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The Effect of Dietary Approaches to Stop Hypertension on Weight, Body Composition, and Blood Pressure of Children with Attention Deficit Hyperactivity Disorder: A Randomized Controlled Clinical Trial

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	<p>Background: Attention deficit hyperactivity disorder (ADHD) is one of the most common psychiatric disorders in children. Children with ADHD usually have low blood pressure and weight disorders. Therefore, the present randomized clinical trial was conducted to evaluate the effect of Dietary Approaches to Stop Hypertension (DASH) on weight and blood pressure of children with ADHD. Methods: In this research, 86 children aged 6 to 12 years with diagnosed ADHD according to Conner’s Teacher’s Questionnaire and DSM-4 criteria were investigated. Participants were randomly assigned into two groups to receive a DASH diet and a control diet for 12 weeks. Participants’ anthropometric indices, blood pressure, physical activity, and dietary compliance were evaluated each month. Adherence to the diet was studied using a three-day food report completed by the participants’ parents. Results: A total of 80 children completed the study (40 in each group). No significant difference was observed in any of the weight composition indices measured before and after the intervention between the study groups ($P > 0.05$). No significant difference was reported in the systolic and diastolic blood pressure between the study groups at the baseline. However, diastolic blood pressure increased in the DASH group significantly compared to the control group ($P = 0.02$). Conclusion: The DASH diet might increase the diastolic blood pressure in children with ADHD. Further studies with a longer follow-up period are necessary to confirm these results.</p> <p>Keywords: Dietary approaches to stop hypertension (DASH); Attention deficit disorder with hyperactivity (ADHD); Children; Weight; Blood Pressure</p>

Introduction

Attention deficit hyperactivity disorder (ADHD) is one of the most common neurobehavioral disorders in children (Attention-deficit, 2011). The ADHD symptoms include hyperactivity, inattention,

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and impulsivity (Attention-deficit, 2011). The exact etiology of developing ADHD is still unknown, but environmental and genetic factors are proposed to be involved in its development (Biederman, 2005). This disorder is also associated with depression (Elia *et al.*, 2008). This disorder in children may lead to lower educational and occupational levels, personality disorders, depression, delinquency, addiction, and marital problems in adulthood (Klein *et al.*, 2012, Mannuzza *et al.*, 1993). The prevalence of ADHD in the world is estimated to be 5.29% (Polanczyk *et al.*, 2007). It is also proposed that 16.3% of the 6-year-old Yazdi children have ADHD (Akhavan Karbasi *et al.*, 2008).

Weight and blood pressure (BP) are factors associated with ADHD (Byrd *et al.*, 2013, Wilens *et al.*, 2005). In a study on a large number of German teenagers, Meyer *et al.* found a significant relationship between low BP and ADHD symptoms (Meyer *et al.*, 2017). Several studies examined the relationship between ADHD and obesity (Azadbakht and Esmailzadeh, 2012, Fliers *et al.*, 2013). A systematic review and meta-analysis also showed that ADHD had a significant relationship with overweight and obesity. The study also found that prevalence of obesity in children with ADHD was about 40% higher than the healthy children. Moreover, the prevalence of obesity in adults with ADHD was 70% higher than the normal population (Cortese *et al.*, 2015).

Different nutritional factors are effective on ADHD including food and artificial colors, artificial sweeteners and sugars, amino acids (tryptophan, phenylalanine and tyrosine), vitamins and minerals, essential fatty acids, and restrictive diets (Heilskov Rytter *et al.*, 2015). Dietary Approaches to Stop Hypertension (DASH) is a diet rich in fruits, vegetables, whole grains, low-fat dairy products, cereals, and low-fat meals. It also contains low levels of sodium, saturated and total fat, as well as high levels of calcium, magnesium, potassium, and vitamin C (Sacks *et al.*, 2001). This is a low-glycemic and low-energy diet effective in managing the BP (Sacks *et al.*, 2001). Recent studies showed that this diet, affects not only BP (Saneei *et al.*, 2014), but also other diseases such as type 2

diabetes (Shirani *et al.*, 2013), cardiovascular disease (Shirani *et al.*, 2013), lipid profile, and glucose tolerance in pregnancy diabetes (Asemi *et al.*, 2013).

The DASH diet lowers BP in people with hypertension, but it does not affect normal BP (Saneei *et al.*, 2014). This diet also controls weight and causes weight loss in adults with overweight and obesity (Soltani *et al.*, 2016).

The prevalence of ADHD is high in the world and in Iran, especially Yazd. Furthermore, no study has ever investigated the effect of a healthy diet on weight and BP in children with ADHD. So, the present controlled clinical trial evaluated the effect of DASH diet on weight and BP in children with ADHD.

Materials and Methods

Study design and participants: A total of 253 children within the age range of 6 to 12 years were diagnosed with ADHD according to the Conner's Teacher's Questionnaire and DSM-4 criteria by a specialist. Of these, 27 did not meet the inclusion criteria and 140 were not willing to participate in the study. Finally, 86 children entered the study (**Figure 1**). The exclusion criteria were having other neurological diseases associated with ADHD, low IQ (less than 70), prematurity at birth, sudden dietary changes or non-compliance with the prescriptive diet, and reluctance to continue to participate in the study with any reason, being an adopted child, and using drugs.

This randomized clinical trial was conducted in Yazd, Iran. A total of 86 children were randomly divided into two groups of DASH diet and control diet by simple random sampling using SPSS software. The intervention lasted 12 weeks. The participants' anthropometric indices, BP measurements, physical activity, and dietary compliance were evaluated each month. This process was conducted every month until the end of the third month of follow-up.

Diets: The required energy intake was calculated for each child by the researcher using the American Institute of Food and Drug Administration's Medical Institute formula based on their weight, height, age,

and physical activity level determined by a questionnaire at the beginning of the study (Gidding *et al.*, 2006). The children were randomly assigned into two diet groups: DASH diet and control diet. DASH diet was given to participants according to macronutrient ratio of 50-60% carbohydrate, 25-30% fat, and 15-20% protein for the intervention group along with a succession of food groups. The DASH diet contains high amounts of whole grains, fruits, vegetables and low-fat dairy products, cereals, as well as low amounts of saturated fats, cholesterol, refined grains, sweets, and red meat (Sacks *et al.*, 2001). In this diet, calcium, potassium, and magnesium contents of DASH diet are higher than the recommendations provided by the US Department of Agriculture. Control group diet was similar to the DASH diet with regard to the macronutrient contents: 60-50% carbohydrates, 25-30% fat, and 15-20% protein, which was similar to the usual Iranian diet (Azadbakht *et al.*, 2005). **Table 1** shows the food groups of the DASH diet compared to the control diet for a 1500 kcal diet.

Measurements: The participants' weight was measured using the Omron BF511 (Omron Inc. Osaka, Japan) body analyzer with a precision of 0.1 kg, while people stand in the middle of the balance in light clothing. Height was also measured in cm in standing position by a fixed height gauge. Body mass index (BMI) was measured by dividing the weight (in kilograms) by height (in squared m). To determine the waist circumference (WC), an elastic plastic meter was applied with a precision of 0.5 cm. The WC was measured at the distance between the three iliac crests and the lowest rib in standing position. To measure the hip circumference, the largest hip circumference was measured with a precision of 0.5 cm. The percentage of body fat and body muscle percentage were also measured using Omron BF511 (Omron Inc. Osaka, Japan) body analyzer. All anthropometric measurements were performed by a trained nutritionist. Anthropometric measurements were performed for each person three times and the values were recorded at least twice for each person.

BP was also measured three times using a standard mercury pressure gauge with a 5-minute interval.

For evaluation of the dietary intakes, the 24-hour recall was initially administered and the three-day dietary records including two workdays and a weekend day were used before each visit, which were completed by parents. Dietary records were analyzed for their energy and nutrient content using Nutritionist-IV software (version 3.5.2, Axxya Systems, Redmond, Washington, USA) modified for Iranian food items. Parents were also asked to record their children's physical activity before each visit. Physical activity information was converted to metabolic equivalent-hour/day (Met-h/day) using the MET intensity, type, and duration of each activity.

Data analysis: The normal distribution of quantitative data was investigated using Kolmogorov-Smirnov statistical test. All data had normal distribution. Independent samples t-test was used to compare the quantitative variables between the intervention and the control groups. Paired samples t-test was used to evaluate the within group changes in the two groups. The age and gender comparisons for the quantitative variables were done using analysis of covariance (ANCOVA) by bonferroni correction. Data were reported in mean \pm standard error (SE). P-values of less than 0.05 (2-tailed) were considered as statistically significant. Statistical analyses were performed using statistical package for social sciences software version 25 (IBM SPSS, Tokyo, Japan).

Ethical considerations: The study protocol was approved by Ethics Committee of Faculty of Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran (Ethics code: IR.SSU.SPH.REC.1395.106). The study was also registered in the Iranian Registry of Clinical Trials on January 8, 2018 (IRCT, www.irct.ir, registration ID: IRCT20130223012571N6). The children's parents were provided with verbal and written information about the study goals. They were also asked to sign informed consent forms before participating in the study.

Results

After 12 weeks, three children were removed from DASH group (2 children due to lack of

motivation to continue the study and one due to starting the medication use). In the control group, three children were excluded (2 children due to lack of motivation and one child due to immigration from Yazd city). A total of 80 participants (40 in each group) completed the study (**Figure 1**).

The means (\pm SE) for age, weight, and height at the beginning of the study were 8.67 ± 0.25 , 28.90 ± 1.38 kg, and 129.55 ± 1.44 cm in DASH group and 8.41 ± 0.24 , 27.39 ± 1.17 kg, and 128.44 ± 1.72 cm in the control group, respectively. No difference was observed between the study groups based on the baseline data ($P > 0.05$).

The average consumption of nutrient intake based on a 3-day diet and physical activity during the intervention period are presented in **Table 2**. Based on the 24-hour food intake, the fat, dietary fiber, vitamin C, and potassium groups increased significantly in DASH group. Moreover, a significant increase was observed in energy, fat, carbohydrate, and calcium intakes in control group. No significant difference was seen in dietary intake between DASH group and control at the beginning of the study. However, a significant difference was found in the mean change between the beginning and end of the study regarding the vitamin C intake ($P = 0.002$) and dietary fiber ($P < 0.001$) between DASH and control groups.

At the beginning and end of the study, no significant difference was reported in physical activity between DASH group and control group. Furthermore, no significant difference was found between the mean changes in physical activity between the two groups ($P = 0.35$).

Table 3 shows the body composition indices before and after the intervention period in the intervention group. The results revealed that weight, BMI, middle arm muscle circumference (MUAC), and muscle mass significantly increased, while the body fat percent decreased significantly ($P = 0.02$). The wrists' diameter also marginally increased ($P = 0.06$), but the waist, hip, and neck circumferences did not increase significantly ($P = 0.37$, $P = 0.36$, and $P = 0.27$, respectively). In the control group, weight, height, body mass index, waist circumference, hip circumference, wrist

circumference, MUAC, and body muscle percent increased significantly. The neck circumference marginally increased ($P = 0.05$), but body fat percentage did not decrease significantly ($P = 0.63$). No significant difference was observed in body composition before and after the intervention period. The mean difference was not significant before and after the intervention between the DASH and control groups.

Table 3 represents the systolic BP (SBP) and diastolic BP (DBP) before and after the intervention period in DASH and control groups. No significant difference was observed in the SBP and DBP at baseline between the two groups. According to these data, systolic and diastolic BP increased significantly in the DASH group ($P < 0.05$). In the control group, the SBP marginally increased ($P < 0.05$) and the DBP did not increase significantly ($P > 0.05$). No significant difference was observed at the end of the study in SBP ($P > 0.05$), but a significant difference was found at the end of study in DBP between study groups ($P = 0.02$). The mean change before and after the study between the two groups of DASH and control was not different in SBP ($P = 0.32$); whereas, the change in the DBP was significantly different ($P = 0.02$).

Table 4 shows the mean changes in body composition and BP indices of the DASH and the control groups after adjusting for age and gender. The mean changes in body composition and BP were not significant between the intervention and control groups. The results revealed that the mean changes in SBP were not different between the two groups after adjusting for age and gender. However, the DBP increased significantly in the DASH group compared to the control group ($P < 0.05$).

Figure 2 represents the effect of DASH diet compared to the control diet on SBP (A), DBP (B), body fat percent (C), and BMI (D) according to the study visits after adjusting for age and gender. A significant difference was found in mean difference of DBP only in the last month of the study. However, no significant difference was seen in other visits. Increased trend of SBP and BMI as well as reduction of body fat percentage were not significant.

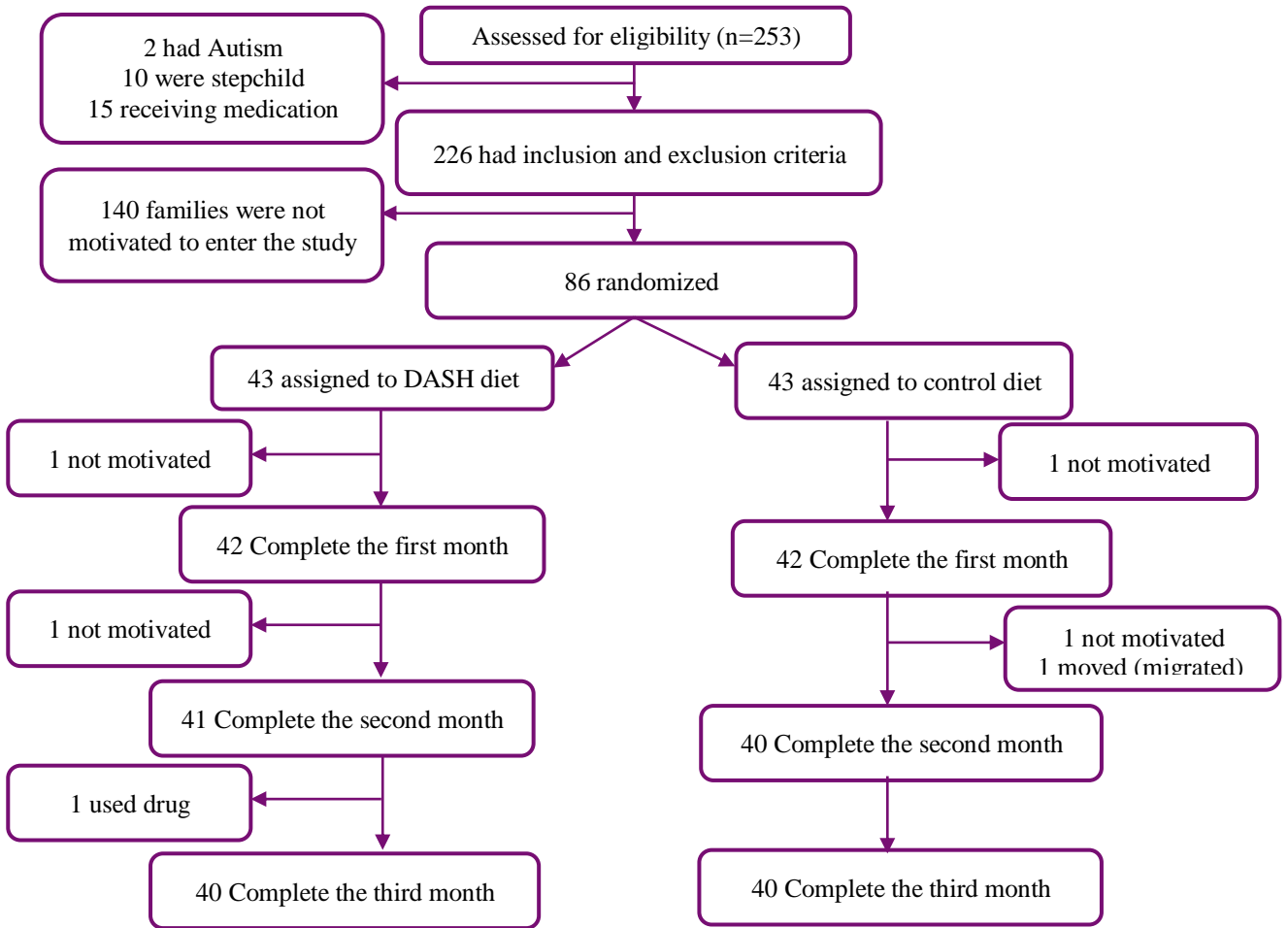
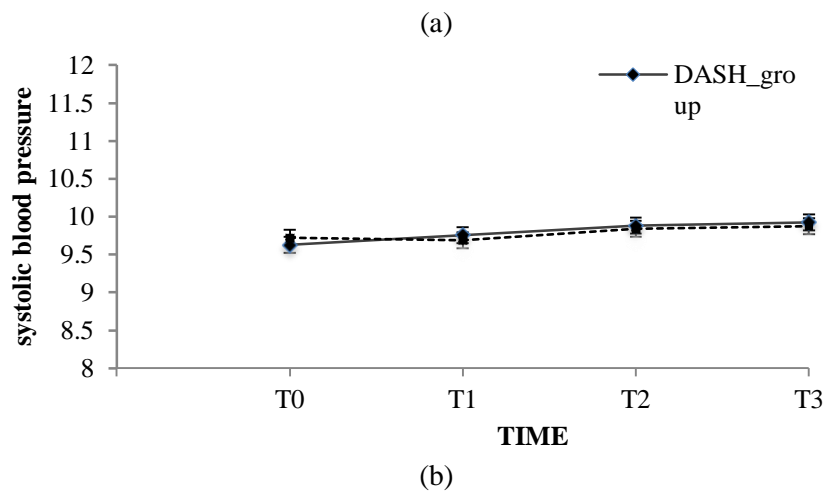
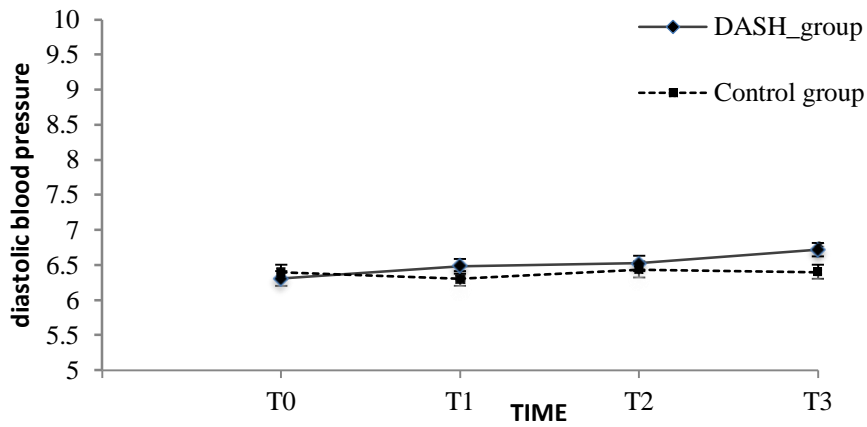
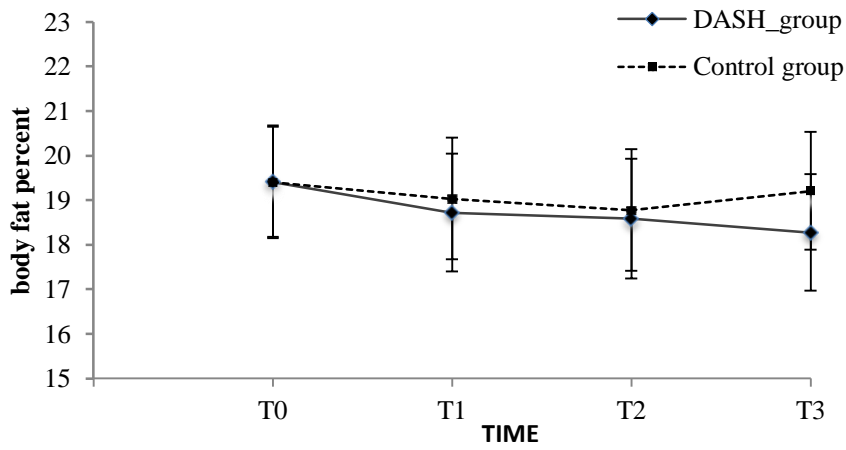


Figure 1. Trial profile





(c)



(d)

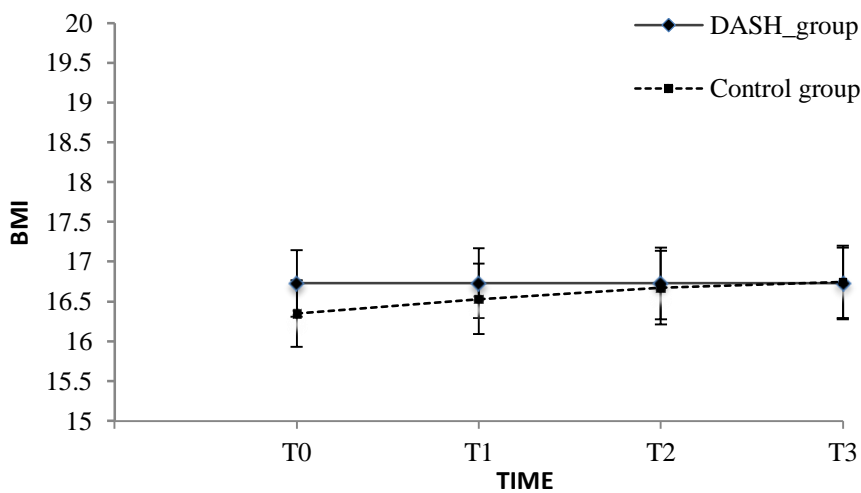


Figure 2. The effect of DASH diet compared to the control diet on SBP (A), DBP (B), body fat percent (C), BMI (D) according to the study visits, after adjustment for age and gender

Table 1. Ingredients of the DASH and control diets used in this study.^a

Food groups	DASH diet	Control diet
Grains (serving) ^b	6.5	7
Dairy (serving) ^c	2	2
Fruit	4	3
Vegetables	5	3
Meat ^d	2	3
Added sugar	-	1
Fats and Oils	4	4
Beans	1	-
Nuts/seeds	2	-

^a: Data are presented for a 1500 kcal/day diet.; ^b: Three servings from whole grains in the DASH diet; ^c: Low-fat (<1.5%) in the DASH diet; ^d: Four servings from lean meat in the DASH diet and two servings from lean meat in the control diet.

Table 2. Changes in dietary intakes for the DASH and control group

Variables	DASH group (N = 40)	Control group (N = 40)	P-value ^b
Energy (kcal/day)	- 356.48 ± 439.30 ^a	188.57 ± 62.44	0.22
Fat (g/day)	49.95 ± 3.89	48.70 ± 3.19	0.45
Saturated fat (g/day)	- 2.94 ± 2.14	1.20 ± 1.37	0.11
Poly fat (g/day)	- 3.46 ± 3.01	1.83 ± 2.51	0.18
Carbohydrate (g/day)	- 69.83 ± 88.18	20.73 ± 9.10	0.31
Protein (g/day)	6.73 ± 14.58	2.14 ± 7.30	0.78
Dietary fiber (g/day)	13.95 ± 1.46	1.56 ± 1.01	<0.001
Sodium (mg/day)	- 802.44 ± 888.06	43.26 ± 218.59	0.36
Potassium (mg/day)	545.34 ± 219.78	285.26 ± 113.80	0.30
Calcium (mg/day)	68.57 ± 148.97	107.91 ± 29.37	0.79
magnesium (mg/day)	72.27 ± 42.59	- 8.64 ± 29.32	0.12
Folate (µg/day)	70.24 ± 43.65	26.12 ± 17.67	0.35
Vitamin C (mg/day)	68.55 ± 13.83	4.52 ± 14.59	0.00
Physical activity	- 305.41 ± 181.78	- 97.03 ± 72.82	0.31

^a: values are reported as Mean ± SE; ^b: Student t-test

Table 3. Body composition and blood pressure at baseline and after 12 weeks of intervention as well as the change values in patients with ADHD according to the intervention group (values are reported as Mean \pm SE)¹

Variables	DASH group (N = 40)				Control group (N = 40)				P-value ^b	P-value ^c	P-value ^d
	Baseline	After	Change	P-value ^a	Baseline	After	Change	P-value ^a			
Weight (kg)	29.02 \pm 1.45	29.67 \pm 1.45	0.65 \pm 0.16	<0.001	27.57 \pm 1.26	28.42 \pm 1.27	0.84 \pm 0.14	<0.001	0.406	0.520	0.376
Height (cm)	130.03 \pm 1.49	131.19 \pm 1.29	1.15 \pm 0.20	<0.001	128.65 \pm 1.83	129.88 \pm 1.86	1.23 \pm 0.08	<0.001	0.623	0.583	0.583
BMI (kg/m ²)	16.80 \pm 0.51	17.01 \pm 0.50	0.21 \pm 0.09	0.032	16.37 \pm 0.42	16.76 \pm 0.44	0.38 \pm 0.10	0.001	0.507	0.704	0.248
WC (cm)	60.72 \pm 1.57	60.97 \pm 1.51	0.25 \pm 0.27	0.375	60.85 \pm 1.23	61.54 \pm 1.16	0.69 \pm 0.25	0.009	0.798	0.766	0.243
MUAC (cm)	18.94 \pm 0.46	19.15 \pm 0.47	0.21 \pm 0.07	0.040	18.74 \pm 0.42	18.94 \pm 0.39	0.20 \pm 0.06	0.005	0.441	0.741	0.940
Hip (cm)	64.44 \pm 2.53	67.18 \pm 1.91	2.74 \pm 3.01	0.369	67.42 \pm 1.37	68.16 \pm 1.34	0.74 \pm 0.29	0.014	0.394	0.676	0.514
Neck (cm)	27.31 \pm 0.35	27.61 \pm 0.44	0.30 \pm 0.27	0.279	27.00 \pm 0.35	27.18 \pm 0.35	0.18 \pm 0.09	0.052	0.443	0.454	0.686
Wrist (cm)	13.36 \pm 0.21	13.79 \pm 0.28	0.42 \pm 0.22	0.066	13.23 \pm 0.21	13.46 \pm 0.22	0.23 \pm 0.05	<0.001	0.512	0.367	0.408
Fat (%)	18.84 \pm 1.33	17.99 \pm 1.40	-0.84 \pm 0.36	0.026	19.65 \pm 1.31	19.45 \pm 1.24	-0.19 \pm 0.40	0.634	0.780	0.420	0.238
Muscle (%)	29.65 \pm 0.70	31.03 \pm 0.64	1.38 \pm 0.19	<0.001	29.40 \pm 0.99	30.59 \pm 0.97	1.18 \pm 0.38	0.004	0.909	0.529	0.644
SBP (mmHg)	9.60 \pm 0.10	9.93 \pm 0.11	0.33 \pm 0.11	0.004	9.66 \pm 0.11	9.85 \pm 0.09	0.19 \pm 0.09	0.054	0.540	0.601	0.327
DBP (mmHg)	6.35 \pm 0.09	6.72 \pm 0.08	0.37 \pm 0.09	<0.001	6.34 \pm 0.11	6.39 \pm 0.11	0.05 \pm 0.10	0.629	0.693	0.027	0.025

DASH: Dietary Approaches to Stop Hypertension, WC: Waist circumference, MUAC: Mid-upper arm circumference, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure

^a: Obtained from paired samples t tests; ^b: p-value of baseline, Obtained from independent samples t tests; ^c: p-value of after intervention, Obtained from independent samples t tests; ^d: p-value of the comparison between the pre-post changes between groups

Table 4. Changes in body composition and blood pressure in Patients with ADHD after adjustment for age and sex (values are reported as Mean \pm SE)

Variables	DASH group (N = 40)	Control group (N = 40)	P-value ^a
Weight (kg)	0.68 \pm 0.15	0.82 \pm 0.15	0.525
Height (cm)	1.14 \pm 0.09	1.23 \pm 0.10	0.522
BMI (kg/m ²)	0.26 \pm 0.09	0.33 \pm 0.09	0.603
WC (cm)	0.27 \pm 0.26	0.66 \pm 0.27	0.317
MUAC (cm)	0.21 \pm 0.07	0.20 \pm 0.07	0.906
Hip (cm)	2.83 \pm 2.20	0.66 \pm 2.22	0.493
Neck (cm)	0.31 \pm 0.20	0.16 \pm 0.21	0.625
Wrist (cm)	0.43 \pm 0.16	0.22 \pm 0.17	0.384
Fat (%)	- 0.81 \pm 0.38	- 0.23 \pm 0.39	0.306
Muscle (%)	1.39 \pm 0.29	1.17 \pm 0.30	0.597
SBP (mmHg)	0.32 \pm 0.10	0.20 \pm 0.10	0.430
DBP (mmHg)	0.38 \pm 0.09	0.03 \pm 0.10	0.015

¹DASH: Dietary Approaches to Stop Hypertension, WC: Waist circumference, MUAC: Mid-upper arm circumference, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure

^a: P-value of the comparison between the pre-post changes between groups

Discussion

The results of our study indicate that compliance with the DASH diet for 12 weeks has favorable effects on DBP of children and adolescents with ADHD compared with the control group. However, following DASH diet did not affect body weight and composition significantly in children with ADHD. To the best of our knowledge, this was the first study that examined the effects of DASH diet on weight and BP indices in children and adolescents with ADHD.

Some studies investigated the effect of foods on weight and body composition in children. Some of these studies confirmed our findings. Berz et al. conducted a study in the United States and showed that adolescent girls with DASH diet gained less weight after 10 years. The results also indicated that such a pattern might help prevent overweight during adolescence (Berz *et al.*, 2011). Similarly, our study also showed that DASH diet could prevent weight gain significantly. Another study showed that a diet containing many components abundant in the DASH dietary pattern led to a lower BMI increase in long term (Newby *et al.*, 2003). Another study reported that the DASH diet might reduce the body composition indices in obese participants (Hajna *et al.*, 2012).

As mentioned above, our results did not show any significant difference in the means of body composition between the two groups, but the results were significant in the control group. This result can be justified by mentioning that the control group diet was also a healthy diet designed based on the amount of energy needed by the participants and the macronutrient percentage, which was similar to the DASH diet.

Our results regarding the effect of DASH diet on BP was different from previous studies. Studies that examined the effect of DASH diet on BP in children and adolescents showed that the DASH diet reduced SBP and DBP (Conlin *et al.*, 2000, Couch *et al.*, 2008). However, our findings showed that the DASH diet increased SBP and DBP in children with ADHD. According to the previous studies, children with ADHD had a low BP (Meyer *et al.*, 2017). Our results showed that the means (\pm SD) of the SBP and DBP in the baseline were 9.67 ± 0.07 and 6.35 ± 0.07 , respectively, which confirmed the results of previous studies. According to the criteria set by the Fourth Report on the Diagnosis, Evaluation, and Treatment of High BP in Children and Adolescents (Pediatrics, 2004), normal BP in children is defined as SBP and DBP less than 90th percentile for age, gender, and height, while hypertension is defined as SBP

and/or DBP of persistent 95th percentile or more. The 90th percentile of SBP in boys and girls with 6-12 years of age was within 113 to 123 and 110 to 121, respectively. The boys' and girls' 90th percentile of DBP was within 72 to 78 and 71 to 78, respectively. In fact, our results increased to a normal blood pressure.

A DASH diet can reduce weight and body fat percentages and increases muscle mass by several mechanisms. This diet is rich in fruits and vegetables and fruits and vegetables reduce weight (Buijsse *et al.*, 2009). The DASH diet has low dietary fat and high protein intake and evidences indicate that high protein diet changes body composition and weight loss (Clifton *et al.*, 2014). Previous reviews showed that other DASH components such as dairy products (Abargouei *et al.*, 2012), dietary fiber (Chew and Brownlee, 2018), and omega-3 fatty acids (Keshavarz *et al.*, 2018) also caused weight loss. The DASH diet, for various reasons, affects blood pressure; for example, since this diet is rich in calcium, potassium, and magnesium, it can contribute to regulation of the blood pressure by regulating vascular resistance and promoting vasodilators (Houston and Harper, 2008).

One of the strengths of this study was including a large number of children in the intervention and the control groups. Furthermore 93% of the participants managed to complete the study. One of the weaknesses of this study can be the evaluation method for assessing the dietary compliance. We could not get a blood sample or 24-hour urine specimen to assess the participants' compliance with DASH diet; so, we only used the 3-day dietary records to examine their compliance. Another weakness of this research was the short duration of the study.

In conclusion, the present clinical trial showed that compliance with DASH diet for 12 weeks could significantly increase the DBP of children with ADHD. The diet did not significantly affect body weight and composition compared to the control diet. Further clinical trials with more follow-up period are needed to confirm these results.

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Authors' contributions

The study was designed by Salehi - Abarghuaei A, Khoshtakht Y, Bidaki R and Hosseinzadeh M. statistical analysis was performed by Salehi - Abarghuaei A. Mirzavandi F helped in drafting and editing the manuscript. All authors have read and approved the final version of the manuscript.

Conflicts of interest

The authors of this article declare no conflict of interest regarding this study.

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