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Associations of sodium and potassium with obesity measures among diverse US Hispanic/Latino adults: Results from HCHS/SOL

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Abstract

Objective—To evaluate cross-sectional associations of sodium and potassium with body mass index (BMI), waist circumference (WC), and body fat and determine whether nativity/duration of US residence modified these associations.

Methods—Sodium and potassium were derived from 24-hour diet recalls from 16,156 US participants of the 2008–2011 Hispanic Community Health Study/Study of Latinos (HCHS/SOL) and from 24-hour urine in 447 HCHS/SOL participants. BMI, WC, and body fat were measured.

Results—500 mg/day higher dietary sodium was cross-sectionally associated with 0.07 kg/m^2 higher BMI ($p<0.05$) and 0.18 cm larger WC ($p=0.04$). 500 mg/day higher dietary potassium was only associated with lower BMI and smaller WC among those foreign-born with 10+ years in the US (−0.13 kg/m^2, $p<0.01$; and −0.36cm, $p=0.01$, respectively) and among the US born (−0.62 kg/m^2, $p<0.01$ and −1.42 cm, $p<0.01$, respectively). 500 mg/day higher urinary sodium was associated with 0.27 kg/m^2 higher BMI ($p<0.01$) and 0.54 kg more body fat ($p<0.01$).

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Author Contributions: Dr. Elfassy conducted the statistical analyses for this study. Drs. Elfassy and Zeki Al Hazzouri interpreted the data and drafted the manuscript. Drs. Elfassy, Mossavar-Rahmani, Van Horn, Gellman, Sostres-Alvarez, Schneiderman, Daviglus, Beasley, Llabre, Shaw, Prado, Florez, and Zeki Al Hazzouri contributed to the methodological aspects of this study.

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Conclusions—Sodium intake was associated with higher BMI, WC, and body fat. Potassium intake, was associated with lower BMI and smaller WC among US-born and participants with longer duration of US residence.

Keywords

Sodium; potassium; body mass index; waist circumference; Hispanics

Introduction

Two of every three adults in the United States (US) are either overweight or obese.[1] The current obesity epidemic in the US has been at least partly attributed to the increasingly processed diet and its composition, which is not only energy-dense but also rich in sodium and low in potassium.[2] Given the ubiquity of sodium in the US diet,[3] coupled with lack of potassium, the sodium to potassium (Na-K) ratio has increased over time and is less than ideal.[2] While emerging evidence suggests that sodium intake may be associated with obesity, independent of energy,[4–12] the relationships of potassium and Na-K ratio with obesity have not been explored in great detail. Findings from limited studies suggest that lower potassium and a higher Na-K ratio are associated with higher rates of obesity.[13]

Among ethnic minority populations, such as US Hispanics/Latinos, the relationships among sodium, potassium, Na-K ratio, and obesity are particularly pertinent and yet they remain underexplored. Hispanics/Latinos have higher dietary sodium intake, lower dietary potassium intake,[14] and higher rates of obesity[15] compared with non-Hispanic whites. Further, Hispanics/Latinos have a unique acculturation experience during which their dietary habits and quality tend to worsen with greater duration of residence in the US.[16] Thus, understanding how dietary nutrients such as sodium and potassium intake are associated with obesity outcomes among Hispanics/Latinos, one of the fastest-growing segments of the US population, is of great medical and public health interest.

Establishing a direct association between dietary nutrients, sodium in particular, and obesity independent of energy intake is important, yet challenging given the strong correlation between nutrients such as sodium and energy intake. Most prior studies have adjusted for energy intake derived from dietary recall or food frequency questionnaire,[4,6,7,9,12,17] both of which are prone to measurement error.[18] Fewer studies have explored sodium density (estimated as sodium divided by energy intake) in relation to obesity,[8,11] and to our knowledge, no prior study in the US has used the doubly labeled water (DLW) method[19] to objectively calculate energy intake and account for it when examining the associations among sodium, potassium, and obesity outcomes.

Using data from the Hispanic Community Health Study/Study of Latinos (HCHS/SOL), we aimed to examine: 1) the associations of dietary sodium, potassium, and Na-K ratio with measures of obesity, and 2) whether these associations varied by duration of US residence. In a subsample, we further examined the associations of 24-urinary sodium, potassium, and Na-K ratio with measures of obesity controlling for DLW derived energy intake.

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Methods

Study population

HCHS/SOL—The HCHS/SOL is a a population based cohort study of 16,415 community dwelling self-identified Hispanics/Latinos of diverse heritage. In brief, participants aged 18–74 years were recruited between 2008 and 2011 in areas in proximity to four field centers in: Bronx, NY; Chicago, IL, Miami-Dade, FL; and San Diego, CA. A two-stage area probability sample of households was selected; stratification and over-sampling at each stage was utilized to obtain a diverse and representative sample of Hispanics/Latinos.[20] Participants were asked to bring in their current medications for review, to undergo a clinical examination, have fasting blood samples collected, answer questionnaires pertaining to their medical history and health behaviors, including two 24-hour diet recalls. After excluding 259 individuals without at least one exposure and outcome measure of interest, our final analytic cross-sectional HCHS/SOL sample was 16,156 (Figure 1). All participants provided informed consent and the study was approved by each site's Institutional Review Board. Details have been described elsewhere.[20,21]

Study of Latinos: Nutrition & Physical Activity Assessment Study (SOLNAS ancillary study)—In 2010–2012, within months of completing the HCHS/SOL, a sub-set of weight stable HCHS/SOL participants enrolled in the SOLNAS ancillary study,[22] designed to assess the measurement error of self-reported energy, protein, sodium, and potassium intake. Spot and 24 hour urine samples were collected at two study visits spanning 12 days. 485 SOLNAS participants attended visit one. Participants arrived at the first visit after a four hour fast and provided a baseline spot urine sample. Participants then ingested a DLW mixture dosed based on body weight[23] and provided in-clinic post-DLW spot urine samples at three and four hours. At the end of visit one, participants received a meal replacement beverage and fluids necessary for the DLW measurement process. Additionally participants were given 24-hour urine collection instructions and advised to collect and return the urine at visit two. At visit two, 478 participants who returned, provided two more timed spot urine collections for the DLW measurement; seven participants did not return with 24-hour urine samples. Of the 471 24-hour urine samples, a total of 36 were subsequently excluded for the following reasons: a urine sample <500 mL (n=5), reporting two or more missed urine collections (n=18), technical issues with the laboratory assay (n=1), or the participant has chronic kidney disease (n=12), resulting in a final analytic size of 435 (see Figure 1). The sample included 44 participants who missed 1 void. All participants provided informed consent.

Dietary Measures

Self-reported measures of energy, sodium and potassium—Two 24-hour dietary recalls were collected from the full sample of HCHS/SOL participants within a three month period.[24] Scores from the two dietary recalls were averaged; 99% of the sample provided at least one recall. Using the Nutrition Data System for Research software which uses the multiple-pass method,[25] values for dietary sodium (mg/day), potassium (mg/day), and energy (kcal/day) were derived. The following measures were further calculated: dietary Na-K ratio as sodium (mmol) divided by potassium (mmol), dietary sodium density as dietary

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sodium intake (mg) per 1000 kcal per day, and dietary potassium density as dietary potassium intake (mg) per 1000 kcal per day.

Biomarker-based measures of energy, sodium and potassium—From 24-hour urine samples, sodium (mmol) and potassium (mmol) were determined using the ion-selective electrode method (Roche Diagnostics, Indianapolis, IN) at the central HCHS/SOL laboratory at the University of Minnesota. Samples were normalized to a 24-hour period and values for sodium and potassium were converted into mg/day. In brief and described elsewhere,[22] DLW, a validated technique known to provide accurate measurement of total energy expenditure,[26] was used to estimate total energy intake—valid among weight stable individuals. Deuterium and oxygen-18, two byproducts of the ingested DLW mixture were measured from each spot urine sample using mass spectrometry at the Gas-Isotope-Ratio Mass Spectrometry Laboratory, US Department of Agriculture/Agriculture Research Service Children's Nutrition Research Center, Baylor College of Medicine, Houston, Texas.[27,28] Deuterium and oxygen-18 elimination rates were calculated from the multiple timed spot urine specimen collected over the 12 day period; with the difference between these rates proportional to carbon dioxide production. The Weir equation was used to estimate total energy expenditure (expressed in kcal/day) from the carbon dioxide production rate.[23] The following measures were also derived: Na-K ratio as the ratio of urinary sodium (mmol/day) to urinary potassium (mmol/day), sodium density as urinary sodium excretion (mg) per 1000 kcal (derived from DLW) per day, and potassium density as potassium excretion (mg/day) per 1000 kcal (derived from DLW) per day.

Measures of Obesity

Body mass index (BMI) in kg/m^2 was measured in both the full HCHS/SOL sample and the SOLNAS sub-sample and derived from measured weight and height wearing light clothing.[21] Waist circumference (WC) in centimeters was measured during the HCHS/SOL study only using standardized reference points. Additionally, in the SOLNAS subsample, DLW methods, described elsewhere,[29] were used to measure body fat in kg and percent body fat.

Other Measures

All study participants reported their language preference (Spanish or English), age, sex, and educational attainment (< high school, high school degree, or > than high school). Individuals also reported their incomes grouped as: < $20,000, $20,000 – $50,000, ≥ $50,000, or missing income. Participants were asked to select a category that best described their Hispanic/Latino heritage, with responses including, Central American, Cuban, Dominican, Mexican, Puerto-Rican, South American, more than one group, or other. Additionally, participants reported their nativity and were classified as US born or foreign born (including Puerto Rico). Participants who were identified as foreign-born further reported the duration that they had lived in the US. Nativity/years in the US was classified as: foreign born, < 10 years in the US; foreign born, 10+ years in the US; or US born.

Participants reported their smoking status (never, current, or former) and alcohol consumption ('heavy drinkers' were defined as having >7 drinks/week for women and >14 drinks/week for men). Physical activity was self-reported using the modified version of the

World Health Organization Global Physical Activity Questionnaire.[30] Described elsewhere, [31] the Alternative Healty Eating Index-2010 (AHEI-2010, range from 0 to 110) was used to assess overall diet, with higher scores indicating a more healthful diet. Three seated blood pressure (BP) measurements were taken using an automatic sphygmomanometer (OMRON HEM-907 L), and hypertension was defined as having average systolic BP ≥ 140 mmHg or diastolic BP ≥ 90 mmHg, or documented use of anti-hypertension medication. Use of diuretic medication was also noted. Diabetes status/impaired glucose classification was defined as fasting plasma glucose ≥126 mg/dL, a 2 hour postload glucose level ≥200 mg/dL, A1C level ≥6.5%, or documented use of hypoglycemic agents.[32] Chronic kidney disease (CKD) was defined as having an estimated glomerular filtration rate <60 ml/min/1.73m[2.33] Depressive symptoms were assessed using the Center for Epidemiologic Studies Depression Scale-10 (CESD range 0 to 30).

Statistical Analysis

For our main analysis, among participants of the HCHS/SOL study demographic and clinical characteristics were assessed along with mean dietary sodium, sodium density, potassium, potassium density, and Na-K ratio across categories of nativity/years in the US. T-tests were used to determine whether means differed by nativity/years in the US. Estimates were age-adjusted to the US 2010 census population

Using multiplicative interaction terms within linear regression models we found that nativity/years in the US modified the associations of dietary potassium, potassium density, and Na-K ratio with BMI and WC (p values of interactions < 0.05), but not sodium or sodium density, thus resulting in stratified models for potassium, potassium density, and Na-K ratio. Models were adjusted for: age, sex, Hispanic/Latino heritage, education, income, language preference, study site, smoking, hypertension, diabetes, chronic kidney disease, alcohol use, depression, and physical activity. Models for sodium, potassium, and Na-K ratio were additionally adjusted for dietary energy intake.

For analyses of the SOLNAS sub-sample, we also assessed demographic and clinical characteristics of the SOLNAS sample (reported in Table S1). We repeated similar linear regression models in the SOLNAS sub-sample using the urinary-based biomarkers but did not test for effect modification by nativity/years in US due to a smaller sample size. Models were adjusted for: age, sex, Hispanic/Latino heritage, education, income, language preference, nativity/years in the US, study site, missed urine voids, smoking, hypertension, diabetes, alcohol use, depression, and physical activity. Models for sodium, potassium, and Na-K ratio were additionally adjusted for DLW derived energy intake. Additionally, we conducted a sensitivity analysis by further excluding participants who missed 1 urine void (n=44) or were on diuretic medications, which are known to effect electrolyte excretion (n=28), for a restricted sample of 363 participants. Analyses were conducted in SUDAAN (Version 11.0.1, Research Triangle Institute, NC) to account for the complex survey design and the sampling weights.

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Results

Overall, mean age was 41 years old (SE: 0.2), and 52.6% (SE: 0.5) were female (Table 1). In total, 34% (SE: 0.7) had less than a high school education, 76% (SE: 0.9) preferred Spanish to English, 25% (SE: 0.5) had hypertension, and 17% (SE: 0.4) had diabetes. Compared with those born in the US, those foreign born were less likely to have CKD but more likely to have lower educational attainment, lower incomes, prefer Spanish, and have higher AHEI-2010 scores.

Mean dietary sodium differed by nativity/years in the US (Figure 2) and ranged from 3071 mg/day (SE: 35) among those foreign born with 10+ years in the US, to 3376 mg/day (SE: 47) among the foreign born with < 10 years in the US. Mean dietary potassium and Na-K ratio—both indicators of diet quality—were least favorable (i.e. lower potassium and higher Na-K ratio) among those born in the US. Results from t-tests showed that compared with the US born, those foreign born with < 10 years had higher dietary potassium (2512 mg/day, SE: 23 vs. 2294 mg/day, SE: 33; p<0.01), higher dietary potassium density (1333 per 1000 kcal, SE: 11 vs. 1198 per 1000 kcal, SE: 11; p<0.01), and had lower mean dietary Na-K ratio (2.40, SE: 0.03 vs. 2.56, SE: 0.03; p<0.01).

From fully-adjusted linear regression models (Table 2), 500 mg/day higher dietary sodium was associated with a 0.07 kg/m^2 higher BMI (95% CI: 0.00, 0.15; p<0.05) and a 0.18 cm larger WC (95% CI: 0.00, 0.36; p<0.05). Likewise, a 250 mg/1000 kcal higher dietary sodium density was associated with a 0.07 kg/m^2 higher BMI (95% CI: 0.01, 0.14) and a 0.17 cm larger WC (95% CI: 0.01, 0.34).

The associations of potassium, potassium density, and Na-K ratio with obesity measures varied by nativity/years in the US (Figure 3 and Table S1). For dietary potassium, a 500 mg/day increment was only associated with lower BMI among the foreign born with 10+ years in the US (−0.13 kg/m^2, −0.25, 0.00, p<0.05) and among those US born (−0.62 kg/m^2, 95% CI: −0.92, −0.31). For dietary potassium density, a 250 mg/1000 kcal increment was associated with higher BMI among the foreign born with <10 years in the US (0.18 kg/m^2, 95% CI: 0.03, 0.34) but not among the foreign born with 10+ years in the US (0.01 km/m^2, 95% CI: −0.10, 0.13) and with lower BMI among the US born (−0.55 kg/m^2, 95% CI: −0.82, −0.28). For dietary Na-K ratio, a 0.50 unit increment was associated with higher BMI among the foreign born with 10+ years in the US (0.13 kg/m^2, 0.04, 0.22) and among the US born (0.23 kg/m^2, 95% CI: 0.05, 0.41). Patterns for WC largely mirrored those of BMI.

Demographic and clinical characteristics of SOLNAS participants are shown in Table S2. Among SOLNAS participants, in fully-adjusted linear regression models (Table 3), a 500 mg/day higher urinary sodium excretion was associated with 0.27 kg/m^2 higher BMI (95% CI: 0.08, 0.45), 0.54 kg higher body fat (95% CI: 0.15, 0.93), and 0.35 higher percent body fat (95% CI: 0.11, 0.58). A 250 mg/1000 kcal increment of urinary sodium density was associated with 0.39 (95% CI: 0.09, 0.68) higher percent body fat. Urinary potassium and potassium density were not associated with BMI, body fat, or percent body fat in fully adjustment models. However, a 0.50 increment of urinary Na-K ratio was associated with a 0.23 kg/m^2 higher BMI (95% CI: 0.04, 0.41), a 0.48 kg higher body fat (95% CI: 0.10,

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0.86), and a 0.34 higher percent body fat (95% CI: 0.12, 0.57). Results from the sensitivity analysis restricted to those without any missing urine voids and not on diuretic medications were unchanged (not shown).

Discussion

In the current study of over 16,000 diverse US Hispanics/Latinos, sodium was associated with measures of obesity—independent of energy intake. Each 500 mg increment of daily dietary sodium was significantly associated with a 0.07 kg/m^2 higher BMI and 0.18 cm larger WC. The associations of dietary potassium, potassium density, and Na-K ratio with BMI and WC were stronger in magnitude with more years spent in the US. For example, whereas higher dietary potassium was not associated with BMI or WC among the foreign-born with <10 years in the US, higher dietary potassium was associated with 0.13 kg/m^2 lower BMI and 0.36 cm smaller WC among foreign-born with 10+ years in the US, among the US born it was association with 0.62kg/m^2 lower BMI and 1.42 cm smaller WC. The magnitude of the associations between urinary-based markers, especially sodium and Na-K ratio, and measures of obesity were much stronger, and independent of DLW derived energy expenditure, suggesting a direct relationship.

Sodium is ubiquitous in the US food supply,[3] and therefore highly correlated with energy intake.[34] High sodium diets are also known to increase fluid intake,[35] such as the consumption of sugary drinks[36] which in turn may contribute to weight gain.[37] Thus, the sodium—obesity relationship has largely been attributed to indirect downstream processes related to increased energy intake. However, emerging evidence suggests a direct relationship between sodium and obesity exists independent of energy intake.[4–12,17,38,39] For example, in a population based UK sample that assessed sodium using 24-hour urine, 400 mg per day higher sodium (or one gram of salt) was independently associated with greater fat mass in children by 0.73 kg and in adults by 0.91 kg even after controlling for energy intake using DLW.[39] In agreement with such findings, our study, which was the first of its kind in the US to use objective measures of both sodium and energy, found a strong and direct association between sodium and measures of obesity, independent of energy intake.

While the biological rationale for this association has not been fully explored, the conventional wisdom that all calories are metabolically equivalent regardless of macronutrient composition is being questioned. For example, a study by Ebbeling et al,[40] showed that isocaloric diets differing in macronutrient composition elicited different declines in resting and total energy expenditure. Similarly, experimental studies in rats showed that high sodium diets induce higher adiposity compared with rats with isocaloric low sodium diets.[41] Consistent with this animal model, we found that a 500 mg/day higher urinary sodium excretion was significantly associated with 0.54 kg more body fat. Additionally, we found that urinary sodium density, a relative measure, was associated with percent body fat, a measure of body composition, but not absolute body fat in kg. Taken together, these results suggest that sodium in itself is associated with increased fat mass, while sodium density is associated with body composition. Though we cannot say for sure why this is the case, the authors note that both sodium density and percent body fat are relative measures.

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In our study, potassium, a nutrient positively associated with healthfulness of diet,[42] was negatively associated with BMI and WC, but showed stronger magnitude with longer duration of US residence. In the context of the acculturation process, the current findings may be the consequence of worsening of dietary habits as subjects become more acculturated (as with greater time in the US).[16] Therefore, we speculate that among individuals with fewer years in the US, potassium may not necessarily reflect diet quality and healthfulness to the extent that it does in a diet among individuals with greater years spent in the US. This would explain the lack of associations between dietary potassium and measures of obesity among the foreign-born with < 10 years in the US. In our study, overall dietary summary scores were indeed higher (i.e. more healthy) among Hispanics/Latinos who were foreign-born vs. US born. Consistent with this speculation, adjusted for age and energy, we found that dietary potassium was a weaker predictor of AHEI dietary summary score among the foreign born with <10 years in the US than among the foreign born with 10+ years in the US or among the US born (data not shown). In the SOLNAS subsample, neither urinary potassium nor potassium density was associated with obesity, though we were underpowered to test for effect modification by nativity/years in the US.

Similar to potassium, the associations between Na-K ratio—another indicator of diet qualty[42]—and measures of obesity also varied by nativity/years in the US, such that the associations were only significant in those with longer years in the US. To our knowledge this has not been previously documented and may again reflect Na-K ratio, similar to potassium, as being a better indicator of healthfulness of diet in more acculturated US Hispanics/Latinos. Results from the SOLNAS subsample showed a strong positive association among urinary Na-K ratio with all measures of obesity including: BMI, body fat, and percent body fat. For example, we found a 0.50 unit increase in Na-K to be associated with 0.23 kg/m^2 higher BMI, 0.48 kg more body fat, and 0.34 greater body fat percent. Consistent with our findings, spot urine Na-K ratio —a more easily available approach to measuring Na-K ratio—was also shown to be independently associated with percent total body fat measured using DXA in a multi-ethnic US cohort.[5]

The current study is not without limitations. First, given the cross-sectional design we could not establish temporality. Sodium reduction is often indicated in the treatment of certain chronic conditions such as hypertension, diabetes, and CKD. Yet, we were unable to account for potential dietary modifications made by these individuals, due to the cross-sectional design of the study. Further, our main measures of sodium and potassium were derived via 24-hour dietary recall, which is subject to measurement error.[22] However, we also found similar associations using density measures, which are less error prone.[22] Further, we were able to repeat our analyses using objective biomarkers from 24-hour urine in the SOLNAS sub-sample, and found consistent associations and sometimes stronger in magnitude. However, even the 24-hour urine biomarker measure has limitations,[18] as it only reflects sodium intake on one day and is not necessarily reflective of habitual sodium intake. Finally, though we used nativity/years in the US as a proxy measure for acculturation,[43] we acknowledge that this measure may not accurately reflect the dynamic acculturation process.

Despite such limitations, our study has several notable strengths. To our knowledge, this was the first study of its kind conducted in a population based sample of diverse US Hispanics/

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Latinos. The sample was large and comprised of mostly immigrants. Thus, we were adequately powered to test for interactions by length of time in the US. Our study included multiple dietary measures each with differing strengths. For example, though dietary sodium collected via diet recall is prone to measurement error, sodium density is a more accurate marker of true sodium density.

In the current sample, dietary sodium density only over-estimates urinary sodium density by 6%.[44] Likewise, it has been noted that potassium, potassium density, and particularly Na-K ratio derived from self-reported measures capture intake quite well.[44,45] In addition to our multiple measures of diet, this study also made use of multiple measures of obesity, including BMI, waist circumference, body fat, and percent body fat. In general, our results were robust across multiple nutrient markers—dietary and urinary biomarkers, measures of obesity, and sensitivity analyses.

Conclusions

In the current population based study of US Hispanics/Latinos, higher sodium intake was associated with higher BMI, WC, and body fat. Lower potassium intake and higher Na-K ratio were more strongly associated with higher BMI and WC with longer duration of US residence. Although the mechanisms underlying such relationships have not been adequately explored, our findings along with other studies suggest that sodium may be directly related to measures of obesity, above and beyond energy intake. Future studies investigating the longitudinal relationship among intakes of sodium, potassium, Na-K ratio, and changes in measures of obesity are warranted.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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What is already known about this subject?

- Emerging evidence suggests that sodium is associated with measures measures of obesity.

What does your study add?

- Higher sodium was associated with higher BMI, waist circumference, and more body fat among diverse US Hispanics.
- Lower potassium and higher sodium to potassium ratio was associated with higher BMI and waist circumference with stronger associations among Hispanics with longer duration of US residence.

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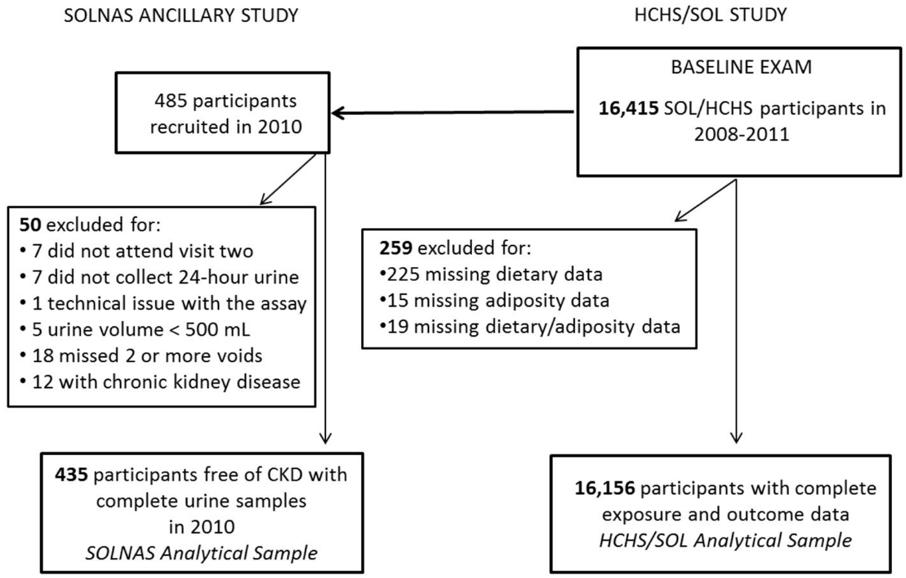

Figure 1.
Study Flow Chart

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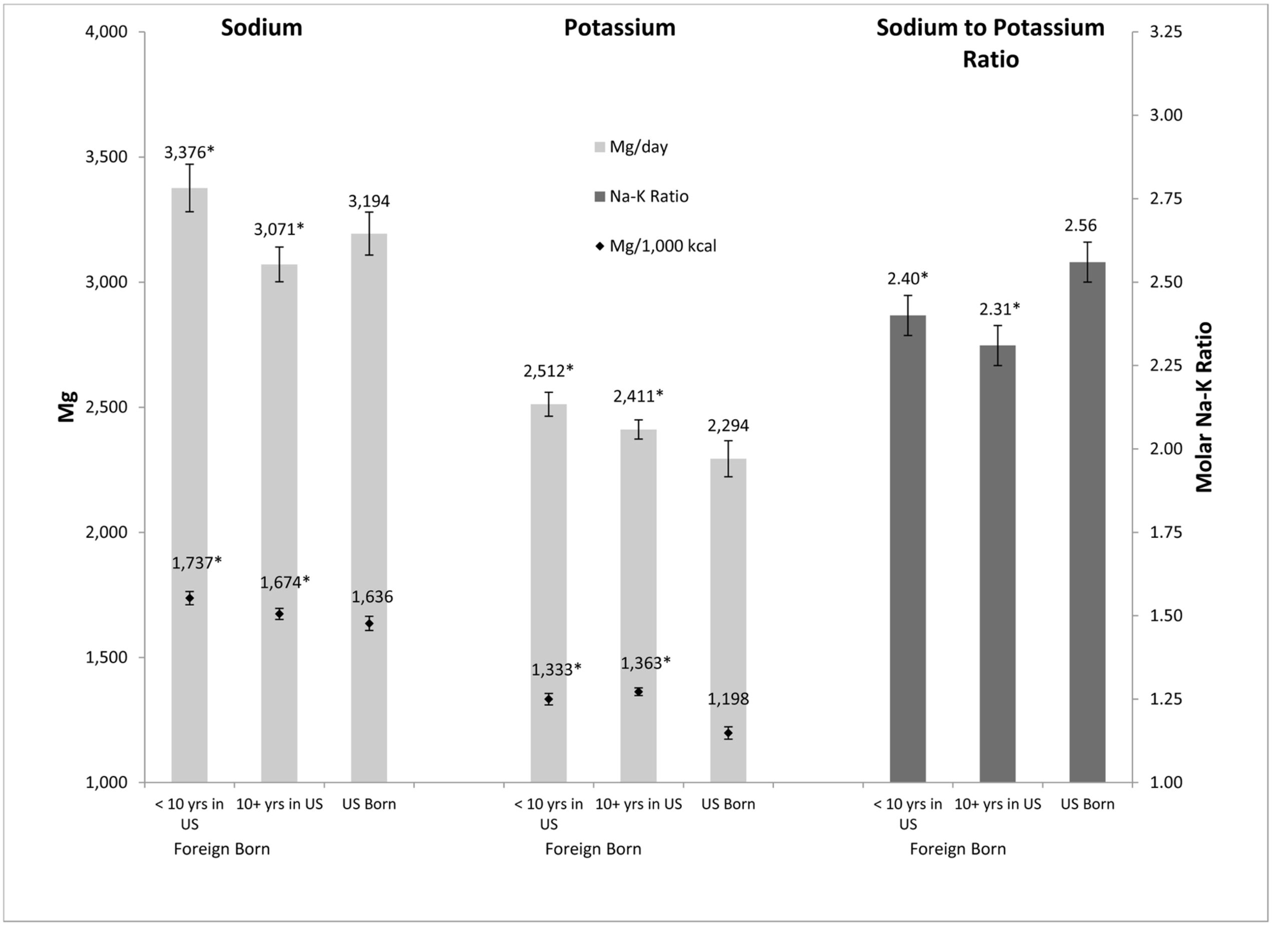

Figure 2.

Age-standardized mean dietary sodium, sodium density, potassium, potassium density and sodium to potassium ratio by nativity/years in the US, HCHS/SOL.

All estimates are age standardized to the US 2010 standard population.

*Mean is significantly different compared with US Born (referent group), $p<0.05$

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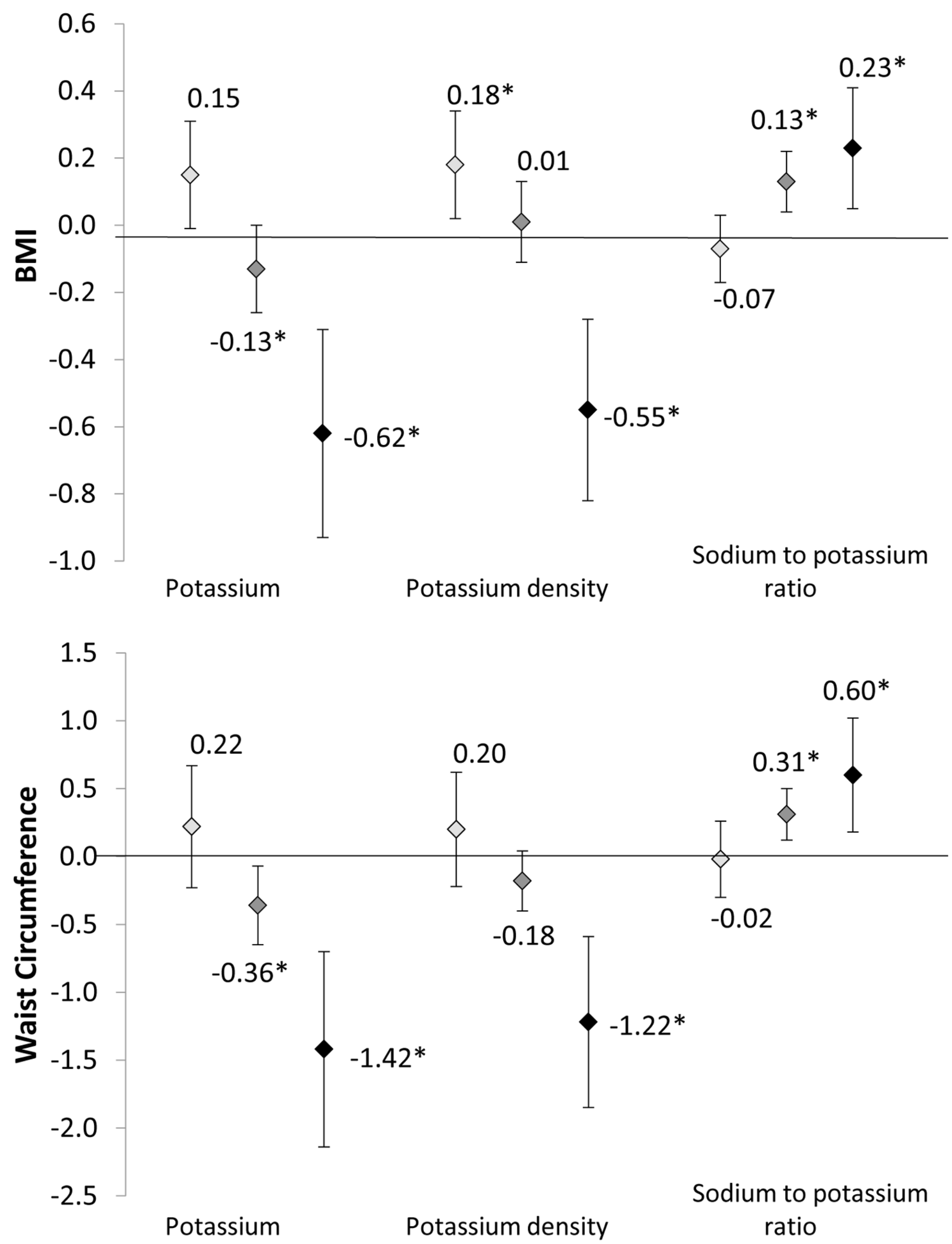

Figure 3.

Fully-adjusted associations of dietary potassium, potassium density, and sodium to potassium ratio with body mass index and waist circumference, stratified by nativity/years in the US, HCHS/SOL.

Models are adjusted for age, sex, heritage, education, income, language preference, study site, smoking, hypertension, diabetes, chronic kidney disease, alcohol use, depression, physical activity (total METs/week), and energy intake (except for in potassium density models).

We modeled 500 mg increments of potassium, 250 mg per 1000 kcal unit increments for potassium density, and 0.50 unit increments of sodium to potassium ratio (mmol/mmol)

◊ Foreign Born < 10 years in US

◆ Foreign Born 10+ years in US

◆ US born

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Table 1

Demographic and clinical characteristics overall and by nativity/years in the US, HCHS/SOL

	Overall (N=16,156)		Nativity/Years in the US: Foreign born, < 10 years in the US (n=3,630)		Foreign born, ≥ 10 years in the US (n=8,964)		US born (n=2,713)	
Characteristic	**% or mean**	**SE**	**% or mean**	**SE**	**% or mean**	**SE**	**% or mean**	**SE**
Age, mean (SE)	41.1	0.2	38.6	0.4	46.9	0.3	31.3	0.3
Female	52.6	0.5	54.8 *	1.0	53.9 *	0.9	49.0	1.8
Hispanic/Latino heritage								
Central American	7.3	0.5	8.8 *	0.9	8.4 *	0.6	1.4	0.3
Cuban	21.1	1.7	40.0 *	2.9	16.5 *	1.4	5.0	0.7
Dominican	9.8	0.7	8.3 *	0.9	12.3 *	0.9	4.2	0.7
Mexican	36.5	1.6	30.1 *	2.3	41.0	1.7	41.0	2.0
Puerto Rican	16.4	0.8	3.6 *	0.6	13.9 *	0.8	39.1	1.8
South American	5.1	0.3	7.2 *	0.7	5.3 *	0.4	0.9	0.1
More than one/other	3.9	0.3	2.0 *	0.3	2.6 *	0.4	8.4	1.0
< HS Education	33.5	0.7	28.7 *	1.1	37.6 *	0.9	21.9	1.3
< $20,000 Income	42.5	0.9	47.8 *	1.4	43.5 *	1.0	31.3	1.6
Spanish language Preference	76.4	0.9	98.2 *	0.3	81.1 *	1.0	25.1	1.4
Current smoker	20.9	0.6	18.6 *	1.0	19.0 *	0.8	28.1	1.4
Heavy drinker	5.8	0.3	4.4 *	0.4	5.8 *	0.4	7.9	0.9
Physical activity (total METS/week), mean (SE)	685.1	13.4	657.7	24.6	665.5	18.6	728.2	33.3
Energy, Kcal, mean (SE)	1892.4	10.3	1951.4	18.7	1844.7 *	14.1	1968.0	22.1
AHEAI-2010[2], mean (SE)	47.8	0.2	47.2 *	0.3	48.7 *	0.2	46.4	0.3
Hypertension	25.1	0.5	24.9	0.9	24.9	0.6	24.7	1.5
Diabetes	16.7	0.4	13.1	0.8	18.1 *	0.5	14.3	1.1
Chronic kidney disase	5.0	0.3	4.6 *	0.5	4.8 *	0.3	8.7	1.4
CESD[1] score, mean (SE)	7.1	0.1	6.6 *	0.1	6.9 *	0.1	7.9	0.2

All estimates are age adjusted to the US 2010 census population aged 18–74 years

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[*] Indicates estimate is significantly different compared with US born as the referent group, $p < 0.05$

[1] CESD: Center for Epidemiologic Studies Depression scale

[2] AHEI-2010: Alternative Heathy Eating Index 2010, range: 0–110

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Table 2

Associations of dietary sodium and sodium density with body mass index and waist circumference, HCHS/SOL

	Body Mass Index (kg/m^2)		Waist Circumference (cm)	
	Beta	**95% CI**	**Beta**	**95% CI**
Sodium				
Model 1	0.00	−0.05, 0.05	0.11	−0.01, 0.24
Model 2	0.07*	0.00, 0.15	0.18*	0.00, 0.36
Sodium Density				
Model 1	0.12*	0.05, 0.18	0.31*	0.13, 0.49
Model 2	0.07*	0.01, 0.14	0.17*	0.01, 0.34

Model 1 is adjusted for age, sex, heritage, education, income, language preference, nativity/years in the US, and study site; Model 2 is additionally adjusted for smoking, hypertension, diabetes, chronic, kidney disease, alcohol use, depression, physical activity (total METs/week), and energy intake (in sodium models only)

We modeled 500 mg increments of sodium and 250 mg per 1000 kcal units for sodium density

* Indicates estimate is statistically significant, $p<0.05$

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Table 3

Associations of 24-hr urinary sodium, potassium, and sodium to potassium ratio with body mass index, body fat, and percent body fat, SOLNAS (N=435).

	Body Mass Index (kg/m^2)		Body Fat (kg)		Percent Body Fat	
	Beta	**95% CI**	**Beta**	**95% CI**	**Beta**	**95% CI**
Sodium						
Model 1	0.46 *	0.26, 0.66	0.83 *	0.41, 1.25	0.40 *	0.16, 0.64
Model 2	0.27 *	0.08, 0.45	0.54 *	0.15, 0.93	0.35 *	0.11, 0.58
Sodium density						
Model 1	0.11	−0.14, 0.37	0.33	−0.18, 0.84	0.37 *	0.06, 0.68
Model 2	0.12	−0.13, 0.37	0.37	−0.11, 0.86	0.39 *	0.09, 0.68
Potassium						
Model 1	0.56 *	0.11, 1.02	0.93 *	0.04, 1.82	0.37	−0.09, 0.83
Model 2	0.22	−0.17, 0.60	0.41	−0.37, 1.20	0.26	−0.20, 0.73
Potassium density						
Model 1	−0.32	−0.80, 0.16	−0.49	−1.35, 0.37	0.10	−0.39, 0.58
Model 2	−0.39	−0.88, 0.10	−0.55	−1.44, 0.34	0.07	−0.44, 0.59
Sodium: Potassium						
Model 1	0.25 *	0.04, 0.45	0.51 *	0.07, 0.94	0.34 *	0.10, 0.59
Model 2	0.23 *	0.04, 0.41	0.48 *	0.10, 0.86	0.34 *	0.12, 0.57

Model 1 is adjusted for age, sex, heritage, education, income, language preference, nativity/years in the US, study site, and missing 1 urine void; Model 2 is additionally adjusted for smoking, hypertension, diabetes, alcohol use, depression, physical activity (total METs/week), and energy intake (in sodium and potassium models only)

We modeled 500 mg increments of sodium and potassium, 250 mg per 1000 kcal unit increments for sodium density and potassium density, and 0.50 unit increments of sodium to potassium ratio (mmol/mmol)

* Indicates estimate is statistically significant, p<0.05