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Childhood Blood Pressure Trends and Risk Factors for High Blood Pressure: The NHANES experience 1988–2008

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Abstract

The obesity epidemic in children makes it plausible that prevalence rates of elevated blood pressure are increasing over time. Yet, previous literature is inconsistent due to small sample sizes. Also, it is unclear whether adjusting for risk factors can explain longitudinal trends in prevalence of elevated blood pressure. Thus, we analyzed a population-based sample of 3,248 children in National Health and Nutrition Examination Survey (NHANES) III (1988–1994) and 8,388 children in continuous NHANES (1999–2008), ages 8–17. Our main outcome measure was elevated blood pressure (systolic blood pressure (SBP) or diastolic blood pressure (DBP) ≥ 90th percentile or SBP/DBP ≥ 120/80mmHg). We found that the prevalence of elevated blood pressure (bp) increased from NHANES III to NHANES 99-08 (Boys: 15.8% to 19.2%, p=0.057; Girls: 8.2% to 12.6%, p=0.007). Body mass index (BMI) (Q4 vs Q1, Odds Ratio (OR) =2.00, p<0.001), waist circumference (Q4 vs Q1, OR=2.14, p<0.001) and sodium (Na) intake (≥3,450mg vs <2,300mg/2,000 calories, OR=1.36, p=0.024) were independently associated with prevalence of elevated blood pressure. Also, mean SBP, but not DBP was associated with increased Na intake in children (quintile 5 (Q5) vs. quintile 1 (Q1) of Na intake, Beta = 1.25 ± 0.58, p=0.034). In conclusion, we demonstrate an association between high Na intake and elevated bp in children. After adjustment for age, gender, race/ethnicity, BMI, waist circumference and sodium intake, OR for elevated bp in NHANES 99-08 vs. NHANES III = 1.27, p=0.069.

Keywords

blood pressure; body mass index; NHANES; nutrition; pediatrics; sodium intake; waist circumference

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Disclosures
None.

Introduction

There has been an epidemic of obesity in the past 20 years among both children and adolescents[1]. Also, sodium intake has been high in both children and adults with a majority of children above the Reference Daily Intake (RDI)[2]. Since BMI and sodium intake are important risk factors for hypertension in adults[3], it is reasonable to consider whether there have been corresponding increases in prevalence of elevated blood pressure (bp) in children. Since NHANES III and continuous NHANES have the same bp measurement protocol, are representative of the general US population, and are of adequate size, we use these populations as the study sample for the current report.

There have been three previous papers comparing mean blood pressure levels and/or prevalence of hypertension and pre-hypertension in children between NHANES III and continuous NHANES. Muntner, et al[4] compared bp levels between NHANES III (1988–1994) and NHANES 99-00 and found significant differences between surveys in both mean SBP and DBP after adjusting for BMI. Din-Dzietham, et al.[5] compared prevalence of pre-hypertension and hypertension between NHANES III and NHANES 99-02. Ostchega, et al.[6] compared prevalence of pre-hypertension and hypertension between NHANES III and each of NHANES 99-02 and NHANES 03-06. In both cases, prevalence was higher in continuous NHANES, more frequently statistically significant for pre-hypertension than hypertension. All three papers used bp percentiles based on Pediatric Task Force Standards.[7]

One recurring theme of the previous literature is small sample sizes for estimates of hypertension prevalence. In this paper, we estimated percentiles using norms based on normal-weight children[8] rather than the Pediatric 2004 report[7] which included both normal-weight and overweight children. This resulted in higher rates of hypertension and pre-hypertension. Also, to maximize power, we focus on elevated bp = either hypertension or prehypertension defined based on a normal weight population. Second, the previous analyses established that mean bp was increasing over time and that increasing BMI was associated with some of the increase. In the current paper, we also look at possible mediating effects of (a) central obesity based on waist circumference, and (b) other dietary factors that have been associated with bp in previous studies.

METHODS

We use data from NHANES III (1988–1994) and continuous NHANES (NHANES 1999–2000, 2001–2002, 2003–2004, 2005–2006, 2007–2008), subsequently referred to as the NHANES 1999–2008 population. To be eligible for the study population, a child had to be ages 8–17 (96–215 months), and have at least one SBP and one DBP measurement. A mean of 3 bp readings was obtained. If < 3 readings were available, then the mean of all available readings was used. All bp measurements were obtained with a sphygmomanometer by certified examiners after children rested quietly while sitting for 5 minutes[9, 10]. BMI values were converted to age-sex-specific percentiles based on Center for Disease Control (CDC) growth charts[11], and converted to BMI z-scores using the probit transformation. Children with outlying BMI z-scores (defined as < -6.0 or > 6.0) were deleted. Waist circumference z-scores were computed by ranking subjects by 1-year age-sex groups and using the probit transformation. Children of self-reported non-Hispanic White, African-American or Mexican-American race/ethnicity were included. The numbers of children of other ethnicities were small and were not included.

Determination of Blood Pressure Percentiles

We used bp percentiles based on normal weight children derived from cubic spline and quantile regression methods to (a) provide for more flexible models to express bp as a

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function of age and height over the entire pediatric age range and (b) relax the assumption of normality in defining percentiles[8]. These percentiles both in tabular form for assessment of bp percentiles for individual children and in a Statistical Analysis System (SAS) macro for assessment of bp percentiles in batch mode for large numbers of children are available at the following website: http://sites.google.com/a/channing.harvard.edu/bernardrosner/pediatric-blood-press

To increase power, we focus on the prevalence of elevated bp (either hypertension or pre-hypertension) = either SBP or DBP ≥ 90th percentile or SBP ≥ 120 mmHg or DBP ≥ 80 mmHg.

Statistical Methods

In all analyses we have used sampling weights provided by NHANES to estimate prevalence of elevated bp in a representative sample of the US pediatric population. Descriptive statistics were obtained from proc surveymeans and proc surveyfreq of SAS 9.2 with standard errors accounting for sampling weights separately for NHANES III and NHANES 99-08, and compared using a z statistic. Nutrient intake was measured by a single day of 24-hour recall, and expressed in categorical format compared with the RDI based on nutritional guidelines for children[12]. Although two days of 24-hour recall was available for NHANES 99-08, we only used the first day for comparability with NHANES III, where only a single 24-hour recall was available. In addition, sodium (Na) intake was adjusted for total caloric intake = (Na intake) x 2000/total caloric intake and expressed in quintiles. Recommended caloric intake (RCI) for children corrected for age and sex[13] was obtained. Children were excluded from nutrient analyses if their actual caloric intake was < 0.5 RCI or > 2 RCI for their age-sex norms. Overall, there was an initial sample of 16,693 children age 8–17 of whom 1,226 (7%) were of other races, 1,515 (9%) were missing either SBP or DBP, 129 (1%) were either missing BMI or had outlying BMI, 158 (1%) were missing waist circumference and 2,029 (12%) had either missing or out of range caloric intake. This left a study sample of 3,248 children in NHANES III and 8,388 children in NHANES 99-08. Associations between the prevalence of elevated bp and each of 9 nutrients were assessed after adjustment for gender, age, race/ethnicity, BMI z-score (in quartiles), and waist circumference z-score (in quartiles), separately by study and then combined using proc surveylogistic of SAS. The prevalence of elevated bp was compared between the NHANES 99-08 and NHANES III population by adding an indicator variable for study and study x gender after adjustment for selected sets of covariates. In addition, the association between mean SBP and DBP (as continuous variables) and adjusted Na intake (expressed in quintiles) was assessed after adjustment for the above variables using proc surveyreg of SAS.

RESULTS

The demographic characteristics, anthropometric characteristics and bp levels of the study populations are presented in Table 1. For both boys and girls, there has been a shift in the ethnic distribution between studies with a significant decrease in the % of non-Hispanic whites ($p<0.05$) and a significant increase in the % of Mexican Americans ($p<0.01$). There were significant increases in weight and BMI for both boys ($p \leq 0.016$) and girls ($p < 0.001$). The % of overweight children (≥ 85th percentile) also significantly increased ($p<0.001$) and there were also large increases in waist circumference for boys and especially for girls ($p < 0.001$).

Mean SBP significantly increased for both boys (106.1 vs. 107.8 mmHg, $p = 0.001$) and girls (102.3 vs. 104.9 mmHg, $p < 0.001$). However, mean DBP significantly increased among girls (57.0 mmHg vs. 59.0 mmHg, $p = 0.003$), but not boys (57.7 mmHg vs. 56.7

mmHg, p = 0.13). The prevalence of elevated bp significantly increased among girls (8.2% vs 12.6%, p=0.007), but was only of borderline significance among boys (15.8% vs 19.2%, p = 0.057).

We compared nutrient intake between surveys in relation to the RDI using the % of children who are above the RDI for specific nutrients by survey and gender (Table 2). For total fat, saturated fat, and protein a large majority of children (70–80%) were above the RDI, with a slight decline over time. Correspondingly, there was an increase in the % of children above the RDI for carbohydrate intake. Approximately 45–50% of boys and 30% of girls were above the RDI for calcium at both surveys. Less than 11% of boys and 8% of girls were above the RDI for each of fiber, magnesium and potassium which declined slightly over time. Over 80% of children were above the RDI for Na at both surveys. However, the % of children > 50% over the RDI (i.e., >3450 mg per 2000 calories) declined significantly for both boys (38% vs. 31%, p = 0.012) and girls (40% vs. 31%, p < 0.001). Total caloric intake declined slightly for boys (mean 2,349 vs. 2,255 Kcal, p = 0.011), but did not change for girls (mean 1,868 vs. 1,887 Kcal, p = 0.51).

A majority of children were above the RDI for total fat, saturated fat, protein and Na (Table 2). Hence, to maximize statistical power we represented these nutrients in 3 categories (<RDI(ref)/ >=RDI, ≤1.5RDI/ >1.5RDI). Also, a majority of the children were below the RDI for calcium, carbohydrates, fiber, magnesium, and potassium. Hence, for these nutrients, we used the categories (>RDI(ref)/ >(2/3)RDI, ≤RDI/ ≤(2/3)RDI). In all analyses we controlled for age (continuous), male gender, race/ethnicity and study (Table 3, model 1). In Table 3, models 2–4 we additionally adjust for BMI age-sex-specific z-score (in quartiles) based on CDC growth charts and/or waist circumference age-sex specific z-score (in quartiles) based on NHANES 99-08 and NHANES III, combined.

In model 1 (demographic adjusted) there were significant positive associations between prevalence of elevated bp and each of elevated Na intake (> 3,450 mg vs. ≤ 2,300 mg, OR = 1.37, p = 0.017, p_trend = 0.038) and reduced carbohydrate intake (≤ 200g vs > 300g, OR=1.33, p = 0.20, p_trend = 0.021). However, after adjustment for BMI z-score and waist circumference z-score (models 2–4), only the association with Na intake remained statistically significant (> 3,450 mg vs. ≤ 2,300 mg, OR = 1.36, p = 0.024; 2301 – 3450mg, OR = 1.17, p = 0.21), p_trend over all 3 Na groups = 0.045.

In Table 4, we present a multivariate model concerning the association between elevated bp and other risk factors. The odds for elevated bp increased 12% for every 1-year increase in age (p < 0.001), was higher for boys than girls (OR=1.85, p<0.001) and was higher for African-Americans than non-Hispanic white children (OR=1.28, p=0.002). Mexican-American children had no excess risk vs. non-Hispanic white children (OR = 0.99, p = 0.92). The ORs for elevated bp for BMI z-score quartiles 2 (Q2), 3 (Q3) and 4 (Q4) vs quartile 1 (Q1) were respectively 1.33 (p = 0.094), 1.43 (p = 0.024), and 2.00 (p < 0.001). After controlling for BMI, the association between waist circumference z-score and elevated bp was not monotone. Relative to Q1, there was no significant difference in the prevalence of elevated bp for Q2 (OR = 0.98, p = 0.90) or Q3 (OR = 0.96, p = 0.84). However, there was a highly significant increase for Q4 vs. Q1 (OR = 2.14, p < 0.001) even after controlling for BMI z-score quartile. Thus, both BMI and waist circumference made independent contributions to the prevalence of elevated bp. Finally, after adjusting for other risk factors, there was a significant increase in the prevalence of elevated bp between children with Na intake > 3,450 mg vs. Na intake <2,300 mg per 2,000 calories (OR = 1.36, p = 0.024).

We also looked at effect modification of Na intake by the other variables in Table 4. There was no significant effect modification of Na intake by age, gender, BMI z-score or waist

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circumference z-score. However, there was significant effect modification of Na intake by race/ethnicity (p = 0.019). For non-African-American children, comparing risk for Na intake > 3450 mg vs ≤ 2300 mg, OR = 1.50 (95% CI = 1.08–2.07), p = 0.016, p_trend = 0.028. However, for African-American children, OR = 0.90 (95% CI = 0.70–1.16), p = 0.40, p_trend = 0.26.

We now explore the association between SBP and DBP when represented as continuous variables and Na intake. To minimize the effect of outliers and not make the arbitrary assumption of a linear relationship between Na intake and blood pressure, we categorized adjusted Na intake into quintiles and controlled for the same variables as in Table 4. The results are given in Online Supplemental Table 1. There was a significant difference in mean SBP between Q5 (≥ 3754 mg/2000 kcal) and Q1 (≤2332 mg/2000kcal) (Beta ± se= 1.246±0.577, p=0.034). For DBP, no significant effects were seen at any level of Na intake.

In Table 5, we compare the prevalence of elevated bp between NHANES 99-08 and NHANES III both crudely and after adjusting for the covariates in Table 4. Overall, the crude prevalence of elevated bp was significantly higher in NHANES 99-08 vs NHANES III (model 1, OR = 1.39, p = 0.007). The association was virtually unchanged after adjusting for age, gender and race/ethnicity (model 2, OR = 1.38, p = 0.009). However, after further adjusting for BMI z-score quartile and waist circumference z-score quartile (model 3), the association weakened and became only borderline significant (OR = 1.25, p = 0.089), reflecting the increase in obesity between NHANES III and continuous NHANES. After further adjusting for Na intake (model 4), the association strengthened slightly but remained only borderline significant (OR = 1.27, p = 0.069), reflecting the slight reduction in % children > 1.5 RDI (i.e., > 3450 mg/2000 calories) in NHANES 99-08 vs NHANES III (see Table 2). The OR was somewhat stronger in girls (OR = 1.43, p = 0.12) than boys (OR = 1.18, p = 0.24), however the difference was not statistically significant (p = 0.44). Thus, overall roughly 1/3 of the excess prevalence for NHANES 99-08 vs NHANES III is explained by differences in known risk factors between the two surveys.

DISCUSSION

In the present paper, we focus on elevated bp = combination of hypertension and pre-hypertension. As noted by Din-Dzietham[5], pre-hypertension is clinically relevant because children whose bp is repeatedly ≥ 90th percentile exhibit signs of very early target-organ damage in young adulthood[14–16]. Also, since NHANES doesn't have repeated bp measurements over time, it is not possible to make a diagnosis of hypertension[7].

Second, to maximize precision we compared NHANES III to NHANES 99-08 data rather than focusing on smaller time-periods within continuous NHANES. Third, we consider the independent contribution of both BMI and waist circumference as predictors of elevated bp. Finally, we considered dietary intake as an additional predictor of elevated bp. After adjusting for the above risk factors, we found a higher prevalence of elevated bp in NHANES 99-08 vs NHANES III which was of borderline statistical significance (OR = 1.27, p = 0.069).

As with adults, the average dietary Na intake of children exceeds nutritional needs, is well above recommended levels, and has been progressively increasing[17]. Although a significant relationship between high Na intake and hypertension is well established in adults, previous studies that examined associations between Na intake and bp levels in healthy children and adolescents report mixed or no relationships[2]. In an older study, Cooper et al[18] demonstrated a quantitatively weak but significant linear relation between bp and Na excretion in a sample of 73 children aged 11–14 years of age. These observation required seven consecutive 24-

hour urine collections per subject to adjust for intra-individual variation. More recently, He and MacGregor[19] performed a meta-analysis of 10 published controlled clinical trials that investigated the effect of a reduction in Na intake on bp among children age 6 – 15. Changes in salt intake were monitored from urinary Na excretion and in some studies, Na intake from food diaries. The overall meta-analysis showed a significant reduction in both SBP (mean change = −1.17mmHg, 95% CI = −1.78, −0.56), p < 0.001 and DBP (mean change = −1.29mmHg, 95% CI = −1.94, −0.65, p < 0.001). In a study of bp sensitivity to Na, Rocchini, et al[20] measured bp in 60 obese and 18 non-obese adolescents after successive 2-week periods on a high-salt diet (> 250mmol of Na per day) and a low-salt diet (< 30 mmol per day). The obese children had a significantly greater change (±se) in mean arterial pressure (−12±1mmHg) than the non-obese children (+1±2mmHg), ($p_{interaction} < 0.001$) following the change from high Na to low Na intake.

Yang, et al[21] also considered the association between Na intake and blood pressure level among children in NHANES 2003–2008. They found that there was a positive association between Na intake (as a continuous variable) and z-score of SBP, but not DBP, after adjusting for age, gender and height using Pediatric Task Force Standards[7], similar to the findings in the present report. In addition, there was a trend towards statistical significance between quartile of Na intake and elevated bp (combined pre-hypertension and hypertension) based on task force standards (p=0.062) which was significant when restricted to overweight/obese subjects (p=0.013). This observation of a stronger association of elevated bp with Na intake among overweight/obese subjects in a population study is consistent with earlier findings in the clinical study on Na sensitivity by Rocchini et al[20]. In the present study (a) we consider additional NHANES surveys yielding a sample size (n=11,636) roughly double that of Yang, et al (n=6235); (b) use bp standards based on normal weight children thus providing additional endpoints for elevated bp and a resulting increase in power; (c) restrict analyses to children with caloric intake between 0.5 and 2.0 times the recommended age-sex-specific caloric intake; (d) correct for both overall obesity (BMI) as well as central obesity (waist circumference); and (e) use an index of Na intake corrected for calories rather than age and race as in Yang, et al., which is important in looking at interactions of Na intake by ethnic group.

To our knowledge, our study represents the largest study of the effect of Na intake on the prevalence of elevated bp in children. After controlling for both overall and central obesity, we found a significant increase in the prevalence of elevated bp for children > 1.5*RDI for Na (OR = 1.36, 95% CI = 1.04–1.77, p = 0.024) vs children with intake < RDI. Children with intake ≥ RDI but ≤ 1.5 RDI had an OR = 1.17 (95% CI = 0.92–1.49, p = 0.21). Also, we found significant effect modification of Na intake by race, with a stronger association of elevated bp with Na for non-African-American children vs. African-American children. However, this finding was unexpected and requires confirmation in other studies. None of the other nutritional risk factors considered was significantly associated with the prevalence of elevated bp either in multivariate analyses controlling for age, gender, race/ethnicity, BMI and waist circumference (Table 3) or additionally adjusted for Na intake (data not shown). Finally, we found a significant effect of African-American (OR = 1.28 vs non-Hispanic White), but not Mexican-American ancestry (OR = 0.99 vs non-Hispanic White) after controlling for obesity and Na intake.

A limitation of the Na findings is that dietary intake was only assessed by a single 24-hour recall and validation by 24-hour urinalysis was not possible. Nevertheless, 80% of children had a reported Na > RDI which is consistent with previous literature[2]. Also, we did not have enough power to assess lower levels of Na intake since only 20% of children were below the RDI. Finally, although physical activity might be a relevant confounder for pediatric bp, it was only available in NHANES for children age 12–17 and hence was not used in our analyses.

Perspectives

We observed that the odds of elevated bp in children increased an estimated 27% between NHANES III and NHANES 99-08 (p=0.069), two surveys approximately 12 years apart with identical bp protocols after accounting for differences in age, gender, ethnicity, BMI, waist circumference and Na intake. We also observed an increase in the odds of elevated bp of 36% between children with Na intake > 3450 mg (≥ 1.5 RDI) vs. < 2300 mg (<RDI) even after controlling for age, gender, race, BMI and waist circumference. Furthermore, we observed a significant difference in mean SBP but not DBP between children in Na Q5 (≥ 3754 mg/2000kcal) vs. Na Q1 (≤ 2332 mg/2000 kcal), cutpoints that are similar to ≥ 1.5 RDI and < RDI, respectively. Largely due to secular changes in the food supply, dietary patterns, and dependence on processed foods, dietary Na intake has increased in the U.S. population of children as well as adults. The findings in this report demonstrate an association between high Na intake and elevated bp in childhood and provide support to an Institute of Medicine Report on Strategies to Reduce Na Intake in the U.S.[22]

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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This study was approved by the Brigham and Women's Hospital Institutional Review Committee. Subjects in NHANES gave informed consent.

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Novelty and Significance

What is New?

- Prevalence of elevated blood pressure in children has significantly increased from 1988 to 2008, although part of the increase is attributable to changes in obesity and Na intake.
- Na intake above 1.5 times the recommended daily intake is associated with increased risk of elevated blood pressure in children

What is Relevant?

- Pediatricians should monitor
  - overall obesity (e.g., BMI)
  - central obesity (e.g., waist circumference)
  - and Na intake

  to prevent elevated blood pressure among pediatric patients.

Summary

Both prevalence of elevated bp (either pre-hypertension or hypertension) and mean level of SBP is associated with elevated Na intake in children.

Table 1

Demographic, Anthropometric and Blood Pressure variables – NHANES Study 1988–2008

Variable	Boys			Girls		
	NHANES III (1988–1994)	NHANES 99-08 (1999–2008)		NHANES III (1988–1994)	NHANES 99-08 (1999–2008)	
	mean ± se	mean ± se	p-value	mean ± se	mean ± se	p-value
N	1564	4186		1684	4202	
Age	13.0 ± 0.1	13.0 ± 0.1	0.89	12.9 ± 0.1	13.1 ± 0.1	0.33
Race						
Non-Hispanic White	74.8 ± 1.9	69.9 ± 1.7	0.051	74.9 ± 2.0	69.8 ± 1.5	0.041
African-American	16.0 ± 1.4	16.2 ± 1.3	0.94	16.1 ± 1.6	16.6 ± 1.3	0.81
Mexican-American	9.2 ± 1.4	14.0 ± 1.1	0.009	9.1 ± 1.1	13.6 ± 1.1	0.003
Overweight (%) *	27.2 ± 1.9	35.1 ± 1.2	<0.001	25.4 ± 2.0	33.3 ± 1.3	< 0.001
Height (cm)	157.1 ± 0.6	157.9 ± 0.4	0.30	153.0 ± 0.6	153.6 ± 0.3	0.31
Weight (kg)	52.7 ± 0.9	55.1 ± 0.5	0.016	49.4 ± 0.7	52.1 ± 0.4	< 0.001
BMI (kg/m^2)	20.6 ± 0.2	21.3 ± 0.1	0.004	20.6 ± 0.2	21.6 ± 0.1	< 0.001
Waist circumference (cm)	72.3 ± 0.6	75.4 ± 0.3	<0.001	70.6 ± 0.5	75.2 ± 0.4	< 0.001
SBP (mmHg)	106.1 ± 0.4	107.8 ± 0.3	0.001	102.3 ± 0.5	104.9 ± 0.3	< 0.001
DBP (mmHg)	57.7 ± 0.6	56.7 ± 0.4	0.13	57.0 ± 0.6	59.0 ± 0.3	0.003
Elevated bp †	15.8 ± 1.5	19.2 ± 1.0	0.057	8.2 ± 1.4	12.6 ± 0.8	0.007

BMI indicates body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; se, standard error

* Overweight = ≥ 85th age-sex specific percentile for BMI based on CDC standards

† Elevated bp = either hypertension or pre-hypertension

Computer runs: /proj/bkcbps/bkcbp00/nhanes/table1c.weighted.overall.corrected.sas

:/proj/bkcbps/bkcbp00/nhanes/hypertension.overall.overwgt.corrected.sas

Table 2

Percent of Children above the RDI for selected nutrients – NHANES Study 1988–2008

Variable (unit)	**RDI**	**Boys**			**Girls**		
		NHANES III (%)	**NHANES 99-08 (%)**		**NHANES III (%)**	**NHANES 99-08 (%)**	
		mean ± se	**mean ± se**	**p-value**	**mean ± se**	**mean ± se**	**p-value**
N		1564	4186		1684	4202	
Total Fat (g)	65g*	74.5 ± 1.8	68.8 ± 1.1	0.006	74.4 ± 2.2	70.2 ± 1.0	0.085
Saturated Fat (g)	20g*	82.9 ± 1.6	77.8 ± 0.9	0.006	79.1 ± 2.1	77.3 ± 0.9	0.43
Carbohydrates (g)	300g*	21.1 ± 1.6	26.1 ± 1.0	0.007	25.2 ± 1.7	27.7 ± 0.9	0.19
Protein (g)	50g*	87.0 ± 1.7	85.6 ± 0.8	0.47	86.1 ± 1.5	82.4 ± 0.8	0.036
Calcium (mg)	1000mg	49.2 ± 2.3	46.7 ± 1.3	0.34	30.3 ± 1.8	31.5 ± 1.1	0.55
Fiber (g)	25g*	4.2 ± 0.7	2.6 ± 0.3	0.049	5.1 ± 0.9	4.0 ± 0.4	0.29
Magnesium (mg)	400mg	11.0 ± 1.5	7.5 ± 0.5	0.038	5.0 ± 0.7	3.0 ± 0.4	0.015
Potassium (mg)	3500mg	5.6 ± 1.0	4.1 ± 0.6	0.18	7.9 ± 1.1	4.8 ± 0.5	0.010
Na (mg)	2300mg	83.8 ± 1.3	81.9 ± 0.8	0.21	82.4 ± 1.4	81.7 ± 0.7	0.67
> RDI, ≤ 1.5 RDI		46.3 ± 1.7	50.6 ± 1.2	0.039	42.6 ± 2.4	51.2 ± 1.3	0.002
> 1.5 RDI		37.5 ± 2.1	31.3 ± 1.3	0.012	39.7 ± 2.3	30.5 ± 1.2	< 0.001
Calories (Kcal)		2349 ± 33	2255 ± 17	0.011	1868 ± 25	1887 ± 15	0.51

RDI indicates reference daily intake; Kcal, kilocalories; se, standard error

*RDI per 2000 calories

Computer runs:

/proj/bkcbps/bkcbp00/nhanes/nutrients.rdi.xtab.corrected.sas

/proj/bkcbps/bkcbp00/nhanes/nutrients.rdi.overweight.xtab.corrected.sas

/proj/bkcbps/bkcbp00/nhanes/logistic.nutrients.rdi.sodium4.sas

Table 3

Association between intake of selected nutrients and the prevalence of elevated bp, NHANES study 1988–2008, age 8–17

		Model 1‡		Model 2‡		Model 3‡		Model 4‡	
Nutrient	Intake	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Calories	0.5 RCI ≤ Kcal < 2/3 RCI	1.04 (0.81–1.35)	0.75	0.92 (0.71–1.20)	0.55	0.90 (0.68–1.20)	0.47	0.89 (0.67–1.17)	0.57
	2/3 RCI ≤ Kcal ≤ 1.5 RCI (ref)	1.0		1.0		1.0		1.0	
	1.5 RCI < Kcal ≤ 2.0 RCI	1.03 (0.78–1.35)	0.85	1.07 (0.82–1.39)	0.64	1.08 (0.83–1.40)	0.57	1.08 (0.83–1.40)	0.57
	P_trend		0.71		0.80		0.77		0.80
Total Fat	< 65 g* (ref)	1.0		1.0		1.0		1.0	
	65 – 97.5 g	1.13 (0.93–1.36)	0.22	1.11 (0.92–1.33)	0.29	1.11 (0.92–1.35)	0.27	1.11 (0.92–1.34)	0.29
	> 97.5 g	1.12 (0.78–1.62)	0.53	1.11 (0.78–1.58)	0.55	1.10 (0.78–1.57)	0.58	1.10 (0.77–1.56)	0.60
	P_trend		0.37		0.42		0.43		0.45
Saturated Fat	< 20 g* (ref)	1.0		1.0		1.0		1.0	
	20 – 30 g	1.23 (1.00–1.52)	0.055	1.23 (0.99–1.53)	0.059	1.24 (0.99–1.54)	0.058	1.24 (0.99–1.54)	0.057
	> 30 g	1.14 (0.91–1.42)	0.26	1.12 (0.89–1.43)	0.33	1.13 (0.89–1.44)	0.32	1.13 (0.88–1.44)	0.34
	P_trend		0.11		0.14		0.14		0.15
Carbohydrates	> 300 g* (ref)	1.0		1.0		1.0		1.0	
	201 – 300 g	1.32 (1.09–1.59)	0.005	1.27 (1.05–1.54)	0.014	1.27 (1.05–1.53)	0.014	1.26 (1.05–1.53)	0.016
	≤ 200 g	1.33 (0.86–2.05)	0.20	1.27 (0.82–1.95)	0.28	1.24 (0.81–1.92)	0.32	1.24 (0.81–1.91)	0.33
	P_trend		0.021		0.054		0.063		0.067
Protein	< 50 g* (ref)	1.0		1.0		1.0		1.0	
	50 – 75 g	1.28 (0.99–1.66)	0.058	1.25 (0.91–1.72)	0.17	1.25 (0.91–1.71)	0.17	1.24 (0.90–1.71)	0.18
	> 75g	1.27 (0.93–1.73)	0.13	1.20 (0.91–1.57)	0.20	1.17 (0.89–1.54)	0.25	1.16 (0.88–1.53)	0.28
	P_trend		0.070		0.17		0.19		0.21
Calcium	> 1000 mg† (ref)	1.0		1.0		1.0		1.0	
	667 – 1000 mg	0.97 (0.76–1.24)	0.83	0.96 (0.75–1.22)	0.73	0.95 (0.74–1.22)	0.70	0.95 (0.74–1.22)	0.70
	≤ 666 mg	1.06 (0.86–1.31)	0.60	1.02 (0.83–1.25)	0.89	1.00 (0.81–1.23)	0.97	0.99 (0.81–1.22)	0.94
	P_trend		0.97		0.83		0.76		0.75
Fiber	> 25 g* (ref)	1.0		1.0		1.0		1.0	

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Nutrient	Intake	Model 1‡		Model 2‡		Model 3‡		Model 4‡	
		OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
	16.7 – 25 g	1.03 (0.59–1.79)	0.92	0.96 (0.54–1.78)	0.89	0.94 (0.53–1.66)	0.84	0.93 (0.52–1.64)	0.79
	≤ 16.6 g	1.20 (0.73–1.97)	0.48	1.12 (0.65–1.91)	0.69	1.11 (0.66–1.89)	0.69	1.09 (0.64–1.87)	0.74
	P_trend		0.76		0.97		1.00		0.95
Magnesium	> 400 mg† (ref)	1.0		1.0		1.0		1.0	
	266.7 – 400 mg	1.28 (0.85–1.92)	0.24	1.18 (0.78–1.78)	0.44	1.18 (0.78–1.78)	0.43	1.16 (0.77–1.75)	0.49
	≤ 266.6 mg	1.32 (0.90–1.95)	0.16	1.19 (0.81–1.77)	0.37	1.16 (0.80–1.70)	0.44	1.15 (0.78–1.68)	0.49
	P_trend		0.19		0.40		0.42		0.47
Potassium	> 3500 mg* (ref)	1.0		1.0		1.0		1.0	
	2333.4 – 3500 mg	0.87 (0.52–1.46)	0.60	0.89 (0.53–1.52)	0.68	0.89 (0.53–1.50)	0.67	0.91 (0.54–1.53)	0.71
	≤ 2333.3 mg	0.82 (0.49–1.39)	0.46	0.86 (0.51–1.46)	0.58	0.87 (0.52–1.45)	0.60	0.89 (0.53–1.48)	0.64
	P_trend		0.53		0.63		0.63		0.68
Na	≤ 2300 mg* (ref)	1.0		1.0		1.0		1.0	
	2301 – 3450 mg	1.16 (0.92–1.46)	0.23	1.15 (0.91–1.47)	0.24	1.18 (0.92–1.50)	0.19	1.17 (0.92–1.49)	0.21
	> 3450 mg	1.37 (1.06–1.78)	0.017	1.34 (1.03–1.75)	0.031	1.37 (1.05–1.78)	0.021	1.36 (1.04–1.77)	0.024
	P_trend		0.038		0.057		0.038		0.045

OR indicates odds ratio; RCI, recommended caloric intake; RDI, reference daily intake

*RDI per 2000 calories

†RDI

‡model 1: after adjustment for age (continuous), male gender, race/ethnicity (Non-Hispanic White(ref), African-American, Mexican-American), and study (NHANES 99-08 vs NHANES III)

model 2: after adjustment for the model 1 variables and BMI z-score quartile

model 3: after adjustment for the model 1 variables and waist circumference z-score quartile

model 4: after adjustment for the model 1 variables, BMI z-score quartile and waist circumference z-score quartile

Computer run: :/proj/bkcbps/bkcbp00/nhanes/logistic9.pt_score.nutrients.sas

Table 4

Association between demographic, anthropometric and nutritional variables with elevated blood pressure among children, ages 8 – 17, NHANES study, 1988–2008

Variable	Total population		Non-African-American		African-American	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Age (continuous)	1.12 (1.08–1.15)	< 0.001	1.11 (1.07–1.16)	< 0.001	1.13 (1.09–1.17)	< 0.001
Male gender	1.85 (1.52–2.26)	< 0.001	1.77 (1.38–2.27)	< 0.001	2.23 (1.76–2.82)	< 0.001
Race/Ethnicity						
Non-Hispanic White (ref)	1.0		1.0		---	
African-American	1.28 (1.09–1.50)	0.002	---		---	
Mexican-American	0.99 (0.82–1.20)	0.92	0.99 (0.82–1.20)	0.93	---	
BMI z-score *						
Q1 (ref)	1.0		1.0		1.0	
Q2	1.33 (0.95–1.87)	0.094	1.34 (0.90–2.00)	0.15	1.26 (0.76–2.07)	0.37
Q3	1.43 (1.05–1.95)	0.024	1.31 (0.87–1.98)	0.20	1.96 (1.19–3.23)	0.008
Q4	2.00 (1.34–2.99)	< 0.001	1.92 (1.18–3.12)	0.009	2.07 (1.16–3.71)	0.015
Waist circumference z-score †						
Q1 (ref)	1.0		1.0		1.0	
Q2	0.98 (0.67–1.42)	0.90	0.99 (0.62–1.58)	0.96	0.95 (0.68–1.32)	0.34
Q3	0.96 (0.64–1.45)	0.84	0.95 (0.57–1.60)	0.86	1.26 (0.79–2.00)	0.34
Q4	2.14 (1.48–3.12)	< 0.001	2.24 (1.39–3.60)	< 0.001	2.18 (1.34–3.52)	0.002
Na intake ‡						
<2300mg (ref)	1.0		1.0		1.0	
2300 – 3450mg	1.17 (0.92–1.49)	0.21	1.26 (0.93–1.70)	0.13	0.84 (0.65–1.09)	0.19
> 3450mg	1.36 (1.04–1.77)	0.024	1.50 (1.08–2.07)	0.016	0.90 (0.70–1.16)	0.40
Number of children with elevated blood pressure	1834		1112		722	
Number of children	11636		7610		4026	

OR indicates odds ratio

* Adjusted for age and sex based on CDC growth charts (1 year age-sex groups)

† Adjusted for age and sex based on NHANES 1 year age-sex groups

‡ per 2,000 calories

Computer runs: :/proj/bkcbps/bkcbp00/nhanes/logisitc10.pt_score.sas

:/proj/bkcbps/bkcbp00/nhanes/attrib_risks.sas

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Table 5

Comparison of prevalence of elevated bp between NHANES III and NHANES 99-08

Model		Boys		Girls		Overall	
		OR* (95% CI)	p-value	OR* (95% CI)	p-value	OR* (95% CI)	p-value
1	Unadjusted	1.27 (0.96–1.68)	0.090	1.61 (1.06–2.43)	0.025	1.39 (1.09–1.77)	0.007
2	Adjusted for age, gender, race/ethnicity	1.27 (0.96–1.67)	0.089	1.58 (1.03–2.42)	0.035	1.38 (1.09–1.76)	0.009
3	Model 2 + BMI quartile and waist circumference quartile	1.16 (0.88–1.53)	0.28	1.41 (0.90–2.21)	0.14	1.25 (0.97–1.62)	0.089
4	Model 3 + Na intake	1.18 (0.90–1.55)	0.24	1.43 (0.91–2.24)	0.12	1.27 (0.98–1.64)	0.069

OR indicates odds ratio

* comparing prevalence of elevated bp in NHANES 99-08 vs NHANES III

Computer runs

:/proj/bkcbps/bkcbp00/nhanes/logistic7c2.pt_score.sodium.sas

:/proj/bkcbps/bkcbp00/nhanes/logistic7b2.pt_score.sodium.sas

:/proj/bkcbps/bkcbp00/nhanes/logistic7a2.pt_score.nutrients.test2.sas