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The Dietary Approaches to Stop Hypertension (DASH) Diet Affects Inflammation in Childhood Metabolic Syndrome: A Randomized Cross-Over Clinical Trial

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Key Words
Dietary Approaches to Stop Hypertension diet · Inflammation · Childhood metabolic syndrome

Abstract
Background: The effects of the DASH (Dietary Approaches to Stop Hypertension) diet on inflammation in childhood metabolic syndrome (MetS) have still to be identified. ***Objective:*** To examine the effects of the DASH diet on markers of systemic inflammation in adolescents with MetS. ***Methods:*** In this randomized, cross-over clinical trial, 60 postpubescent girls with MetS were randomly assigned to receive either the DASH diet menu cycles or usual dietary advice (UDA) for 6 weeks. After a 4-week washout period, participants were crossed over to the alternate arm. The DASH diet was designed to maintain the current body weight. This diet contained high amounts of fruit, vegetables and low-fat dairy products and was low in saturated fats and cholesterol. UDA consisted of general oral advice and written information about healthy food choices based on the Healthy Eating Plate. Compliance to the DASH diet was assessed through quantification of plasma vitamin C levels. Fasting venous blood samples were taken 4 times from each participant: at baseline and at the end of each study arm. Circulating levels of biomarkers of systemic inflammation were quantified according to standard protocols. ***Results:*** Mean (SD) age and weight of participants was 14.2 years (1.7) and 69 kg (14.5), respectively. Serum vitamin C levels tended to increase during the DASH phase compared with the UDA phase (16.8 ± 12.9 vs. –13.8 ± 9.7 ng/dl, respectively, p = 0.06) indicating a relatively good compliance to the DASH diet. Adherence to the DASH diet, compared to the UDA, had a significant effect on serum high-sensitivity C-reactive protein levels (p = 0.002). This effect remained significant even after adjustment for weight changes and after further controlling for changes in lipid profiles. We did not observe any significant effect of intervention on levels of serum tumor necrosis factor-alpha, interleukin (IL)-2, IL-6 and adiponectin, in either the crude or adjusted models. There were no significant group*time interactions for any dependent variable, except for IL-6; this was close to the significant level. ***Conclusion:*** In summary, consumption of the DASH eating pattern for 6 weeks may reduce circulating levels of hs-CRP among adolescents with MetS. Other inflammatory markers were not affected by the DASH diet.

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Introduction

Metabolic syndrome (MetS), a constellation of metabolic risk factors, is a fast-growing entity. Core components of the syndrome include: insulin resistance, impaired glucose tolerance, hypertension, dyslipidemia and central obesity [1]. The syndrome is highly prevalent not only among adults but also among children. In Iran, it has been indicated that one tenth of adolescents have the syndrome [2]. Earlier studies have shown that low-grade inflammation is involved in the pathogenesis of MetS, even in children [3]. Elevated levels of inflammatory markers such as high-sensitivity C-reactive protein (hs-CRP), interleukin (IL-2), IL-6 and tumor necrosis factor-alpha (TNF-α) are associated with features of childhood MetS [4, 5].

Diet plays an important role in the development of inflammation, especially in children [6]. Since the progression of MetS might be mediated through inflammation, finding an ideal diet that targets inflammation must be the initial step in the management of childhood MetS [7]. There is no 'all-inclusive' diet for controlling inflammation in MetS. It must be kept in mind that the appropriate dietary recommendation for these children is the one that not only improves their metabolic profile, but also meets their nutrient requirements for growth and development. The beneficial effects of some components of the Dietary Approaches to Stop Hypertension (DASH) diet, like antioxidants [6, 8], magnesium [9], dietary fiber, fruit and vegetables [6], on inflammation in children with MetS have separately been documented in previous studies. However, most available evidence in this regard is cross-sectional, indicating only a general association rather than causality. Furthermore, prior investigations have recommended a holistic approach of dietary patterns instead of traditional nutrient or food approaches in diet-disease relations [6]. We are not aware of any clinical trials that assess the effects of dietary patterns on childhood MetS. Our previous study revealed that the DASH eating plan could reduce the prevalence of MetS in adolescents with the syndrome [10]. The DASH diet may reduce the MetS prevalence through its content of antioxidants, fiber, calcium, magnesium, potassium and other phytochemicals [11]; however, it is unclear if the impact of this diet on childhood MetS could be mediated through cooling down inflammation. Moreover, the DASH diet has been effective in weight management which could, in turn, help reduce inflammation [8]. Despite the prior evidence of the effect of the DASH diet on systemic inflammation among adults, we are aware of no study that has examined its influence in childhood MetS. The aim of this study was to evaluate the effects of the DASH diet on markers of systemic inflammation in adolescents with MetS. We hypothesized that the DASH diet would be an appropriate approach for treatment of inflammation in children with MetS.

Subjects and Methods

Participants

In this randomized, controlled, cross-over clinical trial, 60 postpubescent girls aged 11–18 years with MetS were examined. The study pediatrician (M.H.) diagnosed their postpubescent status using the definitions of Marshall and Tanner. Adolescent girls were included in the study if they had had a menstrual cycle for at least 6 months [12]. Enrolment of subjects was made from those that attended nutrition and diet therapy clinics or had been referred to a pediatrician. Individuals with MetS, as defined by the modified National Cholesterol Education Program Adult Treatment Panel III criteria [13] were included in the study. Participants were not included in the study if they were taking medications affecting lipid and carbohydrate metabolism, supplements or hormone therapy. Individuals with diabetes, hyper- or hypothyroidism, liver or kidney disorders, those using corticosteroids, anti-inflammatory drugs, aspirin and other NSAIDs or those with a history of major cardiovascular events were also not included. Eleven subjects dropped out during the study: 5 after the baseline measurements, 2 at the end of the first phase and 4 before the last measurements. The reasons for dropping out in the DASH group were: blood sampling scar (n = 3), educationally busy (n = 2) and surgery (n = 1). The reasons in the usual dietary advice (UDA) group were: blood sampling scar (n = 3), personal reasons (n = 1) and the death of the mother (n = 1) (fig. 1). The study was ultimately completed by 49 female adolescents. It was ethically approved by the Food Security Research Center of the Isfahan University of Medical Sciences and was registered (No. IRCT201110191485N6) on the Iranian website for the registration of clinical trials (www.irct.ir). All participants and their parents provided written informed consent.

Study Design

Prior to the dietary intervention, all patients completed a 2-week run-in period during which essential information about recording dietary intakes and physical activity were given by the study dietician. Three-day food records (2 week days and 1 weekend day) and 2-day nonconsecutive physical activity records were completed by each participant during this run-in period. Participants were then randomly allocated to follow the DASH diet or UDA for 6 weeks. After a washout period of 4 weeks, during which participants were consuming the prestudy diet, subjects were requested to shift their diets to the other dietary plan. Participants were asked to not change their habitual levels of physical activity during the intervention, and to record their dietary intake (for 3 days) and physical activities (for 2 days) during each phase. Diet compliance was assessed using serum vitamin C levels and the self-reported dietary records. The records consisted of all foods consumed by an individual. Participants were requested to record

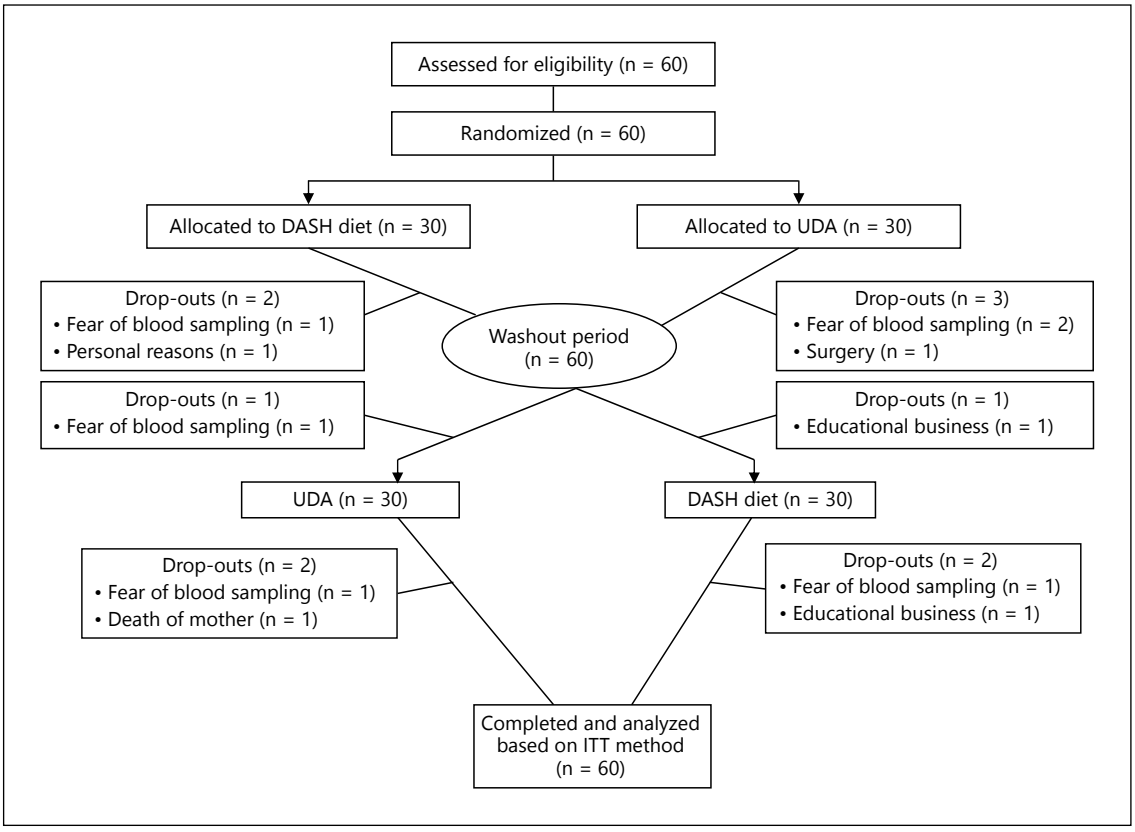

Fig. 1. Participants' flow diagram.

their food intake at the time the foods were eaten, in order to minimize reliance on memory. Dietary records were analyzed for their energy and nutrient content using Nutritionist-IV software which was modified for Iranian food items.

Diets

The calorie requirement of each individual was estimated based on the 2005 US Institute of Medicine recommendations for weight management [14]. We used two dietary plans. The first was a DASH diet consistng of 55–58% carbohydrates, 15–18% proteins and 26–30% total fats. The diet was designed to be rich in fruits, vegetables, whole grains and low-fat dairy products and low in saturated fats, cholesterol, refined grains and sweets and contained one serving of red meat. Prescribed sodium was <2,400 mg/day. The diets were individually prescribed using a 'calorie count' system. To facilitate the compliance, subjects were given a list and instructions. In addition, a 7-day-cycle menu was provided for each participant. Table 1 presents the dietary goals of the DASH intervention in comparison to the UDA. The second diet plan was according to UDA and included general oral and written information about healthy food choices based on the Healthy Eating Plate [15] with a macronutrient composition of 50–60% carbohydrates, 15–20% protein and 30% total fat. This composition was more similar to the Iranian dietary pattern [16]. The participants of this group did not receive dietary menus. All participants spent about 45 min with a dietician learning the basics of their diets.

Measurements

Clinic visits were made at baseline as well as before and after each intervention phase. Measurements taken at clinical visits were blood pressure, weight, height and waist circumference. Blood pressure was measured twice using a digital sphygmomanometer (OMRON, M2, HEM-7117-E) with appropriate cuff size with the subjects seated for 5 min: 2 measurements were obtained at a 5-minute interval and the mean was used for the analysis. For the weight and height measurements, subjects were dressed lightly for indoors and their shoes were removed. Height was recorded using a wall-mounted tape-meter. Weight was measured at each visit using a digital scale and was recorded to the nearest 0.1 kg. BMI was calculated. Waist circumference was measured to the nearest 0.5 cm using an unstretched tape, over light clothing and without pressure to the body surface. All measurements were conducted following an overnight fast. Data from the physical activity records were expressed as metabolic equivalent (MET) intensities that were computed by taking into consideration the type, intensity and duration of activities. At the beginning and end of each phase of intervention, blood samples were drawn after an overnight fast (>12 h). Serum was collected for the measurement of hs-CRP, IL-2, IL-6, TNF-α and adiponectin. These dependent variables were measured by using the commercially available enzyme-linked immunosorbent assay (ELISA) kits. Plasma vitamin C levels were measured using commercially available kits (Glory Science Co., USA) by ELISA method. The sensitivity of the assay for IL-2 and IL-6 was 1 and 0.3

Table 1. Dietary goals of the DASH intervention versus the UDA and a sample menu of the DASH diet

DASH goals		UDA sample
Includes at least 8 servings/day of fruits and vegetables, 2–3 servings/day of low-fat dairy foods, 30 g/day of red meat and <2,400 mg/day of sodium.		Consisted of healthy food choices based on Healthy Eating Plate. – Eat slowly and chew food well and enjoy your food. – Steam, boil and grill foods instead of frying them. – Remove the fat and skin of chicken and meat before cooking. – Try to use wholewheat and barley bread instead of rice and pasta. – Do not skip meals. – Eat frequently but in low amounts. – Minimize intake of sugar, sweets, cakes, cookies and sweetened drinks. – Try to have a variety of food groups in your daily diet including dairy products, fruits and vegetables, meat, whole grains and cereals, nuts and oils.
A sample of the DASH diet		
Calories	1,800	
Servings/day		
Grains (1 oz)	7	
Vegetables (1/2 cup)	5	
Fruit (1/2 cup)	5	
Dairy (1 cup)	3	
Meat (1 oz)	3	
Nuts/seeds (1/4 cup)	1	
Fats and oils (1 tsp)	7	

A menu sample of the DASH diet
(Containing 1,800 kcal, 55% carbohydrate, 17% protein, 28% fat, 3,512 mg potassium, 1,457 mg calcium, 508 mg magnesium and 2,347 mg sodium)
Breakfast: 2 slices of wholewheat bread (60 g) and 1 egg white
Snack 1: 1 medium-sized orange and 1 medium-sized apple
Lunch: 15 tbsp cooked rice along with a stew made with 1/2 cup snap beans, onions, tomatoes and carrots, 30 g red meat and 4 tsp canola oil, 1 cup low-fat yogurt, Salad made with 2 cups fresh lettuce, green pepper, cucumber and 1 tsp lemon juice
Snack 2: 1 cup low-fat milk, 2 dates and 2 walnuts
Snack 3: 1 cup tea, 1 date and 1/2 cup pomegranate
Dinner: 2 slices of wholewheat bread (60 g) with 45 g chicken, 1 cup cooked vegetables (mushrooms, onions, tomatoes and carrots) and 2 tsp canola oil
Snack 4: 1 cup low-fat milk and 2 dates

pg/ml, respectively. The sensitivity of the assay for TNF-α and adiponectin was 1 and 10 pg/ml, respectively. The inter- and intra-assay coefficients of variation for all tests were 10%.

Statistical Methods

To ensure the normal distribution of variables, we applied the Kolmogrov-Smirnov test. Log transformation was applied for nonnormally distributed variables. The analyses were done based on the intention-to-treat approach. Missing values were treated based on the last-observation-carried-forward method. Descriptive statistics (means, SEMs and range) for the general characteristics of the study participants were reported. Data on dietary intakes were compared by paired Student t test. To determine the effect of the DASH diet on biomarkers of systemic inflammation, we applied repeated-measures analysis of variance. In these analyses, the treatments (i.e. DASH and UDA) were regarded as between-subject factors and time was considered as a within-subject factor. To assess the carry-over effect, we computed the average of the end-of-trial values for each variable for two treatments separately and compared the means of the two treatment orders by means of a Student t test. To assess if the magnitude of the change is independent of changes in weight and lipid profiles, we conditioned all analyses on these changes in additional models. All statistical analyses were done using the Statistical Package for Social Science version 18 (SPSS Inc., Chicago, Ill., USA).

Results

This clinical trial was performed with 60 female adolescents, whose mean (SD) age, weight and BMI were 14.2 (1.7) years, 69 kg (14.5) and 27.3 (4.1), respectively. All subjects had MetS. Nutrient intakes of participants based on their 3-day dietary records during the run-in period as well as throughout the intervention are provided in table 2. During this run-in period, the average energy intake of participants was 1,795 kcal/day and they were consuming 1 serving/day of dairy products and 10 servings/day of fat. Throughout the interventions, the mean fruit and vegetable intake of participants was significantly higher and the oil and sugar consumption lower in the DASH phase than in the UDA phase. Based on food diaries, the mean energy intakes during the DASH and UDA phases were not significantly different (1,622.4 ± 64.4 vs. 1,691.7 ± 71.1 kcal/day, respectively, $p = 0.31$). However, dietary energy density was significantly lower during the DASH phase than in the UDA phase (1.0 ± 0.0 vs. 1.2 ± 0.0 kcal/g, respectively, $p = 0.01$). During the DASH phase, partici-

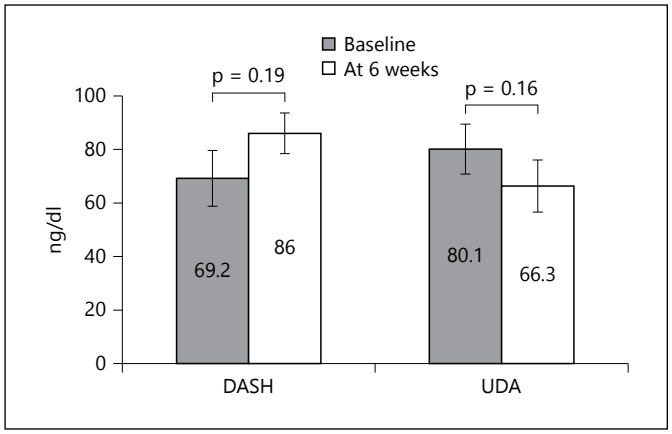

Fig. 2. Serum vitamin C levels of participants at study baseline and end of trial; p values were obtained by paired t test. p value for comparison of changes between the two groups was 0.06.

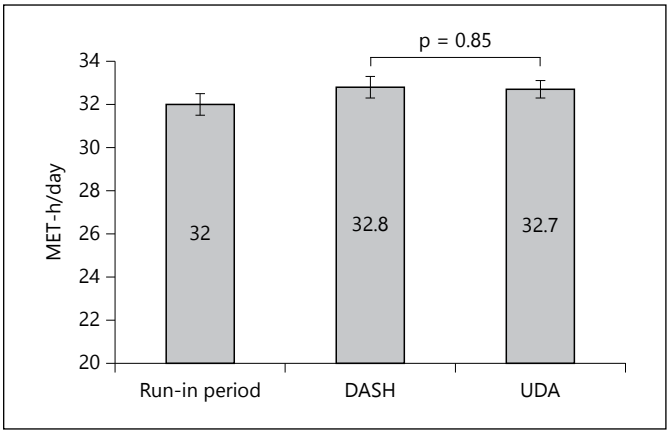

Fig. 3. Physical activity levels of participants throughout the study.

pants also received a greater percentage of their energy from carbohydrates and a lower percentage from fats. As expected, dietary intakes of saturated fatty acids and sodium were significantly lower while potassium and calcium intakes were higher during the DASH phase than those in the UDA period. Individuals in the DASH group tended to have higher intakes of fiber (16.6 vs. 14.9 g/day, p = 0.07) and lower intakes of n-3 fats (0.76 vs. 0.95 g/day, p = 0.07) compared with those in the UDA period.

Mean serum vitamin C levels at the study baseline and the end of the interventions are shown in figure 2. We found that participants experienced an increase in their serum vitamin C levels during the DASH period and a reduction in the UDA period. These data indicated a relatively good compliance of the participants to the DASH diet.

As expected, the physical activity level of the participants did not change throughout the interventions (32.8 ± 0.5 MET-h/day during the DASH phase vs. 32.7 ± 0.4 MET-h/day during the UDA phase; p = 0.85; fig. 3). After 6 weeks of the intervention, no significant differences were found in changes of weight (DASH –0.16 ± 0.18 vs. UDA –0.14 ± 0.20 kg, p = 0.94), BMI (DASH –0.28 ± 0.08 vs. UDA –0.14 ± 0.08, p = 0.17) and waist circumference (DASH –1.77 ± 0.33 vs. UDA –1.18 ± 0.36 cm, p = 0.23) between the two intervention arms.

The effects of the DASH diet on the biomarkers of systemic inflammation are shown in table 3. Adherence to the DASH diet, compared to the UDA, had a significant effect on serum hs-CRP levels (p_{group} = 0.002). This effect remained significant even after adjustment for weight changes and after further controlling for changes in lipid profiles. We did not observe any significant effect of the intervention on levels of serum TNF-α, IL-2, IL-6 and adiponectin, in either the crude or adjusted models. The effect of time was only significant for IL-6. There were no significant group*time interactions for any dependent variable, except for IL-6; this was close to the significant level. We did not find any significant carry-over effect for any biomarker.

Table 2. Dietary intake of participants during the run-in and intervention periods

	DASH diet	UDA	p*
Energy, kcal	1,622.4±64.4	1,691.7±71.1	0.31
Energy density, kcal/g	1.0±0.0	1.2±0.0	0.01
Carbohydrates, %	57.2±0.9	51.7±1.1	<0.001
Proteins, %	14.8±0.4	13.9±0.4	0.11
Fats, %	30.1±0.9	36.1±1.0	<0.001
SFA, g/day	14.6±0.6	18.7±0.9	<0.001
Cholesterol, mg/day	168.3±10.9	194.1±14.9	0.16
Sodium, mg/day	1,894.1±50.5	2,025.7±55.5	0.02
Potassium, mg/day	2,503.6±119.8	2,286.6±106.4	0.04
Magnesium, mg/day	209.5±11.2	199.2±9.3	0.35
Calcium, mg/day	773.7±52.2	662.2±38.0	0.02
Folate, mg/day	229.0±12.8	227.0±12.2	0.88
Vitamin C, mg/day	168.7±12.3	144.9±13.9	0.14
Dietary fiber, g/day	16.6±1.0	14.9±0.9	0.07
n-3 fatty acids, g/day	0.76±0.1	0.95±0.1	0.07
Ratio of n-3/n-6 fatty acids	0.07±0.0	0.07±0.0	0.59

Data are presented as means ± SE. SFA = Saturated fatty acids.
* Comparison of two intervention groups by paired t test.

Table 3. The effects of the DASH diet on serum levels of inflammatory indices of MetS in participants

Biomarkers	The DASH diet[1]		UDA[2]		p		
	baseline	6th week	baseline	6th week	time	group	time*group
hs-CRP, mg/l							
Crude	2.15±1.09	2.06±1.10	2.91±1.09	2.73±1.09	0.51	0.002	0.89
Model 1	2.15±2.36	2.06±2.39	2.91±2.36	2.73±2.39	0.54	0.002	0.89
Model 2	2.18±2.34	2.03±2.41	2.86±2.34	2.76±2.41	0.42	0.002	0.83
TNF-α, pg/ml							
Crude	25.84±1.22	18.57±1.28	32.49±1.29	21.35±1.26	0.13	0.38	0.83
Model 1	25.84±1.26	18.85±1.27	32.95±1.26	21.35±1.27	0.13	0.39	0.83
Model 2	25.92±1.26	18.84±1.28	32.88±1.26	21.03±1.28	0.21	0.45	0.80
IL-2, pg/ml							
Crude	39.19±1.18	42.33±1.22	42.92±1.19	42.23±1.21	0.77	0.85	0.66
Model 1	39.15±1.19	42.28±1.22	42.97±1.19	42.28±1.21	0.79	0.85	0.66
Model 2	39.45±1.19	42.41±1.22	42.65±1.19	42.16±1.21	0.79	0.88	0.69
IL-6, pg/ml							
Crude	21.95±1.15	9.31±1.22	17.35±1.15	11.96±1.21	<0.001	0.97	0.07
Model 1	21.93±1.15	9.31±1.21	17.36±1.15	11.96±1.21	<0.001	0.97	0.08
Model 2	22.09±1.15	9.24±1.21	17.24±1.15	12.05±1.21	<0.001	0.97	0.07
Adiponectin, pg/ml							
Crude	4.89±1.10	3.99±1.15	4.20±1.12	3.53±1.11	0.11	0.21	0.90
Model 1	4.89±1.11	3.99±1.13	4.21±1.11	3.53±1.13	0.12	0.22	0.90
Model 2	4.87±1.11	3.90±1.13	4.22±1.11	3.60±1.13	0.11	0.31	0.79

All data are geometric means ± SE. Results of repeated measures ANOVA are presented.

[1] The DASH diet was high in fruits, vegetables, whole grains and low-fat dairy products, and low in saturated fat, total fat, cholesterol, refined grains and sweets. The amount of sodium intake was 2,400 mg/day.

[2] The UDA group received general oral and written information about healthy food choices and their intakes were as per the usual Iranian diet (carbohydrates 50–60%, proteins 15–20% and total fat <30%). p values from the repeated-measures ANOVA.

Discussion

We found that adherence to the DASH eating pattern for 6 weeks among adolescents with MetS had favorable effects on serum hs-CRP levels compared with the UDA; however, no significant effect on other inflammatory markers and adiponectin concentrations were seen following the DASH diet. To our knowledge, this is the first study that has examined the effects of the DASH diet on markers of systemic inflammation and adiponectin levels in adolescents with MetS.

A growing body of evidence indicates the involvement of low-grade systemic inflammation in MetS, cardiovascular disease and diabetes [3]. Although prior investigations have documented the relationship between dietary factors and inflammation in children, most have focused on nutrients and foods [6, 8, 9]. Nowadays, it is assumed that the overall diet rather than individual nutrients or foods affects inflammation [17]. Although several studies have reported the impact of dietary patterns on inflammation, the effect of the DASH diet has been tested in only a few reports [18–22]. A previous study of ours found the DASH eating pattern to have desirable effects on MetS and its features in this population [10]. Consumption of the DASH diet has also been shown to favorably influence systemic inflammation in adults with MetS [18] or diabetes [19] as well as pregnant women with gestational diabetes [22]. Another study has reported a 14% reduction in serum hs-CRP levels in normotensive and hypertensive adults by adherence to a high-fiber DASH diet [21]. No information is yet available that assesses the effect of the DASH diet on circulating levels of inflammatory markers in children.

In our study, we found that serum hs-CRP levels, a surrogate measure of inflammation, were significantly reduced by consumption of the DASH diet. This finding was in agreement with previous clinical trials in adults [18–22] as well as with the results of observational cross-sectional studies [23]. Empirically derived healthy and prudent dietary patterns (i.e. a high consumption of fruits, vegetables, poultry, legumes and whole grains) have also been inversely related to plasma concentrations

of C-reactive protein [17, 24]. It seems that the content of the DASH diet, i.e. high in fruit [25, 26], low-fat dairy [27], vitamin C [26] and dietary fiber [28], might explain its beneficial effects on serum hs-CRP levels. The inverse association between dietary intakes of fruit, vitamin C, folate, antioxidants [6], magnesium [9] and serum hs-CRP levels has been shown in adolescents as well. Given the fact that the DASH diet can provide adequate nutrients for the growth and development of adolescents, it seems that this healthy dietary pattern can be recommended for cooling down inflammation in children with MetS. Our previous study suggested that consumption of the DASH diet could decrease the prevalence of MetS [10], probably through its effect on serum hs-CRP levels.

We did not find significant changes in other inflammatory markers including serum IL-2, IL-6, TNF-α and adiponection levels following DASH diet adherence. This is in line with other studies [8] that have reported no significant associations between dietary intakes of antioxidant vitamins and serum IL-6 and TNF-α levels in children. However, some studies have reached contrasting findings. Lower levels of IL-6 were seen with greater adherence to the DASH diet in adults [23]. A significant association between components of DASH diet and inflammation has also been found, e.g. a high intake of low-fat dairy products was inversely related to serum IL-6 levels in an adult population [27]. Some investigations among adolescents have reported an inverse association between high intakes of legumes, vegetables, beta-carotene, vitamin C and serum IL-6 levels [6]. In addition, an observational study in children introduced meat intake as a significant predictor of serum IL-6 [8]. Serum TNF-α was also inversely associated with components of the DASH diet in earlier studies [6]. It must be kept in mind that despite having MetS, our study population had normal levels of inflammatory markers. They were also eating a relatively nutrient-dense diet with fairly high amount of fruits and vegetables before intervention. These points might have reduced the chance for achieving significant changes in all inflammatory markers following the intervention.

The mechanisms by which the DASH diet might affect systemic inflammation are unknown. The high amounts of dietary fiber, fruit and vegetables in the DASH diet may mediate the effects of this dietary pattern on inflammation [29, 30]. Furthermore, dietary fiber is fermented by colonic bacteria and could, in turn, result in the growth of microbial species that produce anti-inflammatory cytokines [31]. Sodium intake was restricted in the DASH diet. High sodium intake is associated with increased levels of inflammation [32], so the low sodium content of the DASH diet might provide another explanation. The high content of antioxidants in the DASH diet could also explain its beneficial effects on inflammation. Antioxidants, essential fatty acids and plant extracts have been shown to reduce systemic inflammation [8]. Dietary antioxidants can influence the expression of proinflammatory cytokines [33].

Our study has some limitations worth noting. We used a single measurement of proinflammatory status to achieve the serum levels of inflammatory markers, but markers of systematic inflammation actually fall and rise from day to day, so multiple measurements would address these variations much more efficiently. In addition, as participants received only menu cycles to follow a particular diet rather than receiving prepared foods, their adherence to the prescribed DASH diet was not absolute; better compliance might result in greater changes in inflammatory markers. Furthermore, subjects met the criteria for MetS; however, they were not at the upper end of abnormal cut-off points for this condition and they had near-normal levels of inflammatory markers, which might have further reduced the chance for achieving significant changes in inflammatory markers following the intervention.

In summary, consumption of the DASH diet for 6 weeks may reduce circulating levels of hs-CRP among adolescents with MetS. Other inflammatory markers were not affected by the DASH diet. Further long-term interventions among children with high levels of inflammatory markers are needed to show the beneficial effects of this eating pattern.

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