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The Relationship Between Adherence to a Dietary Approach to Stop Hypertension Diet with Oxidative Stress and Antioxidant Capacity in Young Women

ABSTRACT

Objective: The dietary approaches to stop hypertension diet is a healthy dietary pattern that may have advantageous effects on oxidative stress and antioxidant status. This study evaluated the relationship between adherence to the dietary approaches to stop hypertension diet with total antioxidant capacity and markers of oxidative stress in healthy young women.

Methods: In this study, 155 young girls were included. A validated food frequency questionnaire was employed to explore the dietary intake of participants. The total antioxidant capacity and free radical scavenging activity of serum and urine were quantified using the ferric reducing/antioxidant power and α, α-diphenyl-β-picrylhydrazyl methods, respectively. Malondialdehyde was measured through the formation of thiobarbituric acid reactive substances. A colorimetric assay was used to quantify pro-oxidant antioxidant balance.

Results: Individuals with the greatest adherence to dietary approaches to stop hypertension diet consumed more fruits, vegetables, low-fat dairy products, nuts, legumes, and seeds and lower intake of sugar-sweetened beverages and sodium compared to those with the lowest adherence. Women with the greatest adherence to the dietary approaches to stop hypertension style diet (those in the third tertile) were more likely to have a lower urinary ferric reducing/antioxidant power, α, α-diphenyl-β-picrylhydrazyl, and malondialdehyde than those in the first tertile ($P < .05$). In logistic regression, a higher adherence to a dietary approaches to stop hypertension pattern was associated with lower levels of urinary ferric reducing/antioxidant power (odds ratio = 0.82; 95% CI: 0.71-0.94, $P = .005$), urinary α, α-diphenyl-β-picrylhydrazyl (odds ratio = 0.47; 95% CI: 0.28-0.78, $P = .003$), and urinary malondialdehyde (odds ratio = 0.13; 95% CI: 0.02-0.81, $P = .029$).

Conclusion: Adherence to the dietary approaches to stop hypertension diet was related to better oxidative stress and antioxidant capacities in healthy young girls of an Iranian population.

Keywords: Anti-oxidant, DASH diet, oxidative stress, pro-oxidant antioxidant balance, reactive oxygen species

Introduction

Diet is important for human health at different stages of life.[1,2] The dietary approaches to stop hypertension (DASH) eating plan is a diet that has a low glycemic index and energy-condense foods and is rich in minerals such as potassium (K), magnesium (Mg), calcium (Ca), as well as antioxidant constituents. The DASH diet as healthy dietary pattern advocates high intake of fruits, vegetables, whole grains, omega-3 fatty acids, and low-fat dairy; encourages moderate intake of different protein sources including poultry, fish, legumes, nuts, and seeds; and restricts intake of red and processed meats, sodium (Na), saturated fats, sugar-sweetened beverages (SSB), desserts, and sweets.[3] The DASH diet was originally developed for mitigating a high blood pressure; though its beneficial impacts on cardiovascular disease risk factors and components of metabolic syndrome or diabetes have been reported.[4]

Reactive oxygen species (ROS) and free radicals are raised in the human body under normal physiologic conditions and are eliminated by complex and cooperative array of antioxidant defense system. Aberrantly higher ROS formation is closely related to oxidative stress (OS). Long-lasting OS becomes very dangerous and can alter the structure and activities of cellular macromolecules, causing disruptions in cell metabolism, tissue destruction, and cell death. For the maintenance of pro-oxidant/antioxidant balance, free-radical cascade and ROS should be neutralized by endogenous and exogenous antioxidants or antioxidant enzymes.[5-8]

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There is evidence suggesting that a DASH diet may have advantageous effects on OS and antioxidant status and that this may be beneficial in different pathologies. For instance, compliance with a low sodium DASH diet for 3 weeks in salt-sensitive participants causes a decrease in urinary F2-isoprostanes, a well-established biomarker of OS,[9,10] Although another study reported no considerable effect of the DASH diet on the markers of OS in healthy individuals.[11] On the other hand, intake of different fruits and vegetables increased serum, salivary, and urinary total antioxidant capacity (TAC).[5-8]

With respect to the importance of a DASH dietary pattern for well-being and health, we performed a cross-sectional survey to investigate the association between adherence to DASH style diet and antioxidant properties of the serum and urine of apparently healthy young women.

Materials and Methods

Study Design

This study was conducted in Birjand city, in northwestern Iran, in January 2020. A total of 155 university girl students aged 18-24 years were recruited from 5 universities in Birjand. The sample size required for 80% power and $\alpha' = 0.05$ (z value of 1.96) was calculated using results from a former study ($r = 0.25$ for correlation between DASH score and theobromine).[12] Based on these assumptions, at least 140 participants were required. Since we aimed to conduct our investigation on a homogeneous population, to control for potential confounding variables, only single, apparently healthy women were included. We excluded those having any acute or chronic complications or taking medications. The Ethical Committee of Birjand University of Medical Sciences approved the study (code: IR.BUMS.REC.1400.128), and informed written consent was obtained from all volunteers.

Adherence to Dietary Approaches to Stop Hypertension Diet

A validated food frequency questionnaire (FFQ) was employed to estimate the food intake of individuals. A proficient dietitian instructed study volunteers to report their food intake frequency for each item within the last year on per day, week, month, rarely, or never basis. Food analysis was performed using Diet Plan 6 software (forest field Software Ltd, Horsham West Sussex, UK). The DASH style diet score was calculated concerning the approach developed by Fung *et al*.[13] The DASH score was estimated according to the 8 food components, i.e., ingestion of controlled diets high in vegetables, fruits, legumes and nuts, whole grains, and fewer consuming of sodium, low-fat dairy products, red and processed meats, as well as SSB. In order to calculate the DASH score, values of 1 or 5 were allocated for each food group by considering the quintiles as cut-off thresholds. The ranking system is based on quintiles with the lowest consuming rating as 1 point and the top quintile rating as 5 points for healthy food groups including vegetables, fruits, legumes and nuts, whole grains, and fat-free dairy products. The scoring of unhealthy foods (red and processed meats, salt, and SSB) is inversely coded so that quintile 1 gets 5 points and quintile 5 gets 1 point. Eventually, the score of each group was summed up to yield a total score ranging from 8 (least adherence) to 40 (greatest adherence).

Sampling

Blood and urine samples were collected after a 12-hour fasting. The participants were instructed to avoid intense physical activity 24 hours before the sampling. Blood specimens were collected into serum tubes and centrifuged to separate the serum. Based on a standard protocol, sterile disposable container was used for collecting urine specimens from the first-morning section of urine from the middle stream. Serum and urine specimens were stored at −80°C.

Anthropometric Parameters and Blood Pressure

Anthropometric parameters including height, weight, systolic, and diastolic blood pressure were measured using standard protocols and then, body mass index (BMI) was calculated.[14]

Biochemical Analysis

The serum concentrations of urea, creatinine, alanine transaminase, aspartate transaminase, alkaline phosphatase, total and direct bilirubin, total protein, albumin, Ca, phosphate, Mg, uric acid, and fasting blood glucose (FBG) were determined using commercial kits (Pars Azmun, Iran) and an auto-analyzer (Prestige 24i, Tokyo Boeki Ltd., Japan).

Serum and Urine Oxidative Stress Parameters

Total Antioxidant Capacity: Total antioxidant capacity (TAC) was measured using the ferric reducing/antioxidant power (FRAP) way which was introduced by Benzie and Strain.[15] This procedure is based on the reducing ability of ferric–tripyridyl triazine (Fe^{3+}-TPTZ) complex to ferrous (Fe^{2+})-colored appearance in the presence of antioxidant compounds. The tests were carried out in 260 µL of reaction mixtures including 250 µL of FRAP solution and 10 µL of serum, standard ($FeSO_4$), and blank (for each sample, a blank sample was used to remove turbidity). The absorbance was measured colorimetrically at 593 nm. All tests were performed in duplicate and TAC of samples was measured as µmol TAC/L. For urine samples, the specimens were diluted as 1 : 10 and the findings are measured as µmol TAC/mg creatinine.

Free-Radical Scavenging Activity: The free radical scavenging action in samples was assessed using the A-diphenyl-B-picrylhydrazyl (DPPH) method of Janaszewska and Bartosz.[16] Tests were conducted in reaction mixtures including 1 mL of 100 mM DPPH solution and 40 µL of each serum and blank samples. After incubation at room temperature for 10 minutes, each sample was centrifuged at 4000 g for 5 minutes at 37°C to remove cells. Absorbance was read using a microplate reader (Epoch Biotek, Winooski, VT, USA) at 517 nm and compared with that of blank samples, containing only DPPH and methanol solution. The results are reported in mmol trolox equivalent per liter. The urine tests were performed in reaction mixtures including 250 µL of DPPH reagent and 10 µL of urine (the samples diluted as 1 : 10) and blank samples. The results are shown in mmol trolox equivalent/mg creatinine.

MAIN POINTS

- A high adherence to dietary approaches to stop hypertension (DASH)-type diet was associated with a greater intake of fruits and vegetables, whole grain, low-fat dairy, legumes, and fewer intake of sugar-containing beverages and sodium.
- This was also associated with lower urinary levels of ferric reducing/antioxidant power, α, α-diphenyl-β-picrylhydrazyl, and malondialdehyde compared to individuals with low adherence to this diet.
- Adherence to the DASH diet was related to better oxidative stress and antioxidant capacities.

Malondialdehyde Assay: The thiobarbituric acid reactive substances (TBARS), a representor of lipid peroxidation, were determined using the method described by Kei and co-researchers.[17] The end product of fatty acid peroxidation, malonyldialdehyde (MDA), interacts with TBA to generate a colored complex. Thiobarbituric acid reactive substance reagent (1 mL) was mixed with samples (100 µL), and the admixture was heated in a boiling water bath for 20 minutes. Then 1 mL of n-butanol was used to extract TBARS adducts and solution was centrifuged at 1500 g for 10 minutes at 4°C. The supernatant was collected and the fluorescence intensity at excitation and the emission wavelengths of 515 and 553 nm were recorded. Findings were quantified by comparing them to the standard curve obtained from standard solutions under the same conditions. The TBARS concentration of samples was measured in µmol TBARs/L. For urine samples, the results are presented in µmol TBARs/mg creatinine.

Pro-Oxidant Antioxidant Balance: The PAB method has previously been described by Alamdari *et al*.[18] For the comparison of oxidant burden and antioxidant capacity of each serum specimens, 2 major solutions were prepared, standard and working solutions as described previously.[18] A standard curve was constructed using standard samples, and concentrations were expressed as arbitrary Hamidi Koliakos (HK) unit, which demonstrates the percentage of hydrogen peroxide in the standard solutions. The amounts of the measured specimens were computed according to the values obtained from standard curve and were presented as HK units.

Statistical Analysis

Subjects were sub-grouped into 3 categories according to tertiles of their DASH dietary scores. One-way analysis of the variance test (normal distribution parameters) or Kruskal–Wallis test (non-normal distribution parameters) were employed for the comparison of quantitative variables between the tertiles of DASH diet score. Moreover, we performed a multivariable logistic regression to investigate the association between adherence to DASH diet and OS parameters using the lowest DASH tertile as dependent variable, after correction for age, energy intake, and BMI. All statistical analyses were performed using the statistical package for the social sciences software version 16.0, and $P \leq .05$ were considered significant.

Results

The DASH diet scores were used for grouping of the participants into tertiles, with T1 set as the bottom tertile (minimal adherence; score: 15-22; n = 50) and T2 (score: 22-25; n = 51) and T3 as top tertile (maximal adherence; score: 25-33; n = 50).

No significant difference was observed between the participants across tertiles of DASH diet with respect to demographic and anthropometric parameters, lipid profile, liver function enzyme tests, FBG, albumin, and total protein levels ($P > .05$; Table 1). However, mean BMI was higher in the third tertile than in the second and first tertiles ($P = .006$). Participants in the top tertile of the DASH style pattern tended to be having significantly higher serum levels of uric acid and lower creatinine and Mg concentrations compared to those in the lowest tertiles ($P < .05$; Table 1).

The subjects with a highest adherence to a DASH dietary pattern consumed more fruits, vegetables, low-fat dairy products, whole grain, nuts, legumes, and seeds ($P < .05$). Intake of SSB and sodium was significantly lower among the subjects in the third tertile of DASH diet group than the first tertile ($P < .05$). Additionally, eating food rich in fiber, folate, Ca, Mg, and K was significantly higher in participants who were placed in the third tertile of DASH diet than the first tertile ($P < .05$; Table 2).

The women with the greatest adherence to the DASH eating pattern had lower urinary FRAP, DPPH, and MDA compared to those in the lowest tertile ($P = .013$ and $P = .011$, respectively). Serum FRAP was found to be lower in the second tertile than in the third tertile ($P = .003$; Table 3).

Multivariable-adjusted odds ratios (ORs) [95% CIs] showed that concomitance to DASH dietary pattern (third tertile vs first tertile) was related to lower levels of urinary FRAP (odds ratio (OR) = 0.82; 95% CI: 0.71-0.94, $P = .005$), urinary DPPH (OR = 0.47; 95% CI: 0.28-0.78, $P = .003$), and urinary MDA (OR = 0.13; 95% CI: 0.02-0.81, $P = .029$; Table 4).

Table 1. Baseline Characteristics of Study Participants

	Tertiles of DASH Diet			
	T1 (n = 50)	T2 (n = 51)	T3 (n = 50)	*P*†
Age, year	21.0 ± 2.0	20.8 ± 1.6	21.0 ± 1.7	.97
BMI (kg/m²)	20.3 ± 2.3	20.5 ± 2.7	21.8 ± 3.4	**.006**$^{\alpha,\beta}$
WHR	0.73 ± 0.04	0.73 ± 0.03	0.74 ± 0.04	.24
SBP (mm Hg)	105 ± 9.4	108 ± 9.9	105 ± 9.5	.29
DBP (mm Hg)	71 ± 7.4	71 ± 7.8	70 ± 7.6	.61
HDL-C (mg/dL)	51.3 ± 7.2	50.5 ± 8.5	50.2 ± 10.5	.84
LDL-C (mg/dL)	71.6 ± 16.5	83.3 ± 35.2	70.2 ± 15.9	.23
TG (mg/dL)	68.6 ± 31.3	74.0 ± 31.2	81.4 ± 46.9	.25
TC (mg/dL)	153 ± 28.6	151 ± 21.3	151 ± 23.7	.89
FBG (mg/dL)	83.7 ± 7.8	84.3 ± 5.8	82.8 ± 6.6	.57
Urea (mg/dL)	29.2 ± 6.3	28.4 ± 5.3	31.8 ± 9.5	.06
Creatinine (mg/dL)	1.1 ± 0.62	0.94 ± 0.09	0.98 ± 0.14	**.047**$^{\gamma}$
ALT (IU/L)	19.8 ± 11.3	21.8 ± 16.8	17.8 ± 4.2	.26
AST (IU/L)	15.3 ± 7.0	19.4 ± 17.5	14.3 ± 7.1	.09
ALP (IU/L)	188 ± 41.6	194 ± 43.9	184 ± 39.7	.53
Direct bilirubin (mg/dL)	0.33 ± 0.16	0.33 ± 0.17	0.27 ± 0.13	.11
Total bilirubin (mg/dL)	0.68 ± 0.29	0.68 ± 0.34	0.27 ± 0.13	.12
Total protein (g/day)	8.0 ± 0.41	7.9 ± 0.42	8.0 ± 0.47	.37
Albumin (g/dL)	5.1 ± 0.28	5.0 ± 0.29	5.1 ± 0.28	.83
Calcium (mg/dL)	10.1 ± 0.49	10.2 ± 0.46	10.1 ± 0.5	.65
Phosphate (mg/dL)	5.1 ± 0.69	5.1 ± 0.59	5.1 ± 0.82	.99
Magnesium (mg/dL)	2.4 ± 0.32	2.3 ± 0.19	2.3 ± 0.28	**.037**$^{\gamma}$
Uric acid (mg/dL)	3.0 ± 0.63	3.0 ± 0.79	3.3 ± 0.78	**.04**$^{\beta}$

Data are presented as mean ± SD or median (interquartile range).
†Obtained from ANOVA test and post hoc Tukey;
$^{\alpha}$Significance between tertiles 1 and 3;
$^{\beta}$Significance between tertiles 2 and 3;
$^{\gamma}$Significance between tertiles 1 and 2.
BMI, body mass index; WHR, waist to hip ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; LDL-C, low-density lipoprotein-cholesterol; HDL-C, high-density lipoprotein-cholesterol; TG, triglyceride; TC, total cholesterol; ALT, alanine transaminase; AST, aspartate transaminase; APT, alkaline phosphatase; DASH, dietary approaches to stop hypertension. Significance of bold values was P < .05.

Table 2. Daily Intakes of Study Cases Across Tertiles of the Adherence to the DASH Eating Plan Scores

	Tertiles of DASH Diet			
	T1	T2	T3	*P*
DASH score, median (IQR)	20 (18-21)	23.5 (23-24)	26 (27-29)	-
Nutrients				
Total energy (kcal)	2175 ± 874	2100 ± 589	2135 ± 792	.89
Carbohydrate (g/1000 Kcal)	64.2 ± 37.8	55.2 ± 21.8	66.3 ± 28.8	.18
Protein (g/1000 Kcal)	33.5 ± 15.3	31.8 ± 13.7	33.1 ± 14.2	.85
Fat (g/1000 Kcal)	15.4 ± 12.6	17.2 ± 9.4	14.4 ± 10.6	.49
Fiber (g/1000 Kcal)	5.8 ± 3.2	6.4 ± 2.2	8.1 ± 3.6	**.003**
Zinc (mg/1000 Kcal)	2.4 ± 1.2	2.3 ± 1.0	2.6 ± 1.1	.54
Folate (µg/1000 Kcal)	73.8 ± 39.6	83.9 ± 28.1	108.8 ± 41.1	**<.001**
Calcium (mg/1000 Kcal)	232 ± 147	188 ± 96	257 ± 138	**.038**
Magnesium (mg/1000 Kcal)	160.8 ± 64.0	188.8 ± 68.3	221.4 ± 77.5	**.017**
Potassium (mg/1000 Kcal)	2079 ± 524	2367 ± 458	2862 ± 872	**.004**
Food group of DASH diet (daily serving)				
Total fruits	1.5 ± 1.1	2.3 ± 1.6	2.8 ± 2.1	**.002**
Vegetables	0.6 ± 0.4	1.3 ± 1.0	2.5 ± 1.1	**<.001**
Nuts, legume, seed, and peas	1.3 ± 2.4	1.7 ± 1.1	2.6 ± 2.0	**.021**
Fat-free dairy	1.8 ± 0.3	4.3 ± 0.5	6.9 ± 6.9	**<.001**
Grains	2.4 ± 0.5	3.1 ± 3.8	4.1 ± 3.9	**.028**
Red and processed meat	3.0 ± 3.8	2.6 ± 2.1	2.4 ± 2.0	.51
Sweets	1.2 ± 0.9	0.7 ± 0.7	0.5 ± 0.8	**.001**
Sodium (mg/1000 Kcal)	1778 ± 623	1499 ± 889	1258 ± 810	**.03**

All values are mean ± SD.
†Using ANOVA test.
DASH, dietary approaches to stop hypertension; ANOVA, analysis of variance; SD, standard deviation.

Table 3. Antioxidant Status of Study Participants Across Tertile Categories of the DASH Dietary Pattern Scores

	Tertiles of DASH diet			
	T1	T2	T3	*P*
Urinary FRAP (µmol TAC/mg Cr)	11.1 ± 13.0	8.0 ± 3.3	6.3 ± 2.8	**.013**$^{\alpha}$
Urinary DPPH (mmol trolox equivalent/mg Cr)	2.7 ± 2.4	2.2 ± 0.99	1.7 ± 0.6	**.011**$^{\alpha}$
Urinary MDA (µmol TBARs/mg Cr)	0.7 6 ± 0.57	0.66 ± 0.35	0.57 ± 0.17	**.041**$^{\beta}$
Serum FRAP (µmol TAC/L)	672 ± 124	640 ± 89	723 ± 134	**.003**$^{\beta}$
Serum DPPH (mmol trolox equivalent/L)	80.2 ± 60.5	82.6 ± 53.4	92.0 ± 62.0	.59
Serum MDA (µmol TBARs/L)	0.62 ± 0.21	0.75 ± 0.26	0.69 ± 0.55	.63
Serum PAB (HK)	232 ± 42.3	222 ± 52	229 ± 57	.56

Data are presented as mean ± SD.
†Obtained from ANOVA test and post hoc Tukey;
$^{\alpha}$Significance between tertiles 1 and 3;
$^{\beta}$Significance between tertiles 2 and 3.
FRAP, ferric reducing/antioxidant power; DPPH, α, α-diphenyl-β-picrylhydrazyl; MDA, malondialdehyde; Cr, creatinine; PAB, pro-oxidant antioxidant balance; SD, standard deviation; ANOVA, analysis of variance.

Discussion

In this study, high adherence to a healthy DASH type diet, achieved by high intake of fruits and vegetables, whole grains, low-fat dairy, legumes, and fewer intake of sugar-containing beverages and sodium, was in relation to lower urinary FRAP, DPPH, and MDA levels among young apparently healthy female.

We found that young healthy women with a high dependence on DASH nutrition have significantly lower urinary levels of FRAP, DPPH, and MDA. There have been inconsistent reports from studies investigating the relationship between dietary fruit and vegetables and urinary biomarkers of OS. Hassimotto et al[5] found reduced urinary TAC concentrations after a single ingestion of blackberry juices. There have been inconsistent reports on elevated urinary TAC after bolus administration of spinach,[6] strawberries,[6] and Jerte Valley cherry.[19] In addition, grape juice intake for 5 days raised urinary TAC,[20] while tomato juice supplementation for 14 days did not.[7] Tsang et al[21] reported an increase in plasma but not urinary FRAP following fruit juice consumption. Moreover, urinary TAC was unaltered after 3 weeks intake of dried fruit and vegetable extracts with antioxidants fortification.[8]

In the present study, regression analysis showed that adherence to DASH pattern had no significant association with serum FRAP, DPPH, MDA, and PAB levels. There are multiple clinical trials that have explored the impact of the DASH diet on TAC in various clinical conditions. Attachment to the DASH eating plan for 8 weeks significantly decreased plasma MDA and increased plasma nitric oxide (NO) and glutathione (GSH) concentrations but did not influence

Table 4. Adjusted OR and 95% CI for Antioxidant and Oxidative Parameters Between Tertiles of DASH Dietary Plan Scores

Parameters	T1	T2	T3
Urinary FRAP	Ref.	0.95 (0.88-1.01)	0.82 (0.71-0.94)**
Urinary DPPH	Ref.	0.86 (0.67-1.01)	0.47 (0.28-0.78)**
Urinary MDA	Ref.	0.60 (0.24-1.5)	0.13 (0.02-0.81)*
Serum FRAP	Ref.	0.99 (0.98-1.0)	1.00 (0.99-1.03)
Serum DPPH	Ref.	1.0 (0.99-1.00)	1.0 (0.98-1.1)
Serum MDA	Ref.	2.5 (0.33-5.8)	1.9 (0.26-4.7)
Serum PAB	Ref	0.99 (0.98-1.0)	1.0 (0.99-1.0)

Tertile 1 was considered as reference group.
*$P < .05$;
**$P < .01$ a
Adjusted for age, BMI, and energy intake.
FRAP, ferric reducing/antioxidant power; DPPH, α, α-diphenyl-β-picrylhydrazyl; MDA, malondialdehyde; Cr, creatinine; PAB, pro-oxidant antioxidant balance; BMI, body mass index.

serum TAC compared to the control diet in overweight and obese cases with non-alcoholic fatty liver disease.[22] Elevated levels of TAC and GSH were also reported in the DASH group compared to the normally healthy group in overweight/obese women suffering from polycystic ovary syndrome.[23] In another study, 4 weeks on the DASH diet caused an increase in FRAP concentrations only in obese subjects but not in lean cases.[24] In women with gestational diabetes, commitment to a DASH diet after 4 weeks caused a significant increment in plasma TAC and total GSH values,[25] but DASH diet for 3 months has resulted in a non-significant elevation in plasma TAC in healthy volunteers.[11] Three months commitment to DASH style diet in migraine patients significantly decreased total oxidative status (TOS) compared to that of control. Nevertheless, no significant alterations were found in TAC, oxidative stress index (OSI), MDA, and total thiol content in these patients .[26] In a recent meta-analysis including 4 studies with 200 participants, adherence to the DASH diet was related to a significant decline in MDA and a significant increment in glutathione (GSH) but had no effect on TAC values.[27] This discrepancy with our finding may be because of the different population samples, various biomarkers which were assessed, and the health status of our participant.

The DASH style diet is rich in fruits, vegetables, and dietary fiber, which is associated with high serum concentrations of α-carotene, β-carotene, lycopene, and ascorbic acid. Vitamin C, Mg, Ca, and arginine amino decrease NADPH oxidase to a superoxide-producing enzyme, which supports that elevating antioxidant capacity can cause the mitigation of ROS.[24,28] Low induction of NADPH oxidase would inhibit the production of the oxygen free radicals; since this enzyme is a necessary source of superoxide anion in vasculature. Calcium as a DNA damage-inhibiting element[29] may possibly quench free radical and enhance serum TAC and GSH amounts. The DASH diet is a source of arginine which will decrease angiotensin II levels and serum biomarkers of OS.[30] Moreover, the Mg content of DASH dietary pattern potentially restores the action of anti-oxidative enzymes and scavenges oxygen radicals.[31] Mg deficiency triggers the generation of free radicals, as well as secretion of interleukin (IL-6) and tumor necrosis factor–α (TNF-α), and eventually an inflammatory response. In a large study conducted on 3042 adults, serum levels of TAC were directly related to the intake of total fruits and vegetables but negatively related to the intake of red meat.[32] Holt et al[33] also reported that urinary F2-isoprostane as an index of OS was inversely associated with consumption of fruit and vegetables. Grains and legumes are food groups that are rich in macronutrients. Cereal grains are source of dietary antioxidants such as phenolic acids, phytosterols, saponins, and phytoestrogens. Legume seeds also contain a high amount of different bioactive phytochemicals, i.e. isoflavones, coumestrol, saponins, phytate, lecithin, phytosterols, and tocopherol. Djordjevic et al[34] showed that cereals and legumes have remarkable free radical-quenching power, ferric-reducing action, and potency for preventing lipid peroxidation and total phenolic concentrations. Altogether, the DASH diet is rich in health food groups which have beneficial effects on OS.

Reactive oxygen species have a very short half-life, so its direct measurement is complex. Nonetheless, ROS-associated tissue damage could be detected by the final product of lipid peroxidation. The most well-known biomarker MDA, a product of the peroxidized polyunsaturated fatty acids, is commonly used to evaluate OS. The sources of urinary MDA consist of dietary intake of food rich in MDA adducts with proteins and endogenous MDA originating from lipid peroxidation and metabolism of prostaglandin.[35]

Oxidative stress is associated with an imbalance between free radical synthesis and antioxidant defenses of the body, and it is often essential to evaluate the counterpart of oxidation, the total antioxidant status. Additional biomarkers have pointed out associated antioxidant status/capacity status, rather than OS. As antioxidants can act additively or synergistically, they are absorbed and used in the human body in various ways, and the evaluation of total antioxidant activity yields more reliable data compared to the measurement of 1 antioxidant individually. These include indices that reflect the total scavenging potency of a plasma or serum aliquot, following, for instance, the addition of a radical-forming compound. As of now, the most frequent tests recruited for evaluation are FRAP method, along with the DPPH assay. Moreover, the PAB assay was also developed to evaluate the balance of pro-oxidants and antioxidants at the same time to provide a redox index. Pro-oxidant antioxidant balance measures the pro-oxidant burden and the antioxidant capacity by 3,3′,5,5′-tetra methylbenzidine in 2 separate oxidation–reduction reactions in 1 assay simultaneously.

Our findings demonstrate that participants in the upper tertile of the concomitant DASH pattern tended to be having higher BMI and serum levels of uric acid compared with those in the lowest tertile. Previous studies showed that adherence to DASH diet lowered serum uric acid, especially among individuals with hyperuricemia.[36,37] A higher DASH score was related to lower BMI and chances of being overweight in girls; although all of these investigations were performed on obese participants.[38] The inconsistency between our findings with previous studies may be due to that we only included apparently healthy young women whose BMI, uric acid, and other biochemical variables are within normal range.

The study has also several limitations. In observational investigations, evaluation of adherence of DASH diet depends on self-reported information which is susceptible to systematic biases, that is, recall bias, interviewer bias, social desirability bias, or mistakes in estimating nutrient values from food composition databases. Eventually, the cross-sectional nature of this work does not make it conceivable to disclose a causality effect.

Conclusion

Dietary intakes complying with the DASH diet are related to lower OS and increased antioxidant capacities in healthy subjects. Our results also indicated that serum and urine metabolites may provide different information in nutritional metabolomics. Since antioxidants are an important defense mechanism to overcome ROS overproduction, future research will concentrate on underlying mechanisms. Also, future dietary modification studies may provide public health knowledge on whether simple food-based interventions may be useful in our war against OS-induced pathologies.

Data Availability: The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Committee Approval: Ethical approval was obtained from the Birjand University of Medical Sciences (code: IR.BUMS.REC.1400.128).

Informed Consent: Informed consent was obtained from all individual participants included in the study.

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Author Contributions: Supervision – A.Z., A.B., G.F.; Materials – A.Z., H.D.; Data Collection and/or Processing – A.Z., H.D.; Analysis and/or Interpretation – A.B.; Literature Search – A.Z., M.M., S.T.; Writing Manuscript – A.B., A.Z., G.F.

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