The effect of dietary approaches to stop hypertension (DASH) diet on attention deficit hyperactivity disorder (ADHD) symptoms: a randomized controlled clinical trial

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Research

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Abstract

Background The dietary approaches to stop hypertension (DASH) diet has several components that might improve attention deficit hyperactivity disorder (ADHD) symptoms. This randomized controlled clinical trial (RCT) aimed to investigate the effect of the DASH diet on ADHD symptoms in children, for the first time.

Methods Children (aged 6-12 years) with ADHD were randomized to receive a DASH or a control diet for 12 weeks. The severity of ADHD symptoms [determined by abbreviated 10-item Conner's scale (ACS), 18-item Swanson, Nolan and Pelham (SNAP-IV) scale and strengths and difficulties questionnaire (SDQ)], as well as dietary intakes, physical activity, and anthropometric measurements, were assessed every four weeks. The symptom scores provided by teachers, parents, and children were compared between the two groups, in multivariable-adjusted models.

Results A total of 80 children completed the study. After adjustment for age, sex, energy intake, and baseline values significant group effects were observed for parent-reported ACS score, children-reported emotional symptoms and peer relationship problems, and parent-reported scores of prosocial behaviors based on the SDQ scale (Pgroup<0.05). Significant group*time effects were indicated in teacher-reported ACS score, teacher-reported Hyperactivity and impulsivity, and parent-reported combined score based on SNAP-IV, and teacher/child-reported scores for hyperactivity, parent and teacher-reported scores of emotional symptoms, peer relationship problems, and prosocial behavior, and also teacher/parent/child-reported total SDQ score (Pgroup*time<0.05). The adjusted mean in teacher/parent-reported ACS scores, teacher/parent/child-reported hyperactivity, and total SDQ scores, teacher-reported emotional symptoms, conduct problems, peer relationship problems, and prosocial behaviors assessed by the SDQ were significantly improved in the DASH compared to the control group (P<0.05).

Conclusions Adherence to the DASH diet might beneficially improve ADHD symptoms. Further RCTs with more follow-up period which include participants from both sexes are needed to confirm these results.

Trial registration: The trial was registered in the Iranian registry of clinical trials (registration code: IRCT20130223012571N6).

Introduction

Attention deficit hyperactivity disorder (ADHD), defined as functional impairment due to persistent inattention, hyperactivity, and impulsivity, is one of the most common psychiatric disorders in school-aged children (1). The prevalence of ADHD is estimated to be 5.29%, worldwide (2). This amount was shown to be 12.6% in Tehran (3) and 16.3% of children living in Yazd, Iran (4). The disease might lead to a lower educational, occupational, and social level in later life (5–7). Several genetic and environmental factors are proposed to be associated with the development of the disease (8).

Different dietary interventions including restriction and elimination diets (the removal of food colors and other additives, sugars, and sweeteners), few food diets, as well as supplementation of essential fatty acids, amino acids, vitamins, and minerals are investigated for their possible effect on children with ADHD (9). Previous studies on the effect of supplementation with different amino acids (phenylalanine, tyrosine and tryptophan) (10, 11), vitamins (B complex and vitamin C)(12, 13), minerals (iron, zinc and magnesium) (14, 15) and essential fatty acids [omega-3, omega-6, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)](16, 17) have led to conflicting results. Studies investigating the effect of elimination diets on ADHD have also led to inconsistent results (18–20). A recent systematic review and meta-analysis suggested that the few-foods diet (FFD) followed by food challenge might be an effective strategy in controlling ADHD (21, 22). Indeed, FFD is not regarded as a treatment and the approach of starting with diet and following the food challenge might take at least one year (22). As the diet puts a high burden on children and their families, it is recommended for children with ADHD who do not respond to medications or those who are too young for the medication (21) and children who live in highly motivated families (22). The FFD is a restrictive diet and might not fully meet the nutritional needs and growth of the children (9).

The Dietary Approaches to Stop Hypertension (DASH) is a diet rich in fruits, vegetables, whole grains, fish, and low-fat dairy products (23). This diet was initially designed for hypertension treatment, however, later investigations observed that the DASH might be beneficial in improving blood glucose (24) and lipid profile (25) control. It was shown that children who consume fewer amounts of fruits and vegetables have more ADHD-like symptoms (26, 27). Furthermore, a clinical trial revealed that the inactivity score in children with ADHD is significantly related to the consumption of fruits and vegetables (28). The fish consumption that provides essential fatty acids such as eicosapentaenoic acid (EPA) is also recommended in the DASH diet and docosahexaenoic acid (DHA). The consumption of these n-3 fatty acids might significantly reduce ADHD symptoms (29, 30). Thus, diet also contains high amounts of calcium and magnesium, which their supplementation is suggested to be effective in the treatment of ADHD (31–33). This diet is also rich in vitamin C that might reduce the total hyperactivity scores in participants with ADHD (34). While it can provide enough amounts of nutrients for supporting children’s growth, the DASH diet is low in food colors, simple sugars and artificial sweeteners (35); therefore, we hypothesized that this diet might be a good choice for the ADHD treatment. Therefore, the present randomized controlled clinical trial (RCT) was conducted to examine the possible effect of the DASH diet compared to an isocaloric control diet in children with ADHD.

Methods

Study protocol

The present study was a randomized controlled clinical trial conducted in children aged 6 to 12 years attending the psychology clinics of Shahid Sadoughi University of Medical Sciences who were recently diagnosed with ADHD according to the Conner's teacher questionnaire and the DSM-4 criteria by a psychiatrist. The children were excluded from the study if: 1) they used medication or behavioral therapy for ADHD prior to or during the intervention period; 2) had a history of any other neurological diseases associated with ADHD like anxiety; 3) had a low intelligence quotient score (less than 70) (assessed by using the Wechsler IQ test); 4) were adopted or foster child; 5) experienced a recent major dietary change; 6) the participants or their parents decided not to participate or refused to continue the study with any reason. Parents were given verbal and written information about the study and signed informed consent before participation. The present study was conducted in accordance with the declaration of Helsinki and its protocol was approved by the ethics committee of Shahid Sadoughi University of Medical Sciences, Yazd, Iran (ethical approval code: IR.SSU.SPH.REC.1395.106) and registered in the Iranian registry of clinical trials (IRCT) with the registry code of IRCT20130223012571N6 on 8th February 2018 (URL: http://irct.ir/trial/12623). We followed the Consolidated Standards for Reporting Trials (CONSORT) statement for reporting the current study (36).

Study Design

The eligible children were randomly assigned to receive a DASH or a control diet for three months (12 weeks). A simple randomization was conducted using the statistical package for social sciences (SPSS) software. The randomization concealment was done by putting the allocated intervention in sealed and opaque envelopes until the assignment. Both randomization and randomization concealment were conducted by an independent researcher. Children and their parents were visited each month up to three months, in order to determine the severity of ADHD by using Abbreviated 10-item Conner’s scale (ACS), 18-item Swanson, Nolan and Pelham (SNAP-IV) scale and strengths and difficulties questionnaire (SDQ), assess the dietary intake, physical activity, and to measure the anthropometric indices.

Intervention diets

The estimated energy requirement (EER) was estimated using a formula proposed by the American Institute of Medicine based on weight, height, age, and physical activity level for each participant (37). The intervention diets were designed by a trained nutritionist. Either DASH or control diets were designed to provide 50-60% of EER from carbohydrates, 25-30% from fats and 15-20% from proteins. The DASH and the control diets were different in the prescribed dietary food groups. The DASH diet was designed to contain higher amounts of whole grains, fruits, vegetables, low-fat dairy products, nuts, and beans, as well as low amounts of saturated fats, cholesterol, refined grains, sweets and red meat (23). The Control diet was designed to be similar to the usual diet of Iranian children (38). **Table 1** compares the food group servings for a 1500 kcal DASH and a 1500 kcal control diet prescribed in the present study.

ADHD severity assessment

Three questionnaires including abbreviated 10-item Conner’s scale (ACS), 18-item SNAP-IV scale and SDQ were used to assess the ADHD severity. Conner’s questionnaire consists of ten behavioral questions focusing on hyperactivity and inattention. According to Conner's questionnaire, children with a score of 15 and above might have attention-deficit/hyperactivity disorder. The validity and reliability of this questionnaire were shown in Iranian children (39). The questionnaire was filled by the participants’ teachers and parents in each visit. The 18-item Swanson, Nolan, and Pelham (SNAP-IV) Rating scale has 9 questions about attention deficit disorder (ADD), 5 questions about hyperactivity and 4 questions about impulsivity. The overall hyperactivity and impulsivity were called as the hyperactivity disorder (HD). Three measures were assessed by using this questionnaire: total score (combined), attention deficit disorder (ADD), and hyperactivity and impulsivity (HD) score. The validity and reliability of this questionnaire were shown for Iranian children (40). This questionnaire was also filled by the parents and teachers. The SDQ questionnaire which has 25 questions was filled by children, their parents and the teachers in each visit. The SDQ provides data on five subscales of emotional symptoms, hyperactivity, conduct problems, peer relationship problems, and prosocial behavior. The total subscale is generated by adding all components except prosocial behavior together. The reliability and validity of the questionnaire in the Iranian children were also previously investigated (41).

Anthropometric measurements

Anthropometric measurements were performed for each person at baseline and each month up to three months. The weight of participants was assessed using a digital body analyzer (Omron Inc. Osaka, Japan; model no: BF511), with a precision of 0.1 kg, with the minimum possible clothing. Height was also measured using a wall-fixed height gauge to the nearest 0.5 cm. Body mass index (BMI) was calculated by dividing the weight (in kilogram) by height (in meter squared). The waist circumference (WC) and hip circumference were measured using a non-stretchable measuring tape with a precision of 0.5 cm by following the standard guidelines. The body fat and muscle percentage were also measured using Omron BF511 (Omron Inc. Osaka, Japan) body analyzer. All anthropometric measurements were performed three times on each visit by a trained nutritionist and the mean values of them were recorded.

Dietary assessment

The dietary intake of the children was assessed using a 24-h dietary recall interview with parents which was done by a trained nutritionist at baseline. Furthermore, the parents were trained to keep three-day dietary records (two workdays and a weekend day), at the beginning and each month up to three months. The recorded food items were converted to grams using household measures and then the daily intake of macro- and micronutrients were calculated using Nutritionist IV software (version 3.5.2, Axxya Systems, Redmond, Washington, USA).

Physical activity measurement

Participants and their parents were recommended to maintain the child's usual physical activity during the study period. This was checked by asking parents to record the daily physical activity of children at the beginning and each month up to the end of the intervention period using three-day records (two workdays and a weekend day). The recorded physical activities and their duration were converted to metabolic equivalent-hour/day (Met-h/day) using the MET intensity of each activity (42).

Sample size calculation and statistical analysis

Based on the following formula: $n = [(Z\alpha/2 + Z\beta)^2 \times \{2(ó)^2\}.]/ (\mu1 - \mu2)^2$ (43) and assuming the mean difference ($\mu1 - \mu2$) of 8.4 in teachers' ACS score, standard deviation (ó) of 9.14, alpha of 0.05 and power of 80%. based on a previously published study (20), the sample size was calculated to be at least 19 participants in each intervention group. We anticipated a high attrition rate and lower effects because of the nature of the diet; furthermore, the study team had access to children with ADHD. Therefore, we aimed to include at least 40 participants in each study arm. The normal distribution of quantitative data was evaluated by looking at histograms and incorporating the Kolmogorov-Smirnov test. Independent samples t-test and Chi-square test were used for comparing qualitative and quantitative variables between the DASH and control groups, respectively. Paired samples t-test was used for intra-group comparisons of quantitative variables between baseline and after the intervention period. Linear mixed model was used to assess the time, group and time*group interaction effects on ADHD symptoms assessed by ACS, SNAP-IV and SDQ scales after adjustment for participants' age, sex, energy intakes and the baseline values. The change in ADHD symptoms' scores and the scores at each month of follow-up were also compared between the intervention and control groups using the analysis of covariance (ANCOVA) considering the participants' age, sex, energy intakes and the baseline values as covariates. The Quantitative values are reported as means ± standard deviations (SDs) unless indicated. Statistical package for social sciences (SPSS) software version 20 was used for data analysis and P values less than 0.05 were considered as statistically significant.

Results

A total of 86 participants met the inclusion criteria and were allocated to the intervention and control groups (43 children in each group) and 80 children completed the study. Three participants from each group left the study during the follow-up period with these reasons: lack of motivation (n=4), taking medication (n=1), and migration (n=1). Therefore, 80 participants (40 in each group) were included in the statistical analyses. The study flow process is detailed in **Figure 1**.

With respect to the baseline characteristics, there were no significant differences in age, anthropometric measurements, sex, and parental education and occupation between the two groups **(Table 2)**.

The baseline and after follow-up dietary macro and micro-nutrients, as well as their change values, are provided in **Table 3**. There was no difference in the two groups regarding the nutrients intake, at baseline. The mean changes in dietary total fat, fiber, pyridoxine, vitamin C, vitamin A, vitamin K, and potassium intakes were significantly increased in the DASH diet group ($P < 0.05$). Also, in the control group the energy, total fat, total carbohydrates, sugar, vitamin A, vitamin K, potassium and calcium intakes were significantly increased ($P < 0.05$). After the follow-up period, children in the DASH diet consumed higher amounts of protein, dietary fiber, thiamin, riboflavin, niacin, pyridoxine, folate, vitamin C, vitamin K, potassium, calcium, and magnesium when compared to controls ($P < 0.05$). It should be noted that only the mean changes in dietary fiber and vitamin C intakes were significantly different between the two groups ($P < 0.05$).

The baseline and after intervention ADHD symptoms' scores, assessed using ACS, SNAP-IV, and SDQ questionnaires are summarized in **Table 4**. There was no difference between the two groups at baseline ($P > 0.05$). After adjustment for age, sex, energy intake, and baseline values, both DASH and control diets led to significant improvements in scores based on all three questionnaires ($P_{time} < 0.05$, Table 4). Whereas the group effect was significant for parent-reported ACS score ($P_{group} = 0.05$). However, no significant group effect was indicted in any subscales of the SNAP-IV questionnaire ($P_{group} > 0.05$). Significant group effects were also observed in some SDQ subscales including parent and child-reported scores of emotional symptoms and peer relationship problems, also the group effect for parent-reported scores of prosocial behavior was significant ($P_{group} <0.05$). A significant group*time effect was indicated in teacher-reported ACS score, teacher-reported HD and parent-reported combined score based on SNAP-IV questionnaire, and teacher and child-reported scores of hyperactivity, parent and teacher-reported scores of emotional symptoms, teacher reported scores of peer relationship problems and prosocial behavior, and also teacher, parent and child-reported total score according to reports based on SDQ scale ($P_{group*time} <0.05$).

According to Table 5, after adjustment for possible confounders, the mean changes in ACS score were significantly higher in the DASH group when compared to the control group either for parents or teachers ($P < 0.05$). However, there was no significant difference between the two groups based on SNAP-IV questionnaire. However, the reduction in mean hyperactivity score and the total SDQ score was higher in the intervention group compared to the control group, according to reports provided by parents, teachers, and children ($P < 0.05$). Furthermore, teachers reported more improvements in emotional symptoms, conduct problems, peer relationship problems, and prosocial behavior in children assigned to DASH diet compared to those received the control diet ($P<0.05$).

The age, sex, energy intake, and baseline values-adjusted mean for ACS, combined subscale of SNAP-IV, and hyperactivity component of SDQ scores at baseline, months 1, 2 and 3 of follow-up are depicted in **Supplemental Figures 1-3.** The parents and teachers-reported ACS scores were significantly lower in the children assigned to the DASH diet at the second and the third months of the follow-up (**Supplemental figure 1**, $P < 0.05$). The total SNAP-IV score was significantly different only in scores provided by parents in the third month of follow-up (**Supplemental figure 2**, $P<0.05$). According to the parents, the SDQ hyperactivity score was significantly lower in the DASH group compared to the control group at the second and the third months of follow-up (**Supplemental figure 3A**, $P < 0.05$). The teachers and children-reported scores were significantly different in the third month of follow-up (**Supplemental figures 3B and C**, $P < 0.05$).

Discussion

The present study revealed that adherence to the DASH diet might significantly improve the ADHD symptoms assessed by ACS and SDQ questionnaire in children when compared to a healthy control diet. This is while the effect was found to be marginal for the combined inattention and hyperactivity score assessed by SNAP-IV questionnaire. To the best of our knowledge, the present study is the first randomized controlled clinical trial investigating the effect of the DASH diet on children with ADHD.

The previous investigations have usually examined the effect of dietary components or restrictive diets on ADHD. For instance, in a study on 100 children aged 4-8 years, Pelsser et al. (44) reported that a restricted elimination diet can significantly improve ADHD symptoms. They revealed that the ACS score was significantly lower in the intervention group than in the control group. Moreover, in another study examining the effect of restricted elimination diet on the behavior of 27 children with ADHD, it is indicated that the mean scores of the questionnaires significantly decreased in the intervention group (20). Furthermore, in a meta-analysis assessing the role of food color additives and restriction diets on ADHD, it was shown that the effect of restriction diets was notable (45). Since the restrictive diet may not fully meet the nutritional needs of children, long term adherence to this diet might not be applicable (20). Several studies indicated that examining the effect of dietary patterns versus nutrients is more informative specifically in health promotion such as mental health (46, 47).

The DASH diet was initially designed to improve blood pressure and emphasizes the high intake of vegetables, fruits, and low-fat dairy products and includes fish, whole grains, poultry, and nuts; the diet is also limited in red meat, salt, and sweetened beverages (23). In line with our results, Ghanizadeh et al. (28) have reported that the high intake of vegetables and dairy products may improve the behavioral problems in children with ADHD. Also, Park et al. (27) found that the high intake of dairy products and vegetables and low adherence to a diet high in fried food, sweetened desserts, and salt might have beneficial effects on ADHD symptoms. Generally, it is asserted that inflammation can cause neurodegeneration due to the activation of immune cells in the brain which in turn might lead to the production of pro- inflammatory factors (48). Therefore, a fruit and vegetable-rich diet’s beneficial effects on cognitive behavior might be due to their high antioxidant content and anti-inflammatory properties (49). Furthermore, it is asserted that adherence to the plant-rich diets significantly increases the short-chain fatty acids (SCFAs) levels (50). The researches have shown that SCFAs may increase the production of leptin which is proposed to be reduced in impulsivity disorders; therefore SCFAs might have beneficial effects on psychiatric conditions (51-53). The DASH dietary pattern also emphasizes the consumption of dairy products, especially low-fat dairy products, which might have positive effects on cognitive behaviors by improving glucose and calcium regulation (54). Indeed, a number of studies indicated that poor glucose regulation is associated with cognitive impairments (55, 56). Additionally, calcium dysregulation has been suggested to be a considerable factor in neurodegeneration (57, 58). In addition, alpha-lactoalbumin, a protein found in dairy products, has beneficial effects on increasing serotonin levels which is effective in the improvement of mood and cognitive behavior (54, 59, 60). The lower plasma levels of Omega-3 polyunsaturated fatty acids (PUFAs) have also been demonstrated in children with ADHD (61). In addition, the efficacy of the Omega-3 PUFAs namely eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) supplementation in the improvement of ADHD symptoms has been indicated by a number of investigations (17, 18, 62). The DASH diet which includes fish as a good source of EPA and DHA may be effective in improving symptoms of ADHD. Indeed, it has been shown that polyunsaturated fatty acids have an important role in regulating cell survival, synaptic function, and neurogenesis (63). Therefore, omega-3 PUFAs deficiency may alter dopaminergic and serotonergic neurotransmission systems and might lead to mood and cognitive disorders (63, 64). Moreover, it is suggested that DHA is associated with dopamine which is shown to be dysregulated in ADHD (65). The DASH dietary pattern is rich in magnesium-containing food sources. It is mentioned that magnesium deficiency is associated with several cognitive disorders which usually can be manifested in ADHD including lack of concentration, fatigue, and aggression (66). The reduced serum magnesium levels have been indicated by several studies in patients with ADHD (31, 67-69).

There are some limitations in this current study which should be taken into account when interpreting the results. We could only use three-day dietary food records to assess the adherence to the intervention diets, while measurement of 24-hour urine potassium, blood vitamin C, and other biochemical tests would be better for assessing the compliance of the study participants to the intervention protocol. In addition, the current study was not a feeding trial and no food was provided for the study participants. Furthermore, although we tried to include eligible children from both sexes only one girl was included; because, we did not use a stratified randomization based on the participants' sex. Therefore, the study results might not be attributed to female children with ADHD.

In conclusion, the present study provides evidence that adherence to the DASH dietary pattern might be effective in improving ADHD symptoms. Performing other clinical trials with a larger sample size which also include female children and with longer duration of follow-up are needed to confirm these results.

Declarations

Ethics approval and consent to participate

Parents of the study participants were given verbal and written information about the study and signed informed consent before participation. The present study was conducted in accordance with the declaration of Helsinki and its protocol was approved by the ethics committee of Shahid Sadoughi University of Medical Sciences, Yazd, Iran (ethical approval code: IR.SSU.SPH.REC.1395.106) and registered in the Iranian registry of clinical trials (IRCT) with the registry code of IRCT20130223012571N6 on 8th February 2018 (URL: http://irct.ir/trial/12623). We followed the Consolidated Standards for Reporting Trials (CONSORT) statement for reporting the current study.

Consent for publication

No individual detail is presented in this manuscript.

Availability of data and material

The data of the present study will be available for the corresponding author. The data used for the current study are already published in individual papers. The data can be obtained from the corresponding author.

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Authors' contribution:

The authors' contributions were as follows— ASA and YK conceptualized and designed the study, carried out the statistical analyses, drafted the initial manuscript, and approved the final manuscript as submitted. FM and RB contributed in data interpretation, reviewed the manuscript and approved the final manuscript as submitted. MH contributed in the design of the study, reviewed the manuscript and approved the final manuscript as submitted. All authors agreed to be accountable for all aspects of the work.

Conflict of interest:

There is no conflict of interest to report for this study.

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Tables

Table 1- The food group servings designed for the DASH and the control diets (both diets were designed to provide 1500 kcal/day) [1].

	DASH Diet					Control diet				
Food groups	**Servings**	**CHO(g)**	**PRO (g)**	**FAT (g)**	**Energy (Kcal)**	**Servings**	**CHO (g)**	**PRO (g)**	**FAT (g)**	**Energy (Kcal)**
Meat	2	-	14	6	110	3	-	21	15	225
Dairy	2	24	16	6	200	2	24	16	10	240
Fruit	4	60	-	-	240	3	45	-	-	180
Vegetables	5	25	10	-	125	3	15	6	-	75
Grains	5.5	82.5	16.5	low		7	105	21	low	560
Whole	3	45	9	low	240	Not defined	-	-	-	-
Refined	2.5	37.5	7.5	-	200	Not defined	-	-	-	-
Fats and Oils	4	-	-	20	180	4	-	-	20	180
Beans	1	15	7	2	125	-				
Nuts/seeds	2	-	-	10	90	-				
Added sugar	-	-	-	-	-	1	15	-	-	60
Total		206.5	63.5	44	1510		204	64	45	1520
Energy percent		55%	17%	28%			55%	17%	28%	

[1] CHO: carbohydrate, PRO: protein

Table 2- Baseline characteristics of the study participants[1]

Variables	DASH (n=40)	Control (n=40)	P value
Body weight (kg)	28.90 ± 1.38[2]	27.39± 1.17	0.406
Height (cm)	129.55 ± 1.44	128.44 ± 1.72	0.623
WC (cm)	61.04 ± 1.50	60.55 ± 1.88	0.798
BMI (kg/m2)	16.74 ± 0.49	16.33 ± 0.38	0.507
Body fat (percent)	19.17 ± 1.28	19.66 ± 1.19	0.780
Male (%)	100	95.3	0.494
Education mother (%)			
High school and Diploma	77.4	67.5	0.665
Associate Degree	6.5	10.0	
Bachelor's degree and higher	16.1	22.5	
Education father (%)			
High school and Diploma	63.3	70.3	0.625
Associate Degree	6.7	10.8	
Bachelor's degree and higher	30.0	18.9	
Occupation mother (%)			
Government employee	14.7	17.1	0.820
Self employed	23.5	14.6	
Manual worker	2.9	2.4	
Unemployed	58.8	65.9	
Occupation father (%)			
Government employee	31.4	13.5	0.115
Self employed	48.6	48.6	
Manual worker	8.6	27.0	
Unemployed	11.4	10.8	

[1] WC, waist circumference; BMI, body mass index

[2] Values are expressed as means ± standard error (SE), otherwise indicated.

Table 3- Macronutrients intakes, micronutrients intakes, and physical activity of participants in the intervention and control groups

	DASH (N = 40)				Control (N = 40)						
	Baseline	**After**	**Change**	**P[1]**	**Baseline**	**After**	**Change**	**P[1]**	**P[2]**	**P[3]**	**P[4]**
Macronutrients											
Energy	2280.28 ± 431.78[5]	1923.80 ± 71.78	- 356.48 ± 439.3	0.422	1561.71 ± 67.55	1750.28 ± 50.39	188.57 ± 62.44	0.005	0.153	0.053	0.229
Fat	18.84 ± 1.32	68.79 ± 3.95	49.95 ± 3.89	<0.001	19.67 ± 1.27	68.38 ± 3.26	48.70 ± 3.19	<0.001	0.876	0.706	0.456
Saturated fatty acid	18.71 ± 2.15	15.76±1.09	- 2.94 ± 2.14	0.177	16.32 ± 1.13	17.53 ± 1.07	1.20 ± 1.37	0.388	0.930	0.254	0.110
Mono-unsaturated fat	17.64 ± 1.58	16.31 ± 0.86	- 1.32 ± 1.77	0.457	16.62 ± 1.40	16.46 ± 0.90	- 0.16 ± 1.56	0.918	0.859	0.905	0.623
Poly-unsaturated fat	26.15 ± 3.33	22.68 ± 1.54	- 3.46 ± 3.01	0.257	22.63 ± 2.28	24.47 ± 1.48	1.83 ± 2.51	0.469	0.446	0.407	0.181
Carbohydrate	333.02 ± 86.94	263.19 ± 12.22	- 69.83 ± 88.18	0.433	204.59 ± 9.06	225.32 ± 7.47	20.73 ± 9.10	0.028	0.182	0.010	0.316
Sugar	59.34 ± 6.21	70.22 ± 3.80	10.88±3.70	0.112	44.99 ± 4.96	58.29 ± 4.97	13.29 ± 5.86	0.029	0.459	0.060	0.787
Protein	72.94 ± 14.00	79.68 ± 2.46	6.73 ± 14.58	0.647	61.34 ± 6.81	63.48 ± 2.01	2.14 ± 7.30	0.771	0.502	<0.001	0.781
Dietary Fiber	10.51 ± 0.91	24.46 ± 1.30	13.95 ± 1.46	<0.001	9.45 ± 0.92	11.02 ± 0.61	1.56 ± 1.01	0.131	0.707	<0.001	<0.001
Micronutrients											
Thiamin	2.30 ± 0.93	1.67 ± 0.07	- 0.62 ± 0.93	0.508	1.27 ± 0.05	1.40 ± 0.06	0.12 ± 0.08	0.140	0.297	0.007	0.435
Riboflavin	1.94 ± 0.50	1.84 ± 0.08	- 0.09 ± 0.51	0.849	1.51 ± 0.20	1.51 ± 0.05	-.00076 ± 0.21	0.997	0.465	0.002	0.863
Niacin	23.34 ± 7.30	19.11 ± 0.95	- 4.22 ± 7.46	0.575	14.60 ± 1.05	16.46 ± 0.71	1.85 ± 1.01	0.076	0.247	0.030	0.427
Pyridoxine	0.97 ± 0.08	1.60 ± 0.09	0.63 ± 0.12	<0.001	5.56 ± 4.65	1.12 ± 0.05	- 4.44 ± 4.66	0.347	0.325	<0.001	0.274
Folate	238.44 ± 38.94	308.68 ± 20.31	70.24 ± 43.65	0.116	170.09 ±15.01	196.22 ± 11.42	26.12 ± 17.67	0.148	0.160	<0.001	0.356
Cobalamin	1.83 ± 0.18	1.91 ± 0.09	0.07 ± 0.19	0.715	1.77 ± 0.19	3.78 ± 1.92	2.00 ± 1.95	0.312	0.885	0.327	0.323
Vitamin C	71.84 ± 11.73	140.39 ± 11.30	68.55 ± 13.83	<0.001	77.54 ± 11.93	82.06 ± 10.28	4.52 ± 14.59	0.758	0.536	<0.001	0.002
Vitamin A	474.83 ± 88.58	831.60 ± 86.97	356.77 ± 115.94	0.004	317.11 ±42.79	623.20 ± 93.33	306.08 ± 103.01	0.005	0.627	0.106	0.745
Vitamin E	20.77 ± 1.85	22.31 ± 1.22	1.53 ± 1.90	0.425	20.25 ± 1.86	22.31 ± 1.29	2.06 ± 1.93	0.293	0.792	0.996	0.846
Vitamin K	38.67 ± 4.25	67.89 ± 4.46	29.22 ± 5.82	<0.001	30.13 ± 4.45	47.93 ± 3.31	17.80 ± 4.89	0.001	0.220	0.001	0.138
Sodium	3817.18 ± 881.01	3014.74 ± 144.97	-802.44±888.06	0.372	2497.86 ±185.06	2541.13 ± 133.85	43.26 ± 218.59	0.844	0.182	0.019	0.363
Potassium	1861.64 ± 215.28	2406.99 ± 108.57	545.34 ± 219.78	0.018	1564.05 ± 120.06	1849.31 ± 82.03	285.26 ± 113.80	0.017	0.428	<0.001	0.300
Calcium	679.57 ± 140.38	748.15 ± 45.77	68.57 ± 148.97	0.648	434.42 ± 32.69	542.33 ± 26.15	107.91 ± 29.37	0.001	0.171	<0.001	0.799
magnesium	204.28 ± 43.16	276.56 ± 12.29	72.27 ± 42.59	0.098	183.42 ± 26.77	174.77 ± 8.41	- 8.64 ± 29.32	0.770	0.807	<0.001	0.123
Physical activity	2555.06 ± 182.44	2249.64 ± 39.46	-305.41±181.78	0.101	2317.43 ± 48.35	2220.40 ± 73.86	- 97.03 ± 72.82	0.192	0.224	0.945	0.315

[1] P values for within group comparisons using paired t-test analysis

[2] P values for comparison of baseline values between two groups using independent samples t-test analysis

[3] P values for comparison of after values between two groups using independent samples t-test analysis

[4] P values for comparison of change values between two groups using independent samples t-test analysis

[5] Values are reported as mean ± standard error (SE)

Table 4- The comparison of mean baseline and after intervention in the behavior score derived using different questionnaires between children assigned to the dietary approaches to stop hypertension (DASH) and those the control diet.

	DASH (N = 40)		Control (N = 40)					
	Baseline	After	Baseline	After	P[1]	P_{time} [2]	P_{group} [3]	$P_{time*group}$ [4]
Abbreviated ten item Conner's scale (ACS)								
Parent	18.22 ± 0.60[5]	13.62 ± 0.71	19.05 ± 0.61	15.92 ± 0.72	0.394	<0.001	0.05	0.21
Teacher	20.75 ± 0.62	15.51 ± 0.79	20.25 ± 0.63	18.25 ± 0.80	0.394	<0.001	0.10	0.001
SNAP-IV scale								
Attention deficit disorder (ADD)								
Parent	14.35 ± 0.93	11.90 ± 0.87	15.74 ± 0.94	14.35 ± 0.88	0.426	<0.001	0.26	0.07
Teacher	16.51 ± 1.01	14.35 ± 0.93	18.02 ±1.01	16.56 ± 0.93	0.520	0.001	0.12	0.89
Hyperactivity and impulsivity (HD)								
Parent	14.85 ± 0.92	11.82 ± 0.95	16.10 ± 0.94	14.97 ± 0.97	0.399	<0.001	0.11	0.06
Teacher	18.10 ± 0.94	15.17 ± 0.99	17.48 ± 0.94	16.12 ±0.99	0.336	<0.001	0.74	0.03
Combined								
Parent	29.20 ± 1.64	23.72 ± 1.60	31.84 ± 1.66	29.33 ± 1.62	0.358	<0.001	0.13	0.01
Teacher	34.61 ± 1.52	29.53 ± 1.67	35.51 ± 1.52	32.66 ± 1.67	0.871	<0.001	0.30	0.15
Strength and Difficulties Questionnaire (SDQ)								
Hyperactivity								
Parent	7.52 ± 0.30	6.22 ± 0.31	7.89 ± 0.30	7.12 ± 0.31	0.447	<0.001	0.07	0.44
Teacher	8.80 ± 0.27	6.87 ± 0.29	8.17 ± 0.27	7.51 ± 0.30	0.078	<0.001	0.84	0.003
Child	7.40 ± 0.32	5.80 ± 0.28	7.30 ± 0.33	6.87 ± 0.28	0.774	<0.001	0.21	0.002
Emotional symptoms								
Parent	3.72 ± 0.43	2.42 ± 0.34	4.56 ± 0.44	3.89 ± 0.35	0.413	<0.001	0.04	0.001
Teacher	4.32 ± 0.42	3.02 ± 0.40	4.41 ± 0.43	4.28 ± 0.41	0.876	0.002	0.25	0.002
Child	3.70 ± 0.40	2.42 ± 0.35	4.82 ± 0.41	4.02 ± 0.36	0.147	<0.001	0.008	0.22
Conduct Problems								
Parent	4.20 ± 0.33	2.90 ± 0.29	4.07 ± 0.34	3.48 ± 0.29	0.379	<0.001	0.60	0.09
Teacher	5.12 ± 0.35	3.70 ± 0.29	4.89 ± 0.36	4.25 ± 0.29	0.317	<0.001	0.55	0.26
Child	4.45 ± 0.33	3.42 ± 0.30	4.84 ± 0.34	4.15 ± 0.30	0.853	<0.001	0.26	0.11
Peer relationship problems								
Parent	4.30 ± 0.28	3.42 ± 0.26	4.82 ± 0.29	4.38 ± 0.26	0.357	0.001	0.05	0.54
Teacher	5.05 ± 0.25	4.12 ± 0.23	4.69 ± 0.26	4.66 ± 0.24	0.314	0.007	0.49	0.03
Child	4.05 ± 0.26	3.42 ± 0.28	4.79 ± 0.27	4.46 ± 0.29	0.208	0.04	0.04	0.06
Prosocial behavior								
Parent	7.40 ± 0.28	8.25 ± 0.28	6.92 ± 0.29	7.53 ± 0.29	0.314	<0.001	0.05	0.50
Teacher	4.92 ± 0.32	6.20 ± 0.31	4.82 ± 0.32	5.00 ± 0.31	0.665	<0.001	0.12	0.02
Child	7.65 ± 0.29	8.22 ± 0.29	7.43 ± 0.29	7.94 ± 0.30	0.701	0.002	0.42	0.51
Total								
Parent	27.00 ± 0.93	23.37 ± 0.79	28.23 ± 0.94	26.38 ± 0.80	0.698	<0.001	0.10	0.02
Teacher	28.30 ± 0.85	24.17 ± 0.83	26.94 ± 0.86	25.71 ± 0.84	0.106	<0.001	0.73	0.009
Child	27.35 ± 1.01	23.30 ± 0.90	29.17 ± 1.03	27.51 ± 0.91	0.508	<0.001	0.34	0.002

[1] P values for comparison of baseline values between two groups using independent samples t-test analysis
[2] P values for time - effect using linear mixed effects model
[3] P values for group - effect using linear mixed effects model
[4] P values for group*time interaction using linear mixed effects model
[5] Values are reported as mean ± standard error (SE)

Table 5- The mean changes in the behavior scores derived using different questionnaires during the follow-up period between children assigned to the dietary approaches to stop hypertension (DASH) and the control diet[1]

	DASH (N = 40)	Control (N = 40)	P value
Abbreviated ten item Conner's scale (ACS)			
Parent	-4.71±0.57	-3±0.58	0.04
Teacher	-5.28±0.57	-1.94±0.57	<0.001
SNAP-IV scale			
Attention deficit disorder (ADD)			
Parent	-2.40±0.53	-1.43±0.53	0.21
Teacher	-2.13±0.67	-1.48±0.67	0.50
Hyperactivity and Impulsivity (HD)			
Parent	-2.86±0.73	-1.29±0.74	0.13
Teacher	-2.99±0.66	-1.28±0.66	0.07
Combined			
Parent	-5.26±1.03	-2.72±1.05	0.09
Teacher	-5.14±0.93	-2.69±0.94	0.07
Strength and Difficulties Questionnaire (SDQ)			
Hyperactivity			
Parent	-1.37±0.22	-0.68±0.22	0.03
Teacher	-2±0.26	-0.57±0.27	<0.001
Child	-1.63±0.23	-0.40±0.24	0.001
Emotional symptoms			
Parent	-1.29±0.27	-0.67±0.28	0.12
Teacher	-1.37±0.37	-0.05±0.37	0.01
Child	-1.26±0.27	-0.80±0.28	0.26
Conduct Problems			
Parent	-1.29±0.24	-0.59±0.25	0.050
Teacher	-1.47±0.27	-0.58±0.27	0.02
Child	-1.01±0.26	-0.70±0.27	0.41
Peer relationship problems			
Parent	-0.83±0.24	-0.48±0.24	0.32
Teacher	-0.90±0.23	-0.04±0.24	0.01
Child	-0.64±0.24	-0.31±0.24	0.34
Prosocial behavior			
Parent	0.83±0.25	0.63±0.25	0.57
Teacher	1.35±0.28	0.10±0.28	0.003
Child	0.57±0.23	0.51±0.24	0.85
Total			
Parent	-3.65±0.62	-1.81±0.63	0.04
Teacher	-4.23±0.81	-1.12±0.82	0.01
Child	-4.08±0.69	-1.63±0.70	0.01

[1] Values are reported as mean ± standard error (SE)

Figures

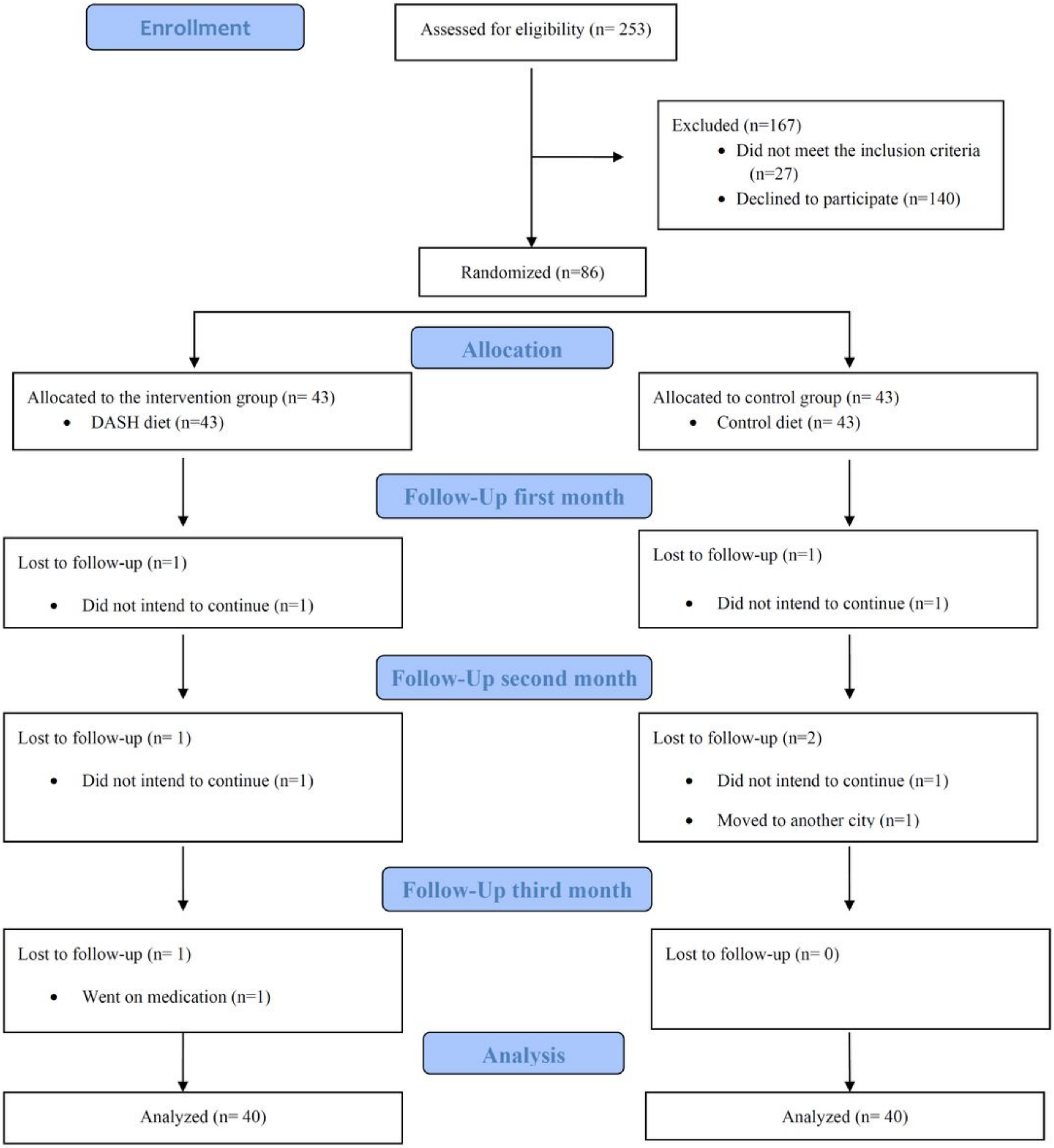

Figure 1

The study flow diagram

Supplementary Files

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