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Comparison of Nutrients' Intakes in Children with and without Attention Deficit Hyperactivity Disorder

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ABSTRACT

Background: Attention deficit hyperactivity disorder (ADHD) is the most common chronic mental disorder among children. Children with ADHD may be at risk for a variety of nutrients' deficiencies. We aimed to assess the nutrients' intakes among ADHD children and compare them with the healthy ones. **Methods:** This was a hospital-based case-control survey over 120 ADHD as the cases and 240 non-ADHD children as the control participants aged 6-13 years. Usual dietary intakes were assessed using a validated semi quantitative food-frequency questionnaire (FFQ). The P-values were considered significant if they were < 0.05 . **Results:** Energy: 2812.2 ± 1029.9 kcal/day vs. 3136.4 ± 1360.3 kcal/day, $P = 0.001$, fat: 78.3 ± 28.8 g/day vs. 87.2 ± 44.9 g/day, $P < 0.001$, and carbohydrate: 436.8 ± 192.6 g/day vs. 479.9 ± 244.2 g/day, $P = 0.009$ intakes were significantly lower in ADHD than healthy children. Similarly, consumption of calcium: 968.5 ± 358.3 mg/day vs. 1055.7 ± 453.4 mg/day, $P = 0.03$ and magnesium: 363.1 ± 173.9 mg/day vs. 411.9 ± 220.8 mg/day, $P = 0.01$ were significantly lower in the cases than control group. However, intakes of thiamin: 34.4 ± 18.8 mg/day vs. 40.4 ± 25.6 mg/day, $P = 0.002$, riboflavin: 1.99 ± 0.76 mg/day vs. 2.21 ± 0.95 mg/day, $P = 0.01$, niacin: 24.9 ± 10.6 mg/day vs. 27.5 ± 13.2 mg/day, $P = 0.01$, and vitamin B5: 6.85 ± 3.35 mg/day vs. 7.49 ± 3.84 mg/day, $P = 0.02$ were significantly lower in the case than control group. **Conclusion:** Children with ADHD consumed significantly lower quantities of energy, macronutrients, calcium, magnesium, B vitamins (B1, B2, B3, B5), and vitamin C compared with the healthy children.

Key words: Nutrients; Dietary assessment; Nutritional status; ADHD; Children

Introduction

Attention deficit hyperactivity disorder (ADHD) is the most common chronic mental and behavioral disorder among children (Izquierdo-Pulido *et al.*, 2015). The prevalence of ADHD was 7.2% all over the world, while its prevalence was 17% in Iran (Meysamie *et al.*,

2011). This disorder has a growing trend every year around the world (Thomas *et al.*, 2015, Visser *et al.*, 2010). Unlike those showing simple hyperactivity features, children with ADHD have three subtype symptoms of predominantly hyperactive-impulsive, predominantly inattentive,

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and combined hyperactive-impulsive and inattentive (Lahey *et al.*, 2006, Rader *et al.*, 2009, Schnoll *et al.*, 2003). Children with ADHD may be at risk for a variety of nutrients' deficiencies due to their disorderd attention and appetite suppressant effects of treatment (Goldfield *et al.*, 2007). Increased availability of the processed food, rich in sugar and fat, has increased the consumption rate by children and adolescents (Øverby *et al.*, 2004).

Nutritional status is very important during childhood, which is a period of vigorous growth, increased activity, and developed body functions, and social cognitive ability. As showed in previous studies, ADHD children are at risk for different nutrients' deficiencies including zinc (Bilici *et al.*, 2004), iron (Konofal *et al.*, 2008), magnesium (Mousain-Bosc *et al.*, 2004), copper (Kiddie *et al.*, 2010) vitamin D (Kamal *et al.*, 2014), and long-chain polyunsaturated fatty acids (Chang *et al.*, 2016). Poly unsaturated fatty acids have fundamental role in neurotransmitters' function (Erikson *et al.*, 2001, Neuringer *et al.*, 1988, Solanto, 2002). Vitamin C and iron are also needed in synthesis of the serotonin and dopamine, respectively (Gershoff, 1993, Konofal *et al.*, 2004). A recent study on sugar consumption suggested that higher consumption of sugar was significantly correlated with a higher level of hyperactivity and attention deficiency (Choi *et al.*, 2008, Dykman and Dykman, 1998, Kavale and Forness, 1983, Lee and Rhie, 2008).

Considering assessment of the nutrients' intake in ADHD, seven studies have been conducted (Arnold *et al.*, 2005, Bekaroğlu *et al.*, 1996, Chang *et al.*, 2016, Chen *et al.*, 2004, Jang and Bu, 2017, Kaplan *et al.*, 1989, Kiddie *et al.*, 2010). A Korean study reported that overweight ADHD participants consumed significantly less amounts of iron in comparison to the normal weight individuals with ADHD. Serum ferritin level was also lower in the overweight group (59.0 ng/ml) than the normal weight group (47.9 ng/ml). After adjusting for the total energy intake, total vegetable consumption was 14.3% lower in overweight group compared with the normal weight group (Jang and Bu, 2017). Another research assessing dietary intakes and

nutrients status among children with ADHD indicated that 66% of children had zinc and 23% had copper deficiency (Kiddie *et al.*, 2010). A study among ADHD Korean children found that these children consumed protein twice higher than the recommended level (Kim and Chang, 2011); whereas, another case-control study showed no significant difference in terms of macronutrients intake between ADHD and non ADHD children (Kiddie *et al.*, 2010). Moreover, a Chinese research reported an inverse association between ADHD and the mineral-protein nutrient pattern rich in zinc, protein, phosphorus, selenium, calcium, and riboflavin (Zhou *et al.*, 2016).

Methodological limitations existed in the former research, including use of dietary assessment tools not validated for pediatric use (Arnold *et al.*, 2005). Furthermore, inconsistent results were observed regarding the nutrients' intakes. Regarding the above-mentioned ideas and the fact that dietary habits of Iranians are very different from western countries, it is worth to explore the nutritional status of children and adolescents with ADHD in Iran.

Materials and methods

Study design and participants: We conducted a hospital-based case-control study using elementary school students (aged 6 to 13 years) who visited clinics of Shahid Sadoughi University of medical sciences from June to February, 2016.

The ADHD group was recruited from two clinics (Khatam al Anbia and Imam Hossein). Inclusion criterion was having ADHD diagnosed by psychiatrists based on the Text Revision of Statistical Manual of Mental Disorders-Fourth Edition (DSM-IV-TR). Exclusion criterion included having concurrent condition, such as tic disorder (motor type), anxiety disorder, oppositional defiant disorder, Tourette's disorder, depression, and learning disability. A total of 120 patients were selected as the case group

Control group members were recruited from four elementary schools. Exclusion criteria were having a history of ADHD, any mental disorder, and tic disorder. The test used to confirm lack of

ADHD in controls was DSM-IV-TR. All questionnaires were completed and a total of 240 controls were recruited.

ADHD diagnosis: The presence of ADHD was confirmed using the DSM-IV TR by a psychiatrist (Owens and Hoza, 2003). According to the DSM-IV TR, a person with ADHD must have at least six symptoms of inattention or hyperactivity–impulsivity persisted for at least 6 months to a maladaptive and inconsistent degree with the person's developmental level (Owens and Hoza, 2003). The reliability and validity of this questionnaire was confirmed previously (Owens and Hoza, 2003). Newly and previously diagnosed patients participated in the present study.

Measurements: Usual dietary intakes were assessed using a semi quantitative food-frequency questionnaire (FFQ), which consisted of supplement intake and 186 food items commonly consumed by the Iranian and local foods specify for children. The validity and reliability of the FFQ was evaluated in Tehran lipid and glucose study (TLGS) (Asghari *et al.*, 2012). All questionnaires were administered by a trained dietitian in face-to-face interviews. Parents were interviewed with their children and were requested to report the frequency intakes of food items by their children on a daily (i.e., fruits), weekly (i.e., cruciferous vegetables), and monthly (i.e., pizza) basis during the previous year.

The reported frequency for each food item was converted to daily intake. Portion sizes of the consumed foods were converted into grams using household measures. Each food and beverage was then coded according to the protocol and analyzed for its content of energy and other nutrients using Nutritionist IV (N-Squared Computing, Salem, OR, USA) designed for Iranian foods.

Weight was measured while participants were minimally clothed and without shoes using digital seca scales (Seca, Germany) to the nearest 100 g. Height was measured using a tape measure while the children were standing in a normal position and were not wearing shoes. The participants' BMI was calculated by dividing weight (kilograms) by

the square of height (in meters). Obesity was defined according to the definition provided by the international obesity task force (IOTF) for children (Cole *et al.*, 2000).

To address the important confounding factors, we employed a pair-match design on age and gender. Variables including age, gender, medical history, socioeconomic status current use of medications and drug therapy, family history of ADHD, and screen exposure were obtained by a general information questionnaire. Family history of ADHD was assessed by asking parents about existence of any ADHD case diagnosed by a psychotherapist in the first and second order family members. Socioeconomic status was determined as low, moderate, or high based on the parents' education (undergraduate, postgraduate, and doctorate) and acquisition (house ownership or not). Physical activity was also evaluated using a validate questionnaire (Aadahl and Jørgensen, 2003, Kelishadi *et al.*, 2007) and categorized to less than one a week 2-3 times a week, 3-5 times a week, and more than 5 times a week.

Data analysis: The analyses were performed using the IBM SPSS version 22-0. Values were expressed in mean and standard error for continuous variables and percentages for categorical variables. Chi-square tests were run to determine differences in categorical data between cases and controls. Independent sample t-tests were also applied to evaluate differences between groups of continuous normally distributed variables. P-values were considered significant if they were < 0.05.

Ethical considerations: Written informed consent forms were collected from all participants and their parents. Furthermore, participants of the two study groups were matched in terms of age, gender, and residential area. The study was approved by the Nutrition & Food Security Research Center, Yazd Shahid Sadoughi University of Medical Sciences and Health Services as well as the Ethics Committee of Shahid Sadoughi University of Medical Sciences and Health Services, Yazd, Iran.

Results

Of the 120 children with ADHD diagnosed in clinics, a total of 110 ADHD participants were retained in this analysis, including 85 boys and 25 girls. Additionally, 232 eligible age- and gender-matched controls were recruited from the schools selected from the same region of clinics. In the study process, 18 children from cases and controls were excluded because of unreasonable energy intakes. The general characteristics of study participants are shown in **Table 1**. Compared with the controls, participants with ADHD were more likely to use medication and screen use; they were also more physically active than the healthy controls. The possibility of having a family history of ADHD was also higher in the intervention group. Children with and without ADHD were similar regarding their BMI, household income, parental education, and sleep hours per day.

The macronutrients intakes of the ADHD and non-ADHD children are compared in **Table 2**. As shown in **Table 2**, energy intake, fat, and carbohydrate intakes were significantly higher in controls than the case group.

The vitamins and mineral intakes between ADHD and non-ADHD children are compared in **Table 3**. Although zinc, calcium, and magnesium intakes were significantly lower in cases than controls, iodine intake was significantly higher in ADHD children in comparison to the controls. No significant differences were observed in terms of iron intake between the two groups. Consumption of vitamins including thiamin, riboflavin, niacin, vitamin B5, and vitamin C were also significantly lower in ADHD children than non-ADHD ones. However, vitamin E intake was significantly greater in than controls.

Table 1. Baseline characteristics in cases and controls^a

Qualitative Variables	Non-ADHD (N = 232)	ADHD (N = 113)	P-value ^b
Boys	76.3 ^a	75.2	0.82
Allergy	5.2	0.0	0.01
Family history of ADHD	0	16.8	<0.001
Parental education status			
Undergraduate	49.1	58.4	0.17
Postgraduate	50.0	39.8	
Doctorate	0.9	0.9	
Economic status			
Low	16.8	15	0.56
Medium	68.1	73.5	
High	15.1	11.5	
Physical activity			
< once per week	22.8	15.0	<0.001
2-3 times per week	51.3	29.2	
3-5 times per week	11.2	38.9	
More than 5 times per week	14.7	16.8	
Medication	0	53.1	<0.001
Quantitative variables	Mean ± SD	Mean ± SD	P-value^c
Age (year)	8.75 ± 1.6	8.79 ± 1.6	0.80
Screen use (hour/day)	3.3 ± 1.4	4 ± 1.9	0.001
Weight (kg)	30.0 ± 10.0	28.9 ± 8.7	0.32
Height (m)	1.31 ± 0.1	1.30 ± 0.1	0.27
Body mass index (kg/m ²)	16.9 ± 3.61	16.7 ± 3.55	0.64

^a: percent; ^b: Chi square test; ^c: Student *t*-test. All analyses were performed with the data matched for age and gender

Table 2. Mean \pm SD differences in daily macronutrients intake in ADHD and non-ADHD children

Variables	ADHD group (N = 113)	Non-ADHD (N = 232)	P-value ^a
Energy intake(kcal)	2812.2 \pm 1029.9	3136.4 \pm 1360.3	0.001
Protein (g)	84.4 \pm 31.7	91.0 \pm 36.2	0.07
Fat (g)	78.3 \pm 28.8	87.2 \pm 44.9	<0.001
Carbohydrate (g)	436.8 \pm 192.6	479.9 \pm 244.2	0.009

^a: Student *t*-test**Table 3.** Mean \pm SD differences in daily micronutrients intake in ADHD and non-ADHD children.

Variables	ADHD (N = 113)	Non-ADHD (N = 232)	P-value ^a
Zinc (mg)	10.3 \pm 4.8	9.4 \pm 4.1	0.02
Iron (mg)	34.9 \pm 37.4	30.7 \pm 22.1	0.13
Iodine (μ g)	0.1 \pm 0.1	0.001 \pm 0.001	0.07
Calcium (mg)	968.5 \pm 358.3	1055.7 \pm 453.4	0.035
Magnesium (mg)	363.1 \pm 173.9	411.9 \pm 220.8	0.011
Thiamin (mg)	34.4 \pm 18.8	40.4 \pm 25.6	0.002
Riboflavin (mg)	1.99.0 \pm 0.76	2.21 \pm 0.95	0.018
Niacin (mg)	24.9 \pm 10.6	27.5 \pm 13.2	0.016
Vitamin B5 (mg)	6.85 \pm 3.35	7.49 \pm 3.84	0.029
Vitamin B6 (mg)	2.12 \pm 1.21	2.21 \pm 1.36	0.23
Vitamin C (mg)	354.0 \pm 288.0	356.2 \pm 345.0	0.019
Vitamin E (mg)	36.5 \pm 44.7	27.7 \pm 35.5	0.018
Vitamin D (mg)	9.9 \pm 29.7	10.8 \pm 24.4	0.81

^a: Student *t*-test

Discussion

Energy, fat, and carbohydrate intakes were significantly lower in ADHD than healthy children. Similarly, consumption of calcium and magnesium were significantly lower in cases than controls. However, intakes of thiamin, riboflavin, niacin, vitamin B5, and vitamin C were significantly lower in cases than controls.

Based on the findings, macronutrient intakes were significantly lower in ADHD children. On the contrary, Stevens reported significantly higher intakes of total fat (g) in ADHD participants when compared to controls (Stevens *et al.*, 1995). Another study showed that ADHD adolescents consumed more energy and fat than controls (Colter *et al.*, 2008). ADHD children in the current study consumed less amounts of high nutrient density foods than normal gender-age matched children. Moreover, the mean age of children in this study was 8 years, but it was 14 in Colter study.

Results of vitamin intakes in this study showed that vitamin intakes were significantly lower in ADHD children than healthy ones. Similar to our results, previous studies showed that consumption of thiamin, riboflavin, niacin, vitamin B5, and vitamin C among ADHD children were lower than non-ADHD participants (Colter *et al.*, 2008, Kiddie *et al.*, 2010). In contrast to our conclusion, a case-control study demonstrated that ADHD participants consumed higher levels of at least 10 different nutrients, than their control counterparts (Colter *et al.*, 2008). Furthermore, Chen *et al.* reported significantly increased vitamin C (mg) consumption in participants with ADHD versus controls (Chen *et al.*, 2004). The difference between our results and previous studies may be due to higher energy intake in normal children than ADHD children. Considering that Iran has undergone a nutritional transition caused by a Westernization in lifestyle (Ghassemi *et al.*, 2002), the availability of low nutrients' density has

extended the related problems (Azadbakht and Esmailzadeh, 2008). Dietary habits and lifestyle characteristics of Iranian children across different cities may be different from those in the present study (Azadbakht *et al.*, 2006, Azadbakht *et al.*, 2005). B vitamins have the main role in brain function, so that niacinamide (vitamin B3) transfers tryptophan to serotonin (Imbalance, 2009, Kaplan *et al.*, 2007). Micronutrient administration and nutritional status are important in ADHD children due to their role in regulating homocysteine metabolism (Huskinson *et al.*, 2007), mood (Taylor *et al.*, 2004, Wilkins *et al.*, 2006), and neurotransmitter synthesis (Bottiglieri *et al.*, 2000). Cobalt included in vitamin B12 (cyanocobalamin) can create behavioral disturbances especially due to its lack of body. It improves functions of the frontal lobe and language in those with cognitive dysfunctions (Tudosie *et al.*, 2017).

According to our results, magnesium and calcium intakes were significantly lower in cases than controls. However, in a case-control study, 11 ADHD participants reported slightly higher intakes of magnesium compared to the controls (Colter *et al.*, 2008). Although the mechanisms linking low-quality diet and ADHD are still unknown, an unbalanced diet can lead to deficiencies in essential nutrients or higher intakes of certain food components (i.e, food additives) (Izquierdo-Pulido *et al.*, 2015). Enzymes involved in the process of ATP hydrolysis by brain microsomes were activated in the presence of Mg and Ca (Nakamaru *et al.*, 1967).

We observed that ADHD children were more active regarding physical activity, had allergies more frequently, used more medication, and had more frequent family history of ADHD than Iranian children without ADHD. Our finding is consistent with previous reports indicating that ADHD children had increased rates of allergic sensitization and allergic rhinitis than non ADHD children (Suwan *et al.*, 2011). Another study also found that neuropsychological performance in ADHD was significantly affected by familial status (Seidman *et al.*, 1995). However, a case-control

study about physical activity experiences of 12 age-matched boys with and without ADHD revealed that boys with ADHD were not as proficient movers as their peers without ADHD (Harvey *et al.*, 2009).

This was the first study in Iran that demonstrated significantly lower dietary intakes of micronutrients in ADHD children compared to non-ADHD children. In the current study, we assessed nutrient intakes in a large sample size of Iranian children. Children in the case and control groups did not have any significant difference with regard to their socioeconomic status. Vitamin and mineral supplementations were also recorded in the present research.

The present study has several limitations. As this was a case-control study, it is possible that dietary intake was affected by an individual's health status. Results could differ by ADHD types, but information about ADHD type was not gathered for subgroup analysis.

Further research is needed to identify the etiology, impact, and possible therapeutic implications of low micronutrient status in ADHD given the essential nature of these micronutrients in producing neurotransmitters involved in ADHD.

Conclusion

This study established the dietary intake of ADHD children from Iranian population in taking nutrients. We found that ADHD children consumed significantly lower quantities of calcium, magnesium, vitamin C, and B vitamins except B6. Similarly, energy, carbohydrate, and fat intakes were lower in ADHD children.

Future studies are required on comparing dietary intakes and nutrients status, controlling for medication and supplementation, and including normal controls. Such research should be conducted to determine if micronutrient deficiency is a cause, effect, or related to a third variable involved in ADHD.

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Authors' contributions

Shareghfarid E and Hosseinzadeh M design the study and implementation of it, Shareghfarid E and Mohammadi M contributed to the data analysis with supervised of Salehi-abarguei A, all authors participated in writing manuscript and discussed the results and commented on the manuscript.

Conflicts of interest

Authors declared no conflict of interest.

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