Correlation between attention deficit hyperactivity disorder and sugar consumption, quality of diet, and dietary behavior in school children

Yujeong Kim[1] and Hyeja Chang[2§]

[1]*Major in Nutrition Education, Graduate School of Education, Dankook University, Yongin-si, Gyeonggi 448-701, Korea*
[2]*Department of Food Science and Nutrition, Dankook University, 126, Jukjeon-dong, Suji-gu Yongin-si, Gyeonggi 448-701, Korea*

Abstract

This study investigated the correlation between consumption of sugar intake by fifth grade students in primary schools and development of Attention Deficit Hyperactivity Disorder (ADHD). A total of 107 students participated, and eight boys and one girl (8.4% of the total) categorized as high risk for ADHD according to diagnostic criteria. There were significant differences in the occupations and drinking habits of the respondents' fathers between the normal group and risk group. In a comparison of students' nutrition intake status with daily nutrition intake standards for Koreans, students consumed twice as much protein as the recommended level, whereas their calcium intake was only 60% of the recommended DRI (dietary reference intake). Regarding intake volume of vitamin C, the normal group posted 143.9% of the recommended DRI, whereas the risk group showed only 65.5% of the recommended DRI. In terms of simple sugar intake from snacks, students in the normal group consumed 58.4 g while the risk group consumed 50.2 g. These levels constituted 12.5% of their total daily volume of sugar intake from snacks, which is higher than the 10% standard recommended by the WHO. In conclusion, children who consumed less sugar from fruit snacks or whose vitamin C intake was less than RI was at increased risks for ADHD ($P < 0.05$). However, no significant association was observed between total volume of simple sugar intake from snacks and ADHD development.

Key Words: ADHD (Attention Deficit Hyperactivity Disorder), sugar consumption, dietary behavior

Introduction

Balanced nutrition is very important during childhood, which is a period of vigorous growth, increased activity, and development of body functions and social cognitive ability. With rapid economic growth and increased personal income, and especially advances in food processing and manufacturing industries, the proportion of processed foods (e.g. snacks and cakes) in children's dietary life has noticeably increased [1-2]. It has also led to larger physiques of pre-adolescent children.

Recently, the interest in attention-deficit hyperactivity disorder (ADHD) during childhood has increased. ADHD is defined as a neurobehavioral developmental disorder characterized by continuous inattention, hyperactivity, and impulsiveness and is especially prevalent in childhood [3-4]. Unlike those showing simple hyperactivity features, children with ADHD have three subtype symptoms: predominantly hyperactive-impulsive, predominantly inattentive, and combined hyperactive-impulsive and inattentive [5-7]. The Conner Abbreviated Teacher Rating Scale (CATRS) is widely used to specifically measure the mental pathology behavior of children with ADHD [8]. The etiology of ADHD involves genetic, dietary, and environmental factors.

Especially, dietary factors such as color agents or simple sugar have been determined to increase the risk of ADHD [6,9].

Simple sugar consumption may cause hyperactivity, given that snacks containing high sugar content cause massive secretion of insulin from the pancreas, resulting in hypoglycemia [9]. This stimulates an increase in epinephrine, leading to activation of nervous reactions and hyperactivity disorder behaviors [9]. In other words, elevated intake of snacks might increase the potential of nutritional imbalance, lower emotional intelligence [10-11], and ADHD [12-14]. A recent study on sugar consumption suggested that higher consumption of sugar is positively correlated with a higher level of hyperactivity and attention deficiency similar to ADHD [1,9,11,15]. However, it is still controversial whether or not there is an association between ADHD and sugar consumption. A study by Wolraich *et al*. found that diets high in sucrose had no significant effects on behavior and cognitive performance in children [16]. Moreover, in Korea, there are little data on how much simple sugar children obtain from snacks or if higher consumption of simple sugar is associated with ADHD risk.

Snacks play a critical role in the diets of school-age children, given that they supply additional nutrients as well as refreshment,

mental relaxation, and emotional stability [2]. However, in Korea as well as other developed countries, sugar consumption has steadily increased with economic growth [17]. Over-consumption of saturated fat and simple sugar from fast foods, instant foods, and carbonated drinks is considered a potential risk factor for obesity, decayed teeth, and diabetes [18]. Due to these problems, the World Health Organization (WHO) has proposed that the proportion of daily calories obtained from simple sugar be 10% or less.

Therefore, this study was designed to investigate the consumption of simple sugar from snacks, the relationship between ADHD and sugar consumption, and the quality of diet and dietary behaviors of fifth graders at primary schools in Seoul. For this, we investigated sugar consumption from meals and snacks over 1 day and examined ADHD development based on teachers' ratings.

Subjects and Methods

Participants

A total of 112 students, 58 boys and 54 girls, enrolled in the fifth grade at two elementary schools in Seoul participated in this study. Data collection was conducted from December 17, 2008 to April 10, 2009 using a questionnaire that was administrated to subjects and completed individually with the help of trained researchers. Questionnaires were collected from 112 subjects and five were excluded due to incompleteness. The data of 107 subjects were used in the final analysis, representing a response rate of 95.5%.

Measurements and procedure

Two types of questionnaires, one for teachers and one for students, were used for data collection. The questionnaire for teachers was based on the Conner Abbreviated Teacher Rating Scale (CATRS-10) [3,4,19], which is a widely accepted measurement tool for ADHD symptoms, and a revised 'hyperactivity rating scale' developed by Goyette, Conners, and Ulrich [20] with 10 question items. A total score was obtained for the 10 items (0 = not at all, 1 = just a little, 2 = pretty much, and 3 = very much hyperactive), which characterized subjects based on deficit-attention, hyperactivity, and impulsiveness. The homeroom teachers completed the questionnaire by considering students' behaviors displayed over the previous 10 months. Possible scores ranged from 0 to 30 points, with higher scores indicating higher severity of the listed behavioral issues.

The second questionnaire for students was separated into three sections: dietary assessment, 10 items about dietary behaviors, and demographic variables. Demographic information included 12 items, such as gender, height, weight, and parents' information, including education, age, job, drinking, and smoking habits. Dietary habits consisted of six items, including breakfast intake frequency, regularity of meals, sweetness preference, reasons for eating high-sugar containing foods, allowance, and degree of unbalanced diets.

All data were collected by self-reporting with the help of a researcher for accurate data collection. BMI was calculated on the basis of self-reported data from the students. Dietary assessment was carried out based on 1-day food record in conjunction the 24-hour recalled method and specifically focused on eating place, food items, and quantity of each meal (breakfast, lunch, and dinner). The survey researcher helped students to complete the food record questionnaire, which included the amounts and types of foods consumed. CAN-Pro 3.0 [21] was used to analyze the nutrient contents and amounts of food consumed by children.

Snack consumption was surveyed using a structured questionnaire consisting of nine categories, including cookies and chips, dairy products, beverages (carbonated beverage, ion beverage, juice, children beverage, etc), bread and sandwiches, flour-based convenience foods (Ramyeon, Mandu, Odeng, hotdog etc), fast food, sweets and chocolate, rice cakes, and fruits. The subjects answered by writing the names of the foods and the quantity, such as units, slice, can, etc. To help children's answers, leaflets displaying the quantity and volume of a single serving of various foods were provided. Sugar contents were calculated based on the product label information regarding sugar content per one serving size or 100 g. In addition, USDA Nutritional Nutrient Database [22] and simple sugar contents of selected snacks published by the KFDA [23] were used to analyze sugar consumption.

Statistical analysis

Data were analyzed using Statistical Package for Social Science (SPSS) software for windows, version 14.0. Two groups were made according to the ADHD ratings provided by the teachers. The recommended cutoff score was a total score of 16 points, even though there is controversy that this cutoff score could classify more children as having ADHD [4,5,9]. Thus, we named the group of students scoring 16 points and less as the normal group and the group of students scoring 16 points higher as the risk group. Frequency analysis and a non-parametric independent test were used to identify the distribution and compare means between the two groups. To determine whether or not the risk factors were associated with ADHD, odd ratios were calculated using the Manel-Haenszel-Cochran test.

Results

Profiles of the respondents

Among the 107 children that participated in this study, 54 were boys and 53 were girls. As presented in Table 1, parents' age was 43.1 years for the father and 40.6 years for the mother. The majority of fathers (80.0%) and mothers (66.7%) had at least

ADHD and sugar consumption in school children

Table 1. General Characteristics of the subjects   N (%)

Characteristics	Total (n = 107)	Normal group			Risk group			z-value / χ^2-value[2]
		Boy (n = 46)	Girl (n = 52)	Sub-total (n = 98)	Boy (n = 8)	Girl (n = 1)	Sub-total (n = 9)	
Father's age (yr)[1]	43.1 ± 3.5	43.1 ± 3.1	43.3 ± 3.7	43.2 ± 3.4	44.0 ± 5.1	36	42.7 ± 5.7	-0.600
Mother's age (yr)[1]	40.6 ± 3.6	40.8 ± 3.3	40.4 ± 3.6	40.5 ± 3.4	43.8 ± 4.1	32	41.8 ± 6.0	-0.857
Father's education								
High school	20 (20.0)	8 (18.6)	12 (24.5)	20 (21.7)	0 (0.0)	0 (0.0)	0 (0.0)	2.719
University	58 (58.0)	26 (60.5)	27 (55.1)	53 (57.6)	4 (57.1)	1 (100.0)	5 (62.5)	
Graduate school	22 (22.0)	9 (20.9)	10 (20.4)	19 (20.7)	3 (42.9)	0 (0.0)	3 (37.5)	
Mother's education								
Middle school	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
High school	33 (33.3)	11 (25.6)	22 (44.9)	33 (35.9)	0 (0.0)	0 (0.0)	0 (0.0)	3.782
University	46 (46.5)	25 (58.1)	16 (32.7)	41 (44.6)	4 (66.7)	1 (100.0)	5 (71.4)	
Graduate school	20 (20.2)	7 (16.3)	11 (22.4)	18 (19.6)	2 (33.3)	0 (0.0)	2 (28.6)	
Father's job								
Professional	4 (3.8)	2 (4.5)	2 (3.8)	4 (4.2)	0 (0.0)	0 (0.0)	0 (0.0)	
Technician	14 (13.3)	8 (18.2)	6 (11.5)	14 (14.6)	0 (0.0)	0 (0.0)	0 (0.0)	
Clerks	53 (50.5)	20 (45.5)	26 (50.0)	46 (47.9)	7 (87.5)	0 (0.0)	7 (77.8)	
Service worker	6 (5.7)	3 (6.8)	3 (5.8)	6 (6.3)	0 (0.0)	0 (0.0)	0 (0.0)	15.224*
Own business	25 (23.8)	11 (25.0)	13 (25.0)	24 (25.0)	1 (12.5)	0 (0.0)	1 (11.1)	
Primary industry[3]	1 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)	1 (11.1)	
Unemployed	1 (1.0)	0 (0.0)	11 (1.9)	1 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Etc	1 (1.0)	0 (0.0)	1 (1.9)	1 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Father's smoking								
Smoking	47 (43.9)	19 (41.3)	25 (48.1)	44 (44.9)	2 (25.0)	1 (100.0)	3 (33.3)	0.448
Not smoking	60 (56.1)	27 (58.7)	27 (51.9)	54 (55.1)	6 (75.0)	0 (0.0)	6 (66.7)	
Mother's smoking								
Smoking	1 (0.9)	0 (0.0)	1 (1.9)	1 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)	0.093
Not smoking	106 (99.1)	46 (100.0)	51 (98.1)	97 (99.0)	9 (100.0)	1 (100.0)	9 (100.0)	
Father's drinking								
Never	13 (12.1)	6 (13.0)	6 (11.5)	12 (12.2)	1 (12.5)	0 (0.0)	1 (11.1)	
Little	19 (17.8)	9 (19.6)	8 (15.4)	17 (17.3)	1 (12.5)	1 (100.0)	2 (22.2)	
Sometimes	56 (52.3)	23 (50.0)	29 (55.8)	52 (53.1)	4 (50.0)	0 (0.0)	4 (44.4)	11.315*
Often	18 (16.8)	8 (17.4)	9 (17.3)	17 (17.3)	1 (12.5)	0 (0.0)	1 (11.1)	
Everyday	1 (0.9)	0 (0.0)	0 (0.0)	0 (0.0)	1 (12.5)	0 (0.0)	11 (11.1)	
Mother's drinking								
Never	38 (35.8)	12 (26.1)	22 (42.3)	34 (34.7)	3 (42.9)	1 (100.0)	4 (50.0)	
Little	44 (41.5)	23 (50.0)	18 (34.6)	41 (41.8)	3 (42.9)	0 (0.0)	3 (37.5)	
Sometimes	22 (20.8)	10 (21.7)	11 (21.2)	21 (21.4)	1 (14.3)	0 (0.0)	1 (12.5)	0.964
Often	2 (1.9)	1 (2.2)	1 (1.9)	2 (2.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Everyday	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	

[1] Values are Mean ± SD
[2] χ^2-value from Chi-square test and z-value from Mann-Whitney
[3] Primary industry: skilled agriculture, forestry, and fishery workers

a university level education. Exactly 50.5% of the respondents answered white-collar employee as their father's job, whereas 40.0% described their mother's job as housekeeper. The paternal smoking rate was 43.9% (n = 47 persons) while that of the mother was 0.9% (n = 1). Regarding drinking, most answered 'sometimes' for father and 'little' for mother.

ADHD evaluation score

The abbreviated ADHD rating scale was used to measure children's behaviors. The average ADHD score was 7.41 for boys and 2.91 for girls (Table 2). The mean difference of 4.42 between the boy and girl groups was significant ($P < 0.01$). Among the 10 items, the 'excitable, impulsive' item received the highest score of 0.68, whereas the 'cries often and easily' item received the lowest score of 0.37, resulting in a total mean score of 5.18. The items 'disturbs other children (t = 3.607)', 'restless or overactive

Table 2. Results of ADHD evaluation scores from the teachers

Observation	Total (n = 107)	Boy (n = 54)	Girl (n = 53)	z-value
Restless or overactive	0.61 ± 0.87	0.89 ± 0.96	0.32 ± 0.64	3.589**
Excitable, impulsive	0.68 ± 0.98	0.98 ± 1.05	0.38 ± 0.79	3.357**
Disturbs other children	0.40 ± 0.70	0.63 ± 0.81	0.17 ± 0.47	3.607**
Fails to finish things he starts -short attention span	0.63 ± 0.95	0.89 ± 1.09	0.36 ± 0.68	3.017**
Constantly fidgeting	0.37 ± 0.72	0.59 ± 0.88	0.15 ± 0.41	3.336**
Inattentive, easily distracted	0.65 ± 0.99	0.89 ± 1.11	0.42 ± 0.80	2.541*
Demands must be met immediately-easily frustrated	0.44 ± 0.80	0.67 ± 0.99	0.21 ± 0.45	3.091**
Cries often and easily	0.37 ± 0.72	0.48 ± 0.86	0.26 ± 0.52	1.577
Mood changes quickly and drastically	0.54 ± 0.80	0.69 ± 0.89	0.40 ± 0.69	1.885
Temper outbursts, explosive and unpredictable behavior	0.48 ± 0.78	0.70 ± 0.92	0.25 ± 0.52	3.177**
Mean of total score	5.18 ± 6.93	7.41 ± 8.12	2.91 ± 4.51	3.555**

Values are Mean ± SD.
4-point scale: 0 = not at all, 1 = just a little, 2 = pretty much, and 3 = very much
z-value from Mann-Whitney test
*$P < 0.05$, **$P < 0.01$

(t = 3.589)', 'excitable, impulsive (t = 3.357)', 'constant fidgeting (t = 3.366)', 'easily frustrated (t = 3.091)', and 'temper outbursts (t = 3.177)', were significantly higher scores in boys than girls.

Demographical profiles and dietary habits of the normal and risk groups

According to the ADHD scores, 46 boys and 52 girls who got a score of 16 points or less were categorized into the normal group, accounting for 91.6% of the total 107 students surveyed, whereas the remaining 8 boys and 1 girl were categorized into the risk group, accounting for 8.4% of the total subjects.

According to the demographic characteristics presented in Table 1, the mean age of parents of the two groups ranged from 40.5 to 43.2 years among mothers and fathers ($P > 0.05$). There were no statistically significant differences in education level or smoking habit of the parents as well as drinking frequency of the mother between the two groups. However, job type and drinking frequency of the father were significantly different between the two groups ($P < 0.05$).

In the anthropometric results, as shown in Table 3, the height and weight of the normal group was approximately 6 cm higher and 1.7 kg more than those of the risk group. Although the risk group had a higher BMI than the normal group, there was no

significant difference between the two groups ($P > 0.05$) as both fell within the normal range of 18.5 to 23.5 kg/m² for Korean children [24]. Specifically, BMI was measured to be 18.7 kg/m² for boys and 18.4 kg/m² for girls in the normal group and 19.8 kg/m² for boys and 18.8 kg/m² for girls in the risk group.

Dietary behaviors between the normal and risk groups, in terms of frequencies of breakfast intake per week, regularity of meals, preference of sweetness, reasons for eating sugar, and levels of unbalanced diet, were similar and no significant differences were observed the between groups (Table 4). Exactly 61.7% of the respondents answered that they ate breakfast every day, only 12.1% of respondents ate meals irregularly, and 58.9% answered their main reason for eating sugar was delicious taste. Four children out of nine (44.4%) belonging to the risk group answered that their main reason for eating sugar was due to hunger, as compared to 14.3% in the normal group.

Daily nutrient intake of the ADHD normal and risk groups

Daily nutrient intakes of the two groups are presented in Table 5. Energy intake of all of the subjects was measured as 1,813.2 kcal, comprised of 292.5 g of carbohydrates, 65.4 g of protein, and 54.1 g of fat. The ratio of carbohydrate : protein : fat was 71.0:15.9:13.1. These results were similar between the normal group and risk group. For the risk group, the energy intake was 1,810.2 kcal, comprised of 289.8 g of carbohydrates, 67.0 g of protein, and 52.0 g of fat in a ratio of 70.9:16.4:12.7. Therefore, no significant differences existed in terms of nutrient intake between the two groups. Comparing the consumption of other minerals and vitamins between the two groups, only the level of vitamin C was significantly different ($P < 0.05$), constituting 100.7 mg for the normal group and 45.9 mg for the risk group.

Fig. 1 presents the intake rate of nutrients based on the recommended levels of intake for Korean children [21]. Intakes of energy and vitamin B_2 by the two groups were within the optimal range from 96.7 to 110.2%. However, the subjects consumed higher levels of protein (170.6~228.9%), vitamin B_1 (112.6~155.6%), and vitamin B_6 (127.3~200.0%) than the daily recommended intake levels for Korean children. On the contrary, intakes of calcium (33.0~72.5%) and vitamin A (28.8~87.6%) did not reach the daily recommended levels. Especially, the risk group showed a tendency of consuming less calcium (63.6 vs 68.1%), iron (79.7 vs 108.6%), and vitamin C (63.6 vs 143.9%) compared to the normal group, although only the level of vitamin C consumption was significantly different ($P < 0.05$).

Table 3. Mean anthropometry of normal group and risk group

Anthropometry	Total (n = 107)	Normal group			Risk group			z-value[1]
		Boy (n = 46)	Girl (n = 52)	Total (n = 98)	Boy (n = 8)	Girl (n = 1)	Total (n = 9)	
Height (cm)	148.72 ± 7.59	148.46 ± 7.31	149.49 ± 7.96	149.01 ± 7.64	143.00 ± 4.76	146.0 ± 0	143.60 ± 4.34	-1.775
Weight (kg)	41.15 ± 8.64	41.85 ± 9.82	40.76 ± 7.98	41.27 ± 8.86	39.50 ± 5.54	40.0 ± 0	39.57 ± 5.06	-0.152
BMI[2]	18.58 ± 2.88	18.71 ± 3.33	18.35 ± 2.56	18.52 ± 2.94	19.80 ± 1.17	18.76 ± 0	19.60 ± 1.19	-1.150

[1] z-value from Mann-Whitney
[2] BMI = Weight (kg)/Height (m²)

Table 4. Dietary behaviors between normal group and risk group   N (%)

Variables	Total (n = 107)	Normal group			Risk group			x^2-value / z-value[2]
		Boy (n = 46)	Girl (n = 52)	Total (n = 98)	Boy (n = 8)	Girl (n = 1)	Total (n = 9)	
Breakfast intake (per week)								
Everyday	66 (61.7)	26 (56.5)	33 (63.5)	59 (60.2)	6 (75.0)	1 (100.0)	7 (77.8)	
4~6 day	19 (17.8)	10 (21.7)	7 (13.5)	17 (17.3)	2 (25.2)	0 (0.0)	2 (20.0)	2.543
1~3 day	18 (16.8)	10 (21.7)	8 (15.4)	18 (18.4)	0 (0.0)	0 (0.0)	0 (0.0)	
Never	4 (3.7)	0 (0.0)	4 (7.7)	4 (4.1)	0 (0.0)	0 (0.0)	0 (0.0)	
Regularity of meal								
Regular	46 (42.1)	22 (47.8)	19 (36.5)	41 (41.8)	4 (50.0)	0 (0.0)	4 (44.4)	
Partially regular	49 (45.8)	17 (37.0)	28 (53.8)	45 (45.9)	3 (37.5)	1 (100.0)	4 (44.4)	0.026
Irregular	13 (12.1)	7 (15.2)	5 (9.6)	12 (12.2)	1 (12.5)	0 (0.0)	1 (11.1)	
Sweetness preference								
Extremely dislike	1 (0.9)	1 (2.2)	0 (0.0)	1 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Dislike	5 (4.7)	2 (4.3)	2 (3.8)	4 (4.1)	1 (14.3)	0 (0.0)	1 (12.5)	
Neutral	53 (50.0)	20 (43.5)	28 (53.8)	48 (49.0)	4 (57.1)	1 (100.0)	6 (62.5)	2.566
Like	36 (34.0)	17 (37.0)	17 (32.7)	34 (34.7)	2 (28.6)	0 (0.0)	2 (25.0)	
Extremely like	11 (10.4)	6 (13.0)	5 (9.6)	11 (11.2)	0 (0.0)	0 (0.0)	0 (0.0)	
Reason of eating sugars								
Delicious	63 (58.9)	28 (60.9)	31 (59.6)	59 (60.2)	4 (50.0)	0 (0.0)	4 (44.4)	
Habit	4 (3.7)	2 (4.3)	2 (3.8)	4 (4.1)	0 (0.0)	0 (0.0)	0 (0.0)	
Cheap	1 (0.9)	1 (2.2)	0 (0.0)	1 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Hungry	18 (16.8)	7 (15.2)	7 (13.5)	14 (14.3)	4 (50.0)	0 (0.0)	4 (44.4)	5.730
Boredom	18 (16.8)	6 (13.0)	11 (21.2)	17 (17.3)	0 (0.0)	1 (100.0)	1 (11.1)	
Etc	3 (2.8)	2 (4.3)	1 (1.9)	3 (3.1)	0 (0.0)	0 (0.0)	0 (0.0)	
Allowance a day (won)[1]	586 ± 375	579 ± 368	607 ± 389	593 ± 377	530 ± 374	350 ± 0	510 ± 355	-0.396
Unbalanced diet								
Never	19 (18.1)	7 (15.2)	11 (22.0)	18 (18.8)	1 (12.5)	0 (0.0)	1 (11.1)	
Sometimes	73 (69.5)	34 (73.9)	32 (64.0)	66 (68.8)	7 (87.5)	0 (0.0)	7 (77.8)	0.375
Very often	13 (12.4)	5 (10.9)	7 (14.0)	12 (12.5)	0 (0.0)	1 (100.0)	1 (11.1)	

[1] Values are Mean ± SD.
[2] x^2-value from Chi-square test and z-value from Mann-Whitney

Table 5. Daily nutrient intake including snacks

Nutrients	Total (n = 107)	Normal group			Risk group			z-value[1]
		Boy (n = 46)	Girl (n = 52)	Total (n = 98)	Boy (n = 8)	Girl (n = 1)	Total (n = 9)	
Energy (kcal)	1,813.2 ± 562.8	1,944.3 ± 583.6	1,697.8 ± 513.0	1,813.5 ± 558.2	1,784.8 ± 686.4	2,013.6 ± 0	1,810.2 ± 646.6	-0.112
Protein (g)	65.4 ± 22.8	71.4 ± 23.6	59.7 ± 19.5	65.2 ± 22.2	65.4 ± 32.1	80.1 ± 0	67.0 ± 30.4	-0.034
Fat (g)	54.1 ± 20.8	59.3 ± 21.5	49.8 ± 19.0	54.2 ± 20.7	51.3 ± 25.3	57.6 ± 0	52.0 ± 23.7	-0.191
Carbohydrate (g)	292.5 ± 93.5	310.2 ± 102.0	277.2 ± 83.4	292.7 ± 93.6	288.6 ± 104.3	299.9 ± 0	289.8 ± 97.7	-0.034
Ca (mg)	542.1 ± 542.1	579.6 ± 250.1	514.7 ± 228.5	545.1 ± 239.8	539.3 ± 311.4	264.3 ± 0	508.7 ± 305.4	-0.797
Fe (mg)	12.7 ± 8.1	15.2 ± 10.1	11.1 ± 5.8	13.0 ± 8.4	9.4 ± 4.8	10.9 ± 0	9.5 ± 4.6	-1.089
Vit A (μg-RE)	437.9 ± 247.2	442.5 ± 260.4	438.1 ± 214.4	440.1 ± 235.8	447.7 ± 376.9	144.0 ± 0	414.0 ± 366.8	-0.965
Vit B_1 (mg)	1.2 ± 0.5	1.4 ± 0.6	1.1 ± 0.4	1.2 ± 0.5	1.4 ± 0.7	0.9 ± 0	1.3 ± 0.7	-0.561
Vit B_2 (mg)	1.1 ± 0.4	1.2 ± 0.5	1.0 ± 0.4	1.1 ± 0.4	1.2 ± 0.6	0.6 ± 0	1.1 ± 0.6	-0.359
Vit B_6 (mg)	1.6 ± 0.6	1.7 ± 0.7	1.5 ± 0.5	1.6 ± 0.6	1.4 ± 0.6	2.0 ± 0	1.4 ± 0.6	-0.741
Niacin (mg)	13.9 ± 5.4	15.6 ± 5.3	12.5 ± 4.9	14.0 ± 5.3	11.7 ± 6.3	21.9 ± 0	12.8 ± 6.8	-0.718
Vit C (mg)	96.1 ± 89.3	107.2 ± 102.8	95.0 ± 81.1	100.7 ± 91.6	47.7 ± 27.7	31.5 ± 0	45.9 ± 26.5	-2.043*
Sodium (mg)	4,062.5 ± 1,598.1	4,227.0 ± 1,646.7	3,812.3 ± 1,345.5	4,007.0 ± 1,501.1	4,597.3 ± 2,624.7	5,222.7 ± 0	4,666.8 ± 2,464.0	-0.696
K (mg)	2,275.0 ± 860.4	2,447.7 ± 990.7	2,139.1 ± 663.5	2,283.9 ± 843.1	2,207.2 ± 1,157.6	1,945.7 ± 0	2,178.1 ± 1,086.4	-0.471

Values are Mean ± SD.
[1] z-value from Mann-Whitney test
* Significantly different between normal group and risk group at $P < 0.05$

Table 6. Daily nutrient intake from snacks

Nutrients	Total (n = 107)	Normal group			Risk group			z-value
		Boy (n = 46)	Girl (n = 52)	Total (n = 98)	Boy (n = 8)	Girl (n = 1)	Total (n = 9)	
Energy (kcal)	688.2 ± 466.3	732.7 ± 486.7	651.5 ± 458.1	689.7 ± 471.1	611.5 ± 423.8	1157.6	672.2 ± 436.2	-0.224
Protein (g)	18.7 ± 14.6	19.6 ± 12.4	17.4 ± 15.9	18.5 ± 14.3	18.5 ± 15.9	47.9	21.8 ± 17.8	-0.174
Fat (g)	22.3 ± 16.8	24.3 ± 16.3	20.6 ± 17.0	22.3 ± 16.7	19.1 ± 18.6	43.8	21.8 ± 19.2	-0.404
Carbohydrate (g)	111.5 ± 78.6	118.2 ± 87.5	107.0 ± 74.5	112.3 ± 80.7	98.6 ± 55.1	143.1	103.5 ± 53.6	-0.022
Ca (mg)	292.5 ± 206.6	315.4 ± 218.6	279.0 ± 200.8	296.1 ± 209.1	273.5 ± 185.7	96.4	253.8 ± 183.5	-0.325
Fe (mg)	4.8 ± 7.1	6.7 ± 8.9	3.6 ± 5.2	5.0 ± 7.3	1.9 ± 1.2	5.0	2.3 ± 1.6	-0.673
Vit A (μg-RE)	117.6 ± 106.2	119.8 ± 102.3	119.6 ± 114.7	119.7 ± 108.5	98.6 ± 81.7	68.0	95.2 ± 77.1	-0.511
Vit B_1 (mg)	0.4 ± 0.4	0.4 ± 0.3	0.4 ± 0.4	0.4 ± 0.4	0.3 ± 0.3	0.2	0.3 ± 0.3	-0.567
Vit B_2 (mg)	0.5 ± 0.3	0.5 ± 0.4	0.5 ± 0.3	0.5 ± 0.3	0.5 ± 0.3	0.4	0.5 ± 0.3	-0.034
Vit B_6 (mg)	0.4 ± 0.3	0.4 ± 0.4	0.4 ± 0.3	0.4 ± 0.4	0.3 ± 0.2	0.9	0.3 ± 0.3	-0.892
Niacin (mg)	2.6 ± 3.2	2.6 ± 2.3	2.7 ± 3.7	2.6 ± 3.1	1.6 ± 1.4	14.2	3.0 ± 4.4	-0.393
Vit C (mg)	53.7 ± 85.5	63.4 ± 101.2	52.7 ± 75.6	57.7 ± 88.2	11.1 ± 17.4	1.6	10.1 ± 16.6	-2.313*
Sodium (mg)	757.4 ± 672.9	775.7 ± 525.2	718.0 ± 789.2	745.1 ± 675.5	816.4 ± 672.7	1486.4	890.9 ± 667.7	-0.853
K (mg)	800.5 ± 557.0	890.5 ± 671.3	754.4 ± 468.5	818.3 ± 573.7	581.5 ± 280.8	812.6	607.2 ± 273.7	-0.988

Values are mean ± SD.
*Significantly different between the normal and risk group by Mann-Whitney test at $P < 0.05$

Nutrient intake from snacks between the ADHD normal and risk groups

Daily nutrient intakes from snacks excluding meals of the ADHD normal and risk groups are presented in Table 6, and their rates are compared with the daily recommended intake levels shown in Fig. 1. The average intake of energy from snacks ranged from 672.2 to 689.7 kcal/day, which is equivalent to 36.2 to 37.3% of the estimated energy requirement for children aged 10 to 12. On the other hand, intakes of calcium (31.7 to 37.0%), protein (52.2-62.2%), vitamin B_1 (32.4 to 47.4%), vitamin B_2 (45.4 to 50.9%), and vitamin B_6 (34.3 to 38.3%) from snacks were also higher, showing similar tendency between the normal and risk groups.

In the normal group, the intakes of iron (42.1% of RI) and vitamin C (82.5% of RI) from snacks were much higher compared to those of the risk group, which were 18.7 and 14.5% of the DRI, respectively. Only the intake level of vitamin C was significantly different between the normal and risk group ($P < 0.05$). Another interesting point is that the intakes of vitamin A and niacin by the risk group were fairly lower compared to other nutrients and those of the normal group (3.2% and 13.4%, respectively), although the differences were not significant.

Sources of simple sugar consumption between the two groups

The levels of sugar intake from various snacks are presented in Fig. 2. We categorized the snacks consumed by students into nine types. Cookies and chips, dairy products, beverages, bread, flour-based meal, fast food, sweets, and rice cakes were the processed food types, all of which contain high content of simple sugar, preservatives, or coloring agents. Fruits were the sole natural food type.

The total daily intake of simple sugar from the nine categories of snacks consumed by all the subjects was 57.2 g, specifically

(a) Meals including snack
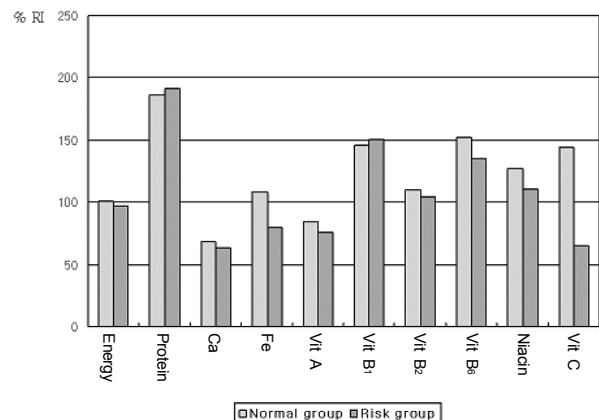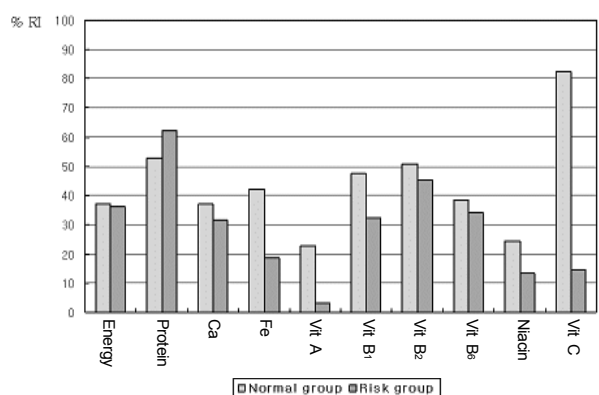

(b) Snack excluding meals

Fig 1. Daily nutrient intakes as percentage of recommended intake (RI) from (a) meals including snacks and (b) only snacks

57.7 g for the normal group and 51.1 g for the risk group ($P > 0.05$). Excluding fruits, the students in the normal group consumed 41.7 g of total sugar, whereas those in the risk group
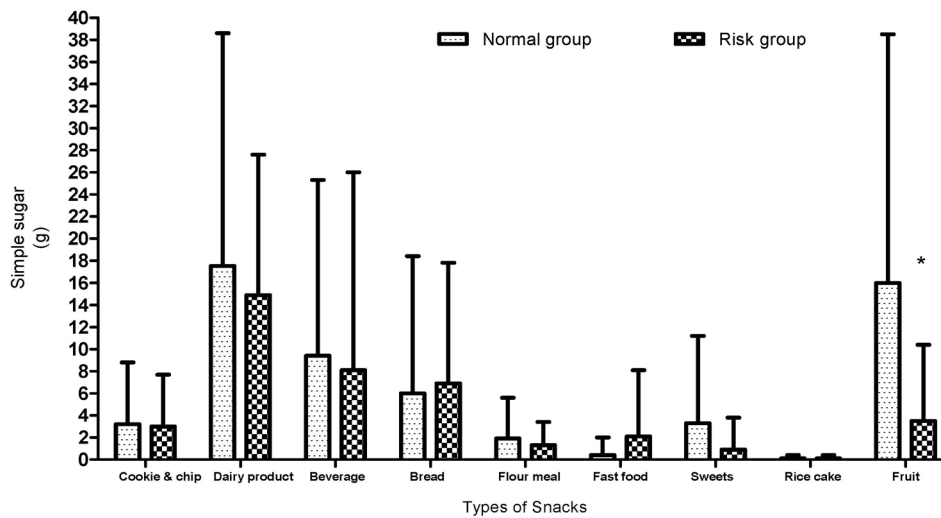
Fig 2. Daily total sugar intake from nine types of snacks. Star indicates significant difference between the normal group and risk group at $P < 0.05$ (by Mann-Whitney test)

consumed 47.6 g, which was not significantly different ($P >$ 0.05). However, these levels almost reach the level of sugar intake per day as recommended by the WHO. According to WHO guidelines, the proper consumption level of simple sugar is 10% of one's total calorie intake per day, which translates to 47.5 g for boys and 42.5 g for girls aged 7 to 12 in Korea. Put together, there was no observed association between the total volume of sugar intake obtained from snacks and ADHD development.

Among the nine types of snacks, dairy snacks were the top source of simple sugar for both groups, constituting 17.5 g in the normal group and 14.9 g in the risk group. Meanwhile, the lowest priority sugar source was rice cakes, constituting only 0.1 g of sugar in both groups. There were no significant differences according to snack type ($P > 0.05$). Regarding individual snack types, there was a significant difference between the two groups with respect to sugar intake from fruits, liquefied yoghurt (normal group 2.8 g, risk group 5.0 g) among milk products, and pizza (normal group 0.1 g, risk group 2.0 g) among fast food. Regarding sugar intake from fruits, the normal group consumed 16.0 g while the risk group consumed 3.5 g, constituting a significant difference ($P < 0.05$).

Relationship between sugar consumption and children with/without ADHD risk

Odd ratios, which calculated from the data such as parents education levels, smoking habit, drinking frequency, students BMI, vitamin C intake, and consumption of simple sugar from snacks, are presented in Table 7. Only vitamin C from meals including snacks and simple sugar from fruits had significant effects on ADHD risk in children. The ADHD risk group consumed less than 3.5 g of simple sugar from fruits, while normal group consumed more sugar from fruits ($P < 0.05$). In addition, the group that consumed less than the daily RI of

Table 7. Odd ratio of exposure variables on ADHD

Characteristics	Odd ratio	MHC value
Father's education[1]	0.210	2.821
Mother's education[1]	0.848	0.031
Father's smoking[2]	1.351	0.001
Mother's smoking[2]	0.000	0.193
Father's drinking[3]	1.764	0.142
Mother's drinking[3]	0.000	0.193
BMI[4]	2.343	0.001
Vit C[5]	8.269	3.890*
Sugar consumption		
Cookie & chip[6]	0.685	0.032
Dairy products[7]	1.785	0.347
Beverage[8]	0.345	1.065
Bread[9]	1.207	0.012
Flour-base meal[10]	0.887	0.020
Fast food[11]	2.286	0.145
Sweets[12]	0.273	0.836
Rice cake[13]	4.821	2.619
Fruit[14]	5.892	4.397*
Total sugar[15]	0.317	1.334

[1] University and higher = 1, High school and lower = 0
[2] Smoking = 1, No smoking = 0
[3] Often and more = 1, Sometimes and less = 0
[4] 23.0 kg/m^2 and more = 1, less than 23.0 kg/m^2 = 0
[5] Boy: less than 70 mg (DRI of Vit C) = 1, 70 mg and more = 0; Girl: less than 80 mg = 180 mg and more = 0
[6] Cookie & chip 3.0 g (mean of the risk group) and more = 1, less than 3.0 g = 0
[7] Dairy products 14.9 g (mean of the risk group) and more = 1, less than 14.9 g = 0
[8] Beverage 8.1 g (mean of the risk group) and more = 1, less than 8.1 g less than = 0
[9] Bread 6.9 g (mean of the risk group) and more = 1, less than 6.9 g = 0
[10] Flour-based meal 1.3 g (mean of the risk group) and more = 1 less than 1.3 g = 0
[11] Fast food 2.1 g (mean of the risk group) and more = 1, less than 2.1 g = 0
[12] Sweet 0.9 g (mean of the risk group) and more = 1, less than 0.9 g = 0
[13] Rice cake 0.1 g (mean of the risk group) and more = 1, less than 0.1 g = 0
[14] Fruit sugar 3.5 (mean of the risk group) and less = 1, over 3.5 g = 0
[15] Boy: less than 47.5 g (10% of recommended kcal) of total sugar = 147.5 mg and more = 0 ; Girl: less than 42.5 mg = 142.5 mg and more = 0
* Significant difference at $P < 0.05$

vitamin C from meals and snacks was also significantly associated with ADHD risk in child ($P < 0.05$). Unlike our expectations, a consumption level of simple sugar higher than that of the WHO recommended level was not related to ADHD risk.

Discussion

ADHD is characterized by symptoms of inattention, hyperactivity, and impulsivity in children [5-6]. ADHD is diagnosed in approximately 2% to 16% of school children [7] and is 6 to 9 times more common in boys than girls [6]. In this study, the prevalence rate of ADHD was 8.4% of the total subjects and was 8 times more common in boys than girls. This result is similar with a previous study that determined the prevalence rate of ADHD in elementary school age children to be 9.6% [25].

Based on previous studies, the causes of ADHD have been determined to be food additives [26], environmental factors [25,27], and sugar [6]. Artificial color agents and sodium benzonate preservative have been linked with increased hyperactivity in 3 year olds and 8-9 year olds [26]. Cigarette smoking and alcohol consumption also are strongly associated with ADHD [28]. In our study, relationships between smoking or alcohol consumption and ADHD were only partially observed. Only alcohol drinking by the father was linked with ADHD in a comparison of the normal and risk groups, and no relationship was found regarding smoking. However, the findings do suggest that the job type of the father might be associated with ADHD in the child. Therefore, future study is needed to further investigate this correlation.

This study did not observe any link between dietary behaviors and ADHD in school age students. The first reason for consuming sugar in both the risk and normal groups was taste, whereas the second reason was hunger for the ADHD group (44.4%) and boredom for the normal group. As a result, dietary behaviors involving regular eating of meals that can eliminate hunger should be recommended to prevent overconsumption of sugary snacks by children.

In a previous study, factors affecting snack intake during childhood were determined to be amount of allowance and TV viewing; a higher allowance and higher amount of TV viewing result in higher snack intake [18]. Another reason for consuming snacks is hunger [3], and eating less regular meals is associated with higher intake of high carbohydrate processed snacks [11]. In the snacking consumption part of this study, energy intake from snacks by school-aged children was too high. Children obtained about 37% percent of their total energy requirement and approximately 50% of protein DRI through snacks. In general, the rate of nutrient intake from snacks is recommended to be between 10 to 20% of the RDA (Recommended Daily Allowance), according to child nutrition guidelines suggested by the Ministry of Health and Welfare [29]. Based on this, we concluded that the subjects of this study were provided excessive

nutrients from snacks as opposed to meals. Thus, dietary education is needed to help children choose healthy beverages/snacks [27]. From study identified needs for nutrition education on snack intake of child, the dietary education issues that parents gave their children at home were balanced diet (83.9%) and eating a healthful food (53.7%). Moreover, 18.2% of parents answered that their kids consumed the snacks much more than needed. Snack items frequently provided to kids were fruits (62.8%), followed by milk (55.5%), bread (47.1%), and yogurt (21.1%), whereas cola and cider constituted only 1.2% [30].

On the other hand, when comparing students' nutrition intake status with the DRI for Korean children aged 10-12, the students consumed 186.3 to 191.6% of the DRI of protein but less calcium (33.0~72.5% of DRI) and vitamin A (28.8~87.6% of DRI). Surprisingly, the ADHD group consumed less calcium (63.6% of DRI), iron (79.76%), and vitamin C (63.6%) compared to the normal group ($P < 0.05$) in terms of nutrition. Moreover, the risk group consumed less natural fruit ($P < 0.05$) (risk group: 45.9 mg; control group 100.7 mg) as well as less milk compared to the normal group. These results suggest that ADHD is linked with vitamin C consumption from vegetables and fruits. It also suggested that, consistent with previous study, less milk intake link with less calcium intake [27]. More study for investigating the relationship between fruit consumption and ADHD should be conducted.

Several recent studies suggested that ADHD development is related with consumption of coloring agents and preservatives in processed food [6,26]. ADHD could also be connected with intake of simple sugar [26]. Based on this, we compared the levels of sugar consumption between the normal and risk groups. Unexpectedly, the risk group consumed less fruits than the normal group and obtained almost the same amounts of sugar from the other types of snacks as compared to the normal group. Therefore, we concluded that the total consumption of simple sugar from snacks is not associated with ADHD (odd ratio = 0.317, $P > 0.05$). This result does not support a previous study in which a large amount of sugar consumption caused hyperactivity [6]. Similar to our results, a study by Wolraich et al. [16] that investigated the effects of sugar on behavior and learning competence in 32 hyperactive boys aged 7 to 12 suggested that sugar intake (1.75 g/kg of body weight) has no influence on attention and learning competency.

A study investigating the relationship between beverage intake and health in adolescent girls pointed that public health efforts should be actively employed to promote healthy beverage choices and decrease soda consumption [27]. Among all beverages, soda consumption is a major positive predictor of increased BMI as well as a negative predictor of calcium intake. In our study, we failed to confirm that sugar consumption from snacks is positively related with BMI, and overweight (BMI over 23.5) was not associated with ADHD (odd ratio 2.343, $P > 0.05$).

Lastly, simple sugar consumption from snacks alone was 41.7 g in the normal group and 47.6 g in the risk group, both of

which are already near the 10% of total energy intake per day limit as recommended by the WHO. Including regular meals, the consumption of simple sugar intake by students reached 57.2 g (58.4 g for the normal group; 50.2 g for the risk group), which is approximately 12.5% of the required level for boy students. The Idaho State Department of Education has restricted simple sugar consumption in school foodservice. The school food authorities suggested that school meals have less than 10 grams of sugar per ounce [31]. In addition, when the amount of added sugar or simple sugar constitutes higher than 25% of the total energy intake per day, it adulterates the quality of the diet [32]. In this respect, school aged children need to consume less simple sugar-containing foods.

In conclusion, this study sought to determine the relationship between consumption of sugar by fifth graders at primary schools in Seoul and development of ADHD. We also tried to determine the relationship between ADHD and quality of diet and dietary behavior. This study did not find any evidence that ADHD development is related with consumption of sugar from snacks. However, we found that low intake of vitamin C or low consumption of fruits as snacks is associated with higher ADHD risk ($P < 0.05$). The intakes of simple sugar from snacks alone were 58.4 g and 50.2 g by the normal group and risk group, respectively, whereas a total of 57.2 g of simple sugar from regular meals was consumed. Therefore, continuing education on the right selection of snacks and on proper nutritional intake is needed for students to prevent unintended overindulgence of simple sugar.

This study had three limitations. The number of subjects was restricted to only fifth grade elementary students in Seoul who voluntarily participated. The second limitation was that the survey was carried out only one-day diets consumption survey. Lastly, this study was a cross-sectional study rather than a randomly assigned blind case and control study. Therefore, interpretation of the results should be done carefully. For the generalization of these results, future study should be designed with the methodology of a double-blind randomized clinical trial.

References

1. Choi MH, Kwon KI, Kim JY, Lee JS, Kim JW, Park HK, Kim MC, Kim GH. Monitoring of total sugar contents in processed foods and noncommercial foodservice foods. Korean J Food Sci Technol 2008;40:337-42.
2. Kim KN, Kim MY, Kim EJ, Park SM, Hong JS, Cho JS. Dietary behaviors and snack consumption of primary school children in Chungbuk area. J Hum Ecol 2007;10:241-50.
3. Jo JI, Kim HK. Food habits and eating snack behaviors of middle school students in Ulsan area. Korean J Nutr 2008;41:797-808.
4. Oh KJ, Lee H. Assessment of ADHD with abbreviated Conners rating scale. Korean J Clin Psychol 1989;8:135-42.
5. Lahey BB, Pelham WE, Chronis A, Massetti G, Kipp H, Ehrhardt A, Lee SS. Predictive validity of ICD-10 hyperkinetic disorder relative to DSM-IV attention-deficit/hyperactivity disorder among younger children. J Child Psychol Psychiatry 2006;47:472-9.
6. Schnoll R, Burshteyn D, Cea-Aravena J. Nutrition in the treatment of attention-deficit hyperactivity disorder: a neglected but important aspect. Appl Psychophysiol Biofeedback 2003;28:63-75.
7. Rader R, McCauley L, Callen EC. Current strategies in the diagnosis and treatment of childhood attention-deficit/hyperactivity disorder. Am Fam Physician 2009;78:657-65.
8. Cho SC, Shin MS. Diagnosis and Assessment of Mental Pathology for Child. Seoul: Hakjisa Publishing Inc.; 2006.
9. Dykman KD, Dykman RA. Effect of nutritional supplements on attentional-deficit hyperactivity disorder. Integr Physiol Behav Sci 1998;33:49-60.
10. Chung HK, Park SS. The effect of sugar intake on attention deficit hyperactivity disorder of school children. Korean J Nutr 1995;28:644-52.
11. Lee JK, Rhie SG. The effect of carbohydrate processed snacks on middle school students' emotional intelligence. Korean J Community Living Sci 2008;19:335-51.
12. Lim KH, Cho BH. The prevalence of ADHD in elementary school children. J Elementary Educ 2004;17:235-60.
13. Im HJ, Ghim HR, Sohn JW, Kim YR. The effects of the combined treatment of social skills training and parent training in school-aged children with ADHD. J Child Educ 2008;17:225-39.
14. Yun JJ, Kim YH. Problem behaviors related to attention-deficit hyperactivity disorder children. J Hum Ecol 1999;2:39-51.
15. Kavale KA, Forness SR. Hyperactivity and diet treatment: a meta-analysis of the Feingold hypothesis. J Learn Disabil 1983;16:324-30.
16. Wolraich M, Milich R, Stumbo P, Schultz F. Effects of sucrose ingestion on the behavior of hyperactive boys. J Pediatr 1985;106:675-82.
17. Korea Health Industry Development Institute. The third Korea National Health & Nutrition Examination Survey, 2005-Nutrition Survey (I). 2006.
18. Park HY, Kim KN. Relationships among snacks, unbalanced diet, and eating behavior of middle school students. J Korean Home Econ Educ Assoc 1995;7:79-89.
19. Cho YK. Survey on screening and subtype of children with attention-deficit/hyperactivity disorder: Based on teachers' observation and rating in the inclusive educare center. Korea J Child Care Educ 2007;50:275-95.
20. Goyette CH, Conners CK, Ulrich RF. Normative data on revised Conners parent and teacher rating scales. J Abnorm Child Psychol 1978;6:221-36.
21. The Korean Nutrition Society. Dietary reference intakes for Koreans. 2005.
22. United States Department of Agriculture (USDA) [Internet]. USDA Nutritional Nutrient Database for Standard Reference, Release 16. Nutrient Lists. 2004. [Accessed on 2009 March 20]. Available from: http://www.usda.gov/wps/portal/usdahome.
23. Korea Food and Drug Administration. Monitoring of total sugar and sodium contents. 2007. [Accessed on 2009 March 20]. Available from: http://www.kfda.go.kr/intro.html.
24. Korean Society for the Study of Obesity. Guideline for Childhood and Adolescent Obesity Management. 2006. p.158.
25. Ministry of Environment [Internet]. Exposure of secondary smoking of elementary school child and an increase of prevalence rate of ADHD. 2008. [Accessed on 2009 March 31]. Available from: http://me.go.kr/kor/notice/notice_02_01.jsp?id=notice_02&

mode=view&idx=166169.

26. McCann D, Barrett A, Cooper A, Crumpler D, Dalen L, Grimshaw K, Kitchin E, Lok K, Porteous L, Prince E, Sonuga-Barke E, Warner JO, Stevenson J. Food additives and hyperactive behaviour in 3-year-old and 8/9-year-old children in the community: a randomised, double-blinded, placebo-controlled trial. Lancet 2007; 370:1560-7.

27. Striegel-Moore RH, Thompson D, Affenito SG, Franko DL, Obarzanek E, Barton BA, Schreiber GB, Daniels SR, Schmidt M, Crawford PB. Correlates of beverage intake in adolescent girls: the National Heart, Lung, and Blood Institute Growth and Health Study. J Pediatr 2006;148:183-7.

28. Braun JM, Kahn RS, Froehlich T, Auinger P, Lanphear BP. Exposures to environmental toxicants and attention deficit hyperactivity disorder in U.S. children. Environ Health Perspect 2006;114: 1904-9.

29. Ministry of Health & Welfare. The 4th Korea National Health and Nutrition Examination Survey. 2008.

30. Kim YK. Parent's behavior and perception of their kids' snacking behavior and dietary life education. Korean J Food Cookery Sci 2010;26:596-602.

31. Idaho State Department of Education [Internet]. New nutrition standards for IDAHO school meals. [Accessed on 2010 November 31]. Available from: http://healthymeals.nal.usda.gov/hsmrs/Idaho/Nutrition%20Standards/NutritionStandardsBookletFinal.pdf.

32. Kim WK, Cho S. Sugar and cognitive performance. Korean J Nutr 2007;40(Suppl):50-65.