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Associations between attention-deficit/hyperactivity disorder symptoms and dietary habits in elementary school children

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ABSTRACT

Objective: The aim of the present study was to investigate the associations between dietary habits and attention deficit/hyperactivity disorder (ADHD) symptoms in elementary school children.
Methods: The parents of 16,831 participating children assessed the ADHD symptoms of their children by responding to the Korean version of the ADHD rating scale (K-ARS). Parents also responded to the food habit questionnaire, which consists of 8 items regarding the eating pace, the frequency of overeating, and patterns of eating six types of food: fast food, soft drinks, instant noodles, fruit and vegetables, and milk.
Results: K-ARS scores were positively associated with higher consumption of foods categorized as unhealthy, including fast food, soft drinks, and instant noodles, and negatively associated with higher consumption of fruit and vegetables categorized as healthy foods. K-ARS scores were also higher in the groups who overate more frequently and ate faster or slower compared to other family members.
Conclusion: Our findings may provide useful clinical information for dietary interventions in children with ADHD.

1. Introduction

Attention deficit/hyperactivity disorder (ADHD) is a major neurodevelopmental disorder studied in the field of child and adolescent psychiatry, which affects approximately 5% of children and 2.5% of the adult population (American Psychiatric Association, 2013). ADHD is characterized by three major symptoms: attention-deficit, hyperactivity, and impulsivity (American Psychiatric Association, 2013). ADHD has a negative impact on academic achievement (Barry, Lyman, & Klinger, 2002) and delinquent behavior in childhood, as well as on functional impairment during adulthood, including decreased occupational productivity (Küpper et al., 2012), marital problems, substance abuse, and involvement in criminal activity (Mannuzza, Klein, & Moulton, 2008; Murphy & Barkley, 1996). Although ADHD is a highly heritable disorder, gene-environment interactions, including diet, play an important role in the occurrence of ADHD (Arnold, Lofthouse, & Hurt, 2012).

Previous studies on the dietary habits of patients with ADHD have reported that there is a positive association between ADHD and uncontrolled eating. For instance, in a review, Nazar et al. (2008) reported that adult women with ADHD are at higher risk of bulimia nervosa, ranging from 1% to 12% compared to 0%–2% in control groups. Cortese, Bernardina, and Mouren (2007) also reported increasing evidence that subjects with ADHD show more binge-eating behaviors than is reported in the general population and examined impulsivity as an underlying mechanism of the high comorbidity between ADHD and binge eating.

Another finding of the previous studies regarding the association between ADHD and dietary habits is consumption of unhealthy food such as fast food, snacks, and sweetened beverages. In a study using the food frequency questionnaire, Howard et al. (2011) divided food categories into “Healthy” and “Western” dietary patterns and reported that the “Western” dietary pattern was associated with an increased odds ratio for ADHD. Although there is no clear definition of fast food, it is associated with higher calorie, fat, sodium, sugar, and food additive intake, such as those contained in burgers, French fries, fried chicken,

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mass-produced pizza, and sweetened beverages (Bahadoran, Mirmiran, & Azizi, 2015; Dunn, Mohr, Wilson, & Wittert, 2011; Fleischhacker, Evenson, Rodriguez, & Ammerman, 2011). Ptacek et al. (2014) reported that boys with ADHD consume more sweetened beverages and less fruit and vegetables compared to controls. Woo et al. (2014) also reported that a diet pattern including more snacks, processed meat, and bread was associated with an increased odds ratio for ADHD. A high consumption of unhealthy foods, such as sweetened beverages, was associated with increased risk of behavioral problems. In contrast, high fruit consumption was associated with decreased risk of behavioral problems (Øverby & Høigaard, 2012).

However, previous studies have reported some inconsistent findings regarding the association between dietary habits and ADHD. For instance, greater rates of bulimia nervosa comorbid with ADHD were only found in women (Biederman et al., 1992, 1994). Moreover, Wiles, Northstone, Emmett, and Lewis (2009) reported that increased consumption of 'junk food' was associated only with hyperactivity, not with conduct problems or behavioral difficulties, contrary to the findings of the study by Øverby and Høigaard (2012).

Additionally, to our knowledge, in spite of multiple studies on the dietary habits of patients with ADHD, there have been few studies on the association between ADHD symptoms and dietary habits, including types of food, overeating, and eating pace in the general population. Notably, there has been no study on these associations with a large sample of Korean elementary school children. Thus, this study aimed to investigate the association between ADHD symptoms and dietary habits, including types of food, overeating, and eating pace.

2. Methods

2.1. Participants

The participants of the present study consisted of the parents of elementary school children aged 6–12 years who participated in screening for neurodevelopmental disorders in Cheonan, a medium-sized city in Korea between 2007 and 2010. Among a total of 30,552 parents who agreed to participate and responded to the ADHD Rating Scale (K-ARS), 16,831 parents who completed both questionnaires assessing ADHD symptoms and the dietary habits of their children were enrolled in this study.

2.2. Measures

2.2.1. ADHD symptom severity

The ADHD rating scale is an assessment tool measuring ADHD symptom severity in children, which was developed by Dupaul, Power, Anastopoulos, and Reid (1998). To assess the ADHD symptom severity of the children of the participants in this study, the Korean version of the ADHD rating scale (K-ARS) was used, which was validated by So, Noh, Kim, Ko, and Koh (2002). The K-ARS consists of 18 items and is rated on a 4-point Likert scale ranging from 0 to 3 points with "never or rarely," "sometimes," "often," and "very often" as responses, and the score ranges from 0 to 54. The nine odd-numbered items of the K-ARS assess hyperactivity-impulsivity symptoms, and the nine even-numbered items assess inattention symptoms. The Cronbach's α value in the present study for the total K-ARS score was 0.909.

2.2.2. Dietary habits

The dietary habits of the children were rated by the parents using the questionnaire used in the Youth Risk Behavior Web-based Survey in Korea. The questionnaire included items for consumption frequencies of food groups including Westernized fast food (i.e., hamburgers, pizza, fried chicken), soft drinks, and instant noodles (i.e., ramen and cup ramen). Instant noodles are a very popular food in Korea. However, they contain high amounts of salt and food additives and are recognized as an unhealthy food. The questionnaire also included items for consumption frequencies of fruit and vegetables. The consumption frequency of each food group was assessed using seven frequency categories (never, 1 to 2, 3 to 4, and 5 to 6 times per week, and 1, 2, and more than 3 times per day). The items for overeating (never, 1 to 2, 3 to 6 times per week, and every day) and eating pace compared with those of other family members (slower, similar, and faster) were also included in the questionnaire. Demographic variables including sex, age, parental education, and household income were also collected from the questionnaire.

2.3. Statistical analysis

Demographic variables and characteristics of dietary habits were analyzed using frequency analysis and descriptive statistics. K-ARS scores according to the score groups of dietary habits were compared with Welch's variance-weighted analysis of variance (ANOVA) because the variance of K-ARS scores in each score group was not equal. Post-hoc analysis was performed using Dunnett's T3 test. Logistic regression analysis was performed to assess the association between dietary habits and ADHD risk. Sex, age, parental education level, and household income level were included in the analysis as covariates. The ADHD high-risk group was defined as a K-ARS score greater than 18. Statistical analyses were conducted using the software package SPSS 18.0 for windows (SPSS Inc., Chicago, IL).

2.4. Ethics statement

The study protocol was approved by the Institutional Review Board for Human Subjects of a university hospital in Cheonan, South Korea. All participants and their parents were provided with information on the study and signed informed consent before enrollment.

3. Results

3.1. Demographic characteristics

The average age of the children of the participants was 9.29 (SD = 1.71) years. Among 16,831 participating children, 8352 (49.8%) were boys and 1515 (9.0%) were included in the ADHD high-risk group. Most parents (97.8%) had graduated from high school. The demographic characteristics are presented in Table 1.

3.2. The number and mean K-ARS score of each response group for the frequency of consuming fast food, soft drinks, and instant noodles

Table 2 shows the K-ARS total scores for the subgroups of each response score for fast food, soft drinks, and instant noodles. K-ARS scores differed significantly among the subgroups. In the post-hoc comparisons, the children who consumed these foods more frequently had higher K-ARS scores than the children who consumed these foods less frequently.

3.3. The number and mean K-ARS score of each response group for the frequency of consuming vegetables, fruit, and milk

The K-ARS scores of the subgroups of each response score for the frequency of consuming vegetables, fruit, and milk are presented in Table 3. K-ARS scores differed significantly among the subgroups for fruit and vegetable consumption. The K-ARS scores of the children who consumed fruit and vegetables more frequently were significantly lower in the post-hoc analysis than those of the children who consumed these foods less frequently. In contrast, the differences in K-ARS scores among children who consumed milk more or less frequently were less remarkable, albeit significant, compared to the other food types.

Table 1
Demographic characteristics of participants.

Variables	Mean	SD
Age	9.29	1.71
	n	**%**
Sex		
Male	8352	49.8%
Female	8423	50.2%
unknown	56	(0.3%)
K-ARS		
Normal (< 19)	15,316	91.0%
High risk (≥19)	1515	9.0%
Paternal education		
< 12 years	358	2.2%
12 years	6382	38.8%
> 12 years	9723	59.1%
unknown	368	(2.2%)
Maternal education		
< 12 years	378	2.3%
12 years	8962	54.5%
> 12 years	7111	43.2%
unknown	380	(2.3%)
Household income		
< 1000	523	3.2%
1000–2000	2189	13.4%
2000–3000	5109	31.3%
3000–4000	4205	25.7%
4000–5000	2244	13.7%
> 5000	2061	12.6%
unknown	500	(3.0%)

Percentage calculated after excluding missing information. Percentage within parenthesis for missing information among total subjects.
The unit of household income: 1000 Korean Won (about 1 US Dollar).

3.4. K-ARS scores of the subgroups of each response score for dietary habits

The K-ARS score of children who ate at a slower or faster pace to that of their family members was significantly higher than that of the children who ate at a similar pace (Table 4). Moreover, more children who overate more frequently were at the ADHD high-risk group.

3.5. Odds rations and 95% confidence intervals of the ADHD high-risk group among the subgroups of response score for the frequency of eating each food

Table 5 shows the odds ratios and 95% confidence intervals of the ADHD high-risk group among the subgroups based on the frequency of eating each type of food. Children who consumed fast food, soft drinks, and instant noodles more frequently showed higher odds ratios for ADHD risk compared to children who 'never' consumed these foods (referent). Additionally, children who consumed fruit and vegetables less frequently showed higher odds ratios for ADHD risk compared to children who consumed these foods 'more than 3 times per day' (referent). For milk consumption, only the group who 'never' consumed milk showed significantly increased odds ratio of high ADHD risk than the referent group (more than 3 times/day). The increased or decreased odds ratio of high ADHD risk according to the type of food showed a dose-dependent tendency (Table 5, Fig. S1).

4. Discussion

The present study investigated the association between diet habits and ADHD symptoms. The findings of the present study indicate that ADHD symptoms are positively associated with higher consumption of food categorized as unhealthy, including fast food, soft drinks, and instant noodles. The odds ratio of the ADHD high-risk group was the highest for instant noodle consumption among the unhealthy foods. ADHD symptoms were also negatively associated with the consumption frequency of vegetables and fruits. Additionally, the association between ADHD symptoms and the frequency of milk consumption had a less remarkable tendency than the association between ADHD symptoms and the other types of food.

These findings are consistent with those of previous studies. Howard et al. (2011) reported that the odds ratio of ADHD in adolescents following highly westernized dietary patterns, including red meat, French fries, and soft drinks was 2.21 compared to that of adolescents with a low Westernized dietary pattern. Another study on the association between mental health issues and soft-drink consumption reported an increased ratio of hyperactivity and conduct problems (4.15 and 5.11, respectively) in boys who consumed more than four glasses of soft drinks per day compared to boys who consumed one to six glasses of soft drinks per week (Lien, Lien, Heyerdahl, Thoresen, & Bjertness, 2006).

These associations between ADHD symptoms and types of food could be explained as follows. First, the impulsivity of children with ADHD may influence the more frequent consumption of unhealthy food, such as fast food, soft drinks, and instant noodles than of healthy food, such as fruit and vegetables. Impulsivity, which is a core symptom of ADHD, has been reported as a vulnerability marker for addiction, including substance abuse and gambling (Belin, Mar, Dalley, Robbins, &

Table 2
K-ARS scores of total participants and of the high-risk group according to the response score for the consumption frequency of fast food, soft drinks, and instant noodles.

Food		0 (never)	1 (1-2 times /week)	2 (3-4 times /week)	3 (5-6 times /week)	4 (more than 1 times/day)	Statistics	Post-hoc
fast food	n (%)	5258 (31.6%)	10,610 (63.8%)	477 (2.9%)	109 (0.7%)	168 (1.0%)		
	Mean (S.D.)	7.78 (7.02)	8.50 (7.18)	10.85 (8.12)	12.13 (8.24)	9.36 (7.96)	27.463**	0 < 1 < 2 = 3
	High-risk; n (%)	412 (7.8%)	961 (9.1%)	79 (16.6%)	22 (20.2%)	20 (11.9%)		
soft drinks	n (%)	6191 (37.1%)	8199 (49.1%)	1214 (7.3%)	225 (1.3%)	859 (5.1%)		
	Mean (S.D.)	7.49 (6.71)	8.53 (7.27)	10.18 (7.75)	11.06 (8.04)	9.86 (7.85)	57.197**	0 < 1 < 2 = 3 = 4
	High-risk; n (%)	422 (6.8%)	760 (9.3%)	172 (14.2%)	33 (14.7%)	112 (13.0%)		
instant noodles	n (%)	3192 (19.1%)	11,460 (68.7%)	1558 (9.3%)	206 (1.2%)	258 (1.5%)		
	Mean (S.D.)	7.11 (6.58)	8.37 (7.14)	10.14 (7.83)	12.45 (9.14)	10.45 (8.2)	62.714**	0 < 1 < 2 < 3
	High-risk; n (%)	192 (6.0%)	1021 (8.9%)	211 (13.5%)	42 (20.4%)	35 (13.6%)		

K-ARS: Korean version of the attention deficit/hyperactivity rating scale.
In each case, the percentage of children in the high-risk group was calculated as the number of high-risk children over the total number of children in each consumption frequency category.
**p < 0.001.

Table 3
K-ARS scores of total participants and of the high-risk group according to the response score for the consumption frequency of fruit, vegetables, and milk.

Food		0 (never)	1 (1-2 times /week)	2 (3-4 times /week)	3 (5-6 times /week)	4 (1 time /day)	5 (2 times /day)	6 (more than 3 times/day)	Statistics	Post-hoc
vegetables	n (%)	1038 (6.2%)	743 (4.4%)	953 (5.7%)	2495 (14.9%)	4601 (27.4%)	4458 (26.6%)	2501 (14.9%)		
	Mean (S.D.)	11.19 (8.83)	10.42 (8.03)	9.78 (7.91)	8.89 (7.38)	8.24 (6.91)	7.55 (6.59)	7.21 (6.77)	55.334**	0 = 1 > 3 > 4 > 5 = 6
	High-risk; n (%)	192 (18.5%)	109 (14.7%)	119 (12.5%)	244 (9.8%)	372 (8.1%)	307 (6.9%)	168 (6.7%)		
fruit	n (%)	240 (1.4%)	2039 (12.2%)	3358 (20.1%)	1863 (11.1%)	5346 (31.9%)	2784 (16.6%)	1118 (6.7%)		
	Mean (S.D.)	10.46 (8.73)	10.10 (8.14)	9.03 (7.4)	8.00 (6.72)	8.14 (7.05)	7.21 (6.65)	7.31 (6.34)	42.563**	0 = 1 > 2 > 3 = 4 > 5 = 6
	High-risk; n (%)	43 (17.9%)	275 (13.5%)	364 (10.8%)	137 (7.4%)	433 (8.1%)	183 (6.6%)	69 (6.2%)		
milk	n (%)	838 (5.0%)	631 (3.8%)	654 (3.9%)	1667 (10.0%)	8567 (51.5%)	3517 (21.1%)	758 (4.6%)		
	Mean (S.D.)	9.29 (8.17)	8.96 (7.69)	9.16 (7.49)	8.66 (7.41)	8.33 (7.16)	7.85 (6.77)	8.18 (7.06)	7.556**	0 = 1 = 2 = 3 = 4 > 5
	High-risk; n (%)	110 (13.1%)	68 (10.8%)	59 (9.0%)	155 (9.3%)	781 (9.1%)	256 (7.3%)	60 (7.9%)		

K-ARS: Korean version of the attention deficit/hyperactivity rating scale.
In each case, the percentage of children in the high-risk group was calculated as the number of high-risk children over the total number of children in each consumption frequency category.
**p < 0.001.

Everitt, 2008; Verdejo-García, Lawrence, & Clark, 2008). Ifland et al. (2009) introduced the concept of refined-food addiction and reported that processed foods with high concentrations of sugar, refined sweeteners, carbohydrates, fat, salt, and caffeine are addictive. Davis et al. (2011) also reported that fast food and soft drinks contain high amounts of sugar, fat, and salt, which potentially have addictive properties and that individuals with food addiction tend to be more impulsive than obese individuals without food addiction.

Moreover, the possibility that frequent unhealthy food consumption may influence ADHD symptoms should also be considered. In a longitudinal study, Wiles et al. (2009) reported that increase in 'junk food' intake at age 4.5 years was associated with increased hyperactivity at age 7 years, which indicates that there may be an effect of 'junk food' on ADHD symptoms. Multiple studies have been conducted on the effects of food on ADHD symptoms, including research on food additives such as artificial colors and flavors, refined sugars, as well as on food allergies and sensitivities (Schnoll, Burshteyn, & Cea-Aravena, 2003). Deficiency in some essential nutrients, such as iron, iodine, magnesium, zinc, B-vitamins, and essential poly-unsaturated fatty acids including docosahexaenoic acid, have been also proposed as other mechanisms involved in the effect of food on ADHD symptoms (Begum, Viiayakumar, & Nazni, 2007; Heilskov Rytter et al., 2015; Schnoll et al., 2003). Moreover, artificial food color elimination, restricted elimination diet, and poly-unsaturated fatty acid supplementation have been studied as strategies of dietary intervention for the treatment of ADHD (Heilskov Rytter et al., 2015; Pelsser, Frankena, Toorman, & Pereira, 2017).

In the present study, the negative association between fruit and vegetable consumption and ADHD symptoms was also found to be significant as well as the positive association between unhealthy food consumption and the K-ARS score. A diet rich in fruit and vegetables, which contain high amounts of dietary fiber, was associated with increased short chain fatty acid (SCFA) level (Gutiérrez-Díaz, Fernández-Navarro, Sánchez, Margolles, & González, 2016). SCFAs were reported to alter hypothalamic leptin gene expression and lower impulsivity (Sfera et al., 2017). Dietary polyphenols rich in fruit and vegetables were also documented to protect against psychiatric conditions characterized by impulsivity (Sfera et al., 2017).

Recent studies have attempted to link the human gut microbiome with ADHD. Aarts et al. (2017) reported that the presence of microbiota predictive of enhanced production of dopamine precursor was increased in patients with ADHD compared to controls, which was linked to altered reward anticipation responses, a hallmark of ADHD. Further, the dietary pattern could induce a shift of the structure, metabolic pathway, and gene expression of the human gut microbiome (Turnbaugh et al., 2009).

Our study also identified a positive association between the frequency of overeating and K-ARS score. This is consistent with the

Table 4
K-ARS scores of total participants and of the high-risk group according to the response score for eating pace and overeating.

Speed	1 (Slower)	2 (Similar)	3 (Faster)	Statistics	Post-hoc
n (%)	3573 (21.3%)	9456 (56.3%)	3771 (22.4%)		
Mean (S.D.)	9.25 (7.61)	7.39 (6.57)	9.97 (7.9)	200.271**	2 < 1 < 3
High-risk; n (%)	403 (11.3%)	621 (6.6%)	487 (12.9%)		

Overeat	1 (None)	2 (1–2 time/week)	3 (3–6 times/week)	4 (Everyday)		
n (%)	9498 (57.4%)	3481 (21.0%)	3243 (19.6%)	322 (1.9%)		
Mean (S.D.)	7.42 (6.83)	8.58 (6.90)	10.31 (7.61)	13.17 (9.50)	157.075**	1 < 2 < 3 < 4
High-risk; n (%)	686 (7.2%)	295 (8.5%)	424 (13.1%)	68 (21.1%)		

K-ARS: Korean version of the attention deficit/hyperactivity rating scale.
In each case, the percentage of children in the high-risk group was calculated as the number of high-risk children over the total number of children in each consumption frequency category.

Table 5
The odds ratios (95% CI) of the ADHD high-risk group by multivariate logistic regression.

Frequency of intaking food	fast food		soft drink		instant noodle	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
never	referent	referent	referent	referent	referent	referent
1-2 times/week	0.95 (0.83–1.08)	1.03 (0.89–1.19)	1.29 (1.13–1.47)	1.25 (1.08–1.44)	1.36 (1.15–1.60)	1.28 (1.08–1.53)
3-4 times/week	1.34 (1.00–1.79)	1.54 (1.13–2.09)	1.81 (1.47–2.23)	1.72 (1.38–2.15)	1.78 (1.43–2.22)	1.64 (1.30–2.08)
5-6 times/week	1.56 (0.92–2.65)	1.57 (0.89–2.79)	1.53 (1.01–2.32)	1.36 (0.87–2.13)	2.53 (1.69–3.80)	2.25 (1.46–3.48)
more than 1 time/day	1.02 (0.58–1.81)	1.11 (0.60–2.06)	1.82 (1.42–2.35)	1.75 (1.33–2.29)	1.64 (1.04–2.60)	1.47 (0.90–2.38)
	vegetable		**fruit**		**milk**	
more than 3 times/day	referent	referent	referent	referent	referent	referent
2 times/day	0.99 (0.81–1.21)	1.03 (0.83–1.28)	1.20 (0.89–1.62)	1.12 (0.82–1.52)	0.94 (0.70–1.28)	0.93 (0.68–1.27)
1 time/day	1.08 (0.88–1.31)	1.14 (0.92–1.41)	1.41 (1.07–1.86)	1.24 (0.93–1.65)	1.09 (0.82–1.44)	1.15 (0.85–1.54)
5-6 times/week	1.25 (1.01–1.54)	1.28 (1.02–1.62)	1.24 (0.91–1.70)	1.12 (0.81–1.56)	1.01 (0.73–1.40)	1.18 (0.85–1.66)
3-4 times/week	1.59 (1.22–2.05)	1.62 (1.23–2.14)	1.83 (1.38–2.43)	1.51 (1.13–2.03)	0.89 (0.60–1.32)	0.99 (0.65–1.49)
1-2 times/week	1.84 (1.41–2.41)	2.01 (1.51–2.67)	2.09 (1.56–2.80)	1.60 (1.18–2.18)	1.14 (0.78–1.66)	1.12 (0.75–1.68)
never	2.49 (1.98–3.14)	2.51 (1.96–3.22)	2.66 (1.72–4.12)	1.83 (1.14–2.95)	1.41 (1.00–1.99)	1.62 (1.12–2.34)

Model 1: included the six types of food as variables.
Model 2: included model 1 plus sex, age, parental education level, and household income level as covariates.
K-ARS: Korean version of the attention deficit/hyperactivity (ADHD) rating scale, CI: confidence interval.

findings of previous studies. Multiple studies have reported a positive association between ADHD symptoms and binge-eating (Cortese et al., 2007; Nazar et al., 2008; Surman, Randall, & Biederman, 2006). The findings on the association between eating pace and ADHD symptom score are interesting. The children eating at a pace similar to that of their family members showed significantly lower ADHD symptom scores compared to the children who ate slower or faster. A plausible explanation may be that the children with higher ADHD symptoms cannot focus on the eating process and are distracted easily by other stimuli or thoughts. However, the mechanism underlying these associations should be investigated in future studies.

4.1. Limitations and future directions

This study has several limitations that should be noted. Our study design was cross-sectional. Therefore, we cannot confirm causality in the association between ADHD symptoms and dietary pattern. Further longitudinal or experimental studies would help reveal the causal mechanism involved in this association. Second, we assessed ADHD symptoms only by a questionnaire rated by parents, our assessment did not include an objective neuropsychological test or a diagnostic interview conducted by a psychiatrist. Moreover, dietary habits were also assessed using a questionnaire completed by parents. This may limit the interpretation of our results due to the possibility of inadequate reporting by parents of the children's symptoms and dietary habits. Future studies, which would include neuropsychological testing and multi-informant reporting, are required for accurate assessment. Third, eating behavior could be affected by the medication prescribed for ADHD. Psychostimulants, which are commonly used in ADHD treatment, are known to suppress appetite (Zachor, Roberts, Hodgens, Isaacs, & Merrick, 2006). Thus, laboratory studies for eating disorders among children with ADHD typically require children to be either medication naïve or to abstain from medication for a period of time prior to participating in the study (Hilbert et al., 2018). However, information on the current medication of children was not collected in our study and we could not evaluate the effect of medication on eating behavior. Finally, ADHD is a highly heritable disorder with estimated heritability of 0.76 (Faraone et al., 2005) and any family history of ADHD should be taken into account. However, we did not include family history data in the analysis. Although we collected family history data, only four parents responded positively to the item regarding parental history diagnosed with ADHD. This may be attributable to the fact that the diagnosis rate and public perception of ADHD were very low during the parents' childhoods.

5. Conclusion

Although ADHD is highly heritable, it is a multifactorial disorder affected by gene-environment interactions, including diet. We identified an association between dietary habits and ADHD symptoms in a large sample derived from the general population. The present study found that ADHD symptoms are positively associated with higher consumption of fast food, soft drinks, and instant noodles. ADHD symptoms were also negatively associated with higher consumption of fruit and vegetables. Overeating and eating pace were also associated with ADHD symptoms. Although further studies are required to delineate the causal mechanism underlying these associations, our study may provide useful clinical information for dietary interventions in children with ADHD.

Conflicts of interest

None of the authors reports any conflicts of interest.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.appet.2018.05.004.

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