Association between dietary behaviors and attention-deficit/hyperactivity disorder and learning disabilities in school-aged children

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ABSTRACT

We aimed to comprehensively investigate the associations between a wide range of measures of dietary behaviors and learning disabilities and attention-deficit/hyperactivity disorder (ADHD) in community-dwelling Korean children in order to generate hypotheses for future work. The present study included 986 children [507 boys, 479 girls; mean (S.D.) age = 9.1 (0.7) years] recruited from five South Korean cities. Children's dietary behaviors were assessed by the mini-dietary assessment (MDA) for Koreans. It consists of ten items to assess the level of intake of dairy products, high-protein foods, vegetables, fried foods, fatty meats, salt, and sweetened desserts and whether the subject is eating three regular meals and has a balanced diet. Learning disability was assessed via the Learning Disability Evaluation Scale (LDES). ADHD was assessed via the Diagnostic Interview Schedule for Children version—IV and the ADHD rating scale, and ADHD-related behavioral problems were assessed via the Child Behavior Checklist. After adjusting for potential confounders, a high intake of sweetened desserts, fried food, and salt is associated with more learning, attention, and behavioral problems, whereas a balanced diet, regular meals, and a high intake of dairy products and vegetables is associated with less learning, attention, and behavioral problems. Our data suggest that existing encouraged dietary habits mostly have beneficial effects on learning, attention, and behavioral problems in Korean children. These findings are in general the same results in other studies on ADHD children in other countries. However, the cross-sectional study design prevents our ability to assess causal relationships.

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1. Introduction

There have been numerous studies about the beneficial and detrimental effects of specific nutrients and ingredients on cognition and behavior (Bryan et al., 2004; Stahl et al., 2008; Itua and Naderali, 2010; Spencer, 2010). Recent years have seen a move away from analyzing the associations between isolated nutrients and health to the consideration of the effects of dietary behavior or patterns such as 'junk food' consumption and a Mediterranean diet, which is heavily loaded with fruits, vegetables, and fish (Hu, 2002; Sofi et al., 2008; Akbaraly et al., 2009; Wiles et al., 2009).

Looking at the potential effects of dietary behavior on learning and behavior in young people is of special importance because childhood and adolescence are crucial periods for acquiring factual knowledge as well as developing behavioral and social skills. Despite this importance, there have been relatively few studies on the learning and behavioral effects of a variety of dietary behaviors in children and adolescents, especially in community samples.

Attention-deficit hyperactivity disorder (ADHD) is a major behavioral problem that has attracted much attention and has been associated with the presence of certain elements in the diet. One hypothesis is that food intolerance, food additives, sugar intake, a low micronutrient intake, and polyunsaturated fatty acid (PUFA) deficiency predispose children to ADHD and related behavioral symptoms, such as hyperactivity, delinquency, and aggressive behaviors (Bellisle, 2004; Benton, 2007, 2008; Sinn, 2008; Sinn et al., 2008; Benton, 2010).

With regard to the cognitive and learning abilities of children and adolescents, the effects of malnutrition (Stevens et al., 1995; Bryan et al., 2004), breakfast consumption (Michaud et al., 1991; Chandler et al., 1995; Wyon et al., 1997), and intake of specific micronutrients and PUFA (Stevens et al., 1995; Bellisle, 2004; Bryan et al., 2004) have been investigated.

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Dietary habits are different in various countries. The traditional Korean diet is characterized by low-fat and high-vegetable and cereal intakes (Kim and Oh, 1996). The dietary pattern of Koreans has changed since the introduction of Western dietary culture, in which caused a large increase in the consumption of animal food products and a fall in total cereal intake. However, cereals and vegetables are still the main ingredients of the Korean diet (Kim et al., 2000; Lee et al., 2002; Ministry of Health and Welfare and Korea Centers for Disease Control and Prevention, 2010). Although fat intake has remained very low compared to Western countries, the percentage of energy from fat increased rapidly from $\approx 7\%$ in 1972 to $\approx 19\%$ in 2009 (Kim et al., 2000), and an increase in the intake of junk food, especially sweetened desserts, including snacks and soda, is of particular concern in Korean children and adolescents (Song et al., 2005; Ministry of Health and Welfare and Korea Centers for Disease Control and Prevention, 2010). Another concern is the high salt content of Korean food such as kimchi, soy sauce, and soybean paste. The Korean population has one of the highest 24-h urinary sodium excretions in the world (Joossens et al., 1996), and high salt consumption has attracted much attention in Korea as an important risk factor for several medical problems (Kesteloot et al., 1980; Sasaki et al., 1995; Joossens et al., 1996).

Previous studies that examined the effect of diet on children's learning and behavior are restricted to only a few specific nutrients or foods, such as PUFA, food additives, and junk food. The impact of several dietary behaviors which are generally encouraged or limited for physical health on learning and behaviors has not been well-studied. In addition, most studies were conducted in Western countries, thus Asian studies are needed to compare similarities and differences between cultures. Moreover, most studies are limited to clinical populations, such as hyperactive children (Wolraich et al., 1985; Kozielec and Starobrat-Hermelin, 1997; Konofal et al., 2004; Sinn et al., 2008), children with PDD (Richardson and Montgomery, 2005), and adolescent offenders (Schoenthaler and Bier, 2000; Gesch et al., 2002), and only a few studies have been performed in large community samples of children (Lien et al., 2006; McCann et al., 2007; Feinstein et al., 2008; Peacock et al., 2011). Thus, we comprehensively investigated the associations between a wide range of measures of dietary behaviors and learning disabilities and ADHD in community-dwelling Korean children in order to generate hypotheses for future work.

2. Methods

2.1. Participants

This study is a part of the three-year research project titled, "The effects of pollution on neurobehavioral development and future policies to protect our children," funded by the Korean Ministry of Environment's Eco-Technopia 21 Project. We recruited participants from five different administrative regions in Korea: Seoul, Seongnam, Incheon, Ulsan, and Yeoncheon. We selected two to three schools from each region that best represented the local demographics, for a total of thirteen schools, and sent letters to the parents of third and fourth grade children (age range 8–11) inviting them to participate in our study. Schools in the center of each region were chosen to reflect a microcosm of each region. We gave the parents and children detailed information about the study and then obtained written informed consent before any child entered the study. The study protocol was approved by the institutional review board of the Seoul National University Hospital.

The parents completed a questionnaire about demographics and other relevant information concerning the children, including questions about their children's dietary behavior and learning, attention, and disruptive behavioral problems.

2.2. Assessment of the children's dietary behavior

We assessed the children's dietary behavior using the mini-dietary assessment (MDA) for Koreans (Kim et al., 2003). It consists of ten items (see Table 2). This ten-component system was devised based on the dietary guidelines and food pyramid for Koreans. The system contains four food elements whose consumption is encouraged (milk, meat, vegetables, and fruits) and three food elements of which use is limited (fat, salt, or sugar). Also included are elements on dietary regulation and variety. The parent of a participating child is to check one of three options, 'always,' 'usually', and 'seldom,' in six items containing encouraged dietary behaviors (items 1, 2, 3, 4, 8, and 10) and in four items containing limited dietary behaviors (items 5, 6, 7, and 9), which have scores

of 5, 3, and 1 and 1, 3, and 5, respectively. The sum of the scores is calculated, and healthier dietary behavior is indicated by higher scores. The mean total MDA score was 31.34 of a possible 50 points in the previous study (Kim et al., 2003).

2.3. Assessment of the children's learning disability

The Learning Disability Evaluation Scale (LDES) was used to evaluate the children's learning disabilities. The LDES (McCarney, 1996) consists of 88 items and seven subscales (listening, thinking, speaking, reading, writing, spelling, and mathematical calculations). The sum of each subscale's item scores are converted to age-adjusted standard scores, in which better performance is indicated by higher scores. In addition, as a global measure of learning disability, the learning quotient (LQ) is derived from the sum of the seven subscales' standard scores. The Korean version of the LDES has been age-standardized and found to be a valid and reliable instrument for screening specific learning disorders (Shin et al., 1998). In this study, the parents completed the LDES.

2.4. Assessment of the children's ADHD and related externalizing problems

We used the Diagnostic Interview Schedule for Children version–IV (DISC-IV) ADHD module for diagnosing ADHD (Shaffer et al., 2000). Trained laypersons conducted face-to-face interviews with the parents at each participant's school and administered the parental version of the DISC-IV. The reliability and validity of the Korean version DISC-IV is well established (Cho et al., 2006). We assessed both definite and probable diagnoses of ADHD. Definite ADHD was diagnosed if all DSM-IV criteria were met. Probable ADHD was operationally defined as the presence of at least three inattentive and/or hyperactive/impulsive symptoms, provided some impairment from the symptoms was present in two or more settings. A child must also meet the DSM-IV ADHD age-of-onset and impairment criteria to be diagnosed with probable ADHD.

We used the parental version of the ADHD Rating Scale–IV (ADHD-RS) (DuPaul et al., 1998) to evaluate the severity of the ADHD symptoms. It is composed of 18 items reflecting the DSM-IV diagnostic criteria. The reliability and validity of the Korean version ADHD-RS (K-ADHD-RS) are well established (So et al., 2002).

We also used the Child Behavior Checklist (CBCL) (Achenbach, 1991) to evaluate externalizing symptoms that commonly present in ADHD children. The CBCL is a parent-report questionnaire by which the child is rated on various behavioral and emotional problems. Among the several subareas included in the CBCL, delinquent behavior, aggressive behavior, and externalizing problems were measured in this study. The reliability and validity of the Korean version of the CBCL (K-CBCL) are well established in Korean children and adolescents (Oh et al., 1997).

2.5. Assessment of the children's cognitive functioning

We administered the abbreviated form of the Korean Educational Development Institute's Wechsler Intelligence Scales for Children (KEDI-WISC) (Park et al., 1996), which tests vocabulary, arithmetic, picture arrangement, and block design, to each child. The sums of the first two subtests' age-adjusted T-scores were used to estimate the verbal intelligence quotient (VIQ), and the sums of the last two were used to estimate performance IQ (PIQ) (Park et al., 1996). Scores from the abbreviated battery correlate well with the WISC full scale IQ (FSIQ) in the widely translated original instrument, the revised version of the WISC, and the standardized Korean version, the KEDI-WISC (Kim and Kim, 1986). The FSIQ was used as a covariate in this study.

2.6. Statistical analysis

Group differences between children included and excluded in this study were compared using Student's t-test for continuous variables and the chi-squared test for categorical variables. Unadjusted and adjusted regression analyses were carried out to examine the association between each dietary behavior, and learning, ADHD symptoms, and related externalizing problems. In all analyses, the three-level dietary behavior variable was treated as a continuous measure (seldom: 1, usually: 2, and always: 3); this approach was supported by examination of the mean learning, attention and behavioral scores in each category and statistical tests for linear trends. We report unadjusted and adjusted coefficients with 95% confidence intervals. To identify possible confounders mediating the association between dietary behavior and learning and ADHD symptoms, we conducted Pearson correlation analyses between possibly relevant variables and each dietary behavior. We selected any variables showing significant association with dietary behavior at an alpha level < 0.05 as covariates in adjusted regression analyses. All adjusted models included age, gender, IQ, paternal and maternal educational years, socio-economic state, residential area (urban or rural), and body mass index (BMI) as covariates.

The ORs and 95% confidence intervals were derived from a series of logistic regression analyses using the diagnosis of definite or probable ADHD as the main outcome variable and each category of dietary behavior as the principal predictor after adjustment for age, gender, FSIQ, paternal and maternal educational years, socio-economic state, residential area, and body mass index (BMI).

All statistical analyses were performed using SPSS (version 12.0; SPSS Inc., Chicago, IL), with statistical significance defined as an alpha level < 0.01 to provide some control for type I errors due to multiple comparisons.