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Relationship of sodium intake with obesity among Korean children and adolescents: Korea National Health and Nutrition Examination Survey

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Abstract

We investigated whether dietary and urinary Na is associated with adiposity in Korean children and adolescents (10–18 years), a population with a high salt intake. Study subjects were Korean children and adolescents who participated in the cross-sectional nationally representative Korea National Health and Nutrition Examination Survey (2010–2011). This study used measures of dietary (24-h dietary recall) and urinary Na (Na:creatinine ratio) and three methods to determine obesity (BMI, waist circumference (WC) and total body per cent fat (TBPF)). Higher Na intake was significantly associated with obesity, adjusting for the covariates. Subjects in the highest tertile of urinary Na excretion had a significantly higher OR for higher adiposity compared with those in the lowest tertile (multivariate-adjusted OR 3·13 (95 % CI 1·81, 5·50) for BMI, 2·15 (95 % CI 1·27, 3·66) for WC and 1·92 (95 % CI 1·29, 2·86) for TBPF, respectively). Na intake estimated by the 24-h recall method also showed significant association with adiposity (multivariate-adjusted OR 2·79 (95 % CI 1·66, 4·68) for BMI and 2·14 (95 % CI 1·25, 3·67) for WC, respectively). The significant associations between Na and adiposity remained significant after additionally adjusting for sugar-sweetened beverage (SSB) consumption. Our results revealed a significant positive association between urinary and dietary Na and adiposity in Korean children and adolescents, independent of SSB consumption.

Key words: Sodium: Obesity: Children: Korea National Health and Nutrition Examination Surveys

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High Na intake has been linked to a variety of increased health risks such as hypertension[1,2], CVD[3,4], stomach cancer[5–7] and type 2 diabetes[8]. In addition to the traditionally recognised health effects of high Na intake, obesity has recently gained much interest as another possible related health outcome[5].

Although several studies including a longitudinal study have reported significant associations between Na intake and obesity among adults[9–14], relatively limited evidence is available among children and adolescents[15–18]. Investigation of the associations between Na intake and obesity, however, has been limited by weakness of assessment methods of both Na intake and obesity. Quantification of dietary salt intake is imperfect because of the limitations in dietary assessment methods and food databases[19,20]. The 24-h urinary Na excretion measurement, generally considered as the gold standard[20], is also limited by the difficulty of urine collection for 24 h. Spot urine or half-day urine measurements have been proposed as substitutes for the 24-h urine measurement in an effort to overcome the difficulty[21–23]. For obesity measures, most studies, except one study[13], used either BMI or waist circumference (WC). Although both BMI and WC are valid and widely used measures, they have their own limitations such as not being able to control for muscle mass or total fat mass[24].

Although mechanisms of the association between Na intake and obesity have not been well established, the role of soft drink consumption has been explored and shown to be significant among children and adolescents in the Western food culture[25]. This hypothesis indicates that higher energy intake from sugar-sweetened beverages (SSB) consumed to quench thirst caused by high Na intake would contribute to obesity[26,27]. Whether this pathway would also be important in non-Western food cultures has not been examined, however, Koreans are reported to have approximately three times more salt intake than the recommended level, affording a large variation of exposure level[28,29]. Korean food culture is strongly preserved with wide-range influences of Western food culture, which makes it an interesting population to investigate for an association between Na and obesity.

Therefore, this study examined whether urinary and dietary Na exposure showed independent associations with obesity across multiple obesity measures – obesity measured by BMI, abdominal obesity measured by WC and per cent body fat measured by dual-energy X-ray absorptiometry (DEXA) – in a

Abbreviations: DEXA, dual-energy X-ray absorptiometry; KNHANES, Korea National Health and Nutrition Examination Survey; MET, metabolic equivalents; SSB, sugar-sweetened beverage; TBPF, total body per cent fat; WC, waist circumference.

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nationally representative sample of Korean children and adolescents aged from 10 to 18 years.

Methods

Study design

This study analysed the Korea National Health and Nutrition Examination Survey (KNHANES). The KNHANES is an annually conducted and nationally representative survey, consisting of a health interview, behaviour and nutrition surveys and a medical examination. This cross-sectional survey utilised a stratified, multistage, cluster probability sampling design with the National Census Registry. More details of the survey design and methods are available elsewhere[30]. This study chose to use data from 2010 to 2011 because urinary Na excretion data were collected only during these 2 years[31].

The KNHANES is conducted in accordance with the Helsinki Declaration. Written informed consent was obtained from parents or guardians. Data without personal identifiable information were provided for this analysis.

Study participants

Among children aged between 10 and 18 years (*n* 1873), whose body weight, height and WC were recorded in the KNHANES 2010–2011, we excluded children with missing diet information (*n* 195) and extreme energy intake (*n* 12); the final analytical sample consisted of 1467 children and adolescents. Extreme energy intake was defined as <1673 kJ/d (400 kcal/d) or >23 848 kJ/d (5700 kcal/d) for 10–11-year-old boys, <2510 kJ/d (600 kcal/d) or >33 890 kJ/d (8100 kcal/d) for 12–18-year-old boys, <1569 kJ/d (375 kcal/d) or >21 338 kJ/d (5100 kcal/d) for 10–11-year-old girls and <2092 kJ/d (500 kcal/d) or >25 104 kJ/d (6000 kcal/d) for 12–18-year-old girls, respectively[32]. For the analysis of per cent body fat measured by DEXA, we only included subjects (*n* 1019) whose DEXA measurements were available. The age of 10 years had to be used as the lowest age because urine samples were available of individuals aged 10 years or above.

Measures

KNHANES utilises mobile examination centres where health interviews and medical examinations are conducted. The nutrition survey was conducted approximately 1 week after the health examination. This study used socio-demographic and health behaviour information from the health interviews, urinary Na, body fat and anthropometric information from the medical examination and dietary information from the nutrition survey.

Sodium intake. Na intake was assessed using two different methods: (1) dietary Na intake per 4184 kJ (1000 kcal) from a 24-h recall and (2) urinary Na:creatinine ratio. Dietary Na intake was calculated from 24-h recalls conducted by trained nutritionists with tools to help portion size estimation. To control for the reported tendency that higher food intake is naturally associated with higher Na intake[33], dietary Na density (dietary Na intake (mg)/4184 kJ (1000 kcal)) was calculated and used in the analyses. The KNHANES provided urinary Na and creatinine values from the overnight spot urine samples. From these values, we calculated the urinary Na:creatinine ratio.

Adiposity was also assessed by measuring three different parameters: (1) BMI, (2) WC and (3) total body per cent fat (TBPF). BMI was selected because it is one of the most widely used and recommended methods to determine the obesity status of children and adolescents[34]. Height and weight were measured in the mobile examination centre following standardised measurement protocols. BMI was calculated by dividing body weight by the squared body height. The age- and sex-adjusted BMI *Z* score was obtained using a Korean growth chart[35]. Children and adolescents were considered to be obese if their BMI was of the 95th percentile or greater for their age and sex or if their BMI was 25 kg/m^2 or higher, and overweight was defined as having 85th ≤ BMI < 95th percentile for age and sex[35,36]. This study used WC as a measure of abdominal adiposity[37]. WC was measured at the narrowest area between the lowest rib and the uppermost lateral border of the right iliac crest, and a WC of the 90th percentile for age and sex or greater was used as a cut-off value for abdominal adiposity[35,38,39]. TBPF was obtained by DEXA using a QDR Discovery fan beam densitometer (Hologic Inc.) according to the recommended procedures from the manufacturer. DEXA examinations were included as a part of the medical examination in 2010 and 2011; therefore, analyses of TBPF were carried out in a smaller sample (*n* 1019). The DEXA method proved to be a valid assessment tool to measure body fat[40]. Adiposity was also defined as having a TPBF >25 % for boys, >30 % for girls younger than 11 years and >35 % for girls aged 11 years or older[41].

Sugar-sweetened beverages. SSB were obtained using a single 24-h recall questionnaire, and included energetic sweeteners such as sugar-sweetened soda, soft drinks, fruit drinks, sport drinks, energy drinks, sugar-sweetened tea or sweetened milk[42]. The KNHANES food-group classification system was used to identify food groups that fell within the definition of SSB. These food codes were used to aggregate data to calculate the SSB (g/d).

Adjusting variables. Adjusting variables included age, sex and household income obtained from the Health Interview and Behavior Surveys, which were obtained through face-to-face interviews by trained interviewers. Household income quartile was used in the analyses. Physical activity was assessed by a pre-validated questionnaire in the Health Interview and Behavior Survey. The subjects specified how many hours of a day they spent doing vigorous, moderate and light activities for a usual 1 week. Subsequently, metabolic equivalents (MET)-h/week was estimated for each subject by multiplying together the number of hours per week a woman spent in a particular activity and the estimated MET score for that activity. Total energy intake was calculated using the 24-h recall data from the Nutrition Survey.

Statistical analysis

All the analyses were carried out using the survey procedures provided in SAS software 9.2, accounting for the complex survey design used, and following the analytical guidelines for KNHANES data from the Korea Center for Disease Control and Prevention[30] to estimate nationally representative values and to extrapolate the findings to the entire Korean population. Distributions of general characteristics are presented as mean values with their standard errors or weighted percentages. Differences between groups were analysed using survey means or weighted percentages for survey design. We checked the normality of urinary and dietary Na variables, which were not normally distributed. These exposure variables were then log-transformed, and we carried out further analysis. In addition, logistic regression analyses were carried out for tertiles of Na variables. A survey logistic regression was used to test the associations between tertile of Na measurements and adiposity and to calculate the crude and multivariate-adjusted OR along with 95 % CI for each tertile compared with the lowest tertile. Two multivariate models were tested to explore the roles of Na in relation to adiposity. Model 1 adjusted for age, sex (only for analysis of sex combined), household income, total daily energy intake (only for urinary Na variables) and physical activity (MET). To examine the effect of soft drink consumption, model 2 additionally adjusted for soft drink consumption in addition to all the mentioned variables in model 1. Separate analyses for each sex were also carried out. The *P* values used to test for linear trends were calculated using Na measurements as continuous variables after adjustment for confounding factors. The significance level of 0·05 was used for all statistical tests.

Results

Characteristics of the participants

Basic characteristics of socio-demographic factors, Na intake, adiposity, soft drink consumption and adjusting variables are presented in Table 1. The participants were 1467 children and adolescents with an average age of 13·4 years, and 43·6 % of the participants were girls. The daily Na intake assessed by 24-h recalls was 4305 mg. The average Na excretion estimated by morning spot urine analysis was 138 mg. Boys excreted Na significantly more than girls ($P=0·0007$), and the difference remained significant after controlling for muscle mass by dividing the Na value with creatinine. The children showed an average BMI of 20·7 kg/m^2 and a WC of 69·5 cm. The average TBPF was 26·6 %. Although average values of WC were significantly higher in boys than in girls ($P<0·0001$), adiposity rate by WC was higher in girls than in boys ($P=0·0254$). Approximately 59 % of the participants reported soft drink consumption, and soft drink consumers drank on average 398 g/d of soft drinks. Boys showed higher soft drink

Table 1. Characteristics of the participants
(Mean values with their standard errors; percentages)

Variables	Total (*n* 1467) Mean	SE	Boys (*n* 827) Mean	SE	Girls (*n* 640) Mean	SE	*P**
Predictor variables							
Dietary Na intake from 24-h recall (mg/d)	4305	104†	4799	138	3640	112	<0·0001
Dietary Na density (mg/4184 kJ per d (1000 kcal per d))	1961	33·9	1976	41·8	1940	47·9	0·5136
Spot urinary Na excretion (mmol/l)	138	1·98	143	2·68	130	2·74	0·0007
Spot urinary Na:creatinine ratio	8·97	0·20	9·33	0·28	8·49	0·26	0·0350
Outcome variables							
BMI (kg/m^2)	20·7	0·12	20·9	0·16	20·4	0·21	0·0689
Overweight by BMI (%)†	6·70		5·44		8·39		0·0498
Obesity by BMI (%)†	12·2		13·2		10·8		0·3433
WC (cm)	69·5	0·34	71·2	0·44	67·3	0·54	<0·0001
Adiposity by WC (%)†	9·81		7·89		12·4		0·0254
TBPF (%)	26·6	0·37	23·0	0·44	32·0	0·41	<0·0001
Adiposity by TBPF (%)†‡	35·2		37·4		32·2		0·1843
Adjusting variables							
Age (years)	13·4	2·53	13·5	2·49	13·4	2·57	0·1435
Household income (%)							0·2143
<$650	16·1		15·8		16·6		
$650–$1265	30·6		28·2		33·8		
$1265–$2047	27·8		28·5		26·8		
≥$2047	25·5		27·5		22·8		
Total energy intake (kJ/d)	9242	137·6	10 263	199·1	7870	137·6	<0·0001
Total energy intake (kcal/d)	2209	32·9	2453	47·6	1881	32·9	
SSB consumer (weighted %)	59·1		58·2		60·3		0·5353
SSB per consumer (g/d)§	398	18·2	437	27·5	347	18·2	0·0059
SSB per capita (g/d)	235	13·7	254	20·0	209	14·2	0·0468
MET (h/d)	31·4	1·69	37·2	2·58	23·6	1·90	<0·0001

WC, waist circumference; TBPF, total body per cent fat; SSB, sugar-sweetened beverages; MET, metabolic equivalents.
* Categorical variables were analysed using the χ^2 test; continuing variables were analysed using the *t* test.
† Obesity was defined as having a BMI ≥95th percentile for age and sex or ≥25 kg/m^2; overweight was defined as having 85th≤ BMI <95th percentile for age and sex; abdominal adiposity as a WC ≥90th percentile for age and sex in the study sample; as a TPBF >25 % for boys, >30 % for girls younger than 11 years and >35 % for girls aged 11 years or older.
‡ Analysis was conducted (*n* 1019) in a subsample of the subjects with dual-energy X-ray absorptiometry, the TBPF.
§ Analysis was completed in a subsample of SSB consumers only.

consumption than girls ($P = 0{\cdot}0059$). The average MET was 31·4 h/d, and boys reported significantly higher MET than girls ($P < 0{\cdot}0001$).

Association between urinary sodium excretion and adiposity

The spot urinary Na:creatinine ratio (Table 2), used to estimate dietary Na intake, showed significant associations with BMI, WC and TBPF ($P < 0{\cdot}05$). Using BMI, risk of 'overweight' was not significantly associated with urinary Na:creatinine ratio, but risk of 'obesity' showed consistent and significant association with higher multivariate OR around three than OR of WC or TBPF. Significant dose–response relationships were also found in associations between urinary Na:creatinine ratio and risk of obesity assessed by BMI in both boys and girls ($P < 0{\cdot}05$).

The urinary Na:creatinine ratio showed significant association with risk of adiposity assessed by WC only in boys in the highest tertile group with OR of 2·26 (95 % CI 1·02, 4·99). The dose–response relationship was also significant at $P < 0{\cdot}05$. The multivariate-adjusted OR for adiposity risk assessed by TBPF in children of the highest tertile of urinary Na:creatinine ratio in model 1, compared with the lowest tertile, were 2·13 (95 % CI 1·15, 3·97; $P_{\text{for trend}} = 0{\cdot}0166$) for boys and 1·75 (95 % CI 0·96, 3·24; $P_{\text{for trend}} = 0{\cdot}0662$) for girls, respectively.

The addition of soft drink consumption into the multivariate logistic model (model 2) did not create any statistically significant differences in the patterns of the association between urinary Na excretion and adiposity (Table 2). Soft drink consumption itself was not significantly associated with the risk of adiposity (data not shown).

Association between dietary sodium intake and adiposity

Table 3 shows varying degrees of associations between dietary Na density (Na/4184 kJ (1000 Kcal) of E) estimated from 24-h recalls and the three adiposity measures. The multivariate-adjusted OR for overweight risk assessed by BMI, obesity risk assessed by BMI and adiposity risk assessed by WC in children of the highest tertile of dietary Na density in model 1, compared with the lowest tertile, were 2·11 (95 % CI 1·14, 3·90), 2·73 (95 % CI 1·65, 4·51) and 1·95 (95 % CI 1·17, 3·26), respectively. Significant dose–response relationships were found with overweight risk assessed by BMI, adiposity risk assessed by BMI and adiposity risk assessed by WC ($P_{\text{for trend}} = 0{\cdot}0207$, $<0{\cdot}001$ and 0·0086, respectively). Although girls showed a significant association of dietary Na intake with overweight risk assessed by BMI and obesity risk assessed by BMI ($P < 0{\cdot}05$), boys reported a significant association with obesity risk assessed by BMI. Significant associations between adiposity risk assessed by WC and dietary Na intake were only found in the total sample, but no consistently significant associations were found for each sex. We found no significant associations between adiposity risk assessed by TBPF and dietary Na intake.

Adding soft drink consumption to the model (model 2) did not alter the general pattern of the associations described above (model 1). Overall, the association between BMI-obesity and dietary Na density appeared to be the strongest in terms of size of OR and consistency of significant dose–response relationships in both models 1 and 2 (Table 3).

Discussion

This study found that higher Na intake was significantly associated with adiposity in children and adolescents, after adjusting for energy intake, SSB intake, physical activity and socio-demographic variables. The results showed generally consistent patterns of association regardless of the assessment methods of Na intake or measure of adiposity. Risk of obesity assessed by BMI was consistently and significantly associated with urinary Na:creatinine ratio and dietary Na intake, whereas risk of overweight assessed by BMI, risk of abdominal adiposity assessed by WC and TBPF showed relatively weaker and less consistent association with Na intake. Along with consistently significant dose–response relationships between Na intake and obesity, findings of this study suggest that higher Na intake was related to obesity and abdominal adiposity to a lesser degree.

This study also explored a possible role of SSB consumption, using soft drink consumption as a proxy variable, in the association between Na intake and obesity in Korean children and adolescents. The addition of soft drink consumption into the multivariate logistic regression models did not make meaningful differences across assessment methods and sex, which means there appears to be Na intake effects independent of soft drink consumption in this population. This finding is not in agreement with previously reported findings from the US population[26] and the Australian population[27]. Approximately 59 % of Korean children and adolescents in this study reported consuming SSB, whereas the US and Australian counterparts reported 64 and 62 %, respectively. This study found the average SSB consumption level per consumer to be 398 (SE 18·2) g/d, which is lower than the consumption of SSB among US children and adolescents (631 g/d) and higher than that of Australian children and adolescents (248 g/d). The link between Na intake and SSB consumption and its impact on obesity should be explored further.

One can also propose that individuals with high Na intake would also practise bad health behaviours leading to adiposity – that is, the association between Na intake and adiposity is an outcome of clustering of unhealthy behaviours[43]. This study controlled for physical activity and consumption of SSB and still found significant associations between Na intake and adiposity independent of physical activity. This finding indicates a possibility of an independent relationship between Na intake and adiposity.

Another possible mechanism between Na intake and obesity is that higher Na intake would result in higher water retention leading to higher body weight. This study used TBPF in an effort to exclude Na-related water retention as a possible reason for the association between Na intake and adiposity. This study found significant associations between urinary Na:creatinine ratio and TBPF among boys in a full model, whereas the association was relatively weaker among girls (model 2, Table 2). The association of TBPF with dietary Na intake was found to be weaker (Table 3). This possible mechanism appears to be worth further examination.

Previous studies have reported sex differences in the associations between Na intake and obesity. Song *et al.*[11] analysed the data of adults from KNHANES 2007–2009 and

Table 2. Risk of adiposity* by urinary sodium:creatinine ratio
(Odds ratios and 95 % confidence intervals)

	Total (*n* 1467)						Boys (*n* 827)						Girls (*n* 640)					
	Urinary Na:creatinine ratio						Urinary Na:creatinine ratio						Urinary Na:creatinine ratio					
		Tertile 2		Tertile 3†				Tertile 2		Tertile 3†				Tertile 2		Tertile 3†		
	Tertile 1	OR	95 % CI	OR	95 % CI	$P_{for\ trend}$‡	Tertile 1	OR	95 % CI	OR	95 % CI	$P_{for\ trend}$‡	Tertile 1	OR	95 % CI	OR	95 % CI	$P_{for\ trend}$‡
Na:creatinine	0·42–7·61	4·28–12·3		7·78–49·5			0·44–7·61	4·28–12·3		7·78–49·5			0·42–7·38	4·89–11·0		7·81–35·4		
BMI																		
Overweight (85–95 %)*																		
No. of participants	457	442		403			254	244		223			203	198		180		
No. of overweight	29	47		42			12	26		24			17	21		18		
Crude model§	1·0	2·00	1·04, 3·87	1·88	0·95, 3·69	0·0549	1·0	2·20	0·98, 4·95	2·49	1·04, 5·95	0·0361	1·0	1·94	0·83, 4·54	1·52	0·63, 3·69	0·3172
Model 1§‖	1·0	2·03	1·01, 4·06	1·80	0·89, 3·64	0·0866	1·0	2·27	0·91, 5·71	2·17	0·80, 5·90	0·1290	1·0	2·09	0·87, 5·02	1·59	0·65, 3·87	0·2703
Model 2§¶	1·0	2·04	1·02, 4·08	1·79	0·88, 3·62	0·0898	1·0	2·33	0·93, 5·82	2·22	0·82, 5·98	0·1149	1·0	2·08	0·85, 5·08	1·60	0·66, 3·89	0·2634
Obesity (≥95 % or ≥25 kg/m^2)*																		
No. of participants	458	444		447			262	251		252			196	193		195		
No. of obesity	30	49		86			20	33		53			10	16		33		
Crude model§	1·0	1·98	1·12, 3·48	3·02	1·76, 5·18	<0·0001	1·0	1·92	0·93, 3·96	2·87	1·45, 5·67	0·0017	1·0	2·03	0·81, 5·11	3·21	1·27, 8·14	0·0127
Model 1§‖	1·0	1·93	1·09, 3·41	3·14	1·81, 5·44	<0·0001	1·0	1·92	0·91, 4·03	3·09	1·54, 6·20	0·0011	1·0	1·97	0·81, 4·83	3·28	1·25, 8·62	0·0148
Model 2§¶	1·0	1·92	1·10, 3·36	3·13	1·82, 5·40	<0·0001	1·0	1·88	0·90, 3·95	3·04	1·52, 6·08	0·0012	1·0	2·10	0·89, 4·96	3·31	1·29, 8·53	0·0127
WC*																		
No. of participants	487	491		489			274	277		276			213	214		213		
No. of adiposity	34	34		68			15	16		35			19	18		33		
Crude model**	1·0	0·98	0·56, 1·72	1·99	1·17, 3·38	0·0110	1·0	0·89	0·37, 2·16	2·04	0·94, 4·43	0·0600	1·0	1·09	0·53, 2·25	2·04	0·94, 4·43	0·0773
Model 1‖**	1·0	0·96	0·55, 1·67	2·14	1·25, 3·65	0·0062	1·0	0·84	0·34, 2·07	2·26	1·02, 4·99	0·0398	1·0	1·05	0·51, 2·14	2·04	0·94, 4·42	0·0787
Model 2¶**	1·0	0·97	0·56, 1·69	2·15	1·27, 3·66	0·0054	1·0	0·85	0·35, 2·06	2·27	1·04, 4·98	0·0369	1·0	1·10	0·54, 2·25	2·05	0·96, 4·38	0·0702
TBPF*††																		
No. of participants	321	346		352			181	203		204			140	143		148		
No. of adiposity	101	126		166			64	83		105			37	43		61		
Crude model‡‡	1·0	1·44	0·99, 2·10	2·00	1·33, 2·99	0·0008	1·0	1·56	0·94, 2·58	2·17	1·22, 3·83	0·0080	1·0	1·25	0·70, 2·26	1·74	0·97, 3·13	0·0615
Model 1‖‡‡	1·0	1·40	0·96, 2·06	1·91	1·28, 2·85	0·0016	1·0	1·60	0·91, 2·82	2·13	1·15, 3·97	0·0166	1·0	1·26	0·72, 2·23	1·75	0·96, 3·19	0·0662
Model 2¶‡‡	1·0	1·42	0·97, 2·07	1·92	1·29, 2·86	0·0013	1·0	1·61	0·92, 2·82	2·14	1·15, 3·97	0·0162	1·0	1·32	0·75, 2·32	1·80	1·00, 3·24	0·0502

WC, waist circumference; TBPF, total body per cent fat; MET, metabolic equivalents.
* Adiposity was defined as having a BMI ≥95th percentile for age and sex or ≥25 kg/m^2; overweight was defined as having 85th ≤ BMI <95th percentile for age and sex; abdominal adiposity as a WC ≥90th percentile for age and sex in the study sample; as a TPBF >25 % for boys, >30 % for girls younger than 11 years and >35 % for girls aged 11 years or older.
† The tertiles of urinary Na:creatinine ratio were based on the distribution of values among subjects after log-transformation.
‡ Test for linear trends used the median value in each tertile as a continuous variable in linear regression.
§ Reference group of BMI was defined as having BMI < 85th percentile for age and sex.
‖ Multiple logistic regression model 1: adjusted for age (continuous), sex (not adjusted for in the stratified models), household income, physical activity (MET) and total daily energy intake (kJ/d (kcal/d)).
¶ Multiple logistic regression model 2: same as model 1 and additionally adjusted for sugar-sweetened beverages.
** Reference group of WC was defined as a WC <90th percentile for age and sex in the study sample.
†† Analysis was conducted (*n* 1019) in a subsample of the subjects with dual-energy X-ray absorptiometry, the TBPF.
‡‡ Reference group of TPBF was defined as a TPBF ≤25 % for boys, ≤30 % for girls younger than 11 years and ≤35 % for girls aged 11 years or older.

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Table 3. Risk of adiposity* by dietary sodium intake
(Odds ratios and 95 % confidence intervals)

	Total (n 1467)						Boys (n 827)						Girls (n 640)					
	Dietary Na intake (mg/4184 kJ (1000 kcal))						Dietary Na intake (mg/4184 kJ (1000 kcal))						Dietary Na intake (mg/4184 kJ (1000 kcal))					
		Tertile 2		Tertile 3†				Tertile 2		Tertile 3†				Tertile 2		Tertile 3†		
	Tertile 1	OR	95 % CI	OR	95 % CI	$P_{for\ trend}$‡	Tertile 1	OR	95 % CI	OR	95 % CI	$P_{for\ trend}$‡	Tertile 1	OR	95 % CI	OR	95 % CI	$P_{for\ trend}$‡
Na (range)	154–1589	1446–2304		2046–12 039			307–1589	1457–2304		2051–6575			154–1492	1446–2173		2046–12 039		
BMI																		
Overweight (85–95 %)*																		
No. of participants	449	443		410			249	248		224			200	195		186		
No. of overweight	29	40		49			15	24		23			14	16		26		
Crude model§	1·0	1·28	0·75, 2·20	2·24	1·24, 4·04	0·0091	1·0	1·26	0·61, 2·58	1·84	0·84, 4·03	0·1266	1·0	1·32	0·56, 3·13	2·64	1·19, 5·86	0·0184
Model 1§‖	1·0	1·35	0·79, 2·32	2·11	1·14, 3·90	0·0207	1·0	1·46	0·68, 3·15	1·68	0·71, 3·98	0·2351	1·0	1·33	0·56, 3·13	2·59	1·14, 5·84	0·0202
Model 2§¶	1·0	1·41	0·82, 2·41	2·23	1·22, 4·08	0·0116	1·0	1·64	0·79, 3·43	1·91	0·81, 4·50	0·1414	1·0	1·33	0·58, 3·07	2·60	1·19, 5·69	0·014
Obesity (≥95 % or ≥25 kg/m^2)*																		
No. of participants	458	451		440			259	253		253			199	198		187		
No. of obesity	38	48		79			25	29		52			13	19		27		
Crude model§	1·0	1·36	0·79, 2·33	2·75	1·68, 4·50	<0·0001	1·0	1·20	0·59, 2·43	2·75	1·47, 5·15	0·0015	1·0	1·65	0·69, 3·95	2·76	1·20, 6·33	0·0216
Model 1§‖	1·0	1·41	0·82, 2·43	2·73	1·65, 4·51	<0·0001	1·0	1·29	0·63, 2·65	2·71	1·42, 5·17	0·0024	1·0	1·69	0·71, 4·03	2·65	1·17, 5·98	0·0277
Model 2§¶	1·0	1·44	0·83, 2·49	2·79	1·66, 4·68	<0·0001	1·0	1·26	0·61, 2·58	2·61	1·39, 4·91	0·0027	1·0	1·88	0·73, 4·80	2·99	1·23, 7·24	0·0226
WC*																		
No. of participants	487	491		489			274	277		276			213	214		213		
No. of adiposity	36	38		62			17	18		31			19	20		31		
Crude model**	1·0	1·00	0·56, 1·78	1·93	1·16, 3·20	0·0092	1·0	0·82	0·37, 1·82	2·07	0·97, 4·42	0·0525	1·0	1·17	0·52, 2·61	1·79	0·88, 3·66	0·0959
Adjusted model 1‖**	1·0	1·04	0·58, 1·86	1·95	1·17, 3·26	0·0086	1·0	0·95	0·42, 2·15	2·10	0·96, 4·61	0·0597	1·0	1·16	0·52, 2·60	1·77	0·86, 3·65	0·1067
Adjusted model 2¶**	1·0	1·12	0·62, 2·03	2·14	1·25, 3·67	0·0044	1·0	0·99	0·43, 2·25	2·22	1·02, 4·82	0·0400	1·0	1·29	0·56, 2·99	1·98	0·93, 4·25	0·0645
TBPF*¶																		
No. of participants	343	343		333			198	199		191			145	144		142		
No. of adiposity	125	128		140			81	84		87			44	44		53		
Crude model‡‡	1·0	0·99	0·665, 1·47	1·32	0·91, 1·90	0·1401	1·0	0·99	0·61, 1·63	1·47	0·89, 2·43	0·1260	1·0	0·97	0·47, 2·00	1·12	0·60, 2·09	0·7149
Adjusted model 1‖‡‡	1·0	1·04	0·697, 1·56	1·31	0·89, 1·92	0·1735	1·0	1·01	0·604, 1·69	1·33	0·76, 2·31	0·3190	1·0	1·06	0·52, 2·18	1·18	0·65, 2·16	0·5791
Adjusted model 2¶‡‡	1·0	1·06	0·70, 1·61	1·33	0·89, 1·99	0·1577	1·0	1·02	0·61, 1·71	1·34	0·77, 2·31	0·9991	1·0	1·07	0·52, 2·23	1·23	0·66, 2·32	0·0643

WC, waist circumference; TBPF, total body per cent fat; MET, metabolic equivalents.
* Adiposity was defined as having a BMI ≥95th percentile for age and sex or ≥25 kg/m^2; overweight was defined as having 85th ≤ BMI <95th percentile for age and sex; abdominal adiposity as a WC ≥90th percentile for age and sex in the study sample; as a TPBF >25 % for boys, >30 % for girls younger than 11 years and >35 % for girls aged 11 years or older.
† The tertiles of dietary Na intake were based on the distribution of values among subjects after log-transformation.
‡ Test for linear trend used the median value in each tertile as a continuous variable in linear regression.
§ Reference group of BMI was defined as having BMI < 85th percentile for age and sex.
‖ Multiple logistic regression model 1: adjusted for age (continuous), sex (not adjusted for in the stratified models), household income, total daily energy intake and physical activity (MET).
¶ Multiple logistic regression model 2: same as model 1 and additionally adjusted for sugar-sweetened beverages.
** Reference group of WC was defined as a WC <90th percentile for age and sex in the study sample.
†† Analysis was conducted (n 1019) in a subsample of the subjects with dual-energy X-ray absorptiometry, the TPBF.
‡‡ Reference group of TPBF was defined as a TPBF ≤25 % for boys, ≤30 % for girls younger than 11 years and ≤35 % for girls aged 11 years or older.

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found significant associations between Na intake and obesity in men but not in women. Jain *et al.*[13] found the opposite in the US population – that is, significant associations after controlling for covariates in women but not in men. This study found that different adiposity measures showed more apparent associations with Na intake in different sexes. Risk of overweight assessed by BMI was significantly associated with dietary Na intake only in girls, whereas adiposity risk assessed by WC was significantly associated with dietary Na intake only in boys. Risks of adiposity assessed by BMI and TBPF were in general consistent in both sexes. These inconsistent sex differences need to be further explored.

This study was limited by the cross-sectional nature of KNHANES; therefore, temporal relationship between Na intake and adiposity could not be established. Morning spot urine rather than 24-h urine samples were used in this study. Although the 24-h urine measurement is the gold standard for assessing salt intake through urinary Na excretion in individuals and in populations, it is often deemed inconvenient for repeated use in large population studies. There are concerns that a high participation burden, a lack of completeness and a high cost will affect the response rate and the practicality of using the test. Alternative methods such as spot and timed urine samples have been derived in an attempt to overcome this concern[33]. The validity of spot urine samples, however, remains controversial. A recent review showed that the correlations between mean Na amount from 24-h urine samples and that from overnight urine samples ranged from 0·62 to 0·95 among children and adolescents, although the authors concluded reliability of alternative methods to replace the 24-h urine Na test[44]. Although an equation has been developed to convert Na from spot urine samples to 24-h urine samples among adults[21], no such equation exists for children. Therefore, this study utilised urinary Na:creatinine ratio value from spot urine samples without converting it to that of 24-h urine samples. Valid and reliable methods to replace 24-h urine Na, including developing equations to convert Na from spot urine to 24-h Na in children, are much needed. Finally, adjustment with urinary K has been recommended in using urinary Na excretion[5]; however, this study was not able to do so because KNHANES did not test for urinary K.

One of the most meaningful contributions of this study was testing multiple assessment methods of not only Na intake but also adiposity. Na intake was assessed by dietary Na intake from 24-h recalls and urinary Na excretion, and significant associations with adiposity were found. For the outcome variable, adiposity, three different assessment methods (BMI, WC and TBPF) were used. This study found that associations with risk of obesity assessed by BMI were most consistent and stronger than other measures, whereas TBPF showed relatively weak association, showing no significant association with dietary Na intake. Using the DEXA method, one of the better assessment methods for total body fat, was a particular strength of this study. The significant findings regardless of assessment methods strongly support the associations between Na intake and adiposity, with suggestions for further studies on mechanisms of the association between Na intake and adiposity and needs of valid and easier assessment methods for Na intake among children.

In conclusion, this study demonstrated the significant associations between Na intake and adiposity in children and adolescents, independent of SSB consumption. The sex difference in this association warrants more research along with further investigations to establish mechanisms for the association. The findings of this study strongly support the worldwide campaign for Na intake reduction and suggest that the campaign would help decrease not only the traditionally discussed Na-related diseases such as hypertension, CVD and stroke but also adiposity.

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The authors' contributions are as follows: M. K. K. designed and conducted the present study, arranged the data and performed the statistical analyses; S.-K. L. was involved in the interpretation of the results and drafted the paper. All the authors contributed to the development of the manuscript.

The authors declare that there are no conflicts of interest.

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