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Association of Usual Sodium Intake with Obesity Among US Children and Adolescents, NHANES 2009-2016

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Abstract

Objective: The purpose of this study was to investigate the association of sodium intake with obesity in US children and adolescents.

Methods: Cross-sectional data were analyzed for 9,026 children and adolescents in the National Health and Nutrition Examination Survey (NHANES) 2009-2016. Usual sodium intake was estimated from 24-hour dietary recalls using a measurement error model. Logistic regression was used to assess the association of sodium intake with overweight/obesity, obesity, and central obesity (waist to height ratio [WtHR] ≥ 0.5; waist circumferences (WC) ≥ age- and sex-specific 90th percentile).

Results: Mean (SE) sodium intake was 3,010 (9) and 3,404 (20) mg/d for children and adolescents, respectively. The adjusted odds ratio (AOR) comparing Q4 versus Q1 (87.5th vs. 12.5th percentile of sodium intake) among children was 1.98 (95% CI: 1.19-3.28) for overweight/obesity, 2.20 (1.30-3.73) for obesity, 2.10 (1.12-3.95) for WC ≥ 90th percentile, and 1.68 (0.95-2.97) for WtHR ≥ 0.5, adjusting for demographics, energy, and sugar-sweetened beverage intake. Among adolescents, AOR was 1.81 (0.98-3.37) for overweight/obesity, 1.71 (0.82-3.56) for obesity, 1.62 (0.71-3.66) for WC ≥ 90th percentile, and 1.73 (0.85-3.50) for WtHR ≥ 0.5.

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Supporting information: Additional Supporting Information may be found in the online version of this article.

Conclusions: Sodium intake was positively associated with overweight/obesity, obesity, and central obesity among US children independent of energy and SSB intake, but the association did not reach significance among adolescents.

Introduction

Childhood obesity is a serious public health problem worldwide, including in the United States. According to the National Health and Nutrition Examination Survey (NHANES) 2015-2016, 18.4% of US children aged 6 to 11 years and 20.6% of adolescents aged 12 to 19 years had obesity (1). Children with obesity are at greater risk of psychological or social problems, of developing chronic diseases, such as hypertension and type 2 diabetes, in the future, and of becoming adults with obesity (2). Thus, it is important to identify risk factors associated with obesity during childhood and adolescence.

Although sugar-sweetened beverage (SSB) intake and excess energy intake (EI) are risk factors for obesity, recent studies also suggest a positive association between sodium intake and overweight and/or obesity among adults and children (3-11). Previous studies in children found that 1 g/d of salt intake was associated with a 17-g/d greater intake of SSBs, and SSB consumption was positively associated with overweight/obesity, indicating a potential association between sodium intake and overweight/obesity (perhaps mediated through high intake of SSBs) (4). The association also may be partially caused by overconsumption of energy-dense salty food. However, recent studies from the United Kingdom (5), Australia (6), Germany (7), Korea (8,9), and Iran (10) suggest a direct association between sodium intake and obesity that is independent of energy or SSB intake in children and adolescents. To our knowledge, only one study examined a direct association between sodium intake and adiposity measures among US adolescents (11). In this cross-sectional study of 766 White and African American adolescents aged 14 to 18 years recruited from local public high schools in Augusta, Georgia, dietary sodium intake was associated with adiposity measures, such as weight, BMI, and waist circumference (WC), independent of energy and SSB intake. However, the generalizability of these results to younger children or US adolescents is uncertain. Hence, the aim of this study was to assess the association of usual dietary sodium intake (milligrams per day) with overweight/obesity and central obesity in a nationally representative sample of US children and adolescents aged 6 to 19 years.

Methods

Data source and participants

The analytical data were from NHANES. 2009-2016, which utilizes a complex, stratified, multistage probability sampling procedure to collect health and nutritional data from a representative sample of the civilian, noninstitutionalized US population. It combines a home interview and physical examination, including an in-person 24-hour dietary recall interview conducted in a mobile examination center (MEC); a second 24-hour dietary recall is administered by telephone 3 to 10 days later. Parental consent was obtained for those younger than 18 years, and youth aged 7 to 17 years of age provided documented assent. Detailed information on the survey design and data collection can be found elsewhere (12).

The overall examination response rates in 2009 through 2016 for youth aged 6 to 19 years was 76.3%. We included youth aged 6 to 19 years who had a reliable in-person 24-hour dietary recall (n = 9,296). We excluded participants who reported consuming a low-sodium diet (n = 17) and who were missing data for measures of adiposity (n = 253), leaving a final sample of 9,026 children and adolescents for analyses (Supporting Information Figure S1).

Measures

Adiposity measures.—Height, weight, and waist circumference (WC) were measured at the MEC by trained health technicians using standard procedures and equipment, as described in detail elsewhere (13). BMI was calculated as body weight in kilograms divided by height in meters squared. Overweight/obesity, obesity, and severe obesity were defined as BMI at or above the age- and sex-specific 85th percentile, 95th percentile, and 120% of the 95th percentile in relation to the 2000 US Centers for Disease Control and Prevention (CDC) growth charts, respectively (14). Central obesity was defined either as WC at or greater than the age- and sex-specific 90th percentile based on the data from NHANES III (1988-1994) or waist to height ratio (WtHR) ≥ 0.5, as there is no consensus on defining central obesity in youth (15).

Dietary sodium intake.—Dietary sodium intake (milligrams per day) was the main exposure of interest. Up to two 24-hour dietary recalls were collected with proxy assistance for children aged 6 to 11 years and directly for participants aged 12 years or older. The proxy was the person responsible for preparing the participant’s meals. The 24-hour dietary recalls were administered in person (first) and over the phone (second) by a trained interviewer. Each participant or proxy was asked to recall all foods and beverages except plain drinking water (i.e., not bottled) consumed during the previous 24-hour time period (midnight to midnight) using the US Department of Agriculture Automated Multiple-Pass Method (16).

Because dietary intake data from a single 24-hour recall or an average of two dietary recalls may not represent a participant’s usual dietary intake because of day-to-day variation in the foods and beverages consumed, use of these measures may bias estimates of the association between nutrient intake and health outcomes (17). To limit such possible bias and to make estimates more precise, we used a method developed by the National Cancer Institute to estimate participants’ usual intakes of sodium, energy, and SSBs (18). The National Cancer Institute method requires that at least some respondents have multiple days of values to estimate the within- and between-person variations (18,19). In our study, 7,745 (85.7%) participants provided two reliable 24-hour dietary recalls. The models for estimating usual intake included the following covariates: an indicator of sequence number (first vs. second day of dietary recall), day of the week the recall was collected (weekday vs. weekends [Friday-Sunday]), age, sex, and race-Hispanic origin. For the association analyses, we further included poverty income ratio (PIR), physical activity (for those aged 12-19 years), and usual energy or SSB intake based on the adjusted covariates in each logistic model.

Covariates.—Age, sex, race-Hispanic origin, and family income were self-reported (20). Race-Hispanic origin was categorized as non-Hispanic White, non-Hispanic Black, Hispanic, and other (including multiracial). PIR was calculated as family income relative to the Department of Health and Human Services poverty guidelines and was categorized as ≤ 130% or > 130% (21). Physical activity was assessed in the MEC only for participants aged 12 years and older. Physical activity was self-reported via a questionnaire about activities in a typical week, which is based on the Global Physical Activity Questionnaire (22). Based on the 2018 Physical Activity Guidelines Advisory Committee Scientific Report, participants were classified as inactive if they reported less than 10 minutes of moderate to vigorous physical activity per week (23,24).

Dietary energy (kilocalories per day) and SSB (grams per day) intakes were examined as potential confounding/mediating factors of the sodium intake–adiposity associations. Nutrient intakes from foods and beverages were estimated by using the US Department of Agriculture's Food and Nutrient Database for Dietary Studies (16). The definition of SSB, consistent with other reports (3,25), includes regular soda, fruit drinks (including sweetened bottled waters and fruit juices and nectars with added sugars), sports and energy drinks, sweetened coffees and teas, and other SSBs (including horchata and sugar cane beverages). SSBs do not include diet drinks, 100% fruit juice, beverages sweetened by the participant including coffee and teas, alcohol, or flavored milks. Food codes for the aforementioned beverages were used to calculate participants' total SSB intake in grams per day.

Assessment of implausible EI

Misreporting of EI was evaluated from the ratio of reported EI (rEI) to predicted energy requirement (pER) using the rEI:pER method proposed by Huang et al. (26). The pER was calculated using age, sex, and weight status-specific equations published in the US Dietary Reference Intakes (27). To identify potentially implausible rEI, we calculated the ± 1.4 SD cutoff for rEI as a percentage of pER (i.e., rEI/pER × 100) according to the procedure proposed by Huang et al. (26). A rEI was considered potentially implausible if the percentage of rEI/pER was outside the ± 1.4 SD range. In sensitivity analyses, we excluded 1,117 children and 1,724 adolescents based on this criterion.

Statistical analyses

Descriptive analyses were conducted on the whole sample, as well as by age group. Participants were stratified into two age groups: children aged 6 to 11 years and adolescents aged 12 to 19 years. Results were presented as weighted mean (SE) or weighted percentage (SE) for baseline characteristics and anthropometric measures. We used multiple logistic regression with estimated usual sodium intake (continuous) as the main exposure variable to assess its associations with overweight/obesity, obesity, and central obesity. To present odds ratios (OR) in a quartile fashion, as in previous analyses (,28,29), we calculated the estimated usual sodium intake at the middle value of each quartile at the 87.5th, 62.5th, 37.5th, and 12.5th percentiles for quartiles four (Q4), Q3, Q2, and Q1, respectively. We then used the β-coefficient of the continuous sodium intake from logistic regression models to estimate the adjusted OR (AOR) by comparing the risk for the 87.5th, 62.5th, and 37.5th percentiles with that for the 12.5th percentile (Q4, Q3, and Q2 vs. Q1). For example, the 12.5th (Q1) and 62.5th (Q3) percentiles of sodium intake among children were 2,583 and

3,125 mg/d, respectively, with β-coefficient=0.00077, and the AOR of Q3 versus Q1was calculated as exp ([3,125 – 2,583] × 0.00077) = 1.52.

For the multivariate logistic regression analyses, we adjusted for age, sex, race-Hispanic origin, and usual EI (model 1). In model 2, we further adjusted for PIR and physical activity (for adolescents only). In model 3, we examined potential mediation by both usual energy and SSB intake, including all variables in model 2 plus usual SSB intake. In model 4, we added the ratio of rEI:pER (rEI/pER), together with covariates of model 3, to attempt to account for potential misreporting (30). In supplemental analyses, we used alternative methods of adjusting for EI (31). In model 5, we replaced usual sodium intake in model 4 with sodium density, which was defined as milligrams of sodium per 1,000 kcal. In model 6, we used the residual method to adjust EI by replacing usual sodium in model 4 with sodium residual obtained from the regression of usual sodium intake on usual EI. We also examined the interactions between usual sodium intake and other covariates by including an interaction term for sodium intake and each covariate in separate multiple regression models (not shown).

In additional sensitivity analyses, we examined the association between usual sodium intake and adiposity among participants with presumed plausible EI by excluding participants with implausible EI based on the aforementioned rEI:pER methods (26).

All statistical analyses were conducted in SAS version 9.4 (SAS Institute, Cary, North Carolina) or SAS-callable SUDAAN (RTI International, Raleigh, North Carolina) with combined dietary sample weights to account for nonresponse and the complex sampling design. All tests were two-sided, and $P < 0.05$ was considered to represent statistical significance.

Results

Sample sizes and baseline characteristics of US youth in NHANES 2009-2016 are presented in Table 1. Children aged 6 to 11 years made up 42.8% of the participants, and 57.2 % were adolescents aged 12 to 19 years. Overall, 51.4% were boys. Mean (SE) usual sodium intake was 3,235 ± 13 mg/d, with higher intakes of sodium, energy, and SSBs in adolescents compared with children ($P < 0.001$) (Table 1). The proportion of adolescents who had central obesity, as defined by WtHR, was higher than that of children (36.8% vs. 31.5%). In contrast, the prevalence of overweight/obesity was comparable among children and adolescents (35.1% vs. 36.2%) (Table 2).

The association of estimated usual sodium intake with overweight/obesity among children and adolescents is summarized in Table 3. In children, the AOR of overweight/obesity in the highest quartile of sodium intake compared with the lowest quartile was 1.65 (95% CI: 1.07-2.55) ($P = 0.025$), adjusting for age, sex, race-Hispanic origin, PIR, and estimated usual intake of energy and SSBs (Table 3, model 3). The positive association became more significant after adjusting for potential misreporting by adding rEI/pER into the model (Table 3, model 4). Moreover, using either sodium density or the residual method to adjust for EI did not alter the association in children (Supporting Information Table S1).

In contrast, the association among adolescents did not reach statistical significance in all the models we examined (Table 3), except for replacing usual sodium intake with usual sodium density in model 5 (Supporting Information Table S1). Similar results were observed in a separate analysis excluding individuals with implausible EI but with a wider CI (Supporting Information Table S1). Similarly, as shown in Table 4 and Supporting Information Table S2, there was a consistent positive association of usual sodium intake with obesity in children, but not in adolescents, after adjusting for various confounding variables in the models. Excluding potential misreporters did not alter the associations (Supporting Information Table S2).

Estimated usual sodium intake was positively associated with central obesity based on WC in children. Those in the highest quartile of sodium intake showed over twofold increased odds of central obesity as compared with those in the lowest quartile (AOR = 2.10, 95% CI: 1.12-3.95) ($P = 0.022$), independent of demographic characteristics, energy, SSB intake, and potential misreporting (Table 5, model 4). The corresponding association became weaker and did not reach statistical significance when we defined central obesity as WtHR ≥ 0.5 (AOR = 1.68, 95% CI: 0.95-2.97) ($P = 0.074$) (Table 6, model 4). However, after replacing usual sodium intake with usual sodium density, we observed a positive association in children (AOR = 1.37, 95% CI: 1.01-1.86) ($P = 0.04$) (Supporting Information Table S4). The association did not reach statistical significance in adolescents, regardless of how we defined central obesity. Similar results were observed in sensitivity analysis after excluding potential misreporters (Supporting Information Tables S3-S4).

Discussion

Using a US nationally representative survey, NHANES 2009-2016, we found that higher usual sodium intake was associated with increased odds of overweight and/or obesity, independent of usual intake of energy and SSBs among US children. After adjusting for potential misreporting, we also found a positive association between estimated sodium intake and central obesity defined by WC > 90th percentile in children. In contrast, the positive associations between sodium intake and adiposity measures did not reach statistical significance in US adolescents.

Our findings in children are consistent with previous studies (5,6). Only a few studies solely focused on adolescents, and results were mixed. A US study of local adolescents aged 14 to 18 years indicated that dietary sodium intake was positively associated with BMI and WC. However, overweight/obesity and central obesity were not examined in the study (11). A study of Iranian youth aged 11 to 18 years revealed a positive association of urinary sodium excretion with overweight/obesity and central obesity based on WC (10). Conversely, a Canadian study of grade 7 students showed that body weight status was not associated with sodium intake, as assessed by a Web-based 24-hour recall (32). In addition, a longitudinal analysis of German children aged 3 to 18 years observed no association between urine sodium excretion and the concurrent change in body weight status (33). The discrepant findings in adolescents could be due to differences in the assessment of sodium intake, study population, design, definition of adiposity measures, and potential confounding factors considered.

None of the previous studies accounted for potential misreporting of EI. Misreporting may be very common among teens, especially among participants with obesity (34). Analysis of 14,044 US children and adolescents from NHANES 2003-2012 indicated that 8.7% of children and 32.6% of adolescents, and collectively 65.7% of youth with overweight/obesity, underreported EI based on the rEI:pER method (34). We have used the same method and identified similar rates of underreporting of EI (not shown). Therefore, accounting for potential misreporting is essential when studying diet and obesity-related outcomes. Failing to do so may change the magnitude or direction of the association (30). In our study, we found a stronger association between sodium intake and all adiposity measures in children after adjusting for potential misreporting, rather than excluding those with implausible values, which may lead to bias (30). However, with the exception of the association with overweight/obesity, the associations among adolescents were not meaningfully affected by adjusting for potential misreporting, which could be due to adolescents' poorer compliance in completing the dietary assessment (35) or much higher prevalence of underreporting of EI as compared with children (34). Besides EI, it appears that daily sodium intake may be also underreported among adolescents with overweight/obesity. Other unidentified confounding factors may be present, especially among adolescents.

The biological mechanisms for a direct association of sodium intake with obesity are unclear. Studies from animals indicated high-salt diets enhanced leptin production and the mass of white adipose tissue in rats (36,37). High-salt intake induced leptin resistance and obesity through fructose production in mice (38). Salt induces adipogenesis/lipogenesis in adipocytes, resulting in fat accumulation (39). A human study suggested that high-salt diets may contribute to the progression of obesity by increasing fasting ghrelin, which regulates appetite, glucose homeostasis, and fat deposition (40). Several epidemiologic studies also showed that salt intake was associated with leptin concentrations, percentage of body fat, and adipose tissue, indicating that sodium might somehow alter body fat metabolism (7,33).

The major strengths of this study include the use of a large, nationally representative sample of the US population of children, with comprehensive anthropometric measures and demographic data; we assessed the potential misreporting of EI and adjusted for EI using different methods; furthermore, we used a measurement error model to estimate usual sodium intake accounting for within-person day-to-day variation. Several limitations should be considered when interpreting our results. First, no causal relationship can be determined because of the cross-sectional study design. Second, the 24-hour dietary recall excluded salt added at the table or during cooking, which might underestimate sodium intake. The potential misreporting of sodium intake in concordance with EI may also affect the validity of the sodium estimate, especially among adolescents with overweight/obesity, because adolescents self-reported dietary intake without assistance from a proxy. The 24-hour urinary sodium excretion criterion standard was not available for youth in NHANES. To minimize the potential bias from misreporting of EI, we used the rEI:pER method to identify or exclude misreporters. Additionally, other unknown residual confounding factors cannot be ruled out.

Conclusion

In summary, sodium intake was positively associated with overweight and/or obesity as well as central obesity among US children aged 6 to 11 years, independent of energy and SSB intake. However, usual sodium intake was not significantly associated with measures of adiposity among US adolescents aged 12 to 19 years, perhaps because of a high percentage of misreporting of both dietary sodium and EI. Our findings, along with those of other recent studies, suggest that higher, rather than lower, sodium intake is associated with higher weight and obesity (41), which indicates that lower sodium intake in children might benefit obesity prevention efforts. More studies in adolescents, especially prospective studies that estimate sodium intake from 24-hour urine collection (a more objective method than dietary recalls), are warranted to identify the causal relationship between sodium intake and obesity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Study Importance

What is already known?

- Childhood obesity is a serious public health problem worldwide.
- Recent studies have indicated a positive association between sodium intake and childhood obesity. However, the association has not been studied in a nationally representative sample of US children and adolescents.

What does this study add?

- This study shows that usual sodium intake is positively associated with overweight, obesity, and central obesity among US children 6 to 11 years old, independent of energy and sugar-sweetened beverage intake. In contrast, the positive association did not reach statistical significance among US adolescents.

How might these results change the direction of research or the focus of clinical practice?

- Our findings support recent research that indicates lower sodium intake does not increase risk of obesity.

TABLE 1

Baseline characteristics of US children and adolescents aged 6 to 19 years, NHANES 2009-2016[a]

	All, 6-19 years		Aged 6-11 years		Aged 12-19 years		
	n	Mean or prevalence (SE)	*n*	Mean or prevalence (SE)	*n*	Mean or prevalence (SE)	*P*
Overall, *n* (%) [b]	9,026	100%	4,298	42.8 (0.8)	4,728	57.2 (0.8)	<0.0001
Age, y	9,026	12.5 (0.1)	4,298	8.5 (0.0)	4,728	15.5 (0.1)	<0.0001
Male, %	4,628	51.4 (0.9)	2,184	52.6 (1.4)	2,444	50.5 (1.1)	0.25
Race-Hispanic origin, % [c]							0.35
Non-Hispanic White	2,482	53.8 (2.5)	1,194	53.0 (2.6)	1,288	54.5 (2.6)	
Non-Hispanic Black	2,223	14.5 (1.4)	1,050	14.1 (1.3)	1,173	14.8 (1.5)	
Hispanic	3,128	22.9 (1.9)	1,520	23.9 (2.2)	1,608	22.2 (1.9)	
Poverty income ratio, % [d]							0.77
<130%	3,764	34.4 (1.9)	1,874	34.7 (1.7)	1,890	34.2 (2.4)	
>130%	4,600	65.6 (1.9)	2,159	65.3 (1.7)	2,441	65.8 (2.4)	
Physical activity [e]							
Active					3,548	78.0 (1.0)	
Inactive					1,112	22.0 (1.0)	
Usual sodium intake (mg/d)	9,026	3,235 (13)	4,298	3,010 (9)	4,728	3,404 (20)	<0.0001
Usual energy intake, kcal/d	9,026	1,985 (7)	4,298	1,915 (5)	4,728	2,038 (12)	<0.0001
Usual sodium density	9,026	1,658 (2)	4,298	1,590 (3)	4,728	1,710 (2)	<0.0001
Usual intake of sugar-sweetened beverages, g/d [f]	6,819	264 (5)	3,254	196 (4)	3,565	314 (7)	0.31

[a] All estimates are weighted except sample sizes (*n*).

[b] Row percentages were presented in this line, and column percentages were presented in all other lines.

[c] Estimates from participants who reported other race-Hispanic origin or more than one race group are not presented separately.

[d] Poverty income ratio was calculated as total family income relative to the Department of Health and Human Services poverty guidelines and was categorized as ≤ 130% or > 130%. Participants with missing income ($n = 662$) are not included.

[e] Physical activity was assessed for participants aged 12 years and older and not for younger participants.

[f] Only 6,819 (73.3%) participants who reported sugar-sweetened beverage consumption were included in this analysis, including 72.4% of patients aged 6 to 11 years and 73.9% of patients aged 12 to 19 years.

[g] For categorical variables, we used Rao-Scott F-adjusted χ^2 test. A *t* test was used to examine whether means of continuous variables varied by age groups. All tests were two-sided.

TABLE 2

Anthropometric measurements among US children and adolescents, NHANES 2009-2016[a]

	All, 6-19 years		Aged 6-11 years		Aged 12-19 years		
	n	**Mean or prevalence (SE)**	***n***	**Mean or prevalence (SE)**	***n***	**Mean or prevalence (SE)**	***P***[f]
WtHR	9,026	0.5 (0.0)	4,298	0.48 (0.002)	4,728	0.50 (0.002)	<0.0001
Weight category							0.12
Underweight	272	3.3 (0.3)	132	3.9 (0.5)	140	2.8 (0.3)	
Normal weight	5,361	61.0 (0.8)	2,590	61.0 (1.1)	2,771	61.0 (1.1)	
Overweight	1,526	16.1 (0.5)	701	16.4 (0.7)	825	15.9 (0.7)	
Obesity	1,867	19.6 (0.8)	875	18.7 (1.1)	992	20.3 (1.0)	
Severe obesity[b]	691	7.1 (0.5)	295	5.7 (0.5)	396	8.1 (0.7)	
Overweight/obesity[c]							0.46
Yes	3,393	35.7 (0.9)	1,576	35.1 (1.2)	1,817	36.2 (1.1)	
No	5,633	64.3 (0.9)	2,722	64.9 (1.2)	2,911	63.8 (1.1)	
Central obesity[d]							0.002
Yes, WtHR ≥0.5	3,201	34.5 (1.0)	1,379	31.5 (1.4)	1,822	36.8 (1.2)	
No, WtHR <0.5	5,825	65.5 (1.0)	2,919	68.5 (1.4)	2,906	63.2 (1.2)	
Central obesity[e]							0.06
Yes	1,821	19.9 (0.8)	837	18.4 (1.0)	984	20.9 (1.0)	
No	7,205	80.1 (0.8)	3,461	81.6 (1.0)	3,744	79.1 (1.0)	

[a]Data are reported as weighted mean (SE) for continuous variables or numbers and weighted percentage (SE for categorical variables.

[b]Severe obesity was defined as a BMI at or above the age- and sex-specific 120% of the 95th percentile of the CDC growth charts published in 2000. Of the 1,867 with obesity, 691 had severe obesity.

[c]Overweight/obesity was defined as a BMI at or above the age- and sex-specific 85th percentile of the 2000 CDC growth charts.

[d]Central obesity was defined as WtHR ≥ 0.5.

[e]Central obesity was defined as waist circumferences of the 90th percentile or greater for the same age and sex based on the data from NHANES III (1988-1994).

[f]For categorical variables, we used Rao-Scott F-adjusted χ^2 test. A *t* test was used to examine whether mean of WtHR varied by age groups. All tests were two-sided.

WtHR, waist to height ratio.

TABLE 3

Adjusted odds ratio (95% CI) of overweight/obesity in US children and adolescents, NHANES 2009-2016

	Midvalue of quartiles of estimated usual sodium intake				
	Q1 OR (95% CI)	**Q2 OR (95% CI)**	**Q3 OR (95% CI)**	**Q4 OR (95% CI)**	***P*** [a]
Aged 6-11 years [b]	2,583	2,871	3,125	3,469	
Model 1 (*n*=4,298)	Ref	1.17 (1.02-1.34)	1.34 (1.05-1.72)	1.61 (1.08-2.40)	0.02
Model 2 (*n*=4,033)	Ref	1.18 (1.02-1.35)	1.35 (1.04-1.76)	1.64 (1.07-2.50)	0.02
Model 3 (*n*=4,033)	Ref	1.18 (1.02-1.36)	1.36 (1.04-1.78)	1.65 (1.07-2.55)	0.03
Model 4 (*n*=4,033)	Ref	1.25 (1.06-1.48)	1.52 (1.11-2.08)	1.98 (1.19-3.28)	0.009
Aged 12-19 years [b]	2,604	3,090	3,560	4,281	
Model 1 (*n*=4,728)	Ref	1.10 (0.92-1.30)	1.20 (0.86-1.69)	1.38 (0.76-2.51)	0.28
Model 2 (*n*=4,272)	Ref	1.11 (0.91-1.34)	1.22 (0.84-1.79)	1.43 (0.73-2.78)	0.29
Model 3 (*n*=4,272)	Ref	1.16 (0.96-1.41)	1.35 (0.92-1.96)	1.68 (0.87-3.28)	0.12
Model 4 (*n*=4,272)	Ref	1.19 (0.99-1.42)	1.40 (0.99-1.99)	1.81 (0.98-3.37)	0.06

Overweight/obesity was defined as a BMI at or above the 85th percentile of the same age and sex based on the 2000 CDC growth charts.

Model 1, adjusted for age, sex, race-Hispanic origin, and usual energy intake; model 2, adjusted for age, sex, race-Hispanic origin, PIR, physical activity (12-19 years), and usual energy intake; model 3, adjusted for covariates of model 2 plus usual sugar-sweetened beverage intake; model 4, adjusted for covariates of model 3 plus misreporting (rEI/pER).

[a] *P* value for trend across percentiles of estimated usual sodium intake based on Satterthwaite adjusted-F test; all tests were two-sided.

[b] This row contains midvalue of quartiles of estimated usual sodium intake.

OR, odds ratio.

TABLE 4

Adjusted odds ratio (95% CI) of obesity in US children and adolescents, NHANES 2009-2016

	Midvalue of quartiles of estimated usual sodium intake				
	Q1 OR (95% CI)	**Q2 OR (95% CI)**	**Q3 OR (95% CI)**	**Q4 OR (95% CI)**	***P*** [a]
Aged 6-11 years [b]	2,583	2,871	3,125	3,469	
Model 1 (*n*=4,298)	Ref	1.20 (1.02-1.41)	1.40 (1.04-1.89)	1.72 (1.06-2.80)	0.03
Model 2 (*n*=4,033)	Ref	1.23 (1.04-1.44)	1.47 (1.08-1.99)	1.86 (1.14-3.05)	0.01
Model 3 (*n*=4,033)	Ref	1.24 (1.05-1.46)	1.49 (1.10,−2.03)	1.91 (1.16-3.15)	0.01
Model 4 (*n*=4,033)	Ref	1.30 (1.09-1.54)	1.63 (1.17-2.25)	2.20 (1.30-3.73)	0.004
Aged 12-19 years [b]	2,604	3,090	3,560	4,281	
Model 1 (*n*=4,728)	Ref	1.11 (0.92-1.33)	1.22 (0.84-1.77)	1.42 (0.74-2.73)	0.29
Model 2 (*n*=4,272)	Ref	1.09 (0.88-1.35)	1.18 (0.78-1.80)	1.35 (0.64-2.82)	0.43
Model 3 (*n*=4,272)	Ref	1.15 (0.93-1.43)	1.32 (0.87-2.03)	1.64 (0.78-3.47)	0.19
Model 4 (*n*=4,272)	Ref	1.17 (0.95-1.44)	1.36 (0.89-2.06)	1.71 (0.82-3.56)	0.15

Obesity was defined as a BMI at or above the 95th percentile of the same age and sex based on the CDC growth charts published in 2000. Model 1, adjusted for age, sex, race-Hispanic origin, and usual energy intake. Model 2, adjusted for age, sex, race-Hispanic origin, PIR, physical activity (12-19 years), and usual energy intake. Model 3, adjusted for covariates of model 2 plus usual sugar-sweetened beverage intake. Model 4, adjusted for covariates of model 3 plus misreporting (rEI/pER).

[a] *P* value for trend across percentiles of estimated usual sodium intake based on Satterthwaite adjusted-F test; all tests were two-sided.

[b] This row contains midvalue of quartiles of estimated usual sodium intake.

OR, odds ratio.

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TABLE 5

Adjusted odds ratio (95% CI) of central obesity (WC ≥ 90th percentile) in US children and adolescents, NHANES 2009-2016

	Midvalue of quartiles of estimated usual sodium intake				
	Q1 OR (95% CI)	**Q2 OR (95% CI)**	**Q3 OR (95% CI)**	**Q4 OR (95% CI)**	***P*** [a]
Aged 6-11 yeara [b]	2,583	2,871	3,125	3,469	
Model 1 (*n*=4,298)	Ref	1.24 (1.02-1.51)	1.49 (1.03-2.16)	1.91 (1.05-3.47)	0.03
Model 2 (*n*=4,033)	Ref	1.22 (1.00-1.50)	1.46 (1.00-2.13)	1.84 (0.99-3.42)	0.05
Model 3 (*n*=4,033)	Ref	1.22 (1.00-1.50)	1.46 (0.99-2.15)	1.85 (0.99-3.45)	0.05
Model 4 (*n*=4,033)	Ref	1.28 (1.04-1.57)	1.58 (1.07-2.33)	2.10 (1.12-3.95)	0.02
Aged 12-19 years [b]	2,604	3,090	3,560	4,281	
Model 1 (*n*=4,728)	Ref	1.07 (0.88-1.30)	1.14 (0.78-1.68)	1.27 (0.65-2.49)	0.48
Model 2 (*n*=4,272)	Ref	1.06 (0.85-1.33)	1.13 (0.73-1.74)	1.23 (0.57-2.65)	0.59
Model 3 (*n*=4,272)	Ref	1.14 (0.91-1.42)	1.29 (0.82-2.01)	1.56 (0.71-3.41)	0.26
Model 4 (*n*=4,272)	Ref	1.15 (0.91-1.46)	1.31 (0.83-2.09)	1.62 (0.71-3.66)	0.24

Central obesity was defined as WC ≥ 90th percentile for the same age and sex.

Model 1, adjusted for age, sex, race-Hispanic origin, and usual energy intake. Model 2, adjusted for age, sex, race-Hispanic origin, PIR, physical activity (12-19 years), and usual energy intake. Model 3, adjusted for covariates of model 2 plus usual sugar-sweetened beverage intake. Model 4, adjusted for covariates of model 3 plus misreporting (rEI/pER).

[a] *P* value for trend across percentiles of estimated usual sodium intake based on Satterthwaite adjusted-F test; all tests were two-sided.

[b] This row contains midvalue of quartiles of estimated usual sodium intake.

OR, odds ratio; WC, waist circumference.

TABLE 6

Adjusted odds ratio (95% CI) of central obesity (WtHR ≥0.5) in US children and adolescents, NHANES 2009-2016

	Midvalue of quartiles of estimated usual sodium intake				
	Q1 OR (95% CI)	**Q2 OR (95% CI)**	**Q3 OR (95% CI)**	**Q4 OR (95% CI)**	***P*** [a]
Aged 6-11 years [b]	2,583	2,871	3,125	3,469	
Model 1 (*n*=4,298)	Ref	1.13 (0.97-1.32)	1.26 (0.94-1.68)	1.45 (0.91-2.30)	0.12
Model 2 (*n*=4,033)	Ref	1.14 (0.97-1.33)	1.27 (0.94-1.71)	1.47 (0.91-2.38)	0.11
Model 3 (*n*=4,033)	Ref	1.14 (0.97-1.35)	1.29 (0.94-1.75)	1.50 (0.91-2.48)	0.11
Model 4 (*n*=4,033)	Ref	1.19 (0.98-1.43)	1.38 (0.97-1.95)	1.68 (0.95-2.97)	0.07
Aged 12-19 years [b]	2,604	3,090	3,560	4,281	
Model 1 (*n*=4,728)	Ref	1.10 (0.91-1.33)	1.21 (0.83-1.77)	1.40 (0.72-2.74)	0.32
Model 2 (*n*=4,272)	Ref	1.10 (0.88-1.37)	1.21 (0.78-1.87)	1.40 (0.65-3.01)	0.39
Model 3 (*n*=4,272)	Ref	1.16 (0.92-1.44)	1.33 (0.86-2.06)	1.65 (0.76-3.57)	0.20
Model 4 (*n*=4,272)	Ref	1.17 (0.95-1.44)	1.36 (0.91-2.04)	1.73 (0.85-3.50)	0.13

Central obesity was defined as WtHR ≥ 0.5.

Model 1, adjusted for age, sex, race-Hispanic origin, and usual energy intake. Model 2, adjusted for age, sex, race-Hispanic origin, PIR, physical activity (12-19 years), and usual energy intake. Model 3, adjusted for covariates of model 2 plus usual sugar-sweetened beverage intake. Model 4, adjusted for covariates of model 3 plus misreporting (rEI/pER).

[a] *P* value for trend across percentiles of estimated usual sodium intake based on Satterthwaite adjusted-F test; all tests were two-sided.

[b] This row contains midvalue of quartiles of estimated usual sodium intake.

OR, odds ratio; WtHR, waist to hip ratio.