Association between childhood obesity and familial salt intake: analysis of data from Korean National Health and Nutrition Examination Survey, 2014–2017

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Abstract. High salt intake is known as a risk factor of childhood obesity. As family members share not only genes but also their diet habit, parents’ salt intake may affect to their children’s obesity. In this study, we investigated correlations between childhood obesity and parents’ or children’s sodium intakes based on a nationwide survey data. From the Korean National Health and Nutrition Examination Survey data from 2014 to 2017, 802 boys and 657 girls aged 10–18 years, and their parents were included. BMI z-score and 24-hour urinary sodium excretion, which is estimated through Tanaka’s equation, were used to examine associations between obesity and sodium intakes. The BMI status and the prevalence of obesity between children and their parents showed strong positive correlations in both sexes (all \( p \leq 0.001 \)). The urinary sodium excretion between children and their parents showed positive correlations in both sexes (all \( p \leq 0.05 \)). Children with higher urinary sodium excretion showed higher BMI (in both sexes, \( p \leq 0.001 \)) and higher parental obesity compared to those with lower urinary sodium excretion, however, statistical significances of the latter relationship were varied by sex. In conclusion, our study suggests close relationship between childhood obesity and their sodium intakes, which also correlate well with parental BMIs and diet behavior. Therefore, parental education and active participation could be crucial in regulating childhood obesity.

Key words: Pediatric obesity, Sodium intake, Family education
enough data for salt intakes within a family. The Korean National Health and Nutrition Examination Survey (KNHANES) data enabled us to analyze relationships between obesity of children and their parents and dietary salt intakes based on urinary sodium excretions of their family. Therefore, we assumed that salt intakes of parents may affect to child’s obesity and salt intakes even after controlling for parental obesity.

**Methods**

**Subjects**

Study population of this study is based on data from the KNHANES during the period of 2014–2017. The KNHANES is a cross-sectional, nationwide survey, which consists of a health interview, behavioral and nutritional surveys and medical examinations, conducted by the Division of Chronic Disease Surveillance, Korean Centers for Disease Control and Prevention in Korean Ministry of Health and Welfare. Data were collected by household interviews and by standardized physical exam conducted in mobile exam centers [18]. The KNHANES was conducted according to the guidelines from Helsinki Declaration.

During 2014–2017 surveys, 192 sampling units each year, total of 768 sampling units were randomly selected. A total of 31,207 individuals were participated in the health interviews and examinations, as well as the nutrition survey; of these, 2,988 individuals (1,583 boys and 1,405 girls) were aged between 10–18 years. All survey participants provided informed consent. The institutional review board (IRB) of the Korean Centers for Disease Control and Prevention approved using this open data.

From subjects, we excluded those with missing data of their body weight, height, urine sample data or data of their parents (Fig. 1). Therefore, 1,459 children (802 boys and 657 girls) were included in this study.

**Measurements**

The anthropometric measurements of individuals were measured in the mobile exam center following standard KNHANES protocols. Height was twice measured to the first decimal place using a SECA 225 device (Vogel & Halke; Hamburg, Germany) and weight was measured to the first decimal place with a GL-6000-20 digital scale (CAS Korea; Seoul, Korea). Body mass index (BMI) was calculated by dividing weight by height squared (kilograms per square meter) and the z-scores for height, weight, and BMI were derived using the 2017 Korean growth standard [19]. The waist circumference (WC) was measured at the narrowest part between the lower rib margin and the iliac crest to the nearest 1 mm and presented in waist to height ratio (WHR) to establish standardization [20]. The definition of BMI category was as follows; obesity, BMI ≥ 95th percentile; overweight, 94th percentile ≥ BMI ≥ 85th percentile; normal weight, 84th percentile ≥ BMI ≥ 5th percentile; and underweight, 5th percentile ≥ BMI [21]. For parents, obesity was defined when the BMI >25 kg/m², according to Asian BMI guideline proposed by WHO [21]. Therefore, parental obesity was defined when at least one parent’s BMI is over 25 kg/m².

Spot urine samples were obtained from the subjects and stored at –20°C until analysis. Urinary sodium (Na) and urinary creatinine [20] were measured using a Hitachi 7600 automatic analyzer (Hitachi, Tokyo, Japan) in a central laboratory. Using urine lab, sodium intake was assessed by sodium excretion using Tanaka’s formula [22], which is one of the most accurate estimates of 24-hour urine sodium excretion among several equations and it could be applied to children [23].

Predicted 24 h urinary Cr excretion (mg/d) = −2.04 × age (year) + 14.89 × weight (kg) + 16.14 × height (cm) − 2,244.45

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x_{Na}\left(mg/d\right) = \frac{\text{spot urine Na}}{\text{spot urine Cr}} \times \text{Predicted 24 h urinary Cr excretion (mg/d)}
\]

Calculated 24 h urinary Na excretion (mg/d) = 21.98 × \(x_{Na}\)^{0.392}

The metabolic syndrome of parents was defined by NCEP ATP III panel as the presence of three or more of the risk determinants [24]. Sociodemographic information such as education status and monthly household...
incomes from the health reviews were also collected. Median value of household income 4 million Korean Won (KRW), according to ‘2017 Seoul institute policy report’, was used in the analysis. As there were sexual differences in anthropometric characteristics, we analyzed obesity and sodium excretion data separating by sex as previous studies [25, 26].

**Data analysis**

Data were analyzed using PASW statistics software (SPSS version 23.0, IBM SPSS Inc., Chicago, IL, USA). All data are presented as the means ± standard errors or percentages (%) for categorical variables. Because there were sexual differences in clinical/biochemical characteristics, all data was analyzed separately by sex as in previous studies [23, 24]. Subjects were divided into three or four subgroups according to obesity or calculated 24 h urinary sodium excretion, respectively. Comparisons of clinical continuous parameters between groups were analyzed using one-way ANOVA and Scheffe’s tests. Comparison of prevalence of obesity between groups was analyzed by chi-squared test. Simple correlation analysis was used to identify associations between continuous variables like BMI status or sodium excretion. Odds ratio with confidential interval (C.I.) was calculated to predict effect of parental obesity to child’s obesity compared to normal weight parents. Comparison of 24 hr urinary sodium excretion between sexes was analyzed using Student’s t-test. *P*-value of <0.05 was considered as statistically significant.

**Results**

**Clinical characteristics of subjects (Table 1)**

The prevalence rates of obesity were 12.8% in boys and 11.0% in girls. The prevalence rates of their parental obesity (father and mother) were 46.8% and 29.2%, respectively for boys, and 46.1% and 23.1%, respectively for girls. The BMI status showed strong correlation between children (z-score) and their parents in both sexes {boy, \( r = 0.282 \) (father), 0.272 (mother); girl, \( r = 0.259 \) (father), 0.353 (mother); all \( p < 0.001 \)}. The parental obesity were significant predictors of child’s obesity with odds ratio of 2.740 (C.I. 1.785–4.255) with fathers’ and 2.112 (C.I. 1.276–3.498) with mothers’ in boys, and 2.608 (C.I. 1.691–4.022) with fathers’ and 3.784 (C.I. 2.284–6.267) with mothers’ in girls (all \( p < 0.001 \)).

Age of parents, house income, and the prevalence of metabolic syndrome (16.3% in fathers; 7.9% in mothers) showed no relationship with child’s obesity. Child’s obesity and parents’ educational status showed negative relationship in girls (father’s education, \( r = –0.079, p = 0.042 \); mother’s education, \( r = –0.132, p = 0.001 \)), but they showed no significant correlations in boys.

| Table 1 | Clinical characteristics of subjects, KNHANES 2014–2017 |
|---------|--------------------------------------------------------|
| Total (n = 1,459) | Boys (n = 802) | Girls (n = 657) | *p*-value |
| Age (year) | 13.70 ± 0.09 | 13.70 ± 0.10 | 0.996 |
| Height z-score | 0.587 ± 0.038 | 0.401 ± 0.039 | 0.001 |
| Weight z-score | 0.359 ± 0.043 | 0.254 ± 0.436 | 0.091 |
| BMI z-score | 0.107 ± 0.047 | 0.063 ± 0.048 | 0.523 |
| WHtR | 0.444 ± 0.002 | 0.430 ± 0.002 | <0.001 |
| WHtR >0.5, n (%) | 143 (17.8%) | 68 (10.4%) | <0.001 |
| BMI category, n (%) | | | |
| Underweight | 63 (7.9%) | 38 (5.8%) | |
| Normal | 542 (67.6%) | 482 (73.4%) | 0.135 |
| Overweight | 94 (11.7%) | 65 (9.9%) | |
| Obese | 103 (12.8%) | 72 (11.0%) | |
| Father BMI (kg/m²) | 25.08 ± 0.11 | 24.85 ± 0.12 | 0.156 |
| Age of father (year) | 46.22 ± 0.16 | 46.19 ± 0.17 | 0.881 |
| Mother BMI (kg/m²) | 23.07 ± 0.12 | 23.15 ± 0.13 | 0.656 |
| Age of mother (year) | 43.46 ± 0.15 | 43.49 ± 0.16 | 0.896 |
| Education status above college, n (%) | | | |
| Father | 423 (52.7%) | 364 (55.4%) | 0.844 |
| Mother | 388 (48.4%) | 363 (55.3%) | 0.439 |
| House income >4 × 10⁶ KRW, n (%) | 557 (69.5%) | 471 (71.7%) | 0.361 |

Abbreviations: BMI, body mass index; WHtR, waist to height ratio
Sodium excretions of subjects (Table 2)

The mean values of 24 hr urinary sodium excretion are 2,740.8 ± 24.7 mg/day and 2,506.3 ± 26.4 mg/day in boys and girls, respectively, and they showed significant difference between sexes (p < 0.001). The relationship of urinary sodium excretion between children and both of their parents showed significant positive correlations in both sexes {boy, r = 0.131 (father), 0.096 (mother); girl, r = 0.090 (father), 0.163 (mother); all p < 0.05}. The child’s BMI z-score and child’s urinary sodium excretion showed positive relationship in the simple correlation analysis in both sexes (boy, r = 0.308; girl, r = 0.209; both p < 0.001).

When subjects were divided into quartiles according to 24 hr urinary sodium excretion, children with high urinary sodium excretions showed, high height z-score, weight z-score, BMI z-score, and WHtR compared to those with low urinary sodium excretions in both sexes (all p < 0.001, Table 2). The prevalence of child’s obesity was high in high sodium excretion quartile group than in low sodium excretion quartile group in both sexes (boy, r = 0.246; girl, r = 0.168; both p < 0.001, Fig. 2). Parental BMI and parental sodium excretion were significantly different between quartile groups in boys (all p < 0.05). However, in girls, only parental sodium excretion, not parental BMI, showed significance between quartile groups (Table 2). Parents’ education status, monthly house income, and the prevalence of parents’ metabolic syndrome showed no relationship with child’s urinary sodium excretion.

Familial sodium excretions and childhood obesity (Table 3)

The parental BMIs showed significantly different between groups according to child’s BMI category in both sexes (all p < 0.001). Children with overweight and obesity showed high urinary sodium excretion and parental BMI, compared to those with underweight and normal weight groups in both sexes (all p < 0.001). The parent’s urinary sodium excretion showed similar tendency with child’s urinary sodium excretion according to child’s BMI category, but statistical significance was varied according to sex. In girls, father’s urinary sodium excretion showed significant difference between child’s BMI category groups (p = 0.01), however, maternal urinary sodium excretion in girls and parental urinary sodium excretions in boys showed marginal significance (Table 3).

Discussions

In summary, we confirmed strong positive correlations of obesity and urinary sodium excretions between
Higher urinary sodium excretions were more prevalent in obese children than normal weight children aged 10–18 years. Parental urinary excretions tended to have positive correlation with child’s obesity. When children were divided according to urinary sodium excretion, boys show significant correlations with their parental BMIs and urinary sodium excretion. Altogether, this study suggests that childhood obesity is closely related to family’s salt intakes, but strength of association could be different by gender or other confounding factors.

A cross-sectional study of Australian school children aged 4–12 years found a positive association between 24-hour sodium excretion and obesity [27]. Cohort study in Germany suggested that a high intake of processed salty foods could have a negative impact on body weight status in children [28]. Population-based cross-sectional studies in Korea also have found significant positive associations between high sodium intake and obesity risk in children and adolescents as well [29, 30]. In cross-sectional study from US adolescents, this tendency was explained by effects of inflammatory-related markers [31]. Furthermore, it has been suggested in experimental level, that high sodium diet provokes obesity by stimulating thirst and inducing higher adiposity [32, 33].

**Fig. 2** The prevalence of child’s obesity was higher in high sodium excretion quartile group than in low sodium excretion quartile group in boys (A) and girls (B) significantly.

**Table 3** Clinical characteristics of groups according to child’s BMI category

|                  | Boys | Girls |
|------------------|------|-------|
|                  | Underweight (n = 63) | Normal weight (n = 542) | Overweight & Obese (n = 197) | p-value | Overweight (n = 38) | Normal weight (n = 482) | Overweight & Obese (n = 137) | p-value |
| Urinary Na excretion (mg/day) | 2,422.6 ± 75.6 | 2,665.2 ± 28.3 | 3,050.5 ± 52.4 | <0.001 | 2,291.1 ± 93.9 | 2,456.0 ± 29.3 | 2,743.1 ± 64.9 | <0.001 |
| Father’s BMI (kg/m²) | 23.66 ± 0.36 | 24.79 ± 0.12 | 26.32 ± 0.24 | <0.001 | 23.51 ± 0.44 | 24.62 ± 0.13 | 26.02 ± 0.27 | <0.001 |
| Father’s urinary Na excretion (mg/day) | 3,082.9 ± 89.6 | 3,144.8 ± 30.4 | 3,240.1 ± 58.5 | 0.076 | 3,212.1 ± 103.3 | 3,114.7 ± 32.8 | 3,204.6 ± 63.7 | 0.010 |
| Mother’s BMI (kg/m²) | 21.33 ± 0.31 | 22.91 ± 0.13 | 24.09 ± 0.28 | <0.001 | 21.42 ± 0.39 | 22.82 ± 0.14 | 24.79 ± 0.30 | <0.001 |
| Mother’s urinary Na excretion (mg/day) | 2,896.2 ± 83.7 | 2,913.5 ± 29.5 | 2,947.3 ± 51.5 | 0.527 | 2,907.4 ± 95.6 | 2,919.9 ± 30.9 | 3,062.3 ± 67.2 | 0.053 |

Abbreviations: BMI, body mass index; Na, sodium.
regulating salt intake in obesity in children and adolescents.

A high salt diet may stimulate to consume more energy-dense foods and to drink more soft drinks in children, in a sense of being homeostatic trigger of thirst [34]. Proven effectiveness of dietary salt reduction on decreasing risks of cardiovascular disease including hypertension, kidney disease, and metabolic syndrome from many studies can be explained in the same sense [35, 36]. However, in latest works, high salt intakes have solely been proposed as potential risk factor for obesity in children and adolescents, independent of calorie intakes or sugar consume [37]. Mechanism is not clear yet, but cross-sectional and experimental studies have shown positive relationship between dietary salt intake and adipose fat [27-29, 31, 33].

In line with other studies [25, 26], there was gender difference of urinary sodium excretion which might also impact to relationship with parental obesity. The reason for gender difference could not be clearly verified in our study but considering the age of our subjects, which is a period of pubertal maturation, the sex hormone gene on salt sensitivity may have possible role on this gender difference [38].

Lately, family interventions have been emphasized not just for their effectiveness on obesity reduction and metabolic benefits, but for its many beneficial outcomes on public health as well. The clinical practice guideline for children’s obesity prevention also emphasizes the involvement of entire family [39]. Familial intervention program has been conducted in China to reduce salt intake in children and their families and their results showed successful salt reduction in family led to decline in blood pressure [40]. Our study proposes further evidence for the possibility and necessity of family intervention on salt intake reduction and we expect its effect to be similar on obesity prevention as well.

Because of inaccuracy of diet recall and history, 24 hr urine collection is considered to be most reliable in measuring sodium intake [41]. However, collecting complete 24 hr urine sample is quite difficult, many previous studies have used other surrogate measure using spot urine samples and did not provide 24-hour urine collection data, probably due to large number of study population and low compliance during gathering [18, 30]. Therefore, we used Tanaka’s equation to estimate 24 hr urinary sodium excretion in this study. This equation has been used in many of recent studies, not just to estimate sodium intake, but for analyzing relationship between urinary sodium excretion and obesity, fatty liver, and the other metabolic syndrome as well [30, 42, 43].

There are some limitations in this study. First, analysis of many other confounding factors to obesity was limited such as pubertal status, familial history of metabolic syndrome, or levels of several adipokines. Second, there was no additional data related to sodium homeostasis, including total calorie intake, past medical history, or medications, such as diuretics. Regardless of these limitations, it is the first nationwide cross-sectional study to research relationships between parental sodium intake and children’s obesity, as far as we know. It was possible because highly credible survey of the KNHANES used family code to identify familial relationship between data of children and adults. Moreover, its relatively large sample size helped us to stratify subjects into several subgroups to visualize trends with sufficient statistical analysis.

In conclusion, this study suggests close relationships between childhood obesity and their familial obesity and sodium intake. Therefore, importance of parental education and their active participation in regulating childhood obesity should be overemphasized.

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The authors declare no conflict of interest.

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