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Trends in Blood Pressure and Usual Dietary Sodium Intake Among Children and Adolescents, National Health and Nutrition Examination Survey 2003 to 2016

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Abstract

Over the past decade, blood pressure and sodium intake declined among children and adolescents (ie, youths) in the United States. We updated temporal trends and determined if secular changes in blood pressure might be partly associated with usual sodium intake. We included 12 249 youths aged 8 to 17 years who participated in the National Health and Nutrition Examination Survey from 2003 to 2016 and had blood pressure and dietary data. Logistic regression was used to describe secular trends and the association between usual sodium intake and blood pressure categorized according to 2017 Hypertension Guidelines. The prevalence of youths with combined elevated blood pressure/hypertension (ie, either elevated blood pressure or hypertension) significantly

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declined from 16.2% in 2003-2004 to 13.3% in 2015-2016 (P<0.001 for trend), as did hypertension from 6.6% to 4.9% (P=0.005 for trend). Across the same time period, mean usual sodium intake decreased from 3381 to 3208 mg/day (P<0.001 for trend). Holding constant survey cycle, sex, age, race and Hispanic origin, and weight status, the adjusted odds ratio per 1000 mg/day of usual sodium intake for elevated blood pressure/hypertension was 1.18 (95% CI, 1.03–1.35) and for hypertension was 1.20 (95% CI, 0.96–1.50). From 2003 to 2016, blood pressure and usual sodium intake declined among youths. Although 1000 mg/day higher usual sodium intake was associated with ≈20% higher odds of elevated blood pressure/hypertension and hypertension, the association with hypertension was not statistically significant.

Keywords

blood pressure; diet; hypertension; prevalence; sodium

Hypertension is a well-known risk factor for heart disease and stroke, which combined account for more deaths each year than any other major cause of death in the United States.[1] Although hypertension in children and adolescents (hereafter referred to as youths) is less common than in adults, evidence suggests higher blood pressure (BP) levels in childhood are associated with higher BP levels later in life.[2] Previous research has demonstrated a linear, dose-dependent relationship between sodium intake and BP in adults and that sodium intake is associated with BP in children.[3] Over the period of 1999 to 2012, evidence has suggested both sodium intake[4] and BP[5,6] declined slightly among US youths. Whether current temporal trends in BP (up to 2016) might be associated with concurrent changes in population sodium intake is unclear.

Though several studies described temporal changes in BP among US youths,[5-7] few examined concurrent trends in sodium intake.[7,8] To our knowledge, only one examined temporal trends in BP before and after adjusting for sodium intake.[7] In this study, sodium intake was adjusted for energy intake (both estimated from a single 24-hour dietary recall) and differences in BP were examined between 1988-1994 and 1999-2008.[7] The use of a single 24-hour recall does not represent usual intake and may have attenuated the true association between sodium and BP because of the high, within-person, day-to-day variability in foods consumed.[8] Furthermore, evidence suggests that although BP increased between 1988-1994 and 1999-2008, declines occurred from 2007 to 2012.[5,6] We hypothesized that current temporal trends in BP among US youths might be partly associated with shifts in the distribution of usual sodium intake.

The objectives of this study were to describe among US youths aged 8 to 17 years (1) temporal trends in estimated usual sodium intake from 2003 through 2016, (2) concurrent temporal trends in elevated BP (EBP) or hypertension, and (3) to determine if temporal trends in EBP or hypertension were correlated with usual dietary sodium intake.

Methods

We used data from the National Health and Nutrition Examination Survey (NHANES), a nationally representative, multistage survey of the noninstitutionalized US civilian population.[9] All participants provided written informed consent (parental consent was obtained for those <18 years) and NHANES was approved by the National Center for Health Statistics' Ethics Review Board. Detailed information on NHANES data collection and survey procedures used in this analysis are publically available and can be found elsewhere.[10,11] For our analyses, we used data collected from youths aged 8 to 17 years, publically released in 2-year cycles from 2003 to 2004 through 2015 to 2016. Exclusion criteria and additional methods are available in the online-only Data Supplement (Figure S1 and Methods in the online-only Data Supplement, respectively). For the purposes of reproducing this analysis, the analytic code used in this study is available from the corresponding author on request.

Measures

Dietary intake was assessed using up to two 24-hour dietary recalls collected using methods described previously.[4] Nutrient values were assigned to foods and beverages using the United States Department of Agricultures' Food and Nutrient Database for Dietary Studies corresponding with each 2-year cycle. Methods to estimate individual sodium intake changed over the time course of this study, but appropriate data files were used to ensure comparable methods for estimates of sodium intake from 2003 to 2016 (Methods in the online-only Data Supplement). Individual nutrient intake on each recall day was estimated by summing the amount of the specified nutrient consumed from each reported food and beverage for the previous 24-hour period. Total sodium intake excluded sodium from supplements, antacids, and salt added at the table. The National Cancer Institute's method (Methods in the online-only Data Supplement), which accounts for within-person and day-to-day variability, was used to estimate usual daily nutrient intake for each individual in nonlinear mixed effects models. Using this method, we estimated usual daily sodium intake, sodium density, daily energy intake, daily potassium intake, and sodium-potassium ratio.

A certified examiner obtained up to 3 consecutive BP measurements from participants ≥8 years old using an appropriate cuff size and a mercury manometer, after the patient rested for 5 minutes in the seated position with feet flat on the floor.[11] As described in the Methods (in the online-only Data Supplement), minor changes in BP measurement took place over the time course of the study and were not anticipated to affect estimates. Using the 2017 American Academy of Pediatrics guidelines, we classified participants according to their BP percentiles for age, sex, and height and then as having hypertension, EBP, or normal BP (Table S1).[12] To coincide with previous reports, we combined participants classified as having EBP or hypertension into 1 group which we classified as having EBP/hypertension. We also characterized BP using the former 2004 National Heart Lung and Blood Institute guideline criteria[13] to compare estimates with previous publications (Table S1).

Covariates

As potential covariates, we selected age, sex, race and Hispanic origin, and weight status a priori due to the association of these characteristics with BP. We examined trends among Mexican-Americans in accordance with analytic guidelines related to the sampling design.[14] To assess weight status, we compared participants' body mass index in kg/m^2 to age- and sex-specific reference values from the 2000 Centers for Disease Control and Prevention growth charts.[15] Under/normal weight was defined as body mass index for age/sex <85th percentile, overweight as ≥85th to <95th, and obesity as ≥95th. Several variables of interest (ie, self-reported frequency of salt added at the table, poverty-income ratio, and physical activity) were only available among a subset of included participants and were examined in sensitivity analyses (Tables S6 through S8).

Statistical Analyses

We examined frequencies and SE of selected covariates, mean (SE) of usual nutrient intake indicators, and the prevalence (SE) of EBP/hypertension and hypertension by 2-year survey cycle. Regression models are described in the online-only Data Supplement. Unadjusted and multiple logistic regression models with predicted marginals were used to examine frequencies/prevalence of sociodemographic variables and EBP/hypertension by 2-year survey cycle, whereas least squares linear regression models were used to examine mean usual nutrient intakes. We adjusted for age (years) when examining temporal trends in sociodemographic characteristics, weight status, EBP/hypertension, and hypertension, and for survey cycle, age (years), sex, race, and Hispanic origin, and weight status when examining temporal trends in usual sodium intake. Linear and quadratic trends were tested using orthogonal contrast matrices. Next, the associations between indicators of usual sodium intake and EBP/hypertension or hypertension were examined using logistic regression adjusted for survey cycle, sociodemographic characteristics, weight status, and estimated usual energy or potassium intake as applicable.[16] Lastly, logistic regression models were used to examine temporal trends in EBP/hypertension or hypertension per survey cycle, successively adjusting for (1) sociodemographic characteristics, (2) weight status, and (3) indicators of usual sodium intake (including usual energy or potassium intake as applicable).

Statistical analyses were conducted using statistical software (SAS callable SUDAAN, version 11) to account for the complex survey design. Fourteen-year sample weights for NHANES 2003 to 2016 (constructed from day 1 dietary sample weights), were used to account for unequal sampling probabilities, nonresponse, noncoverage, and sample design. We calculated relative SE and according to recommendations: defined unstable estimates, which should be interpreted with caution, as 30%< relative SE ≤40% and suppressed estimates with relative SE >40%.[14] Reported *P* values were not adjusted for multiple comparisons and are based on the Satterthwaite adjusted *F* test. All tests are 2 sided, and a $P<0.05$ was considered statistically significant.

Results

The final sample included 12 249 US youths with a mean age of 12.6 years. Compared with those excluded, higher proportions of included youths were 13 to 17 years, (51.5% versus 38.2%) white, non-Hispanic (27.9% versus 23.8%), and under/normal weight (61.0% versus 50.8%; $P<0.001$, overall difference by characteristic; Table S2). Among included youths, sex, age, and weight status distributions were similar from 2003 to 2004 through 2015 to 2016 ($P>0.05$ for temporal trend; Table 1, sample sizes in Table S3), but the proportion of white, non-Hispanic youths declined ≈11% ($P=0.032$ for trend).

Among youths, usual mean daily sodium intake declined from 3381 mg in 2003 to 2004 to 3208 mg in 2015 to 2016 (Table 2). Holding demographic characteristics and weight status constant, usual mean daily sodium intake declined, on average, by 35 mg per 2-year survey cycle ($P<0.001$ for linear trend; Table 2). Similar temporal linear declines in usual mean daily sodium intake occurred among all subpopulations explored (Table 2). In post hoc exploratory analyses, usual daily sodium density slightly increased from 2003 to 2016 ($P<0.001$ for trend), whereas sodium-to-potassium ratios, energy, and potassium intake declined ($P<0.05$ for trend; Table S4).

Overall, the prevalence of youths with EBP/hypertension declined from 16.2% in 2003 to 2004 to 13.3% in 2015 to 2016 ($P<0.001$ for trend), as did hypertension, from 6.6% to 4.9% ($P=0.005$ for trend; Table 3). Similarly, using the former criteria, the EBP/hypertension prevalence and hypertension declined over this time period (Table S5). In exploratory analyses, significant temporal declines occurred in EBP/hypertension prevalence among most subgroups with a few exceptions: among Mexican-American youths or those who were overweight, temporal linear trends were not significant. Temporal linear trends in the prevalence of hypertension were inconsistent across other subgroups, and some prevalence estimates were statistically unreliable (Table 3).

EBP/hypertension was significantly associated with usual sodium intake among youths (Table 4). Holding constant survey cycle, sex, age, race and Hispanic origin, and weight status, an additional 1000 mg of sodium consumed per day was associated with 18% higher adjusted odds ratio (AOR) of EBP/hypertension (1.18; 95% CI, 1.03–1.35). The AOR for hypertension was 1.20 (0.96–1.50). Additionally adjusting for energy intake, the AORs per 1000 mg sodium consumed per day were 1.39 (1.08–1.80) for EBP/hypertension and 1.33 (0.89–1.98) for hypertension (Table 4). The AOR for EBP/hypertension per mg of sodium per 1000 kcal consumed was 2.53 (1.14–5.60) and per unit difference in the molar ratio of sodium-to-potassium intake was 1.35 (1.12–1.64; Table 4). The AOR for hypertension per unit difference in the molar ratio of sodium-to-potassium intake was 1.58 (1.13–2.21).

The AORs for EBP/hypertension per 2-year survey cycle from 2003 to 2016 were 0.91 (0.86–0.96) when adjusting for sociodemographic characteristics and weight status (model 2) and 0.91 (0.87–0.96) additionally adjusting for usual sodium intake (model 3) and were similar for other sodium intake measures (models 4–7; Table 5). The AOR for hypertension per 2-year survey cycle also was similar across models.

Sensitivity Analyses

The frequency of youths adding salt at the table changed over this time period. Among the subset of participants with data, temporal trends in poverty-income ratio were not significant, and inactivity significantly increased (Table S6).

The AORs for EBP/hypertension and hypertension per 1000 mg of usual sodium intake were similar before and after adjusting for poverty-income ratio and physical activity status. Adjusting for table salt use, the AOR for hypertension with higher usual sodium intake was similar, whereas EBP/hypertension became nonsignificant ($P=0.344$; Table S7). The AOR for EBP/hypertension per survey cycle remained similar before and after adjusting for table salt use, poverty-income ratio, or physical activity status (Table S8).

Discussion

From 2003 to 2016, we observed significant linear declines in both EBP/hypertension and hypertension among a nationally representative sample of US youths. A slight, but statistically significant, temporal linear decline also occurred in usual sodium intake. Although usual sodium intake was positively associated with EBP/hypertension, the temporal linear decline in BP was similar before and after adjusting for usual sodium intake. These results suggest recent temporal linear declines in EBP/hypertension were not correlated with the small linear decline in usual population sodium intake.

This study updates temporal trends in sodium intake and EBP/hypertension prevalence up to 2015-2016. Although there are differences in the estimation of sodium intake, definitions of EBP/hypertension, years included, and population subgroups examined, in general, our study results seem consistent with published trends through 2012, with 1 exception.[4-7] Unlike our study, Xi et al[6] suggested mean population sodium intake did not decline between 2003 and 2012; however, these results might be explained by not accounting for adjustments for salt added during cooking, which could have led to an artificial increase in sodium intake before 2009. Our results are similar to a previous study which also used methods to ensure consistency in sodium estimation over time.[4] Though mean sodium intake slightly declined through 2016, the decline seemed to be related to a lower energy intake rather than less consumption of sodium dense foods.[4] Although the sodium content of some US foods declined, reductions are inconsistent and improvements in diet quality of youths may be primarily driven by decreased empty calorie, and increased whole fruit, consumption.[17,18]

Our results are consistent with recent prevalence estimates among US youth,[19,20] with 1 exception. In 2011 to 2012, EBP/hypertension prevalence was slightly higher in our study compared with previous estimates, perhaps attributed to the use of different definitions for EBP/hypertension.[5,6] The lack of significant decline among Mexican-American youths is consistent with previous research through 2012 despite differences in samples, race categorization (ie, Hispanic), and EBP/hypertension definitions[6] This could be due to a slightly higher proportion of Mexican-American overweight youths (19% versus 16% in non-Hispanic white youths), as EBP/hypertension also did not decline over time among overweight participants. Furthermore, the temporal declines in usual sodium intake were smallest among Mexican-American youths and those who were overweight, which might explain the lack of a secular trend in EBP/hypertension in these groups. Additionally, the EBP/hypertension prevalence and hypertension were significantly lower in 2013 to 2014 compared with other survey cycles, potentially due to the higher level of physical activity seen in 2013 to 2014, chance, or other factors.

To our knowledge, the correlation between temporal trends in BP and sodium intake among US youths has only been investigated in one other study, using NHANES data preceding 2009.[7] Similar to our results, this study indicated after adjusting for demographic characteristics, body mass index *Z* score, and waist circumference *Z* score, further adjusting for sodium intake did not change temporal trends in BP, despite a positive association between BP and sodium intake. Potential reasons for the lack of correlation in the current study are unexplained measurement error, the small magnitude of the decline (<250 mg/day) in usual sodium intake over the time period, or a true null association.

In the current study, usual sodium intake was modestly associated with EBP/hypertension. The odds for EBP/hypertension adjusting for energy and other characteristics were consistent with the 36% higher odds seen in a previous study, despite differences in methods.[7] Additionally, the associations of EBP/hypertension with the molar ratio of sodium-to-potassium and when additionally holding potassium intake constant suggests sodium intake is associated with EBP/hypertension independent of potassium intake.

Our study has some limitations. Although data were weighted to account for nonresponse, NHANES participants may differ from nonparticipants. In our study, hypertension was defined using up to 3 BP readings on a single visit; whereas, a clinical diagnosis requires confirmed readings on 3 separate occasions.[12] This could result in misclassification of some participants, potentially attenuating observed associations with sodium intake. Dietary recalls can be subject to errors in reporting and nutrient estimation.[21] Bias from self-reported intake rather than true dietary sodium intake may attenuate the true association between sodium and BP.[8] Usual sodium intake estimation did not account for the amount of sodium consumed from salt added at the table, estimated to contribute ≈5% of total sodium intake.[22] We could not account for several covariates among the full sample of participants, including income, physical activity, and use of antihypertensive medication. Given the low prevalence (<1%) of antihypertensive use among adolescents aged 16 to 17 years, it is doubtful that increases in medication use could explain the decline in BP. The sample sizes in certain subgroups were small diminishing the reliability of hypertension prevalence estimates for some 2-year survey cycles. Additionally, low statistical power or prevalence may explain the lack of statistically significant associations for some outcomes. However, lack of correction for multiple comparisons could increase the likelihood of statistically significant results due to chance.[23]

Lifestyle modifications, such as maintaining a healthy weight, consuming a Dietary Approaches to Stop Hypertension-type eating pattern, limiting sodium, and increasing physical activity, are reasonable strategies for hypertension prevention.[12] As indicated by the small decline in sodium observed in our study, additional efforts may be required to achieve substantive reductions in sodium intake. Reformulation efforts could support sodium reduction activities as the majority of sodium intake among US youths is estimated to come from salt added to commercially processed foods.[24,25] Additionally, clinician advice can support sodium reduction efforts through increased consumer awareness and motivation to make healthier choices.[12,24,26] This study, along with previous studies,[3,7] indicate higher sodium intake is associated with EBP/hypertension, supporting efforts to reduce population sodium intake.

Perspectives

To our knowledge, this is the first study to assess concurrent temporal trends through 2016 in usual sodium intake and EBP/hypertension defined using the 2017 BP guidelines and to determine if trends were correlated. The decline in EBP/hypertension from 2003 to 2016 was not correlated with usual sodium intake, potentially due to the relatively small decline in sodium intake (≈35 mg/survey cycle). As population distributions of covariates examined were similar over this time period, they also did not account for BP declines. As a greater proportion of youths are classified with EBP/hypertension under the current new guidelines, understanding the contributions of lifestyle factors to temporal decreases could help achieve further declines. Expanding assessment of physical activity and potentially medication use among US youths in nationally representative surveys might help us better understand the contribution of these factors and how they interact with diet in the prevention of EBP/hypertension.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Novelty and Significance

What Is New?

- Temporal trends in elevated blood pressure (EBP)/hypertension (ie, elevated blood pressure or hypertension) and usual sodium intake were updated through 2016 among a nationally representative sample of US youths.
- Significant temporal declines in EBP/hypertension were concurrent with slight temporal reductions in mean usual sodium intake.
- Higher usual sodium intake was associated with ≈20% higher EBP/hypertension. Declines in EBP/hypertension from 2003 to 2016 were not correlated with the concurrent, but slight reductions (mean <250 mg/day over 14 years) in usual population sodium intake.

What Is Relevant?

- About 1 in 8 youth have EBP/hypertension. Evidence suggests that EBP in childhood tracks with age and can increase the risk for high blood pressure in adults, a major risk factor for heart disease and stroke.
- As American youth consume ≈3208 mg of sodium/day, continued efforts are needed to lower intake. Clinicians can provide dietary counseling to reduce sodium consumption to enhance patients' efforts to prevent EBP.

Summary

Modest declines in BP and usual sodium intake were observed from 2003 to 2016 among US youths. The results from this study indicate that usual sodium intake is associated with BP. The small decline in sodium observed over this time period suggests that additional efforts are required to reduce sodium intake among this population. Future studies examining other lifestyle factors are warranted to help us understand how these factors may contribute to prevention efforts.

Table 1.

Estimated Population Characteristics Among US Youths, NHANES 2003–2016 (N=12 249)

Survey Cycles	**2003–2004**	**2005–2006**	**2007–2008**	**2009–2010**	**2011–2012**	**2013–2014**	**2015–2016**	***P* Value Linear Trend***
Age, y, % (SE)								
8–12	47.5 (2.3)	48.3 (2.1)	48.1 (2.4)	49.6 (1.5)	49.2 (1.6)	49.5 (1.7)	48.8 (1.7)	0.494
13–17	52.5 (2.3)	51.7 (2.1)	51.9 (2.4)	50.4 (1.5)	50.8 (1.6)	50.5 (1.7)	51.2 (1.7)	
Sex, % (SE)								
Boys	51.8 (1.8)	51.2 (2.6)	49.5 (2.0)	48.5 (2.3)	48.5 (2.4)	51.6 (1.8)	51.0 (1.8)	0.798
Girls	48.2 (1.8)	48.8 (2.6)	50.5 (2.0)	51.5 (2.3)	51.5 (2.4)	48.4 (1.8)	49.0 (1.8)	
Race and Hispanic origin,† % (SE)								
White, NH	63.9 (4.2)	62.3 (4.2)	60.4 (3.2)	58.9 (4.3)	54.3 (4.6)	54.0 (5.8)	52.5 (5.6)	0.032
Mexican-American	12.1 (2.8)	12.7 (1.2)	13.2 (2.0)	13.4 (2.8)	15.0 (2.7)	16.2 (3.7)	15.3 (3.9)	0.278
Black, NH	15.3 (2.4)	14.2 (2.7)	15.1 (1.8)	13.5 (1.3)	14.0 (2.9)	13.3 (2.4)	13.6 (3.4)	0.600
Weight status, % (SE)								
Under/normal	64.1 (3.0)	67.3 (3.0)	62.9 (1.9)	65.0 (1.4)	62.5 (2.0)	63.2 (2.5)	61.9 (2.5)	0.279
Overweight	16.9 (1.1)	15.8 (1.2)	17.3 (0.7)	16.6 (0.7)	17.4 (0.8)	17.2 (0.9)	17.6 (0.8)	0.272
Obese	19.0 (1.9)	16.9 (1.9)	19.8 (1.5)	18.4 (1.9)	20.1 (1.4)	19.6 (1.8)	20.5 (1.8)	0.283

The unweighted sample size for each subgroup can be found in Table S3. NH indicates non-Hispanic; NHANES, National Health and Nutrition Examination Survey.

* *P* values for quadratic trends were nonsignificant and are not reported.

† Data on other, multiracial is not presented.

Table 2.

Mean Usual Daily Sodium Intake (mg) Among US Youths, 2003–2016, Overall and Among Selected Groups (N=12 249)

Survey Cycles	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	β-Coefficient (95% CI)*	*P* Value Linear Trend†
Population group, mean (SE)									
Overall	3381 (22)	3429 (17)	3307 (15)	3306 (34)	3250 (25)	3226 (26)	3208 (22)	−35 (−43 to −27)	<0.001
8–12 y	3290 (36)	3309 (21)	3215 (28)	3167 (24)	3157 (25)	3140 (22)	3123 (20)	−32 (−42 to −22)	<0.001
13–17 y	3456 (41)	3541 (32)	3399 (20)	3435 (49)	3339 (31)	3317 (32)	3295 (28)	−35 (−48 to −23)	<0.001
Boys	3723 (32)	3777 (29)	3654 (25)	3640 (39)	3598 (31)	3584 (37)	3550 (34)	−34 (−47 to −22)	<0.001
Girls	3034 (17)	3050 (21)	2948 (26)	2971 (25)	2909 (18)	2867 (26)	2877 (16)	−31 (−38 to −24)	<0.001
White, NH	3438 (32)	3526 (28)	3411 (25)	3368 (50)	3289 (31)	3274 (38)	3267 (39)	−40 (−54 to −27)	<0.001
Black, NH	3266 (40)	3243 (30)	3097 (35)	3164 (33)	3100 (16)	3053 (39)	3068 (37)	−34 (−48 to −21)	<0.001
Mexican-American	3331 (22)	3227 (26)	3144 (24)	3153 (39)	3269 (64)	3174 (31)	3083 (26)	−26 (−37 to −14)	<0.001
Under/normal	3429 (28)	3480 (23)	3351 (20)	3350 (34)	3290 (30)	3276 (35)	3260 (26)	−35 (−46 to −25)	<0.001
Overweight	3279 (43)	3292 (38)	3178 (33)	3210 (54)	3211 (50)	3216 (47)	3107 (37)	−24 (−39 to −9)	0.002
Obese	3298 (28)	3380 (36)	3271 (54)	3251 (55)	3142 (33)	3091 (44)	3143 (26)	−42 (−54 to −29)	<0.001

The unweighted sample size (n) for each subgroup can be found in Table S3. NH indicates non-Hispanic.

*β-coefficients (adjusted change in sodium per 2-year survey cycle) were estimated using linear regression models adjusting for all covariates used to estimate the Best Linear Unbiased Predictors.

†*P* values for quadratic trends were nonsignificant and are not reported.

Table 3.

Temporal Trends in the EBP/HTN Prevalence of and HTN Among US Youths, 2003–2016, Overall and Among Selected Groups (N=12 249)*

Survey Cycles	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	*P* Value Linear Trend†
Population group, % (SE)								
Overall								
EBP/HTN	16.2 (1.8)	17.3 (2.2)	15.6 (1.5)	12.3 (1.0)	12.5 (1.2)	8.7 (1.0)	13.3 (1.3)	<0.001
HTN	6.6 (1.3)	7.8 (1.7)	5.8 (0.7)	5.0 (0.7)	4.8 (1.0)	2.7 (0.4)	4.9 (0.7)	0.005
8–12 y								
EBP/HTN	13.1 (2.0)	16.0 (3.1)	13.0 (2.4)	10.6 (1.4)	9.3 (1.7)	9.1 (1.4)	10.8 (1.5)	0.022
HTN	6.6 (1.5)	7.6 (2.2)	6.1 (1.3)	4.8 (0.7)	5.4 (1.6)	3.8 (0.7)	5.3 (1.0)	0.094
13–17 y								
EBP/HTN	19.2 (2.3)	18.5 (1.9)	18.2 (2.1)	14.0 (1.7)	15.7 (2.1)	8.3 (1.7)	15.6 (1.7)	0.002
HTN	6.6 (1.6)	8.1 (1.5)	5.6 (1.3)	5.2 (1.1)	4.3 (1.2)	1.6 (0.5)	4.4 (0.7)	0.001
Boys								
EBP/HTN	20.6 (2.3)	19.4 (2.8)	18.3 (2.3)	16.0 (1.9)	17.4 (2.0)	10.4 (1.8)	16.9 (1.6)	0.009
HTN	7.2 (1.6)	8.0 (2.3)	6.2 (1.2)	6.3 (1.1)	6.8 (1.7)	2.6 (0.6)	5.9 (0.8)	0.063
Girls								
EBP/HTN	11.3 (2.3)	14.8 (2.3)	12.9 (1.8)	9.0 (1.3)	8.1 (2.0)	7.1 (1.2)	9.8 (1.7)	0.018
HTN	5.9 (1.6)	7.6 (1.7)	5.4 (0.9)	3.8 (1.0)	-	2.8 (0.8)	3.8 (0.8)	0.008
White, NH								
EBP/HTN	16.5 (2.4)	17.4 (3.1)	15.5 (1.7)	11.7 (1.4)	10.2 (1.8)	7.3 (1.6)	10.7 (1.7)	<0.001
HTN	7.0 (1.8)	8.4 (2.4)	6.3 (1.0)	4.6 (1.2)	3.8 (1.5)*	1.5 (0.4)	2.7 (0.7)	<0.001
Black, NH								
EBP/HTN	18.4 (2.5)	20.1 (3.6)	18.5 (3.0)	15.5 (2.6)	16.5 (2.0)	9.4 (1.6)	16.4 (1.4)	0.010
HTN	6.8 (1.2)	10.3 (2.1)	7.1 (1.9)	7.8 (1.4)	4.9 (1.2)	3.0 (1.2)*	4.7 (1.4)	0.003
Mexican-American								
EBP/HTN	15.1 (1.7)	16.3 (2.0)	15.5 (4.3)	15.4 (2.8)	13.5 (2.5)	12.4 (1.6)	16.9 (2.9)	0.730
HTN	5.4 (1.5)	4.3 (0.9)	-	5.0 (1.5)	5.8 (1.9)	4.6 (1.8)*	9.0 (2.2)	0.186

Survey Cycles	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	*P* Value Linear Trend[†]
Under/normal								
EBP/HTN	12.9 (1.6)	16.0 (3.3)	12.1 (1.5)	7.8 (0.7)	9.4 (1.1)	6.4 (1.1)	8.7 (1.7)	0.001
HTN	4.9 (0.9)	7.8 (2.4)[*]	4.8 (0.8)	2.8 (0.6)	2.8 (0.6)	1.7 (0.4)	2.7 (1.0)[*]	0.002
Overweight								
EBP/HTN	14.7 (3.2)	10.0 (1.7)	18.2 (3.6)	15.7 (4.1)	14.1 (2.4)	8.0 (2.1)	15.0 (3.1)	0.624
HTN	6.9 (2.7)[*]	3.7 (0.8)	6.6 (1.9)	4.8 (1.9)[*]	6.0 (1.3)	-	4.6 (1.2)	0.300
Obese								
EBP/HTN	30.1 (5.0)	28.6 (3.5)	25.3 (3.5)	24.9 (2.8)	20.9 (3.9)	16.2 (2.5)	25.5 (2.4)	0.029
HTN	12.4 (3.3)	11.8 (2.0)	8.6 (2.6)	13.0 (2.2)	10.1 (3.9)[*]	5.9 (1.6)	11.6 (2.1)	0.347

The unweighted sample size (n) for each subgroup can be found in Table S3. EBP indicates elevated blood pressure; HTN, hypertension; NH, non-Hispanic; and RSE, relative SE.

[*] 30%< RSE ≤40%. RSE >40% are suppressed.

[†] *P* values for quadratic trends were nonsignificant and are not reported.

Table 4.

AORs* for EBP/HTN and HTN Per Unit Difference in Usual Intake Measures Among US Youths, 2003–2016 (N=12 249)

	EBP/HTN		HTN	
Usual intake measure (unit difference)	**AOR (95% CI)**	***P* Value**	**AOR (95% CI)**	***P* Value**
sodium (1000 mg)	1.18 (1.03–1.35)	0.019	1.20 (0.96–1.50)	0.102
sodium (1000 mg) adjusted for energy	1.39 (1.08–1.80)	0.012	1.33 (0.89–1.98)	0.167
sodium density (mg per 1000 kcal) adjusted for energy	2.53 (1.14–5.60)	0.023	2.46 (0.71–8.59)	0.156
sodium/potassium (mmol/mmol)	1.35 (1.12–1.64)	0.002	1.58 (1.13–2.21)	0.008
sodium/potassium (mmol/mmol) adjusted for K	1.49 (1.19–1.88)	0.001	1.76 (1.18–2.62)	0.006

AOR indicates adjusted odds ratio; EBP, elevated blood pressure or hypertension; and HTN, hypertension.

*All models adjusted for survey cycle, age, sex, race and Hispanic origin, and weight status groups

Table 5.

AORs for the Prevalence of EBP/HTN and HTN Per 2-Year Survey Cycle, Among US Youths, 2003–2016 (N=12 249)

	EBP/HTN			HTN		
Model	AOR (95% CI)	β-Coefficient	*P* Value	AOR (95% CI)	β-Coefficient	*P* Value
1[*]	0.92 (0.87–0.96)	−0.086	<0.001	0.89 (0.83–0.95)	−0.118	0.001
2[†]	0.91 (0.86–0.96)	−0.095	<0.001	0.88 (0.82–0.95)	−0.126	0.001
3[‡]	0.91 (0.87–0.96)	−0.089	0.001	0.89 (0.82–0.96)	−0.119	0.002
4[§]	0.91 (0.86–0.96)	−0.096	<0.001	0.88 (0.82–0.95)	−0.123	0.001
5[//]	0.90 (0.85–0.95)	−0.103	<0.001	0.88 (0.81–0.95)	−0.130	0.001
6[¶]	0.91 (0.87–0.96)	−0.093	<0.001	0.88 (0.82–0.95)	−0.123	0.001
7[#]	0.91 (0.87–0.96)	−0.089	0.001	0.89 (0.82–0.96)	−0.118	0.002

AOR indicates adjusted odds ratio; EBP, elevated blood pressure or hypertension; and HTN, hypertension.

[*] Model 1 is adjusted for survey cycle, age (y), sex, and race and Hispanic origin.

[†] Model 2 is model 1 plus weight status

[‡] Model 3 is model 2 plus usual daily sodium intake (mg).

[§] Model 4 is model 3 plus usual daily energy intake (kcal).

[//] Model 5 is model 2 plus usual sodium density (mg/1000 kcal) and usual daily energy intake (kcal).

[¶] Model 6 is model 2 plus usual sodium-to-potassium ratio (mmol/mmol).

[#] Model 7 is model 6 plus usual daily potassium intake (mmol).