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The association of dietary approaches to stop hypertension measured by the food frequency questionnaire with metabolic syndrome and some inflammatory biomarkers in adolescents with obesity: a case-control study

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Abstract

Background Globally, obesity trends are a serious public health concern. Adolescent obesity is associated with cardiometabolic risk and metabolic disorders in adolescence and may persist into adulthood. The current study was designed to explore the Dietary Approaches to Stop Hypertension (DASH) in adolescents and its relationship with obesity, insulin resistance, metabolic syndrome (MetS), and some inflammatory biomarkers.

Methods A total of 90 adolescents with obesity and 90 adolescents with normal weight, participated in the study. Data from a validated 168-item semi-quantitative food frequency questionnaire were used to calculate the DASH score. The association of DASH score with cardiometabolic risk factors was estimated using multivariable logistic regression models. To assess the correlation between the DASH score and dietary factor, the Pearson correlation coefficient (r) was used.

Results Adolescents with a high DASH score had significantly higher intakes of potassium, magnesium, vitamin C, and vitamin K and lower intakes of sodium compared with those with a low DASH score ($P < 0.05$). There were no significant differences in the DASH score and its components between adolescents with and without metabolic syndrome. Adolescents with metabolic syndrome had significantly higher concentrations of triglycerides, low HDL-C, and high blood pressure compared with those without metabolic syndrome ($P < 0.05$). There were no significant associations between DASH score and MetS and other cardiometabolic risk factors in crude and multivariate-adjusted

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models. In addition, the DASH score was positively associated with potassium, magnesium, sodium, vitamins D and C, docosahexaenoic acid, and soluble fiber ($P < 0.05$).

Conclusion In the current study, there was no significant association between adherence to the DASH diet and odds of metabolic syndrome, and other cardiometabolic risk factors in adolescent. Further prospective studies are needed to confirm these findings.

Trial registration Ethics approval was obtained from the research ethics committee of Tabriz University of Medical Sciences (IR.TBZMED.REC.1397.179.).

Keywords Dietary approaches to stop hypertension, Overweight, Obesity, Metabolic syndrome, Insulin resistance, Adolescent

Introduction

Obesity in children and adolescents is a multifactorial and chronic condition that is characterized by a wide range of causes and has serious consequences for health [1]. By 2025, it is estimated that there will be 70 million overweight or obese children and adolescents worldwide [2]. The cluster of chronic diseases, previously seen mainly in adults, is becoming increasingly common in children and adolescents [3]. Adolescent obesity is associated with cardiometabolic risk throughout adolescence and later with cardiovascular disease and metabolic disorders including, obesity, insulin resistance, impaired glucose tolerance, hypertension, and dyslipidemia through adulthood [4]. The most important modifiable cardiometabolic risk factors are the accumulation of excess weight, a sedentary lifestyle, and adherence to unhealthy dietary patterns [5]. However, there is still no consistent evidence of the impact of different dietary patterns in children and adolescents on overall cardiometabolic health.

Dietary patterns analysis is useful for understanding the complex association between combining different foods and nutrients and how they interact to affect metabolic status [6]. Previous studies have shown that unhealthy or Western diets high in refined grains, red meat, processed foods, and saturated fats are positively associated with several metabolic risk factors, including dyslipidemia, obesity, insulin resistance, and low-grade systemic inflammation [7]. Conversely, better metabolic health is associated with a healthy diet high in plant-based foods, seafood, and healthy oils [7]. It is believed that the Dietary Approaches to Stop Hypertension (DASH), as a healthy dietary pattern, could be a strategy for preventing and managing metabolic risk factors and disease-related obesity [8]. DASH is a dietary intervention that encourages the consumption of whole grains, fruits, vegetables, low-fat dairy products, poultry, fish, nuts, and seeds and recommends less intake of red and processed meat, sugary drinks, and sodium [8]. Studies have reported that this type of dietary intervention is effective in reducing blood pressure and body weight because the DASH diet leads to higher intakes of magnesium, calcium, potassium, and fiber [9]. Research has also shown that the DASH dietary pattern improves lipid profile and glycemic control, resulting in a lower risk of cardiovascular disease in adults [10]. In addition, the DASH diet may also suppress the inflammatory process because of its high anti-inflammatory components, such as whole grains, fruits, vegetables, fiber, legumes, and magnesium, which have been suggested to improve low-grade systemic inflammation [11]. However, epidemiological research investigating the effects of the DASH diet on metabolic risk factors in adolescents is limited and has yielded conflicting results. In a cross-sectional study, no association was found between the DASH diet and blood pressure, waist circumference, serum levels of glucose, HDL cholesterol, or triglycerides in 11- to 30-year-olds [12]. In contrast, three cohort studies reported a negative association between a high level of adherence to the DASH diet and body weight and blood pressure in adolescents [13–15]. A recent cohort study found that a higher DASH score was a relationship with a reduction in insulin resistance, but not with an improvement in other metabolic risk factors in children and young adults [16].

Therefore, this case-control study aimed to evaluate the association between the DASH diet score and cardiometabolic risk factors including metabolic syndrome (MetS) and its components, insulin resistance and some inflammatory biomarkers, in adolescents aged 12–18 years.

Materials and methods

Study design and population

The participants in this study were 90 adolescents with obesity and 90 normal-weight adolescents between the ages of 12 and 18 years who were recruited from urban health centers and volunteers who agreed to take part in the study via a public call. The control (normal-weight) and case (obese) groups were matched based on age and gender.

The current study is a sub-analysis of our previous study [17]. For sample size calculation, based on the study by Asghari et al. [18] we used data from the association between DASH diet score and waist circumference using PS software, and the sample size was calculated at

180 participants (OR: 0.35(0.14–0.39); P0: 0.3; Power: 80% ; $N = 180$). As all 180 children and adolescents were not willing to give a blood sample, we calculated another sample size to measure the biochemical parameters. Therefore, the second sample size for biochemical testing were estimated based on the mean and standard deviation of the spexin factor and using PS software according to the study by Kumar et al. (81 participants and with 11% attrition, 90 participants), [$\Delta = 0.13$; $\sigma = 0.21$; $m = 1$; Power = 80%; $N = 90$] [19] .

The inclusion criteria for the case group were adolescents with a body mass index (BMI) at or above the 95th percentile of the Centers for Disease Control and Prevention (CDC) growth charts; and for the control group, adolescents with a BMI between the 5th and 85th percentile. Exclusion criteria included a history of endocrine, neurological, cardiovascular, gastrointestinal, or respiratory disease, following a special diet such as a weight-loss diet or vegetarian diet, suspected obesity-related syndromes (e.g. Prader-Willi syndrome), or cancer. The participants and their parents were informed of the details of the study and were asked to sign an informed consent form.

Biochemical, and blood pressure measurements

Of the 180 participants (90 obese and 90 normal weight) whose completed FFQ and anthropometric data and body composition measurements were available, 90 were willing to take blood. After 12 h of overnight fasting, blood samples were taken from 90 adolescents (45 obese and 45 normal weight). The control (normal weight) and case (obese) groups were matched for age and sex. Serum concentrations of IL-1β and IL-10 were assessed by enzyme-linked immunosorbent assay (ELISA) method (Bioassay Technology Laboratory (BT Lab); Shanghai Korean Biotech Co Ltd) according to the manufacturer's instructions. Serum levels of high-sensitivity C-reactive protein (hs-CRP) were measured using the turbidimetric method. Serum fasting blood glucose (FBG), triglycerides (TG), and high-density lipoprotein cholesterol (HDL-c) were measured enzymatically using a colorimetric technique using commercial kits (Pars-Azmoon Co., Tehran, Iran). The Friedewald equation was used to calculate low-density lipoprotein cholesterol (LDL-c). The concentration of insulin was measured using the ELISA method (Monobind, Lake Forest, CA, USA). The HOMA-IR was calculated using the following formula [20]:

HOMA-IR = [fasting insulin (μIU/ml) × fasting glucose (mg/dl)]/405.

Systolic and diastolic blood pressures (SBP and DBP, respectively) were measured using a mercury sphygmomanometer. The cuff size was appropriate for each adolescent who was placed in a supine position. Blood pressure readings were taken after a 15-minute rest period.

Definition of metabolic syndrome

Based on the criteria of Cook et al. [21], adolescents were diagnosed with MetS if they had at least three of the five criteria, as follows: WC ≥ 90th percentile for age and sex [based on national reference curves [22]]; HDL-C < 40 mg/dL; TGs ≥ 110 mg/dL; FBG ≥ 110 mg/dL [according to the American Diabetes Association [23]]; SBP and DBP ≥ 90th percentile for sex, age, and height [according to the National Heart, Lung, and Blood Institute's recommended cut-off points [24]].

Assessment of insulin resistance

The fasting insulin level was used to diagnose hyperinsulinism. The pre-pubertal, pubertal, and post-pubertal cut-off values for fasting insulin were 15 μU/mL, 30 μU/mL, and 20 μU/mL, respectively [25, 26]. Furthermore, cut-off values for HOMA-IR were determined according to age and sex. Insulin resistance was diagnosed when the HOMA-IR was 2.67/ 2.22 in boys/girls in the pre-pubertal period and 5.22/ 3.82 in boys/girls in the pubertal period [26].

Physical activity and Anthropometric Assessment

The Modifiable Activity Questionnaire (MAQ) was used to assess the level of physical activity in adolescents. The reliability and validity of the Persian version of the MAQ in young people were 97% and 49%, respectively [27]. Participants were requested to report on the physical activities in which they had been involved in the past 12 months including the frequency and duration of each activity identified. Each activity was weighted according to its relative intensity, referred to as the metabolic equivalent of the task (MET). For all levels of activity, the MET obtained has been multiplied by the time spent on each level of activity. MET time from each level was added to a total of 24 h MET time, representing the average daily physical activity.

Adolescents' height was measured by a stadiometer with a precision of 0.5 centimeters while standing and barefoot. The weight of the adolescents was measured using a SECA digital weighing scale (Seca 707; Seca Corporation, Hanover, Maryland; range: 0.1–150 kg) with an accuracy of 0.1 kg while they were wearing light clothing. Weight (kg) divided by the square of height (m) was also used to calculate BMI. Waist circumference (WC) was measured at the site of the umbilicus using an outstretched tape measure and without applying pressure to any surfaces, and was recorded to the nearest 0.1 cm. Hip circumference (HC) was measured with the participants standing at the point where the maximum circumference over the buttocks was obtained using a tape measure

accurate to 0.1 cm. A Tanita MC-780 S MA (Amsterdam, The Netherlands) was used to measure body composition, including fat mass (FM) and fat-free mass (FFM).

Dietary assessment and DASH calculation

A trained interviewer recorded the adolescents' dietary intake over the previous year using a validated 168-item semi-quantitative food frequency questionnaire (FFQ). The reliability and validity of the FFQ have been tested in young people [28]. Food frequency (daily, weekly, monthly, and yearly) was recorded for all participants based on standard portion sizes for each food item. Using standard Iranian household measures, all intakes were converted to grams per day. The parents were asked to help their child remember the type of food and the amount of food consumed in the FFQ items. Values for energy, food group items, and nutrient intakes were determined from the FFQ information using the revised Nutritionist IV software (version 3.5.2). The dietary data from the FFQs were used for the calculation of the DASH scores for all participants. The reproducibility and validity of the FFQ for calculating the DASH score have been previously investigated [29].

According to the Fung et al. study, adherence to the DASH diet was evaluated based on intake of eight food groups, including fruits, vegetables, whole grains, legumes and nuts, low-fat dairy products, red or processed meats, sodium, and sweetened beverages [30]. Daily intakes of eight food groups were calculated in grams per 1000 kcal to adjust for the effect of daily energy intake. The intakes of the eight food groups in grams/1000 kcal were then divided into quintiles to calculate the DASH score. Participants in the lowest quintile of intake of fruits, vegetables, nuts and legumes, low-fat dairy products, and whole cereals received a score of 1, and those in the highest quintile received a score of 5. The scoring method was reversed for red and processed meat, sugar-sweetened beverages, and sodium. Hence, participants in the lowest intake quintile were given a score of 5, and those in the highest intake quintile were given a score of 1. Then, to calculate the participant's score for adherence to the DASH diet, the scores for all eight components were added together for each participant. The overall DASH score ranged from 5 (minimum adherence) to 40 (maximum adherence), with 40 representing greater consistency between the self-reported diet and the DASH diet score.

Statistical analysis

The normality of the distribution of the data was analyzed using the skewness kurtosis test. Mean [standard deviation (SD)] and median [interquartile range (IQR)] were reported for normal and abnormal quantitative variables, respectively. Independent samples t-test (normal variables) or Mann-Whitney U-test (non-normal variables) were used for the determination of differences in quantitative variables. Frequency and percent were used for categorical variables. The chi-squared test was used to assess differences between categories for qualitative variables. Odds ratios (ORs) and 95% confidence intervals (CIs) were estimated using logistic regression models; model 1: crude (unadjusted), multivariable-adjusted model 2: adjusted for sex, age, and maturity, multivariable-adjusted model 3: adjustment for total dietary calorie intake, birth weight, parental obesity plus model 2. To estimate the correlation between the DASH score and dietary factor, the Pearson correlation coefficient (r) was used. The studied adolescents were divided into two groups including *"adolescents with a high DASH score"* and *"adolescents with a low DASH score"* based on the DASH score median (median = 24).

Moreover, the studied population were divided in to three and four groups, based on DASH score (tertiles and quartiles).

SPSS version 23.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. A P-value of less than 0.05 or a 95% CI for the OR that excludes 1.0 is considered to be statistically significant. We used the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement checklist for reporting our data.

Results

As shown in Fig. 1, a total of 90 obese adolescents (45 girls, 45 boys) and 90 normal-weight adolescents (45 girls, 45 boys) between the ages of 12 and 18 years were selected for the study. Among the 90 adolescents who had biochemical data, 14 subjects (one person from the control group and 13 subjects from the obese group) met the criteria for metabolic syndrome and 76 subjects did not have metabolic syndrome.

General characteristics and cardiometabolic risk factors of study adolescents with a high DASH score and adolescents with a low DASH score were compared in Table 1. No significant associations were observed between two groups regarding general characteristics and cardiometabolic risk factors. The results of analyses with tertile and quartile divisions were also non-significant (data not shown). However, potassium, magnesium, vitamin C, and vitamin K intakes were significantly higher in adolescents with a high DASH score, and sodium intake was significantly higher in those with a low DASH score.

Table 2 compares DASH score, dietary intakes, anthropometric measurements, and biochemical characteristics of adolescents with and without metabolic syndrome. No significant associations were observed between adolescents with and without metabolic syndrome regarding DASH score and its components. Participants with metabolic syndrome had significantly lower HDL-C

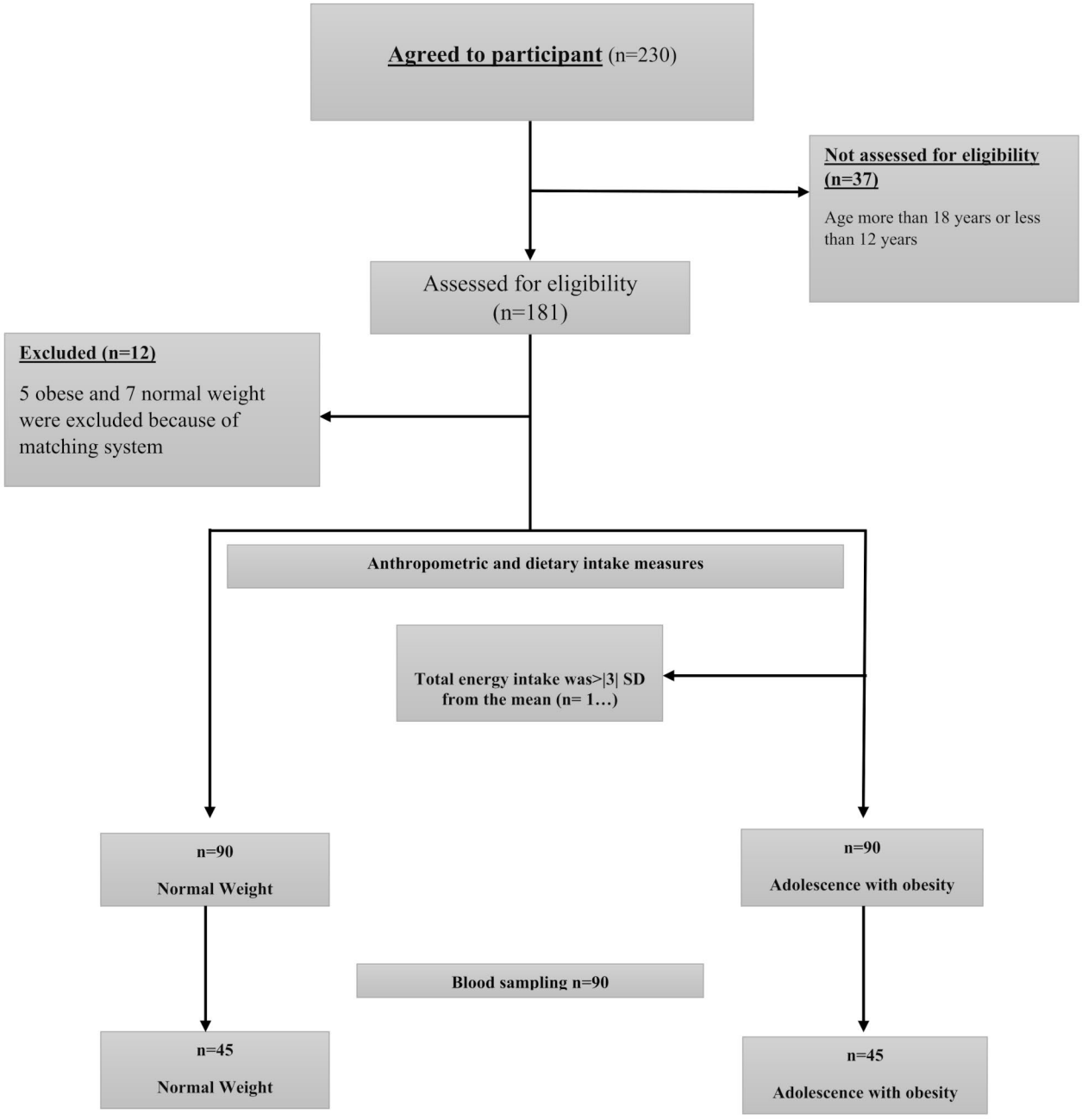

Fig. 1 Flowchart of study

concentrations and higher TG, SBP, DBP, and FM ($P<0.05$) compared with those without metabolic syndrome. However, there was no difference in any other parameter between adolescents with and without the metabolic syndrome.

Table 3 shows the ORs and 95% CIs for the association of the DASH score with MetS and it's components including obesity, TG, WC, HDL, insulin resistance and SBP. In crude and multivariate-adjusted models, there were no significant associations between the DASH score, and MetS and other cardiometabolic risk factors.

Table 4 shows the Pearson correlation coefficient (r) between the DASH score and some dietary factors. The DASH score was positively associated with potassium, magnesium, sodium, vitamins D and C, docosahexaenoic acid, and soluble fiber($P<0.05$).DASH score, dietary intakes, anthropometric measurements, and biochemical characteristics of adolescents with and without obesity were compared in Supplementary Table e1. Adolescents

Table 1 General characteristics and cardiometabolic risk factors comparison of the adolescents with a high and low DASH score

	Adolescents with a low DASH score	Adolescents with a high DASH score	*P*-value
Proportion of boy to girl	44/33	46/57	0.19
Age (year)	14.02 (2.85)	13.50 (2.62)	0.18
Weight (kg)	61.71 (21.70)	58.97 (19.50)	0.34
Height (cm)	160.05 (14.47)	158.42 (12.38)	0.38
BMI (kg/m^2)	23.56 (6.42)	23.00 (5.70)	0.51
WC (cm)	83.57 (16.00)	79.97 (15.48)	0.10
HC (cm)	94.38 (17.52)	95.95 (14.01)	0.81
Physical activity(MET-h/week)	15.11(6.25)	14.11(5.61)	0.37
Birth Weight(gr)	3164.10(701.51)	3297.39(612.50)	0.21
[#]Paternal Obesity(YES) *n* (%)	35(38.8)	37(41.1)	0.41
[#]Maternal Obesity(YES) *n* (%)	50(55.5)	40(44.5)	0.06
SBP (mmHg)	106.94 (12.49)	104.01 (11.22)	0.51
DBP (mmHg)	63.37 (9.9)	63.70 (1.021)	0.90
FFM (kg)	43.34(13.39)	41.56(12.66)	0.37
FM (kg)	16.68(10.63)	15.61(9.41)	0. 45
[$]FBG (mg/dL)	78.18 (5.51)	77.18 (6.47)	0.52
[$]Insulin (μUI/mL) *	7.20 (7.98)	5.50 (8.50)	0.24
[$]TG (mg/dL)	126.85 (66.23)	120.43 (53.50)	0.61
[$]HDL-c (mg/dL)	46.33 (9.61)	47.57 (11.23)	0.57
[$]LDL-c(mg/dL)	121.71(26.90)	128.2(35.2)	0.30
[$]IL-10 *	261.20 (244.85)	281.05 (407.03)	0.70
[$]IL-1beta *	994.50 (948.50)	953.7 (1424.02)	0.82
[$]Hs-CRP *	0.95 (2.54)	0.71 (2.08)	0.14

[*]Median (IQR = Q3-Q1), Mann-Whitney U test

[#]*n* (%) Chi-Square test

[1]BMI: Body mass index; DASH: Dietary Approaches to Stop Hypertension; DBP: Diastolic blood pressure; FBG: Fasting blood glucose; HC: Hip circumference; hs-CRP: High-sensitivity C-reactive protein; IL: Interleukins; SBP: Systolic blood pressure; TG: triglycerides; WC: Waist circumference

[$]DASH < 24 *N* = 45 / DASH > 24 *N* = 45

with obesity were found to have low adherence to the DASH diet, although there were no significant differences from normal-weight adolescents. Moreover, supplementary Table 2 reports the comparison of the adolescents with a high and low DASH score regarding dietary intakes.

Discussion

In this case-control study, we examined the associations of adherence to DASH diet with metabolic syndrome, and other cardiometabolic risk factors in Iranian adolescents aged 12 to 18 years. Our results showed no association between the DASH diet score and cardiometabolic risk factors in the crude and adjusted final analysis models. Adolescents with obesity were found to have low adherence to the DASH diet, although there were no significant differences from normal-weight adolescents.

Although several studies have shown an association between the DASH score and a range of diseases including obesity [31], diabetes mellitus [32], metabolic syndrome [33], neurological diseases [34], and cancer [35] in adults, the association between this healthy dietary score and chronic diseases in children has been less well studied. Consistent with our findings, Bricarello et al. [36] showed no association between the DASH diet score and overweight/obesity in Brazilian adolescents. However, Hajna et al. [37] study reported that a higher DASH score was negatively associated with body composition measures and BMI. The relationship between the DASH diet and MetS in children/adolescents has been analyzed in only a few previous studies. In a cross-sectional study by Heidari et al. [38] greater adherence to the DASH diet was associated with a significantly lower risk of metabolic disorders such as hyperglycemia, insulin resistance, hypertriglyceridemia, and low HDL-c, especially in overweight subjects and girls. Following the DASH diet was inversely associated with the incidence of MetS and some of its components, including abdominal obesity, hyperglycemia, and hypertension, in the Tehran Lipid and Glucose Study, a prospective study of 425 healthy adolescents with a mean age of 13.6 years, followed for 3.6 years [18]. However, in line with our findings in another epidemiological study of 628 young people aged 10–18 years, higher DASH scores were not associated with the risk of dyslipidemia, although DASH was inversely associated with the risk of general and central obesity in adolescents [39]. Furthermore, Park et al. [40] found no association between the DASH diet and cardiometabolic risk factors

Table 2 DASH score, dietary intakes, anthropometric measurements, and biochemical characteristics of adolescents with and without metabolic syndrome

	Children without metabolic syndrome ***N*** **= 76**	**Children with metabolic Syndrome** ***N*** **= 14**	***P*-value**
[1]DASH score	23.69(5.00)	23.53(7.00)	0.90
Total calorie intake (Kcal/day)	2160.17(760.96)	2047.21(587.95)	0.61
Total protein intake (gr/day)	70.73(27.39)	72.72(21.34)	0.080
Total carbohydrate intake (gr/day)	311.73(110.96)	297.90(82.38)	0.67
Total fat intake (gr/day)	72.66(29.03)	66.94(25.18)	0.50
Saturated fatty acid Intake (g/day)	22.51(9.56)	20.60(8.11)	0.50
Total cholesterol intake (mg/day) *	174(150.37)	203.38(110.62)	0.32
Total fiber intake(gr/day) *	44.57(34.72)	40.57(30.23)	0.42
Fruit group	220.95(130.70)	182.57(90.39)	0.26
Vegetable group *	199.45(145.05)	173.26(111.30)	0.77
Legumes and nuts *	34.06(43.96)	37.59(46.90)	0.80
Low-fat dairy *	180.05(192.26)	113.04(103.29)	0.33
Whole grain	127.84(66.20)	110.59(60.61)	0.41
Red meat and processed meat *	17.93(14.48)	16.42(14.35)	0.30
Sodium intake (mg) *	3417.90(1637.60)	3590.43(1748.20)	0.26
Potassium intake (mg)*	2761.18(1334.02)	2693.25(842.44)	0.53
Magnesium intake (mg)	363.59(140.31)	351.02(91.20)	0.88
TG (mg/dl)	108.29(47.03)	202.50(59.51)	**< 0.001**
Total Cholesterol (mg/dl)	157.03(30.30)	168.35(33.95)	0.21
LDL- cholesterol (mg/dl)	125.59(28.15)	120.77(33.24)	0.56
HDL- cholesterol (mg/dl)	48.91(9.83)	35.42(3.93)	**< 0.001**
FFM (kg)	41.38(13.21)	55.71(14.24)	0.001
FM (kg)*	13.05 (11.56)	29.25(11.80)	**< 0.001**
SBP (mmHg)	100.52(11.60)	120.03(11.00)	**< 0.001**
DBP (mmHg)	63.80(9.5.20)	75.35(7.7.14)	**< 0.001**

*Median (IQR = Q3-Q1). Mann-Whitney U test

[1]DASH: Dietary Approaches to Stop Hypertension; DBP: Diastolic blood pressure; FFM: Fat-free mass; FM: Fat mass; SBP: Systolic blood pressure; TG: triglycerides

in young people. In another observational study of overweight and obese Iranian children aged 6 to 13 years, greater adherence to the DASH diet was associated with a reduced likelihood of insulin resistance, but there was no notable association with other cardio-metabolic risk factors [41]. The observed inconsistencies among the results of the aforementioned studies may be explained by several factors. First, differences in the study population age range could lead to varying levels of cardiometabolic risk. Second, the Study features like differences in sample size, retrospective or prospective design, which could impact the ability to detect associations. Third, the criteria used to define cardiometabolic risk factors, such as hypertension, dyslipidemia, or insulin resistance, were not consistent across studies, leading to potential differences in categorization. Finally, the inclusion and control of potential confounders, such as lifestyle factors, medication use, or underlying health conditions, differed between studies, potentially influencing the observed associations. However, we tried to adjust the effect of confounding variables as much as possible, but certainly due to the limitation of the study, we were not able to measure some confounding variables, and the failure to discover the relationship may be because of this fact. The lack of association of the DASH score with cardiometabolic risk factors in this study may be related to the following two reasons. Firstly, although the percentage of metabolic disorders in the obese group was higher than in the control group, 55% of the obese adolescents had a metabolically healthy phenotype, with no evidence of insulin resistance or metabolic syndrome. Second, healthy obese children had higher intakes of protein, fruit, and vegetables, and this may have been a protective factor against changes in their metabolic phenotype to an unhealthy state [42].

In our study, we found no differences in inflammatory biomarkers such as IL-10, IL-1 beta, and Hs-CRP in adolescents with high and low adherence to the DASH diet. To the best of our knowledge, there has been no study that has examined the association between DASH and biomarkers of inflammation in young people. Recently, a study by Zhang et al. [43] showed that a high

Table 3 The association of adherence to DASH diet with odds of metabolic syndrome and it's components in the studied adolescents1

	OR (95% CI)		*P*-value[2]
	Adolescents with a low DASH score (*n* = 90)	Adolescents with a high DASH score (*n* = 90)	
MetS			
Model 1 *	1.00(ref)	0.92(0.28–3.03)	0. 90
Model 2 **	1.00(ref)	0.78(0.22–2.74)	0.69
Model 3 ***	1.00(ref)	0.61(0.15–2.45)	0.49
Obesity			
Model 1 *	1.00(ref)	0.84(0.48–1.46)	0.53
Model 2 **	1.00(ref)	0.83(0.47–1.43)	0.54
Model 3 ***	1.00(ref)	0.79(0.42–1.46)	0.45
TG ≥ 110 mg/dL			
Model 1 *	1.00(ref)	0.85(0.36–1.95)	0. 71
Model 2 **	1.00(ref)	0.87(0.35–2.16	0.87
Model 3 ***	1.00(ref)	0.74(0.33–2.12)	0.62
HDL-C < 40 mg/dL			
Model 1 *	1.00(ref)	0.88(0.33–2.32)	0.80
Model 2 **	1.00(ref)	0.88(0.31–2.51)	0.82
Model 3 ***	1.00(ref)	0.89(0.30–2.69)	0.83
SBP ≥ 90th percentile			
Model 1 *	1.00(ref)	0.51(0.12–2.19)	0.36
Model 2 **	1.00(ref)	0.50(0.18–2.13)	0.38
Model 3 ***	1.00(ref)	0.34(0. 07-1.68)	0.19
WC ≥ 90th percentile	1		
Model 1 *	1.00(ref)	0.52(0.19–1.45)	0.21
Model 2 **	1.00(ref)	0.57(0.20–1.63)	0.30
Model 3 ***	1.00(ref)	0.53(0.19–1.50)	0.30
HOMA-IR#			
Model 1 *	1.00(ref)	0.95(0.29–3.11)	0.93
Model 2 **	1.00(ref)	0.92(0.26–3.18)	0.89
Model 3 ***	1.00(ref)	0.97(0.28–3.72)	0.91

[1]DASH: Dietary Approaches to Stop Hypertension; MetS: metabolic syndrome; WC: waist circumference; HDL-C: high-density lipoprotein cholesterol; TG: triglyceride; SBP: systolic blood pressure

[2]Binary logistic regression

*Crude

**Adjusted for sex, age, maturity, and stress level

***Adjusted for model 2 + total dietary calorie intake + birth weight and parental obesity

#HOMA-IR cut-off values for insulin resistance were calculated to be 2.67 (sensitivity 88.2%, specificity 65.5%) in boys and 2.22 (sensitivity 100%, specificity 42.3%) in girls in the prepubertal period, and 5.22 (sensitivity 56%, specificity 93.3%) in boys and 3.82 (sensitivity 77.1%, specificity 71.4%) in girls in the pubertal period

N = 90

pro-inflammatory diet was associated with higher levels of inflammatory cytokines such as CRP, especially in overweight and obese children and adolescents aged 6–19 years. The DASH diet has a low inflammatory score and may modify systemic inflammation and inhibit the development and progression of inflammatory conditions by reducing serum concentrations of CRP and IL-6 and improving endothelial function parameters [44].

The exact mechanisms by which the DASH diet score might be associated with metabolic conditions are not yet clear. However, several possibilities have been suggested. The favorable effects of the DASH diet on metabolic health may be explained by the lower amounts of saturated fat, refined sugar, and salt in the DASH diet [45]. A DASH diet is rich in whole grains, fruits, vegetables, legumes, and nuts; consequently, the high levels of magnesium, potassium, fiber, and antioxidants, may have benefits for inflammation and cardiometabolic risk factors [46]. In addition, the production of short-chain fatty acids (SCFAs) by the gut microbiota could be increased by high fiber levels [45]. SCFAs have been shown to improve glucose and lipid metabolism in most tissues and to reduce biomarkers of inflammation [47]. In addition, whole-grain foods are associated with a lower incidence of insulin resistance due to their low glycemic index and slow rate of absorption [48]. The key role of

Table 4 Associations of DASH score with some dietary factors ($N = 180$)

Parameters	*r*	*P*-value[#]
Sodium	-0.24	**0.02**
Potassium	0.27	**0.01**
Magnesium	0.28	**0.007**
Calcium	0.10	0.35
Selenium	0.11	0.28
Zinc	0.18	0.08
Vit D	0.32	**0.002**
Vit C	0.26	**0.01**
Docosahexaenoic acid	0.20	**0.05**
Soluble fiber	0.27	**0.009**

[#]Data presented as Pearson correlation coefficient (r)

low-grade systemic inflammation and oxidative stress in the development of cardiometabolic disorders has been well-documented [49]. Therefore, the antioxidant content of healthy foods in DASH scores could reduce oxidative stress through the scavenging of free radicals [9]. In addition, results from previous studies have shown inverse associations between calcium intake and glycemic status, lipid profiles, and hypertension [50].

Some of the strengths and limitations of this survey need to be highlighted. First, to our knowledge, few studies have examined the association between the DASH diet and cardiometabolic risk factors in overweight and obese Iranian adolescents. Second, in the current study, several factors including inflammatory biomarkers, HOMA-IR, MetS, and its components have been assessed concerning cardiometabolic risk factors in adolescents. However, the design of this study was case-control and did not allow us to draw any conclusions about causality. It is, therefore, necessary to carry out further prospective studies. In addition, because of the use of FFQ to assess dietary intake, misclassification of individuals was inevitable. Finally, residual confounders, such as birth weight, paternal obesity, sleep disturbances, and dietary habits, could alter the results despite the control of various covariates.

Conclusion

In conclusion, this case-control study showed that the DASH diet, as assessed by a food frequency questionnaire, was not associated with cardiometabolic risk factors, including MetS, and its components, adiposity and insulin resistance in adolescents with obesity. To confirm these findings, further prospective studies on a larger scale and from different countries are needed.

Abbreviations

DASH	Dietary approaches to stop hypertension
BMI	Body mass index
CVD	Cardiovascular disease
FFQ	Food frequency questionnaire
HDL-C	High-density lipoprotein cholesterol
hs-CRP	High-sensitivity C-reactive protein
IL	Interleukin
LDL-C	Low-density lipoproteins cholesterol
MetS	Metabolic syndrome
IR	Insulin resistance
FBG	Fasting blood glucose
HOMA-IR	Homeostatic model assessment of insulin resistance
TG	Triglyceride
TNF-α	Tumor necrosis factor-α
WC	Waist circumference
SBP	Systolic blood pressure
DBP	Diastolic blood pressure
MAQ	Modifiable activity questionnaire
CDC	Charts of centers for disease control and prevention
OR	Odds ratio
CI	Confidence interval
ELISA	Enzyme-linked immunosorbent assay
SCFAs	Short-chain fatty acids
FFM	Fat-free mass

Supplementary Information

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Supplementary Material 1

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Author contributions

This study was conceptualized by SS, AG, and MB. Data collection was performed by MB, SS, and SH. Formal analysis was conducted by MB and AG, and funding acquisition was by MB and SS. The investigation was carried out by MB, SH, MM, and AO, the methodology was set by MB and SH. The study was supervised by SS and MB. Writing of the original draft was performed by MB, SH, and SS. Reviewing and editing were carried out by AO, MB, SH, MM, and SS.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Ethics approval was obtained from the research ethics committee of Tabriz University of Medical Sciences (IR.TBZMED.REC.1397.179.). The ethical standards of the institutional and/or national research committee and the Helsinki Declaration of 1964 and its subsequent amendments or comparable ethical standards were followed for all procedures in studies involving human participants. Informed consent was obtained from all subjects or their parents on behalf of the participants. The purpose of the study was explained to the participants.

Consent for publication

Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Sidhu SK, Aleman JO, Heffron SP, Arteriosclerosis. Thromb Vascular Biology. 2023;43(10):1764–74.
2. Ho HCH, Maddaloni E, Buzzetti R. Risk factors and predictive biomarkers of early cardiovascular disease in obese youth. Diab/Metab Res Rev. 2019;35(4):e3134.
3. Weihe P, Weihrauch-Blüher S. Metabolic syndrome in children and adolescents: diagnostic criteria, therapeutic options and perspectives. Curr Obes Rep. 2019;8:472–9.
4. Morales-Ghinaglia N, Fernandez-Mendoza J. Sleep variability and regularity as contributors to obesity and cardiometabolic health in adolescence. Obesity. 2023;31(3):597–614.
5. Roth GA, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, et al. Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980–2017: a systematic analysis for the global burden of Disease Study 2017. Lancet. 2018;392(10159):1736–88.
6. Zhao J, Li Z, Gao Q, Zhao H, Chen S, Huang L, et al. A review of statistical methods for dietary pattern analysis. Nutr J. 2021;20:1–18.
7. Funtikova AN, Navarro E, Bawaked RA, Fíto M, Schröder H. Impact of diet on cardiometabolic health in children and adolescents. Nutr J. 2015;14:1–11.
8. Fung TT, Chiuve SE, McCullough ML, Rexrode KM, Logroscino G, Hu FB. Adherence to a DASH-style diet and risk of coronary heart disease and stroke in women. Arch Intern Med. 2008;168(7):713–20.
9. Lari A, Sohouli MH, Fatahi S, Cerqueira HS, Santos HO, Pourrajab B, et al. The effects of the Dietary approaches to stop hypertension (DASH) diet on metabolic risk factors in patients with chronic disease: a systematic review and meta-analysis of randomized controlled trials. Nutr Metabolism Cardiovasc Dis. 2021;31(10):2766–78.
10. Ghorabi S, Salari-Moghaddam A, Daneshzad E, Sadeghi O, Azadbakht L, Djafarian K. Association between the DASH diet and metabolic syndrome components in Iranian adults. Diabetes Metabolic Syndrome: Clin Res Reviews. 2019;13(3):1699–704.
11. Soltani S, Chitsazi MJ, Salehi-Abargouei A. The effect of dietary approaches to stop hypertension (DASH) on serum inflammatory markers: a systematic review and meta-analysis of randomized trials. Clin Nutr. 2018;37(2):542–50.
12. Winpenny EM, van Sluijs EM, Forouhi NG. How do short-term associations between diet quality and metabolic risk vary with age? Eur J Nutr. 2021;60:517–27.
13. Moore LL, Bradlee ML, Singer MR, Qureshi MM, Buendia JR, Daniels SR. Dietary approaches to stop hypertension (DASH) eating pattern and risk of elevated blood pressure in adolescent girls. Br J Nutr. 2012;108(9):1678–85.
14. Berz JP, Singer MR, Guo X, Daniels SR, Moore LL. Use of a DASH food group score to predict excess weight gain in adolescent girls in the National Growth and Health Study. Arch Pediatr Adolesc Med. 2011;165(6):540–6.
15. Loizou P, Taylor CM, Buckland G. The dietary approaches to stop hypertension (DASH) dietary pattern in childhood in relation to cardiometabolic risk in adolescence and early adulthood in the ALSPAC birth cohort. Public Health Nutr. 2024;27(1):e86.
16. Aljahdali AA, Peterson KE, Cantoral A, Ruiz-Narvaez E, Tellez-Rojo MM, Kim HM, et al. Diet quality scores and cardiometabolic risk factors in Mexican children and adolescents: a longitudinal analysis. Nutrients. 2022;14(4):896.
17. Behrooz M. Study of the relationship between some nutritional factors, expression of some obesity related micro RNAs, serum level of spexin and metabolic as well as inflammatory status with obesity in 12–18 years old adolescents. Tabriz University of Medical Sciences, School of Nutrition and Food Sciences; 2020.
18. Asghari G, Yuzbashian E, Mirmiran P, Hooshmand F, Najafi R, Azizi F. Dietary approaches to stop hypertension (DASH) dietary pattern is associated with reduced incidence of metabolic syndrome in children and adolescents. J Pediatr. 2016;174:178–84. e1.
19. Kumar S, Hossain J, Nader N, Aguirre R, Sriram S, Balagopal PB. Decreased circulating levels of spexin in obese children. J Clin Endocrinol Metabolism. 2016;101(7):2931–6.
20. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia. 1985;28(7):412–9.
21. Cook S, Weitzman M, Auinger P, Nguyen M, Dietz WH. Prevalence of a metabolic syndrome phenotype in adolescents: findings from the third National Health and Nutrition Examination Survey, 1988–1994. Arch Pediatr Adolesc Med. 2003;157(8):821–7.
22. Kelishadi R, Gouya MM, Ardalan G, Hosseini M, Motaghian M, Delavari A, et al. First reference curves of waist and hip circumferences in an Asian population of youths: CASPIAN study. J Trop Pediatr. 2007;53(3):158–64.
23. Genuth S, Alberti KG, Bennett P, Buse J, Defronzo R, Kahn R, et al. Follow-up report on the diagnosis of diabetes mellitus. Diabetes Care. 2003;26(11):3160–7.
24. Falkner B, Daniels SR. Summary of the fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. Hypertension. 2004;44(4):387–8.
25. Ten S, Maclaren N. Insulin resistance syndrome in children. J Clin Endocrinol Metab. 2004;89(6):2526–39.
26. Kurtoglu S, Hatipoglu N, Mazicioglu M, Kendirici M, Keskin M, Kondolot M. Insulin resistance in obese children and adolescents: HOMA-IR cut-off levels in the prepubertal and pubertal periods. J Clin Res Pediatr Endocrinol. 2010;2(3):100–6.
27. Delshad M, Ghanbarian A, Ghaleh NR, Amirshekari G, Askari S, Azizi F. Reliability and validity of the modifiable activity questionnaire for an Iranian urban adolescent population. Int J Prev Med. 2015;6:3.
28. Asghari G, Rezazadeh A, Hosseini-Esfahani F, Mehrabi Y, Mirmiran P, Azizi F. Reliability, comparative validity and stability of dietary patterns derived from an FFQ in the Tehran lipid and glucose study. Br J Nutr. 2012;108(6):1109–17.
29. Yue Y, Yuan C, Wang DD, Wang M, Song M, Shan Z, et al. Reproducibility and validity of diet quality scores derived from food-frequency questionnaires. Am J Clin Nutr. 2022;115(3):843–53.
30. Fung TT, Chiuve Se Fau - McCullough ML, McCullough Ml Fau - Rexrode KM, Rexrode Km Fau -, Logroscino G, Logroscino G, Fau - Hu FB, Hu FB. Adherence to a DASH-style diet and risk of coronary heart disease and stroke in women. Arch Intern Med2008. pp. 713 – 20. https://doi.org/10.1001/archinte.168.7.713
31. Farhadnejad H, Darand M, Teymoori F, Asghari G, Mirmiran P, Azizi F. The association of Dietary Approach to stop hypertension (DASH) diet with metabolic healthy and metabolic unhealthy obesity phenotypes. Sci Rep. 2019;9(1):18690.
32. Hosseinpour-Niazi S, Mirmiran P, Hadaegh F, Mahdavi M, Khalili D, Daneshpour MS, et al. Improvement of glycemic indices by a hypocaloric legume-based DASH diet in adults with type 2 diabetes: a randomized controlled trial. Eur J Nutr. 2022;61(6):3037–49.
33. Vasei M-H, Hosseinpour-Niazi S, Ainy E, Mirmiran P. Effect of dietary approaches to stop hypertension (DASH) diet, high in animal or plant protein on cardiometabolic risk factors in obese metabolic syndrome patients: a randomized clinical trial. Prim Care Diabetes. 2022;16(5):634–9.
34. Hajjarzadeh S, Bakhshimoghaddam F, Behrouz M, Nikniaz Z, Mahdavi R, Shalilahmadi D, et al. The relation of adherence to the DASH diet with migraine attack frequency and pain intensity in Iranian women: a cross-sectional study. Nutr Neurosci. 2024;27(4):353–60.
35. Soltani S, Arablou T, Jayedi A, Salehi-Abargouei A. Adherence to the dietary approaches to stop hypertension (DASH) diet in relation to all-cause and cause-specific mortality: a systematic review and dose-response meta-analysis of prospective cohort studies. Nutr J. 2020;19:1–13.
36. Bricarello LP, de Almeida Alves M, Retondario A, de Moura Souza A, Vasconcelos FdAG. DASH diet (Dietary approaches to stop hypertension) and overweight/obesity in adolescents: the ERICA study. Clin Nutr ESPEN. 2021;42:173–9.
37. Hajna S, Liu J, LeBlanc PJ, Faught BE, Merchant AT, Cairney J, et al. Association between body composition and conformity to the recommendations

of Canada's Food Guide and the Dietary approaches to stop hypertension (DASH) diet in peri-adolescence. Public Health Nutr. 2012;15(10):1890–6.
38. Heidari H, Mirzaei S, Asadi A, Akhlaghi M, Saneei P. Association of priori-defined DASH dietary pattern with metabolic health status among Iranian adolescents with overweight and obesity. Sci Rep. 2024;14(1):4993.
39. Farhadnejad H, Asghari G, Mirmiran P, Azizi F. Dietary approach to stop hypertension diet and cardiovascular risk factors among 10-to 18-year-old individuals. Pediatr Obes. 2018;13(4):185–94.
40. Park Y-MM, Steck SE, Fung TT, Zhang J, Hazlett LJ, Han K, et al. Mediterranean diet, Dietary approaches to stop hypertension (DASH) style diet, and metabolic health in US adults. Clin Nutr. 2017;36(5):1301–9.
41. Rahimi H, Yuzbashian E, Zareie R, Asghari G, Djazayery A, Movahedi A, et al. Dietary approaches to stop hypertension (DASH) score and obesity phenotypes in children and adolescents. Nutr J. 2020;19:1–9.
42. Roberge J-B, Van Hulst A, Barnett TA, Drapeau V, Benedetti A, Tremblay A, et al. Lifestyle habits, dietary factors, and the metabolically unhealthy obese phenotype in youth. J Pediatr. 2019;204:46–52. e1.
43. Zhang C, Ren W, Li M, Wang W, Sun C, Liu L, et al. Association between the children's dietary inflammatory index (C-DII) and markers of inflammation and oxidative stress among children and adolescents: NHANES 2015–2018. Front Nutr. 2022;9:894966.
44. Hart MJ, Torres SJ, McNaughton SA, Milte CM. Dietary patterns and associations with biomarkers of inflammation in adults: a systematic review of observational studies. Nutr J. 2021;20(1):1–14.
45. Golzarand M, Moslehi N, Mirmiran P, Azizi F. Adherence to the DASH, MeDi, and MIND diet scores and the incidence of metabolically unhealthy phenotypes. Obes Res Clin Pract. 2023;17(3):226–32.
46. Saneei P, Hashemipour M, Kelishadi R, Esmaillzadeh A. The Dietary approaches to stop hypertension (DASH) diet affects inflammation in childhood metabolic syndrome: a randomized cross-over clinical trial. Annals Nutr Metabolism. 2014;64(1):20–7.
47. Harasym J, Oledzki R. Effect of fruit and vegetable antioxidants on total antioxidant capacity of blood plasma. Nutrition. 2014;30(5):511–7.
48. Mathews R, Chu Y. Global review of whole grain definitions and health claims. Nutr Rev. 2020;78(Supplement1):98–106.
49. Donath MY, Meier DT, Böni-Schnetzler M. Inflammation in the pathophysiology and therapy of cardiometabolic disease. Endocr Rev. 2019;40(4):1080–91.
50. Sahebkar A, Heidari Z, Kiani Z, Atefi M, Zareie A, Shojaei M et al. The efficacy of Dietary approaches to Stop Hypertension (DASH) Diet on lipid Profile: a systematic review and metaanalysis of clinical controlled trials. Curr Med Chem. 2024.

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