable adjusted ORs for MetS and its component across the categories of diversity score of food groups, based on sex. We found a significant inverse association between the vegetable diversity score and odds of hyperglycemia in the male group, in the crude (OR: 0.47; 95% CI: 0.24–0.89) and in the adjusted model (OR: 0.44; 95% CI: 0.22–0.91); subjects in the highest tertile had lower serum fasting glucose concentration compared with those in the lowest category of vegetable diversity score. A significant inverse association was found between vegetables diversity score and odds of MetS in male group, in the crude (OR: 0.50; 95% CI: 0.26–0.93) and in the adjusted model (OR: 0.33; 95% CI: 0.15–0.70); A similar association was also observed for men in the second tertile of DDS, either in the crude (OR: 0.51; 95% CI: 0.29–0.88) or adjusted (OR: 0.40; 95% CI: 0.21–0.76) model, taking into account different confounders. There was no significant association of other food group diversity scores with MetS and its components (Table 3).

4. Discussion

To our review of literature, this is the first time that the association between DDS and MetS and its components were evaluated among hypertensive patients. In this cross-sectional study, we found an inverse association of diet variety with better metabolic features. Male patients in higher DDS categories had lower risk of having low HDL-C levels. In addition, the vegetable diversity score was inversely associated with 54% and 67 % decreased hyperglycemia and metabolic syndrome risk, respectively, after controlling for covariates.

According to previous research, DDS as a diet quality indicator is more useful in predicting nutrient adequacy [28] and also diet–disease relationship than individual foods or nutrients [29, 30]. In the present study, an inverse relationship was seen between DDS and some metabolic disturbances, which were in line with a number of investigations. In this regard, DDS, which is often based on a food guide pyramid, has been indicated to be inversely associated with obesity [31], cancers [30], metabolic syndrome [29], and cardiovascular risk factors [32]. For instance, previous reports by Azadbakht et al. among healthy subjects showed an inverse relation between DDS and metabolic syndrome features [20]. The results of studies evaluating DDS- chronic diseases relation are consistent [33, 34]. On the other hand, in agreement with earlier studies [31, 35], we indicated a higher variety score of diet was related to higher intakes of energy. However, the negative association between the DDS and dyslipidemia remained significant even after controlling for the effect of energy intake. Thus, it appears that another factor such as the type of food consumed might play a role in this regard [31, 36]. In other words, the source of the energy intake is important as well. Interestingly, a favorable effect of higher vegetable diversity scores on glucose homeostasis and metabolic syndrome was observed among the males in our analysis. All of these results suggest that inverse associations between DDS and metabolic risks may be due to the higher intake

of healthier and low-energy-dense food groups such as vegetables. Accordingly, previous study in Iranian adults found significant inverse associations between dietary energy density and the DDS, such that female subjects who were in the highest tertile category of dietary energy density had the lowest means of vegetable diversity score and DDS [37].

It is worth noting that sex inequalities regarding DDS and some metabolic features found in our study are consistent with previous investigations that reported the same results [38]. For example, a systematic assessment of men and women in 187 countries by Imamura et al. showed that females had higher adherence to healthy dietary patterns than males, which have been inversely related to chronic diseases [39].

The exact mechanisms underlying the desirable links between DSS and metabolic risk factors are not fully understood. However, DDS was formed based on the USDA's Food Guide Pyramid which provides healthy balanced diet guidance for the public [25]. As a result, diets with higher varieties of food are accompanied by increased consumption of vitamin C, calcium and dietary fiber intake, which has been favorably linked to obesity and its related consequences. In this regard, considerable evidence has shown beneficial effects of calcium and fiber intake on metabolic disorders such as MetS [40–42]. DDS may be associated not only with diabetes but also with its comorbidities and in particular cardiovascular and metabolic ones. Gholizadeh et al. [43] showed an inverse association between DDS and metabolic syndrome among pre-diabetic subjects. Lower DDS was connected with higher probability of metabolic syndrome and some features. Likewise, diet quality could inhibit the progress of cardio-metabolic risk factors such as abdominal obesity and hypertension in newly diagnosed diabetic subjects.

To the authors' knowledge, this is the first study to evaluate the relationship between DDS and metabolic risks among hypertensive patients. Additionally, the sample size of the present study was enough to stratify analyses in different sex categories. As well, a reliable and validated version of FFQ was used to obtain dietary information.

5. Limitations

Nonetheless, there are several clear limitations in the present study that need to be highlighted. First, the cross-sectional design of this study makes causal inferences impossible, and so prospective relationships remain to be explored. Second, despite carefully controlling for potential confounding factors, unknown or unmeasured confounding variables could not be fully eliminated. Third, since FFQ was used for dietary assessments, misclassification by the participants is a major concern in this research.

6. Conclusion

In conclusion, the present study revealed that higher DDS is associated with better metabolic features in hypertensive patients. Prospective cohort studies are indicated to confirm the results of this study.

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Conflict of interest

The authors state that they have no conflict of interest.

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Ethical Approval

The ethical committee of Ahvaz Jundishapur University of Medical Sciences confirmed the study and the approval of the Ethics Committee was obtained (IR.AJUMS.REC.1398.492).

Informed consent

Signed informed consent was obtained from all participants.

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