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Sodium and potassium intakes among US infants and preschool children, 2003–2010[2,3]

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Abstract

Background—Data are limited on usual sodium and potassium intakes relative to age-specific recommendations and the sodium:potassium ratio in infants and preschoolers, especially among those aged <2 y, who are black or breastfed.

Objective—The usual sodium intake above the Tolerable Upper Intake Levels (ULs), potassium intakes above Adequate Intakes (AIs), the sodium:potassium ratio, and sodium density (mg/kcal) among US infants and preschoolers by age group, as applicable, were estimated and compared by race-ethnicity and current breastfeeding status.

Design—Data were analyzed among 3 groups of children (aged 7–11 mo, 1–3 y, and 4–5 y) from the NHANES 2003–2010 by using measurement error models.

Results—Seventy-nine percent of children aged 1–3 y and 87% of those aged 4–5 y exceeded their sodium UL; among non-Hispanic black children, the estimates were 84% and 97%, respectively. For potassium, 97% of infants, 5% of children aged 1–3 y, and 0.4% aged 4–5 y met their AIs. Compared with non-Hispanic whites and Mexican Americans, non-Hispanic black infants and preschoolers had higher mean sodium density and sodium:potassium ratios. Currently breastfed infants and children consumed, on average, less sodium than those who were not breastfed (382 ± 53 compared with 538 ± 22 mg in those aged 7–11 mo and 1154 ± 88 compared with 1985 ± 24 mg in those aged 1–3 y, respectively), but the sodium:potassium ratio did not differ.

Conclusions—Most US preschoolers, particularly non-Hispanic blacks, consume too much sodium, and nearly all do not consume enough potassium. Data that suggest that currently

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The authors' responsibilities were as follows—NT: full access to all of the data in the study and primary responsibility for the integrity of the data, the accuracy of the data analysis, and the final content; NT, MEC, and FL: study concept and design and drafting of the manuscript; NT and ZZ: statistical analysis; and NT, MEC, and QY: critical revision of the manuscript for important intellectual content.

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breastfed infants consume less sodium than do those who are not breastfeeding merit further investigation.

INTRODUCTION

Excess sodium and inadequate potassium intake are related to hypertension, a major risk factor for cardiovascular diseases, the leading causes of death in the United States (1). Evidence from animal and human studies (2, 3), including randomized clinical trials and meta-analyses (4), indicate a positive dose-response relation between dietary sodium intake and blood pressure (BP)[5], particularly among certain population subgroups, such as non-Hispanic blacks (5). Results from the NHANES 2003–2008 indicated that US children aged 8–18 y consume about the same average amount of sodium per day as adults (3400 mg) and higher sodium intake was associated with higher systolic pressure, particularly among children who were overweight or obese (6). In addition, higher potassium intake can increase urinary sodium excretion through the distal tubule of kidney (7-10) and can decrease BP responses to increased sodium intake (11), with some studies suggesting that the sodium:potassium ratio also may be informative about hypertension (12). Given that high BP tends to persist with age (13, 14), early sodium and potassium intake in line with recommendations might help prevent development of later hypertension (15). In addition, taste preferences for salty foods may be established early in life and may be related to breastfeeding and introduction of complementary foods (16), emphasizing the need for information among the youngest consumers about intake of sodium relative to energy, along with sodium and potassium intakes relative to guidelines, and sodium:potassium ratios.

In 2005, the Institute of Medicine (IOM) established the Dietary Reference Intakes, including Tolerable Upper Intake Levels (ULs) for sodium (2300 mg/d) for adults aged 19–50 y on the basis of a dose-response relation between sodium and hypertension. ULs for children were extrapolated from adult ULs on the basis of averages of median age-specific energy intakes (17). No UL was set for infants, nor was a UL set for potassium. Because of limited data, Adequate Intakes (AIs) were set, rather than Recommended Dietary Allowances, for sodium and potassium and also extrapolated for children on the basis of median energy intakes. In contrast to the IOM Dietary Reference Intakes, the *Dietary Guidelines for Americans* do not adjust sodium and potassium guidelines for children on the basis of energy intake, nor do they include children aged <2 y (18).

Limited data exist on sodium and potassium intakes in relation to age-specific recommendations, usual sodium density, and sodium:potassium ratio, especially among infants and children aged <2 y, black children, and breastfed children. Data from NHANES 2003–2006 were used to estimate the percentage of children aged ≥2 y with sodium intakes above the AI and UL and the percentage of children aged ≥2 y with potassium intakes above the AI (19). Data from the 2002 and 2008 Feeding Infants and Toddlers Study (FITS) included infants and children aged <2 y but did not include separate data for non-Hispanic

[5]Abbreviations used: AI, Adequate Intake; BP, blood pressure; FITS, Feeding Infants and Toddlers Study; FNDDS, Food and Nutrient Database for Dietary Studies; IOM, Institute of Medicine; MEC, mobile examination center; PIR, poverty:income ratio; UL, Tolerable Upper Intake Level.

black children, sodium density, or sodium:potassium ratio (20, 21). In the current study, usual sodium intakes above the UL, sodium and potassium intakes above AIs, the sodium:potassium ratio, and sodium density (mg/kcal) among US infants and preschoolers by age group, as applicable, were estimated and compared by race-ethnicity and current breastfeeding status.

METHODS

Data source and study design

Data were used from NHANES 2003–2010, a nationally representative, cross-sectional survey that used a stratified, multistage, complex sampling design to assess the nutrition and health status of the noninstitutionalized US population (22). Data for NHANES were collected by the National Center for Health Statistics, CDC, via interviews and physical examinations. Detailed information is available elsewhere (22). The survey was reviewed and approved by the National Center for Health Statistics ethics review board, and participants or their proxies provided written informed consent before participation.

Sample selection

Data were analyzed among 3 groups of participants—*1*) infants aged 7–11 mo, *2*) children aged 1–3 y, and *3*) children aged 4–5 y—to investigate intake during the establishment of dietary patterns before entry to school. Infants aged ≤6 mo were excluded because they primarily consume infant formula and breast milk. Four cycles of NHANES (2003–2010) were combined to provide an adequate sample size for stable intake estimates among our subgroups of interest. Of the infants aged 7–11 mo and preschoolers aged 1–5 y who were selected for NHANES, 88% (n = 780) and 85% (n = 5026), respectively, came to the mobile examination center (MEC) in 2003–2010. We sequentially excluded 442 participants with a missing or incomplete first-day dietary recall or an incomplete second-day dietary recall, 12 participants with missing maternal age at birth, and 382 participants with missing income data. The final analytic sample (n = 4970) included 699 infants aged 7–11 mo, 2882 preschoolers aged 1–3 y, and 1389 children aged 4–5 y. When compared with children excluded (n = 394) because of missing or incomplete information on diet or covariates, the children included (n = 4970) in our sample did not differ significantly by sex. However, a higher percentage of children included in the sample were non-Hispanic white (56% compared with 40% of the excluded children aged 1–3 y and 58% compared with 37% of the excluded children aged 4–5 y, respectively; $P < 0.05$) and a lower percentage of children were Mexican American (17% compared with 24% and 16% compared with 22%, respectively; $P < 0.05$).

Nutrient intakes

To assess nutrient intakes (sodium, potassium, and energy), data on the intake or child's intake of foods were reported by a proxy (eg, mother). Dietary intake of foods by infants or children in the previous 24 h was collected from the proxy in the MEC (day 1) and by telephone 3–10 d later (day 2) by trained interviewers using the USDA's Automated Multi-Pass Method described in detail elsewhere (23). The nutrient values for sodium, potassium, and energy were assigned to foods and beverages (including water) by the USDA by using the Food and Nutrient Database for Dietary Studies (FNDDS) corresponding with each 2-y phase (24), with one exception. In the current study, the sodium content of tap and bottled water consumed in 2003–2004 was quantified by using the nutrient profile for those items in FNDDS 3.0 (24) corresponding to NHANES 2005–2006. In 2003–2004, tap and plain bottled water intake information was collected after the 24-h dietary recall and not included in estimates of individual sodium intake. Thus, the sodium content of water was added to individual sodium intake from other sources for intake estimates in 2003–2004. From 2005 to 2010, data on tap and plain bottled water intake were collected as part of the 24-h dietary recall and sodium content was quantified by using the FNDDS corresponding with each 2-y phase. Dietary sodium or potassium intakes were estimated by summing the sodium or potassium consumed from each food and beverage reported during the previous 24 h. We chose to focus on sodium intake from food and beverages excluding salt added at the table, sodium in supplements, and sodium in antacids, because foods and beverages are the primary source of sodium intake (24, 25). For children whose proxies reported that they consumed human milk on one or both recall days, the nutrient intakes from human milk were estimated and added to those from other foods and beverages by using the methods described below.

A total of 230 infants and children aged 7–36 mo were reported to receive human milk. Except for one infant aged 7 mo who was reported to receive only human milk, these children also were reported to receive other beverages or foods. For each child, the number of human milk feedings during the past 24 h was reported on each recall. To assess the amount of human milk consumed, the approach used in the FITS (20) was used. The volume of human milk was assumed to be 600 mL/d for children aged 7–11 mo fed only human milk, 600 mL/d minus the volume of infant formula plus other milk for other children aged 7–11 mo, 89 mL per human milk feeding for children aged 12–17 mo, and 59 mL per feeding for children aged 18–36 mo. Sodium, potassium, and energy concentrations in human milk were assumed to be 177 mg/L, 531 mg/L, and 75 kcal/L, respectively, based on the USDA National Nutrient Database for Standard Reference 25 values for mature human milk and 33.8 fluid ounces per liter (26).

Excess sodium intake was defined as a usual intake greater than the UL for each applicable age group (17). Adequate sodium and potassium intakes were defined as usual intake above the AI for each age group (17). The estimation of usual intakes is described below under “Statistical analyses.”

Covariates

Questionnaire information included sex, age, race-ethnicity, income, household size, and maternal age. Weight, height (for children aged ≥2 y), and length (for infants and children <2 y) were measured in the MEC (21). Three age groups of US children aged 7–11 mo, 1–3 y, and 4–5 y were defined to match the age groups used by the IOM (17). Race-ethnicity was reported by the proxies on the basis of a list that included an openended response. For this analysis, the race-ethnicity groups were limited to non-Hispanic white, non-Hispanic black, and Mexican American because of continuous oversampling in these groups across survey years. Sample sizes for other race-ethnicity groups were too small for stable intake estimates. Current breastfeeding status was based on the proxy reporting that the infant or child consumed human milk one or more times on at least one of the two 24-h dietary recalls.

Other covariates of interest as potential confounders in the comparison of sodium and potassium intake by race-ethnicity or current breastfeeding status were income, maternal age at birth, infant birth weight, and weight-for-length or BMI. To assess income, the poverty:income ratio (PIR) was used. It was defined as household income relative to national poverty thresholds for a household of similar size, composition, and location and was categorized as ≤130% or 130%, which are the categories often used for federal programs. Maternal age at birth was categorized as ≤19, 20–34, and ≥35 y. Infant birth weight was reported by proxy (usually the mother). Infant birth weight was categorized as <2500 g, 2500–4000 g, and.4000 g. By using the CDC 2000 growth charts, the weight status of children aged 7 mo up to 23 mo was classified according to their weight-for-length *z* score (27), and children aged 2–5 y were classified by their BMI-for-age *z* score (28). The *z* scores were converted to percentiles, and children were classified as <85th percentile, ≥85th to <95th percentile, and ≥95th percentile. BMI was defined as weight in kilograms divided by height in meters squared.

Finally, for estimation of usual nutrient intake distributions (*see* Statistical analysis), day of the week of the 24-h dietary recall was examined because nutrient intakes vary within individuals from day to day and from weekend to weekday (29).

Statistical analysis

We estimated usual intake distributions (ie, means, medians, 25th and 75th percentiles) of sodium, sodium density, energy, potassium, and sodium:potassium ratio. In addition, we estimated the prevalence of sodium consumption exceeding the age-specific UL and sodium and potassium exceeding the AI for children among each applicable age group by race-ethnicity or by current breastfeeding status. We used data from up to two 24-h dietary recalls for each participant with statistical software that fits a measurement error model to estimate usual intake distributions [PC-SIDE (Software for Intake Distribution Estimation for the Windows operating system), version 1.0; Iowa State University] (30, 31). A single 24-h dietary recall can be used to estimate mean population intake; however, this approach does not account for day-to-day variation in food consumed by individuals and can overestimate or underestimate the population prevalence above and below specific thresholds (29). PC-SIDE selects the best transformation to normalize the data; adjusts the intake distribution for selected variables such as age, sex, race-ethnicity, and day of the week; and accounts for within- and between-individual variability in nutrient intakes. PC-SIDE can be used to estimate usual nutrient intake distributions when only a subsample of the population has ≥2 independent days of dietary data: 86% of respondents to the first 24-h dietary recall in NHANES 2003– 2010 provided a second 24-h dietary recall. In PC-SIDE, SEs for usual intakes were estimated by using a set of 122 jackknife repeated replication weights based on the 8-y combined first-day dietary sampling weights. In our analyses, we initially adjusted distributions in PC-SIDE for participant age in months, sex, race-ethnicity, current breastfeeding status, maternal age, PIR, infant birth weight, weight status, and day of the week of the 24-h dietary recall. In subsequent analyses, we found that the adjustment of the nutrient intake distributions for birth weight and weight status did not affect the direction or magnitude of the differences in the distributions by race-ethnicity or current breastfeeding status, and thus in the final analyses we adjusted for all the variables listed as above except for birth weight and weight status. For analyses stratified by race-ethnicity we did not adjust distributions for race-ethnicity, and for analyses stratified by current breastfeeding status we did not adjust distributions for current breastfeeding status.

Mean usual nutrient intakes by race-ethnic group were compared by the Z-test. With the exception of estimation of nutrient intakes in PC-SIDE, other analyses used SAS-callable SUDAAN version 9.3 (SAS Institute) and combined 8-y MEC sample weights to account for the complex survey design.

RESULTS

Significant differences ($P < 0.05$) between race-ethnic groups were noted in the PIR and birth weight for all age groups, for maternal age at birth among those aged 1–3 and 4–5 y, for BMI percentile among those aged 1–3 y, and for current breastfeeding status among those aged 7–11 mo and 1–3 y (Table 1). After usual nutrient intake distributions were adjusted for covariates, non-Hispanic black children had the highest mean sodium intake (in mg/d) of the race-ethnic groups examined across all 3 age groups (Table 2). Among infants aged 7–11 mo, non-Hispanic blacks and Mexican Americans had significantly higher mean sodium intakes (~100–150 mg/d) than non-Hispanic whites. Among children aged 1–3 and 4–5 y, non-Hispanic black children had significantly higher mean sodium intakes (~190–310 mg/d) than did non-Hispanic whites or Mexican Americans. Among infants aged 7–11 mo, the majority met their AI for sodium as did >98% of children aged 1–3 y and nearly 100% of children aged 4–5 y. Among children aged 1–3 and 4–5 y, the vast majority consumed more than their UL for sodium, regardless of race-ethnicity. Among children aged 1–3 and 4–5 y, the proportion with usual intake more than the sodium UL varied by race-ethnicity. Among children aged 1–3 y, a significantly higher proportion of non-Hispanic blacks and whites compared with Mexican Americans consumed more than the UL, and among children aged 4–5 y a significantly higher proportion of non-Hispanic blacks compared with non-Hispanic whites and Mexican Americans consumed more than the UL.

Sodium density and energy intake also varied by race-ethnicity in almost all age groups, with non-Hispanic blacks consuming more sodium per kilocalorie and energy, on average, compared with at least one of the other race-ethnic groups (Table 3). Among infants aged 7–11 mo, non-Hispanic blacks consumed more sodium per kilocalorie and energy than did non-Hispanic whites. In addition, non-Hispanic blacks consumed more energy, on average, than did Mexican Americans. Among children aged 1–3 y, non-Hispanic blacks and non-Hispanic whites consumed more sodium per kilocalorie than did Mexican Americans. In addition, non-Hispanic blacks consumed more energy than both non-Hispanic whites and Mexican Americans. Among children aged 4–5 y, non-Hispanic blacks consumed more sodium per kilocalorie than did non-Hispanic whites and Mexican Americans, but energy intake did not vary by race-ethnicity.

Among children aged 1–3 and 4–5 y, Mexican Americans consumed significantly more potassium (~120–330 mg/d) than did non-Hispanic whites or non-Hispanic blacks (*see* Supplemental Table 1 under "Supplemental data" in the online issue). Among children aged 4–5 y, non-Hispanic blacks consumed the least potassium. Among infants aged 7–11 mo, the vast majority of children among all race-ethnic groups consumed more than their AI of potassium. In contrast, across all 3 race-ethnic groups, <8% of children aged 1–3 y and ≤1% of children aged 4–5 y met or exceeded their AI of potassium.

The mean sodium:potassium ratio was lowest among US children aged 7–11 mo (<0.5) compared with older age groups (*see* Supplemental Table 1 under "Supplemental data" in the online issue). Among infants aged 7–11 mo, non-Hispanic blacks and Mexican Americans consumed, on average, more sodium to potassium than did non-Hispanic whites. Among children aged 1–3 and 4–5 y, non-Hispanic black children consumed, on average, more sodium to potassium followed by non-Hispanic whites and Mexican Americans.

Currently breastfed infants and children (Table 4) consumed significantly less sodium, on average, than those who were not breastfeeding. Furthermore, the proportion of children aged 1–3 y who consumed more than the UL was significantly lower among currently breastfed children. Among children aged 1–3 y, those currently breastfed also consumed less sodium, on average, from complementary food and beverages [food and beverages other than human milk, infant formula, and other milks (eg, cow milk)]. Complementary food accounted for ~63–74% of sodium consumed among children aged 7–11 mo and for ~90% among those aged 1–3 y.

Currently breastfed infants and children consumed less sodium per kilocalorie and energy than did thosewho were not breastfeeding (Table 5). The intake of sodium per kilocalorie from complementary foods did not vary by current breastfeeding status. Mean energy intake from complementary foods was lower for children currently breastfed, particularly among children aged 1–3 y.

Similar to the results for sodium intake, currently breastfed infants and children consumed less potassium (*see* Supplemental Table 2 under " Supplemental data" in the online issue). A substantial proportion of potassium intake was from complementary foods: 50–61% among infants aged 7–11 mo and 68–70% among children aged 1–3 y. The sodium:potassium ratio did not vary by current breastfeeding status (*see* Supplemental Table 2 under "Supplemental data" in the online issue).

DISCUSSION

In 2003–2010 the vast majority of US children aged 1–5 y consumed excessive sodium and nearly all children in this age range did not consume enough potassium. The mean intake for preschoolers aged 4–5 y exceeded the UL for adults (2300 mg/d) (17). Notably, non-Hispanic black infants and preschoolers had significantly higher intakes of sodium and higher sodium:potassium ratio than did their non-Hispanic white counterparts, and Mexican Americans had the highest potassium intakes and the lowest sodium:potassium ratio. Results suggest the higher sodium intakes among non-Hispanic black infants and children were at least partially explained by greater intakes of sodium per kilocalorie. Furthermore, infants and children who were currently breastfed consumed less sodium, potassium, and energy than children who were not.

Our report provides the most current and comprehensive data on usual sodium and potassium intakes among US infants aged 7– 11 mo and preschool children, particularly among non-Hispanic blacks. Our results expand previous results to include nutrient intakes among children currently breastfeeding and reinforce other US data (19, 20) that most preschool children still exceed the UL for sodium intake and that non-Hispanic black children aged ≥2 y have significantly higher mean sodium intakes than non-Hispanic whites or Mexican Americans. In addition, our results are the first we know of to suggest that higher consumption of sodium per kilocalorie as well as energy intake are related to the higher sodium intake observed among non-Hispanic black infants and preschoolers. Among US children, sodium is highly correlated with energy intake ($r \sim 0.8$) (32). Among children aged 4–5 y, non-Hispanic blacks consumed higher amounts of sodium per kilocalorie, but not higher energy, suggesting that the types of foods consumed or the greater amount of sodium in similar caloric foods consumed was a factor in their higher sodium intake.

Our results for potassium are also consistent with older data indicating that a small proportion of all US children aged ≥2 y meet the AI for potassium and that mean potassium intake is greater than the AI in infants aged 7–11 mo but lower than the AI in children aged ≥1 y (17, 33). As in previous studies, the usual mean intake of potassium, although still low, was higher among Mexican American preschool children compared with other race-ethnic groups (21).

Our results also confirm previous studies indicating that the majority of sodium and potassium intake is from complementary foods rather than from breast milk or infant formula (34, 35). In addition, the current study shows that the differences in sodium intake by current breastfeeding status are related to the lower energy intake from complementary foods among breastfeeding children.

We know of no previous study examining the sodium:potassium ratio among infants and preschool children. Our results indicate that sodium intake is lower than potassium intake among US infants and that this reverses (ie, higher sodium relative to potassium intakes) among US children aged 4–5 y. In addition, within each age group, non-Hispanic blacks consumed more sodium relative to potassium compared with other race-ethnic groups, whereas among children aged 1–5 y, Mexican Americans consumed lower amounts of sodium relative to potassium. In addition, the consumption of sodium relative to potassium did not vary by current breastfeeding status despite lower sodium and potassium intakes among children who are currently breastfed, suggesting proportionally lower intakes for both of these nutrients among children who are currently breastfed.

On the basis of dietary intake data, the vast majority of US preschool-aged children exceed the UL for sodium and do not meet the AI for potassium, suggesting that they are at increased risk of high BP. We were unable to examine this association in this study because data on BP are unavailable in children aged <8 y in NHANES. Data to directly set a UL on the basis of expected BP change, such as that from the Dietary Approaches to Stop Hypertension sodium trial in adults (36), remain unavailable in children. Data from numerous observational studies documenting the tracking of BP with age and the recognition that the “antecedents of chronic conditions in adults” such as elevated BP occur in childhood led the IOM to extrapolate the adult sodium UL and potassium AI to children (17). The somewhat greater excess sodium intake and sodium:potassium ratio among non-Hispanic black children in this study is a concern given that a higher proportion of non-Hispanic blacks compared with other race-ethnic groups are sodium sensitive as adults (5, 17). However, it is unknown whether these higher sodium intakes in childhood cause sodium sensitivity in later years. Consistent with the approach for setting ULs for children, a recent report indicated expressing recommendations in terms of milligrams of sodium per kilocalorie would help accommodate the energy needs of different subgroups of the population. In addition, the authors argued that this approach is not necessarily inconsistent with the Dietary Guidelines (37) given that current sodium intakes are so much higher than recommended amounts. Further research on the effects of early sodium intake on later hypertension would help inform the Dietary Guidelines, including efforts to support development of guidelines for children aged <2 y (38).

In the current food environment, it is a challenge for US children to meet current recommendations for sodium and potassium intakes, particularly after the introduction of complementary foods. Although race-ethnic differences were apparent in sodium and potassium intake and the sodium:potassium ratio, our data suggest that all race-ethnic groups consumed too much sodium and too little potassium. Previous data indicate that the main sources of potassium in the diets of US infants and toddlers are infant formula, human or other milk, infant and other cereals, and fruit and vegetables (eg, bananas, potatoes). The main sources of sodium are infant formula, human milk or other milk, cheese, breads, rolls, biscuits, non–infant cereals, processed and other meats (eg, hot dogs, chicken), and salty snacks (eg, crackers, pretzels, rice cakes) (35). Data from NHANES 2001– 2004 for 894 children aged 2–3 y suggested that 32%, 80%, and 41% of them consumed fruit, vegetables, and milk below the recommendations, respectively. In children aged 4–8 y, the percentages were 63%, 92%, and 42%, respectively (39).

Several limitations were identified. A potential limitation of our study is underestimation of sodium and potassium intake. The 24-h dietary recall underestimates sodium and caloric intake in adults by approximately <9% and 11%, respectively, and may underestimate sodium and potassium intake in children (40-42). The dietary recalls were reported by a proxy, who may under- or overestimate intake of food consumed at day care or preschool. In addition, the estimated usual sodium intake in our study included sodium intake from foods, beverages (including water), and added sodium during cooking, but it excluded use of salt at the table. The exclusion of table salt is not expected to bias the nutrient intake estimates because <0.5% of sodium intake in children aged 1–3 and 4–8 y is estimated to come from salt added at the table (19). In addition, nonresponse bias may result in an overestimate or underestimate of the usual daily intake of sodium and potassium. Estimates of dietary intake in our study, however, were weighted to account for nonresponse, thus reducing the possibility of response bias, and only ~8% of the sample was excluded because of missing information on covariates. Furthermore, limited differences were noted between those included and those excluded from our analytic sample. Finally, although the FITS approach was used to assess sodium and potassium from human milk, the estimates of the volume of human milk in each age stage are broad and imprecise, and thus differences in total sodium intake by breastfeeding status need to be interpreted with caution.

The early establishment of taste preferences for salty foods (16) and lower estimated sodium and energy intake among infants and children who were currently breastfeeding is another reason to promote breastfeeding for 12 mo as recommended by the American Academy of Pediatrics (43). Furthermore, despite the lower potassium intake among currently breastfed infants, the sodium:potassium ratio did not differ from those not currently breastfed. Finally, after infancy, the increased consumption of sodium-dense foods and reversal of the sodium:potassium ratio emphasize the need to continue efforts to reduce the amount of salt in the US food supply and to increase consumption of good sources of potassium, such as low-fat milk and fruit and vegetables. New regulations in schools call for lowering the amount of sodium in foods (44). Lowering sodium intake and increasing consumption of potassium-containing foods among infants and young children could prevent high BP (15) and subsequently cardiovascular disease. According to a 2013 IOM report on sodium intake in populations, analyses of the health consequences of dietary sodium in combination with potassium in children would strengthen the evidence for sodium reduction (45).

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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TABLE 1

Demographic characteristics of older US infants (7–11 mo) and preschool-aged children (1–5 y) by age and race-ethnicity: NHANES 2003–2010[1]

	Age 7–11 mo (*n* = 699)				Age 1–3 y (*n* = 2882)				Age 4–5 y (*n* = 1389)			
Characteristic	**Non-HW (*n* = 234)**	**Non-HB (*n* = 109)**	**MA (*n* = 263)**	***P*[2]**	**Non-HW (*n* = 956)**	**Non-HB (*n* = 650)**	**MA (*n* = 859)**	***P*[2]**	**Non-HW (*n* = 469)**	**Non-HB (*n* = 346)**	**MA (*n* = 394)**	***P*[2]**
Sex (%)[3]				0.713				0.450				0.803
Male	45.8	48.5	45.4		53.3	51.8	53.9		52.5	49.0	52.4	
Female	54.2	51.5	54.6		46.7	48.2	46.1		47.5	51.0	47.6	
Weight-for-length or BMI-for-age percentile[4] (%)				0.355				0.005				0.076
<85th	70.1	65.3	66.7		79.3	75.0	70.8		78.2	73.1	68.6	
≥85 to <95th	18.6	22.3	18.8		12.8	12.4	15.0		9.7	11.5	12.6	
≥95th	11.4	12.4	14.5		7.9	12.6	14.1		12.1	15.4	18.8	
Poverty:income ratio[5] (%)				<0.001				<0.001				<0.001
≤130%	23.8	50.3	62.1		23.6	59.8	59.2		22.8	55.6	59.6	
>130%	76.2	49.7	37.9		76.4	40.2	40.8		77.2	44.4	40.4	
Maternal age at birth (%)				0.114				0.003				<0.001
≤19 y	7.0	9.0	16.3		7.2	17.8	11.5		7.9	20.6	17.6	
20–34 y	82.8	82.4	76.2		77.1	72.1	77.2		75.4	72.4	74.2	
≥35 y	10.2	8.6	7.5		15.6	10.1	11.3		16.7	7.0	8.2	
Birth weight (%)				0.003				<0.001				0.018
<2500 g	4.6	14.9	8.3		7.5	14.0	7.5		7.7	15.6	8.5	
2500–4000 g	87.2	83.0	81.7		80.0	81.0	80.5		79.8	77.9	80.7	
>4000 g	8.2	2.1	9.9		12.5	4.9	12.0		12.5	6.5	10.8	
Current breastfeeding (%)				0.020				0.006				N/A
Yes	23.0	12.2	23.3		3.2	0.8	2.7		N/A	N/A	N/A	
No	77.0	87.8	76.7		96.8	99.2	97.3		N/A	N/A	N/A	

[1]The category of “other race-ethnicity” is not included in these strata but is included in the totals. All sample sizes are unweighted. MA, Mexican American; N/A, not applicable; Non-HB, non-Hispanic black; Non-HW, non-Hispanic white.

[2]Chi-square test for difference in percentages between race-ethnic groups accounting for the complex survey design.

[3]Weighted percentages.

[4] By using the CDC 2000 growth charts, children aged 7–23 mo were classified according to their weight-for-length *z* score, and children aged 2–5 y were classified by their BMI-for-age *z* score. The *z* scores were then converted to percentiles.

[5] The poverty:income ratio is defined as total household income divided by the poverty threshold for the year of the interview multiplied by 100.

TABLE 2

Usual sodium intake among older US infants (7–11 mo) and preschool-aged children (1–5 y) by age and race-ethnicity: NHANES 2003–2010[1]

		Usual sodium intake				Dietary Reference Intake[3]		Adequate/excessive usual sodium intake	
	Sample size[2]	Mean intake	25th percentile	50th percentile	75th percentile	AI	UL	>AI	>UL
	n	*mg/d*				*mg/d*		%	
Age 7–11 mo						370	N/A		
Total	699	499.7 ± 18.7[4]	320 ± 8.7	438 ± 16.2	614 ± 27.7			63.82 ± 2.56	N/A
Non-Hispanic white	234	447.6 ± 25.5[5]	293 ± 15.2	396 ± 23.5	547 ± 35.8			55.81 ± 5.26	N/A
Non-Hispanic black	109	600.5 ± 65.1[6]	354 ± 35.0	508 ± 56.2	740 ± 88.2			72.24 ± 6.35	N/A
Mexican American	263	559.7 ± 28.8	359 ± 19.1	492 ± 25.5	683 ± 37.0			72.77 ± 3.81	N/A
Age 1–3 y						1000	1500		
Total	2882	1954.2 ± 23.5	1559 ± 20.3	1895 ± 22.0	2282 ± 26.3			97.92 ± 0.27	78.94 ± 1.29
Non-Hispanic white	956	1932.9 ± 35.9[5]	1566 ± 31.8	1887 ± 34.6	2250 ± 43.4			98.36 ± 0.41	79.53[5] ± 2.09
Non-Hispanic black	650	2120.5 ± 58.5[5,6]	1666 ± 47.4	2047 ± 56.7	2491 ± 69.1			98.41 ± 0.39	84.16[5] ± 2.17
Mexican American	859	1807.8 ± 40.4	1433 ± 33.9	1741 ± 40.3	2107 ± 48.8			96.51 ± 0.65	69.80 ± 2.80
Age 4–5 y						1200	1900		
Total	1389	2504.5 ± 35.9	2100 ± 29.0	2441 ± 32.6	2839 ± 41.9			99.90 ± 0.06	86.98 ± 1.42
Non-Hispanic white	469	2473.6 ± 56.8	1999 ± 44.5	2369 ± 51.7	2836 ± 68.4			99.69 ± 0.18	81.13 ± 2.57
Non-Hispanic black	346	2697.3 ± 57.6[5,6]	2362 ± 56.1	2666 ± 57.9	3000 ± 70.7			100	96.51[5,6] ± 1.50
Mexican American	394	2435.4 ± 73.6	2077 ± 64.6	2400 ± 72.3	2755 ± 84.4			99.84 ± 0.11	85.90 ± 3.23

[1] Means and 25th, 50th, and 75th percentiles of usual sodium intakes (mg/d) and proportions above the AI and UL were estimated by using PC-SIDE (Department of Statistics, Iowa State University) with data from up to two 24-h dietary recalls adjusted for the day of the week of the recall, age (mo, continuous), sex, maternal age at birth (continuous), poverty-index ratio, and current breastfeeding status. Individuals with missing data or with incomplete first-day 24-h dietary recall were excluded. Jackknife replicate weights based on first-day dietary weights used to account for the complex sampling design were used in PC-SIDE to estimate SEs. The category of "other race-ethnicity" is not included in these strata but is included in the totals. AI, Adequate Intake; N/A, not applicable; UL, Tolerable Upper Intake Level.

[2] Unweighted sample sizes.

[3] AIs and ULs have been defined for sodium in each age group. N/A indicates that UL was not defined for this age group.

[4] Mean ± SE (all such values).

[5] Significantly different from Mexican Americans, $P < 0.05$ (*Z*-test).

[6] Significantly different from non-Hispanic whites, $P < 0.05$ (Z-test).

TABLE 3

Usual sodium density and energy intake among older US infants (7–11 mo) and preschool-aged children (1–5 y) by age and race-ethnicity: NHANES 2003–2010[1]

		Usual sodium density				Usual energy intake			
Category	**Sample size[2]**	**Mean sodium density**	**25th percentile**	**50th percentile**	**75th percentile**	**Mean energy intake**	**25th percentile**	**50th percentile**	**75th percentile**
	n	*mg/1000 kcal*				*kcal/d*			
Age 7–11 mo									
Total	699	549 ± 15.9[3]	396 ± 13.0	506 ± 14.8	657 ± 25.9	883 ± 12.5	757 ± 10.5	862 ± 13.0	988 ± 16.1
Non-Hispanic white	234	497 ± 19.1[4]	367 ± 16.9	461 ± 19.1	586 ± 36.7	870 ± 18.6	758 ± 16.5	852 ± 21.4	960 ± 22.6
Non-Hispanic black	109	592 ± 52.2[5]	417 ± 40.1	541 ± 50.8	709 ± 66.0	967 ± 39.0[4,5]	802 ± 37.2	947 ± 40.3	1110 ± 46.5
Mexican American	263	618 ± 25.8	450 ± 20.8	576 ± 25.1	742 ± 31.9	882 ± 26.5	742 ± 22.4	859 ± 23.7	994 ± 33.3
Age 1–3 y									
Total	2882	1397 ± 12.0	1232 ± 10.2	1373 ± 10.7	1532 ± 13.7	1400 ± 13.9	1182 ± 12.0	1372 ± 13.6	1590 ± 17.7
Non-Hispanic white	956	1403 ± 17.1[4]	1234 ± 13.5	1379 ± 14.1	1543 ± 18.9	1378 ± 19.9	1176 ± 16.2	1352 ± 19.0	1554 ± 23.9
Non-Hispanic black	650	1441 ± 23.3[4]	1256 ± 20.1	1405 ± 19.0	1582 ± 23.3	1466 ± 27.1[4,5]	1248 ± 23.4	1445 ± 26.9	1661 ± 33.2
Mexican American	859	1313 ± 18.9	1155 ± 17.4	1289 ± 18.8	1442 ± 21.2	1382 ± 22.8	1161 ± 20.0	1356 ± 22.6	1574 ± 27.3
Age 4–5 y									
Total	1389	1514 ± 15.0	1372 ± 12.7	1494 ± 14.5	1633 ± 17.8	1668 ± 19.9	1445 ± 19.5	1639 ± 25.6	1858 ± 30.6
Non-Hispanic white	469	1511 ± 23.8[4]	1344 ± 21.4	1488 ± 22.3	1652 ± 28.4	1646 ± 31.6	1422 ± 22.5	1610 ± 28.8	1828 ± 40.5
Non-Hispanic black	346	1594 ± 25.1[4,5]	1464 ± 42.0	1582 ± 28.9	1710 ± 28.0	1712 ± 31.6	1521 ± 31.3	1699 ± 32.7	1889 ± 35.0
Mexican American	394	1438 ± 22.4	1338 ± 23.3	1435 ± 22.5	1535 ± 22.7	1705 ± 39.2	1457 ± 32.9	1677 ± 38.3	1924 ± 46.6

[1] Sodium density was calculated by using sodium in milligrams divided by calories multiplied by 1000 (mg/1000 kcal). Means and 25th, 50th, and 75th percentiles of usual sodium density and energy intakes were estimated from PC-SIDE (Department of Statistics, Iowa State University) with data from up to two 24-h dietary recalls adjusted for the day of the week of the recall, age (mo, continuous), sex, maternal age at birth (continuous), poverty-index ratio, and current breastfeeding status. Individuals with missing data or with incomplete first-day 24-h dietary recall were excluded. Jackknife replicate weights based on first-day dietary weights used to account for the complex sampling design were used in PC-SIDE to estimate SEs. The category of "other race-ethnicity" is not included in these strata but is included in the totals.

[2] Unweighted sample sizes

[3] Mean ± SE (all such values).

[4] Significantly different from Mexican Americans, $P < 0.05$ (Z-test).

[5] Significantly different from non-Hispanic whites, $P < 0.05$ (Z-test).

TABLE 4

Usual sodium intakes among US infants (7–11 mo) and preschool-aged children (1–3 y) by age and current breastfeeding status: NHANES 2003–2010[1]

Category	Sample size[2]	Usual sodium intake				Dietary Reference Intake[3]		Adequate/excessive usual sodium intake	
		Mean sodium intake	25th percentile	50th percentile	75th percentile	AI	UL	>AI	>UL
	n	*mg/d*				*mg/d*		*%*	
Currently breastfed									
Total intake									
Age 7–11 mo	147	382.6 ± 53.1[4]	254 ± 38.8	341 ± 29.8	463 ± 69.1	370	N/A	42.73 ± 7.41	N/A
Age 1–3 y	83	1153.5 ± 87.7	861 ± 85.5	1109 ± 102.0	1399 ± 109.0	1000	1500	61.10 ± 9.82	18.71 ± 6.11
Intake from complementary food[5]									
Age 7–11 mo	147	267.0 ± 36.1	121 ± 21.3	214 ± 31.0	355 ± 52.4	370	N/A	N/A	N/A
Age 1–3 y	82	1028.0 ± 89.6	746 ± 85.2	981 ± 99.8	1260 ± 119.0	1000	1500	N/A	N/A
Not currently breastfed									
Total intake									
Age 7–11 mo	552	538.0 ± 22.1[6]	370 ± 14.0	484 ± 20.5	650 ± 33.2	370	N/A	74.94 ± 3.09	N/A
Age 1–3 y	2799	1985.1 ± 23.9[6]	1546 ± 22.3	1912 ± 23.3	2347 ± 27.4	1000	1500	97.56 ± 0.33	77.88 ± 1.37
Intake from complementary food[5]									
Age 7–11 mo	547	337.1 ± 26.9	136 ± 10.2	252 ± 19.5	440 ± 35.9	370	N/A	N/A	N/A
Age 1–3 y	2795	1788.0 ± 22.5[7]	1383 ± 19.5	1725 ± 21.0	2121 ± 25.6	1000	1500	N/A	N/A

[1]Means and 25th, 50th, and 75th percentiles of usual sodium intakes (mg/d) and proportions above the AI and UL were estimated from PC-SIDE (Department of Statistics, Iowa State University) with data from up to two 24-h dietary recalls adjusted for the day of the week of the recall, age (mo, continuous), sex, maternal age at birth (continuous), poverty-index ratio, and race-ethnicity. Individuals with missing data on the first-day 24-h dietary recall were excluded. Jackknife replicate weights based on first-day dietary weights were used to account for the complex sampling design in PC-SIDE to estimate SEs. Children aged 4–5 y were not included in this analysis because none were currently breastfed on either day of the 24-h dietary recall. AI, Adequate Intake; N/A, not applicable; UL, Tolerable Upper Intake Level.

[2]Unweighted sample sizes.

[3]An AI and a UL have been defined for sodium. An N/A in the UL column indicates that a UL was not defined for this age group.

[4]Mean ± SE (all such values).

[5] Intake from complementary food was defined as intake from beverages and food other than human milk, infant formula (USDA food code 11710000- 11820000), or milk (USDA food code 11000000-11340000) (20, 21, 24).

[6] Significantly different from total sodium intake in breastfed children by the corresponding month and year, $P < 0.05$ (Z-test).

[7] Significantly different from intake from food and beverages other than milk or infant formula in breastfed children by the corresponding month and year, $P < 0.05$ (Z-test).

TABLE 5

Usual sodium density and energy intakes among US infants (7–11 mo) and preschool-aged children (1–3 y) by age and current breastfeeding status: NHANES 2003–2010[1]

Category	Sample size[2]	Usual sodium density: Mean sodium density	Usual sodium density: 25th percentile	Usual sodium density: 50th percentile	Usual sodium density: 75th percentile	Usual energy intake: Mean energy intake	Usual energy intake: 25th percentile	Usual energy intake: 50th percentile	Usual energy intake: 75th percentile
	n	*mg/1000 kcal*				*kcal/d*			
Currently breastfed									
Total intake									
Age 7–11 mo	147	463.5 ± 35.4[3]	349 ± 23.3	431 ± 46.7	546 ± 59.1	769.7 ± 18.5	678 ± 14.7	753 ± 18.1	843 ± 24.4
Age 1–3 y	83	1255.7 ± 63.8	1060 ± 52.7	1224 ± 133.0	1423 ± 162.0	915.9 ± 52.4	758 ± 65.4	902 ± 59.0	1058 ± 76.3
Intake from complementary food[4]									
Age 7–11 mo	147	838.9 ± 100.8	586 ± 60.9	786 ± 90.5	1033 ± 135.0	320.2 ± 18.3	215 ± 15.0	300 ± 18.3	401 ± 24.4
Age 1–3 y	82	1523.7 ± 70.2	1334 ± 61.0	1493 ± 68.7	1676 ± 94.0	681.0 ± 50.7	533 ± 36.5	655 ± 52.4	804 ± 77.1
Not currently breastfed									
Total intake									
Age 7–11 mo	552	577.5 ± 23.4[5]	433 ± 24.9	540 ± 18.1	680 ± 28.6	919.2 ± 15.8[5]	790 ± 14.0	897 ± 17.4	1026 ± 20.0
Age 1–3 y	2799	1417.9 ± 15.0[5]	1204 ± 12.2	1370 ± 11.6	1572 ± 16.4	1414.5 ± 13.9[5]	1172 ± 19.2	1380 ± 15.0	1620 ± 23.7
Intake from complementary food									
Age 7–11 mo	547	830.7 ± 46.2	467 ± 28.8	719 ± 45.8	1058 ± 57.6	378.7 ± 13.3[6]	261 ± 10.6	351 ± 12.5	464 ± 16.9
Age 1–3 y	2795	1549.4 ± 13.6	1365 ± 13.1	1523 ± 15.3	1701 ± 15.9	1168.3 ± 12.3[6]	935 ± 10.5	1135 ± 12.1	1366 ± 14.8

[1] Sodium density was calculated by using sodium in milligrams divided by calories multiplied by 1000 (mg/1000 kcal). Means and 25th, 50th, and 75th percentiles of usual sodium density and energy intakes were estimated from PC-SIDE (Department of Statistics, Iowa State University) with data from up to two 24-h dietary recalls adjusted for the day of the week of the recall, age (mo, continuous), sex, maternal age at birth (continuous), poverty-index ratio, and race-ethnicity. Individuals with missing data or with incomplete first-day 24-h dietary recall were excluded. Jackknife replicate weights based on firstday dietary weights used to account for the complex sampling design were used in PC-SIDE to estimate SEs. Children aged 4–5 y were not included in this analysis because none were currently breastfed on either day of the 24-h dietary recall.

[2] Unweighted sample sizes.

[3] Mean 6 SE (all such values).

[4] Intake from complementary food was defined as intake from beverages and food other than human milk, infant formula (USDA food code 11710000-11820000), or milk (USDA food code 11000000-11340000) (20, 21, 24).

[5]Significantly different from total sodium intake in currently breastfed children in the corresponding age group, $P < 0.05$ (Z-test).

[6]Significantly different from intake from food and beverages other than milk or infant formula in currently breastfed children in the corresponding age group, $P < 0.05$ (*Z*-test).