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Prevalence of and Trends in Dyslipidemia and Blood Pressure Among US Children and Adolescents, 1999–2012

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Abstract

IMPORTANCE—Recent national data suggest there were improvements in serum lipid concentrations among US children and adolescents between 1988 and 2010 but an increase in or stable blood pressure (BP) during a similar period.

OBJECTIVE—To describe the prevalence of and trends in dyslipidemia and adverse BP among US children and adolescents.

DESIGN—The National Health and Nutrition Examination Survey, a cross-sectional survey.

SETTING—Noninstitutionalized US population.

PARTICIPANTS—Children and adolescents aged 8 to 17 years with measured lipid concentrations (n = 1482) and BP (n = 1665).

MAIN OUTCOMES AND MEASURES—Adverse concentrations of total cholesterol (TC) (≥200 mg/dL), high-density lipoprotein cholesterol (HDL-C) (<40 mg/dL), and non-HDL-C (≥145 mg/dL) (to convert TC, HDL-C, and non-HDL-C to millimoles per liter, multiply by 0.0259) and high or borderline BP were examined. Definitions of BP were informed by the Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents by the National High Blood Pressure Education Program Working Group on High Blood Pressure in

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Study concept and design: Kit, Ostchega, Ogden.

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Children and Adolescents. Analyses of linear trends in dyslipidemias and BP were conducted overall and separately by sex across 7 periods (1999–2000, 2001–2002, 2003–2004, 2005–2006, 2007–2008, 2009–2010, and 2011–2012).

RESULTS—In 2011–2012, 20.2% (95% CI, 16.3–24.6) of youths had an adverse concentration of TC, HDL-C, or non-HDL-C and 11.0% (95% CI, 8.8–13.4) had either high or borderline BP. The prevalences of adverse concentrations decreased between 1999–2000 and 2011–2012 for TC (10.6% [95% CI, 8.3–13.2] vs 7.8% [95% CI, 5.7–10.4]; $P = .006$), HDL-C (17.9% [95% CI, 15.0–21.0] vs 12.8% [95% CI, 9.8–16.2]; $P = .003$), and non-HDL-C (13.6% [95% CI, 11.3–16.2] vs 8.4% [95% CI, 5.9–11.5]; $P < .001$). There was a decrease in high BP between 1999–2000 (3.0% [95% CI, 2.0–4.3]) and 2011–2012 (1.6% [95% CI, 1.0–2.4]) ($P = .003$). There was no change from 1999–2000 to 2011–2012 in borderline high BP (7.6% [95% CI, 5.8–9.8] vs 9.4% [95% CI, 7.2–11.9]; $P = .90$) or either high or borderline high BP (10.6% [8.4–13.1] vs 11.0% [95% CI, 8.8–13.4]; $P = .26$).

CONCLUSIONS AND RELEVANCE—In 2011–2012, approximately 1 in 5 children and adolescents aged 8 to 17 years had an adverse lipid concentration of TC, HDL-C, or non-HDL-C and slightly more than 1 in 10 had either borderline high or high BP. The prevalence of dyslipidemia modestly decreased between 1999–2000 and 2011–2012, but either high or borderline high BP remained stable. The reasons for these trends require further study.

Among children and adolescents, dyslipidemia and elevated blood pressure (BP), in addition to other risk factors, are associated with evidence of atherosclerosis.[1–3] Serum lipid concentrations and BP track from childhood into adulthood.[4–6] Among adults in the United States, dyslipidemia and elevated BP are associated with cardiovascular events, including mortality.[7] Early identification of dyslipidemia and elevated BP may improve long-term health outcomes, and current evidence-based clinical practice guidelines recommend universal screening of serum lipid concentrations and BP during childhood.[1]

Between 1988–1994 and 2007–2010, there were improvements in serum lipid concentrations among US children and adolescents.[8] Several studies using National Health and Nutrition Examination Survey (NHANES) data have examined changes over time in BP among US children and adolescents between 1988–1994 and more recent survey periods, including 1999–2002, 2003–2006, and 1999–2008, and noted an increase in or stable BP among children and adolescents.[9–11] The objectives of this study are to describe the prevalence of adverse serum concentrations of total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), and non-HDL-C as well as adverse BP among US children and adolescents in 2011–2012 and to describe linear trends since 1999–2000.

Methods

Study Design

The NHANES is a nationally representative sample of the civilian noninstitutionalized US population conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention (CDC). Details of the complex survey design are described elsewhere[12–14] and are briefly summarized herein. As part of the survey design, specific groups are oversampled during select years to increase reliability of estimates. Beginning in

2011–2012, non-Hispanic Asian individuals were over-sampled. Serum lipid concentrations were measured in participants aged 6 years and older and BP was obtained from those aged 8 years and older. This article is restricted to nonpregnant children and adolescents aged 8 to 17 years. This age range was chosen because BP in the NHANES is assessed beginning at age 8 years and BP-related definitions change at age 18 years.[1] Written parental consent was obtained for youths younger than 18 years and child assent was obtained for those aged 7 to 17 years. The National Center for Health Statistics Research Ethics Review Board approved the NHANES protocol. The overall un-weighted examination response rate was 69.5% in 2011–2012.

Laboratory Methods

Venous samples were collected from participants, stored frozen, and shipped to a laboratory according to a standardized protocol.[15–17] Similar to previous NHANES data releases, standardization of serum lipid measurements was performed according to the criteria of the CDC's Lipid Standardization Program, which ensures measurements are accurate and comparable across studies.[18] The non-HDL-C concentration was calculated as TC concentration minus HDL-C concentration. In 1999–2002, HDL-C was measured using both the direct immunoassay method and the heparin manganese precipitation method; starting in 2003, all HDL-C samples were analyzed using the direct immunoassay method. In data collected between 2003 and 2006, there was a substantial increase in HDL-C concentration, which is believed to be, in part, a method effect.[19]

Methods of BP Assessment

Three consecutive BP readings were obtained 30 seconds apart from children aged 8 years and older after resting quietly in a sitting position for 5 minutes.[20] For this analysis, an average of up to 3 brachial systolic (first Korotkoff phase) and diastolic (fifth Korotkoff phase) BP readings were used as the participants' systolic and diastolic BP values.[9] Approximately 5% (unweighted) of youths were missing all 3 systolic and diastolic BP readings and approximately 85% had all 3 systolic and diastolic readings. The medical wall-mounted gravity mercury sphygmomanometer (Baumanometer) and appropriate BP cuff sizes were used to obtain all BP values. The BP values were assessed by a trained physician and there were strict quality control and assurance measures.[20] There were no changes between 1999 and 2012 in assessment of BP.

Definitions for Adverse Lipid Concentrations and BP

Adverse lipid concentrations were defined as follows: TC concentration of 200 mg/dL or higher; HDL-C concentration lower than 40 mg/dL; and non-HDL-C concentration of 145 mg/dL or higher[1] (to convert TC, HDL-C, and non-HDL-C to millimoles per liter, multiply by 0.0259). An adverse concentration in 1 or more of the 3 lipids is also presented. Fasting triglycerides and low-density lipoprotein cholesterol levels are reported in the NHANES for adolescents but are not included in this analysis because these values were obtained from only half the sample (those who fasted) and the narrow age range often necessitates combining multiple years of data.

Sex-, age-, and height-specific cut points informed by the Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents by the National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents[21] and incorporated into the Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents[1] were used to define BP categories. Height was measured using a standardized protocol and was converted into a *z* score based on the 2000 CDC growth charts.[22] High BP was defined as a systolic or diastolic BP at the 95th percentile or higher and borderline high BP was defined as a systolic or diastolic BP at the 90th percentile or higher but lower than the 95th percentile or as BP levels of 120/80 mm Hg or higher (but <95th percentile). Categorization of BP is similar to previous reports.[9] We also present estimates for either borderline or high BP, similar to previous reports.[23–25]

Definitions for Sociodemographic and Weight Status Variables

Age was categorized as 8 to 12 years and 13 to 17 years based on age at the time of examination. Race/Hispanic origin was categorized as non-Hispanic white, non-Hispanic black, Hispanic, non-Hispanic Asian, and other, including multiracial. The race/Hispanic origin group indicated as other is included in overall estimates but results for this group are not separately reported. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared, rounded to 1 decimal place. Underweight (BMI <5th percentile), normal weight (BMI 5th to <85th percentile), overweight (BMI 85th to <95th percentile), and obese (BMI ≥95th percentile) were defined based on the 2000 CDC growth charts.[22]

Statistical Analysis

Prevalence estimates and 95% confidence intervals of dyslipidemia and BP are reported. The 95% confidence intervals were calculated using the approach described by Korn and Graubard.[26] Examination sample weights were used to obtain prevalence estimates representative of the civilian non-institutionalized US population. Differences between demographic groups and BMI categories were tested with a *t* statistic. Because previous studies have reported trends in serum lipid concentrations and BP using the Third NHANES (1988–1994) as the initial survey period, this analysis uses 1999–2000 as the initial survey period to examine whether similar trends are observed during a more recent period. To test for a linear trend between 1999–2000 and 2011–2012, the null hypothesis of no linear trend was examined using orthogonal contrast matrices.[27]

Analysis of an outcome with low prevalence is challenging in complex surveys such as the NHANES for a variety of reasons, including assumptions regarding its distribution and appropriate methods for statistical testing, and analyses may be best done on large samples. Initial analysis for this article showed that a low percentage of youths aged 8 to 17 years had high BP in 2011–2012 (1.6%). Thus, we limited statistical testing related to high BP to trend analyses overall and stratified by sex because these groupings had relatively large samples. We also conducted and report sensitivity analyses that combined data from 2001–2004, 2005–2008, and 2009–2012 and tested a linear trend for high BP across these survey periods. Further, the focus of our reporting of high BP is descriptive rather than analytic, and

the reported *P* values associated with high BP trend analyses should be interpreted with caution.

To assess the statistical reliability of estimates, a relative standard error was calculated by dividing the standard error by its respective prevalence estimate, multiplied by 100.[13] Additional considerations for statistical reliability of the estimates with a relative standard error of 40% or greater were examined, including the confidence interval width, where 20% or greater was considered high, and the number of persons in the sample who met criteria for the outcome. There was no instance of a confidence interval width of 20% or greater when the relative standard error was 40% or greater, but there were instances in which the number of cases was less than 10 and these estimates should be interpreted with caution. Statistical analyses were performed using SAS version 9.3 statistical software (SAS Institute Inc) and SUDAAN version 11.0 statistical software (Research Triangle Institute). Analyses accounted for the survey's complex design. Statistical significance was determined at $P < .05$ without adjustment for multiple comparisons.

Missing Data

Of the 1768 nonpregnant children and adolescents aged 8 to 17 years who were examined in the 2011–2012 NHANES, 286 were missing data on serum lipid concentrations, with more missing data among younger children. For the BP analyses, a total of 103 individuals were excluded: 8 were missing height, which is needed for *z* score calculation, and 95 were excluded for missing or incomplete BP data. To investigate the potential for nonresponse bias, we readjusted the examination sample weights using the PROC WTADJUST procedure in SUDAAN.[28] This procedure used a direct adjustment for age groups, sex, and race/Hispanic origin to reweight the data. The adjusted sample weights resulted in similar estimates and overall conclusions; therefore, we used the publicly available sample weights for the reported results to enhance reproducibility of study results.

Results

In 2011–2012 among youths aged 8 to 17 years, 7.8% (95% CI, 5.7–10.4) had an adverse TC concentration, 12.8% (95% CI, 9.8–16.2) had an adverse HDL-C concentration, 8.4% (95% CI, 5.9–11.5) had an adverse non-HDL-C concentration, and 20.2% (95% CI, 16.3–24.6) had an adverse concentration of at least 1 of the 3 measures (Table 1). In 2011–2012, 1.6% (95% CI, 1.0–2.4) had high BP, 9.4% (95% CI, 7.2–11.9) had borderline high BP, and 11.0% (95% CI, 8.8–13.4) had either high or borderline high BP (Table 2). Among non-Hispanic Asian youths, prevalences of adverse concentrations of TC, HDL-C, and non-HDL-C were 7.5% (95% CI, 3.7–13.1), 9.2% (95% CI, 6.0–13.3), and 7.0% (95% CI, 2.6–14.6), respectively, and prevalences of high and borderline high BP were 1.7% (95% CI, 0.5–4.2) and 6.9% (95% CI, 3.3–12.4), respectively. Prevalences of adverse lipid concentrations and borderline or high BP were not statistically different between non-Hispanic Asian and non-Hispanic white youths.

Between 1999–2000 and 2011–2012, there were decreasing linear trends in prevalences of adverse concentrations of TC (10.6% [95% CI, 8.3–13.2] vs 7.8% [95% CI, 5.7–10.4]; $P = .006$), HDL-C (17.9% [95% CI, 15.0–21.0] vs 12.8% [95% CI, 9.8–16.2]; $P = .003$), and

non-HDL-C (13.6% [95% CI, 11.3–16.2] vs 8.4% [95% CI, 5.9–11.5]; $P < .001$) (Table 3). Unweighted sample sizes for lipid analyses in 1999–2000, 2001–2002, 2003–2004, 2005–2006, 2007–2008, 2009–2010, and 2011–2012 were 2182, 2333, 2067, 2062, 1488, 1558, and 1482, respectively.

The prevalence of high BP was 3.1% or lower throughout the study duration, but there was a decrease between 1999–2000 (3.0% [95% CI, 2.0–4.3]) and 2011–2012 (1.6% [95% CI, 1.0–2.4]) ($P = .003$). In a sensitivity analysis with increased sample size for high BP analyses, in 2001–2004, 2005–2008, and 2009–2012, 2.9%, 2.7%, and 1.7% of youths aged 8 to 17 years had high BP and there was a significant linear decrease ($P = .008$). Overall, there was no linear change in prevalence of borderline high BP between 1999–2000 and 2011–2012 (7.6% [95% CI, 5.8–9.8] vs 9.4% [95% CI, 7.2–11.9]; $P = .90$), nor was there a linear change in high or borderline high BP (1999–2000, 10.6% [95% CI, 8.4–13.1]; 2011–2012, 11.0% [95% CI, 8.8–13.4]; $P = .26$). Unweighted sample sizes for BP analyses in 1999–2000, 2001–2002, 2003–2004, 2005–2006, 2007–2008, 2009–2010, and 2011–2012 were 2362, 2486, 2187, 2242, 1620, 1696, and 1665, respectively.

Discussion

Improvements among children and adolescents in serum lipid concentrations during a 22-year period between 1988–1994 and 2007–2010 have been previously reported.[8] Conversely, previous national studies have reported an increase in or stable BP among children and adolescents between 1988–1994 and data points measured between 1999 and 2008.[9–11] In this analysis, we report modest improvements between 1999–2000 and 2011–2012 in adverse concentrations of lipids but not borderline high BP or combined high and borderline high BP. The prevalence of high BP was 3.1% or lower in each of the survey periods and was 1.6% in 2011–2012, the most recent survey. The declines in dyslipidemia we report include a decrease in the prevalence of high non-HDL-C concentration, a recommended assessment measure for dyslipidemia during childhood in part because it is predictive of persistent dyslipidemia.[1] In 2011–2012, approximately 1 in 5 boys and girls aged 8 to 17 years had an abnormal TC, HDL-C, or non-HDL-C concentration and slightly more than 1 in 10 youths aged 8 to 17 years had either borderline high or high BP.

In 2011–2012, the NHANES oversampled non-Hispanic Asian individuals, allowing for the first nationally representative estimates of adverse lipid concentrations and BP for non-Hispanic Asian American children and adolescents. Our data suggest that in 2011–2012, non-Hispanic Asian and non-Hispanic white youths had a similar prevalence of adverse serum lipid concentrations and BP. Lo et al[29] reported that Asian American youths had higher prevalences of prehypertension and hypertension than non-Hispanic white youths in their study of 199 513 children and adolescents living primarily in urban and suburban communities in northern California, Colorado, and Minnesota. Differences in conclusions between our study and that of Lo and colleagues may in part be attributed to differences in the study samples. However, owing to the relatively small samples in our analysis, more detailed analyses may be performed when the 2013–2014 NHANES data are available to combine with the 2011–2012 data. In a study conducted in Toronto, Ontario, Canada,[30] BP measurements in European, Chinese, and South Asian adolescents were similar but South

Asian adolescents had a higher prevalence of adverse cholesterol levels compared with Chinese and European peers.

The cut points to define adverse levels of serum lipids and BP in our analyses are reported in clinical guidelines.[1,21] Conclusions regarding prevalence estimates may differ depending on reference data chosen. For example, based on data collected in China as part of the China Health and Nutrition Survey,[31] reference values for systolic BP were 9 to 10 mm Hg lower than those reported in the Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents.[21] Previous researchers have suggested the cut points for high BP may be too high because the sample used to define the normal range of BP included overweight children and thus may underestimate the prevalence of elevated BP.[10,32] Furthermore, some of the studies included in the Fourth Report[21] were based on only a single BP measurement and the number of BP measurements can affect results.[33–35] Regardless of the source of the cut points used to define adverse lipid and BP levels in children and adolescents, these definitions are not based on cardiovascular events but rather on statistical definitions and/or expert opinion. This differs from adults in whom the associations between cardiovascular events and both dyslipidemia and hypertension are more clearly delineated.[7]

Clinical practice guidelines[1,21] recommend repeated BP measurements on multiple occasions to define hypertension in children and adolescents. Some children and adolescents with an initial BP reading suggestive of hypertension may have subsequent normal BP readings. For example, in the study by Lo et al,[29] 5.4% of children and adolescents had an initial BP reading consistent with hypertension but a small proportion (3.8%) of these children had confirmed hypertension after subsequent assessments. Because BP in our study was assessed using up to 3 measurements on a single visit, the terminology of high and borderline high BP is used, similar to previous reports,[11,24] rather than hypertension and prehypertension even though the same cut points are used. Further, because the reported estimates for high BP are based on only 1 visit, the reported prevalence of high BP may overestimate the prevalence of hypertension using accepted clinical criteria.

In trend analyses, choice of the initial years of data may affect conclusions. Recent BP and lipid trend analyses in children and adolescents have used the Third NHANES, 1988–1994, as the initial years. For this analysis, we a priori chose 1999–2000 as the initial years to examine changes during a more recent period. Previous studies have reported that in 1988–1994, 2.1% and 7.3% of 8- to 17-year-olds had high and borderline high BP, respectively,[9] similar to the 3.0% and 7.6% we report for 1999–2000. In 1988–1994, 11.3%, 17.3%, and 13.6% of youths aged 6 to 19 years had adverse TC, HDL-C, and non-HDL-C concentrations, respectively,[8] similar to the 10.6%, 17.9%, and 13.6% we report for youths aged 8 to 17 years in 1999–2000. Given the similarities between 1988–1994 and 1999–2000 in these outcomes, our conclusions may not be substantially different by using 1999–2000 rather than 1988–1994 as the starting point for our trend analysis. Future surveillance of BP and lipid concentrations in children and adolescents may provide clarity into the reported trends, particularly in the case of high BP in which there are low prevalence estimates.

Population changes in factors associated with serum lipid concentrations and BP, including demographic, dietary,[24] physical activity, environment, and anthropometric factors,[23,25,36] may have contributed to our findings. Body mass index is one anthropometric factor associated with both BP and serum lipid concentrations.[23,25,36] Among school-aged children and adolescents in the United States, there has not been a decrease in obesity during our study period.[37] This seemingly paradoxical finding, ie, improvement in serum lipid concentrations and/or high BP despite stable or higher obesity prevalence, has been previously reported both in the United States, with NHANES[8,38] and Bogalusa Heart Study[23] data, and in other countries, including Korea[39] and Seychelles.[40] As serum lipid concentrations and BP are correlated with a variety of factors, these findings are plausible. Moreover, there have been improvements in other related factors since 1999, including a decrease among high school students in smoking and viewing 3 or more hours of television per day.[41]

Our study is nationally representative of the US population and we present the most recent national estimates of adverse lipid concentrations and BP among children and adolescents. Further, we also present national estimates of adverse serum lipid concentrations among non-Hispanic Asian children and adolescents, which have not been previously published to our knowledge. However, there are limitations to our study. Despite consistent BP assessment methods during our study period, there were changes in assessment of HDL-C concentration and there is a potential for laboratory bias. Given that concentrations of TC, HDL-C, and non-HDL-C vary by age,[38,42] caution in interpretation of these values based on a single measure should be considered. “White coat hypertension,” the transient increase in BP in the presence of a medical professional, has been described in children[43,44]; this effect may increase our estimates of borderline high and/or high BP.

Conclusions

During our study period, there were modest improvements in lipid concentrations among US children and adolescents aged 8 to 17 years but no significant change in borderline high BP or combined high and borderline high BP. The prevalence of high BP was 3.1% or less in each of the survey periods and was 1.6% in 2011–2012, the most recent survey. The reasons for these trends require further study. In 2011–2012, approximately 1 in 5 youths had an adverse serum lipid concentration and slightly more than 1 in 10 youths had either borderline high or high BP.

References

1. Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents; National Heart, Lung, and Blood Institute. Expert panel on integrated guidelines for cardiovascular health and risk reduction in children and adolescents: summary report. Pediatrics. 2011; 128(suppl 5):S213–S256. [PubMed: 22084329]
2. Berenson GS, Srinivasan SR, Bao W, Newman WP III, Tracy RE, Wattigney WA. Association between multiple cardiovascular risk factors and atherosclerosis in children and young adults: the Bogalusa Heart Study. N Engl J Med. 1998; 338(23):1650–1656. [PubMed: 9614255]
3. Raitakari OT, Juonala M, Kähönen M, et al. Cardiovascular risk factors in childhood and carotid artery intimamedia thickness in adulthood: the Cardiovascular Risk in Young Finns Study. JAMA. 2003; 290(17):2277–2283. [PubMed: 14600186]

4. Lauer RM, Clarke WR. Use of cholesterol measurements in childhood for the prediction of adult hypercholesterolemia: the Muscatine Study. JAMA. 1990; 264(23):3034–3038. [PubMed: 2243431]
5. Webber LS, Srinivasan SR, Wattigney WA, Berenson GS. Tracking of serum lipids and lipoproteins from childhood to adulthood: the Bogalusa Heart Study. Am J Epidemiol. 1991; 133(9):884–899. [PubMed: 2028978]
6. Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: a systematic review and meta-regression analysis. Circulation. 2008; 117(25):3171–3180. [PubMed: 18559702]
7. Wilson PW, D'Agostino RB, Levy D, Belanger AM, Silbershatz H, Kannel WB. Prediction of coronary heart disease using risk factor categories. Circulation. 1998; 97(18):1837–1847. [PubMed: 9603539]
8. Kit BK, Carroll MD, Lacher DA, Sorlie PD, DeJesus JM, Ogden C. Trends in serum lipids among US youths aged 6 to 19 years, 1988–2010. JAMA. 2012; 308(6):591–600. [PubMed: 22871871]
9. Ostchega Y, Carroll M, Prineas RJ, McDowell MA, Louis T, Tilert T. Trends of elevated blood pressure among children and adolescents: data from the National Health and Nutrition Examination Survey 1988–2006. Am J Hypertens. 2009; 22(1):59–67. [PubMed: 19039307]
10. Rosner B, Cook NR, Daniels S, Falkner B. Childhood blood pressure trends and risk factors for high blood pressure: the NHANES experience 1988–2008. Hypertension. 2013; 62(2):247–254. [PubMed: 23856492]
11. Din-Dzietham R, Liu Y, Bielo MV, Shamsa F. High blood pressure trends in children and adolescents in national surveys, 1963 to 2002. Circulation. 2007; 116(13):1488–1496. [PubMed: 17846287]
12. National Center for Health Statistics, Centers for Disease Control and Prevention. [Accessed July 22, 2014] National Health and Nutrition Examination Survey: analytic guidelines, 2011–2012. http://www.cdc.gov/nchs/data/nhanes/analytic_guidelines_11_12.pdf
13. Johnson CL, Paulose-Ram R, Ogden CL, et al. National health and nutrition examination survey: analytic guidelines, 1999–2010. Vital Health Stat. 22013; (161):1–24.
14. Curtin LR, Mohadjer LK, Dohrmann SM, et al. The National Health and Nutrition Examination Survey: sample design, 1999–2006. Vital Health Stat. 22012; (155):1–39.
15. National Center for Health Statistics, Centers for Disease Control and Prevention. [Accessed July 22, 2014] Laboratory procedure manual. 2010. http://www.cdc.gov/nchs/data/nhanes/nhanes_11_12/lab_comp_g.pdf
16. National Center for Health Statistics, Centers for Disease Control and Prevention. [Accessed July 22, 2014] Laboratory procedure manual, high-density lipoprotein cholesterol. 2013. http://www.cdc.gov/nchs/nhanes/nhanes2011-2012/HDL_G.htm
17. National Center for Health Statistics, Centers for Disease Control and Prevention. [Accessed July 22, 2014] Laboratory procedure manual, total cholesterol. 2013. http://www.cdc.gov/nchs/nhanes/nhanes2011-2012/TCHOL_G.htm
18. Lipid Standardization Program, Centers for Disease Control and Prevention. [Accessed July 22, 2014] Laboratory quality assurance and standardization programs. http://www.cdc.gov/labstandards/lsp_faq.html
19. National Center for Health Statistics, Centers for Disease Control and Prevention. [Accessed July 22, 2014] Laboratory procedure manual, high-density lipoprotein cholesterol. 2010. http://www.cdc.gov/nchs/nhanes/nhanes2005-2006/HDL_D.htm
20. Centers for Disease Control and Prevention. [Accessed July 22, 2014] National Health and Nutrition Examination Survey (NHANES): physician examination procedures manual. http://www.cdc.gov/nchs/data/nhanes/nhanes_09_10/physician.pdf
21. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. Pediatrics. 2004; 114(2 suppl 4th report):555–576. [PubMed: 15286277]
22. Kuczmarski RJ, Ogden CL, Guo SS, et al. 2000 CDC growth charts for the United States: methods and development. Vital Health Stat. 2002; (246):1–190.

23. Freedman DS, Goodman A, Contreras OA, DasMahapatra P, Srinivasan SR, Berenson GS. Secular trends in BMI and blood pressure among children and adolescents: the Bogalusa Heart Study. Pediatrics. 2012; 130(1):e159–e166. [PubMed: 22665416]
24. Yang Q, Zhang Z, Kuklina EV, et al. Sodium intake and blood pressure among US children and adolescents. Pediatrics. 2012; 130(4):611–619. [PubMed: 22987869]
25. May AL, Kuklina EV, Yoon PW. Prevalence of cardiovascular disease risk factors among US adolescents, 1999–2008. Pediatrics. 2012; 129(6):1035–1041. [PubMed: 22614778]
26. Korn EL, Graubard BI. Confidence intervals for proportions with small expected number of positive counts estimated from survey data. Surv Methodol. 1998; 24(2):193–201.
27. Winer, BJ. Statistical Principles in Experimental Design. New York, NY: McGraw-Hill; 1971.
28. Research Triangle Institute. SUDAAN Language Manual, Release 10. Research Triangle Park, NC: Research Triangle Institute; 2008.
29. Lo JC, Sinaiko A, Chandra M, et al. Prehypertension and hypertension in community-based pediatric practice. Pediatrics. 2013; 131(2):e415–e424. [PubMed: 23359583]
30. Vuksan V, Rogovik A, Jenkins A, et al. Cardiovascular risk factors, diet and lifestyle among European, South Asian and Chinese adolescents in Canada. Paediatr Child Health. 2012; 17(1):e1–e6. [PubMed: 23277758]
31. Yan W, Liu F, Li X, et al. Blood pressure percentiles by age and height for non-overweight Chinese children and adolescents: analysis of the China Health and Nutrition Surveys 1991–2009. BMC Pediatr. 2013; 13:195. [PubMed: 24274040]
32. Neuhauser HK, Thamm M, Ellert U, Hense HW, Rosario AS. Blood pressure percentiles by age and height from nonoverweight children and adolescents in Germany. Pediatrics. 2011; 127(4):e978–e988. [PubMed: 21382947]
33. Fixler DE, Kautz JA, Dana K. Systolic blood pressure differences among pediatric epidemiological studies. Hypertension. 1980; 2(4, pt 2):I3–I7. [PubMed: 7399638]
34. Becton LJ, Egan BM, Hailpern SM, Shatat IF. Blood pressure reclassification in adolescents based on repeat clinic blood pressure measurements. J Clin Hypertens (Greenwich). 2013; 15(10):717–722. [PubMed: 24088279]
35. Park MK. Blood pressure tables. Pediatrics. 2005; 115(3):826–827. [PubMed: 15741400]
36. Freedman DS, Dietz WH, Srinivasan SR, Berenson GS. The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. Pediatrics. 1999; 103(6, pt 1):1175–1182. [PubMed: 10353925]
37. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011–2012. JAMA. 2014; 311(8):806–814. [PubMed: 24570244]
38. Hickman TB, Briefel RR, Carroll MD, et al. Distributions and trends of serum lipid levels among United States children and adolescents ages 4–19 years: data from the Third National Health and Nutrition Examination Survey. Prev Med. 1998; 27(6):879–890. [PubMed: 9922071]
39. Khang YH, Lynch JW. Exploring determinants of secular decreases in childhood blood pressure and hypertension. Circulation. 2011; 124(4):397–405. [PubMed: 21730305]
40. Chiolero A, Paradis G, Madeleine G, Hanley JA, Paccaud F, Bovet P. Discordant secular trends in elevated blood pressure and obesity in children and adolescents in a rapidly developing country. Circulation. 2009; 119(4):558–565. [PubMed: 19153270]
41. Kann L, Kinchen S, Shanklin SL, et al. Centers for Disease Control and Prevention. Youth risk behavior surveillance: United States, 2013. MMWR Surveill Summ. 2014; 63(suppl 4):1–168.
42. Dai S, Yang Q, Yuan K, et al. Non-high-density lipoprotein cholesterol: distribution and prevalence of high serum levels in children and adolescents: United States National Health and Nutrition Examination Surveys, 2005–2010. J Pediatr. 2014; 164(2):247–253. [PubMed: 24139441]
43. Sorof JM, Portman RJ. White coat hypertension in children with elevated casual blood pressure. J Pediatr. 2000; 137(4):493–497. [PubMed: 11035827]
44. Sorof JM, Poffenbarger T, Franco K, Portman R. Evaluation of white coat hypertension in children: importance of the definitions of normal ambulatory blood pressure and the severity of casual hypertension. Am J Hypertens. 2001; 14(9, pt 1):855–860. [PubMed: 11587149]

Table 1

Prevalence of Dyslipidemia in Children and Adolescents Aged 8 to 17 Years, 2011–2012[a]

		% (95% CI)			
Characteristic	**Participants, No.**	**TC ≥200 mg/dL**	**HDL-C <40 mg/dL[b]**	**Non-HDL-C ≥145 mg/dL[c]**	**High TC, Low HDL-C, or High Non-HDL-C[d]**
Total	1482	7.8 (5.7–10.4)	12.8 (9.8–16.2)	8.4 (5.9–11.5)	20.2 (16.3–24.6)
Sex					
Boys[e]	757	6.6 (4.5–9.1)	12.6 (10.3–15.2)	7.5 (5.6–9.9)	19.3 (16.2–22.8)
Girls	725	9.0 (5.4–13.8)	12.9 (8.3–18.9)	9.2 (5.6–14.1)	21.0 (14.8–28.5)
Age, y					
8–12[e]	785	7.0 (4.4–10.4)	10.5 (6.9–15.1)	6.9 (4.2–10.7)	18.1 (12.5–24.9)
13–17	697	8.5 (5.2–12.9)	14.7 (11.7–18.1)	9.6 (6.1–14.2)	22.0 (18.0–26.6)
Race/Hispanic origin[f]					
Non-Hispanic white[e]	346	7.0 (3.7–11.9)	13.9 (9.5–19.3)	7.7 (3.8–13.5)	19.7 (13.7–27.1)
Non-Hispanic black	433	10.0 (8.3–11.8)	5.6 (3.5–8.5)	9.1 (7.5–10.9)	17.6 (15.1–20.4)
Non-Hispanic Asian	176	7.5 (3.7–13.1)	9.2 (6.0–13.3)	7.0 (2.6–14.6)[g]	16.6 (11.2–23.3)
Hispanic	452	8.6 (6.0–11.8)	15.7 (10.9–21.7)	10.4 (7.8–13.5)	24.2 (19.0–29.9)
BMI category[h]					
Normal weight[e]	872	7.7 (5.3–10.8)	6.7 (4.4–9.8)	7.2 (4.3–11.1)	14.6 (11.1–18.6)
Overweight	238	5.8 (2.7–10.9)[g]	12.5 (5.9–22.2)	8.0 (3.8–14.5)	18.2 (11.1–27.3)
Obese	320	9.8 (5.9–15.1)	31.5 (21.0–43.6)	13.7 (8.9–19.8)	39.3 (27.8–51.7)

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); HDL-C, high-density lipoprotein cholesterol; TC, total cholesterol.

SI conversion factors: To convert TC, HDL-C, and non-HDL-C to millimoles per liter, multiply by 0.0259.

[a]The National Health and Nutrition Examination Survey is the source. Prevalence estimates are weighted. Samples sizes are unweighted. Pregnant adolescents are excluded.

[b]For age 8 to 12 years vs 13 to 17 years, $P = .03$; for non-Hispanic white vs non-Hispanic black, $P = .003$; and for obese vs normal weight, $P < .001$.

[c]For obese vs normal weight, $P = .007$.

[d]For obese vs normal weight, $P < .001$.

[e]Reference group for statistical comparisons.

[f] Sample sizes for race/Hispanic origin do not sum to the total because the category of other is not shown separately.

[g] Relative standard error of 30% or higher but less than 40%.

[h] The BMI values were rounded to 1 decimal place, with underweight (BMI <5th percentile), normal weight (BMI 5th to <85th percentile), overweight (BMI 85th to <95th percentile), and obese (BMI ≥95th percentile) defined based on the 2000 Centers for Disease Control and Prevention growth charts.[22] Underweight participants are not shown separately.

Table 2

Prevalence of Adverse BP in Children and Adolescents Aged 8 to 17 Years, 2011–2012[a]

Characteristic	Participants, No.[b]	% (95% CI)		
		High BP	Borderline High BP[c]	Either High or Borderline High BP[d]
Total	1665	1.6 (1.0–2.4)	9.4 (7.2–11.9)	11.0 (8.8–13.4)
Sex				
Boys[e]	842	1.8 (0.6–4.1)[f]	13.7 (9.5–18.8)	15.4 (11.0–20.9)
Girls	823	1.4 (0.8–2.1)	5.4 (3.0–9.0)	6.8 (4.0–10.6)
Age, y				
8–12[e]	904	1.9 (1.1–3.0)	4.7 (2.7–7.4)	6.5 (4.5–9.1)
13–17	761	1.3 (0.5–2.8)[g]	13.7 (10.3–17.7)	15.0 (11.2–19.4)
Race/Hispanic origin[h]				
Non-Hispanic white[e]	388	1.1 (0.5–1.9)	8.3 (5.5–12.0)	9.4 (6.7–12.7)
Non-Hispanic black	483	1.9 (0.6–4.3)[f]	13.5 (10.5–17.0)	15.3 (12.5–18.6)
Hispanic	502	2.4 (0.7–5.6)[f]	9.1 (4.3–16.4)	11.5 (6.3–18.7)
Non-Hispanic Asian	203	1.7 (0.5–4.2)[f]	6.9 (3.3–12.4)	8.5 (3.8–16.0)[g]
BMI category[i]				
Normal weight[e]	1002	1.6 (0.9–2.7)	6.8 (4.3–10.0)	8.4 (5.9–11.5)
Overweight	267	1.9 (0.3–5.9)[f]	10.9 (6.6–16.6)	12.8 (8.6–18.1)
Obese	347	1.3 (0.3–3.6)[f]	16.7 (10.8–24.1)	18.0 (12.0–25.4)

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); BP, blood pressure.

[a]The National Health and Nutrition Examination Survey is the source. Prevalence estimates are weighted. Samples sizes are unweighted. Pregnant adolescents are excluded. High and borderline high BP definitions are informed by the Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents by the National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents[21] and recommendations by the Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents.[1]

[b]Number of cases among those with a relative standard error of 40% or higher is as follows for high BP: boys, n = 17; non-Hispanic black, n = 8; Hispanic, n = 11; non-Hispanic Asian, n = 3; overweight, n = 5; and obese, n = 5.

[c]For girls vs boys, $P = .008$; for age 13 to 17 years vs 8 to 12 years, $P < .001$; and for obese vs normal weight, $P = .01$.

[d]For girls vs boys, $P = .01$; for age 13 to 17 years vs 8 to 12 years, $P = .002$; for non-Hispanic black vs non-Hispanic white, $P = .02$; and for obese vs normal weight, $P = .01$.

[e]Reference group for statistical comparisons.

[f]Relative standard error of 40% or higher.

[g]Relative standard error of 30% or higher but less than 40%.

[h]Sample sizes for race/Hispanic origin do not sum to the total because the category of other is not shown separately.

[i]The BMI values were rounded to 1 decimal place, with underweight (BMI <5th percentile), normal weight (BMI 5th to <85th percentile), overweight (BMI 85th to <95th percentile), and obese (BMI ≥95th percentile) defined based on the 2000 Centers for Disease Control and Prevention growth charts.[22] Underweight participants are not shown separately.

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Table 3

Trends in Dyslipidemia and Adverse BP in Children and Adolescents Aged 8 to 17 Years, 1999–2012[a]

Characteristic	% (95% CI)							*P* Value for Linear Trend
	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	
High TC, ≥200 mg/dL								
Total	10.6 (8.3–13.2)	9.7 (7.1–12.8)	9.8 (7.8–12.2)	9.3 (8.0–10.8)	7.4 (5.6–9.6)	7.0 (5.2–9.2)	7.8 (5.7–10.4)	.006
Boys	9.1 (6.0–13.0)	9.5 (5.3–15.5)	9.1 (6.4–12.4)	10.1 (7.2–13.5)	8.2 (5.4–11.9)	7.8 (5.4–10.9)	6.6 (4.5–9.1)	.14
Girls	12.1 (9.4–15.3)	9.8 (8.1–11.7)	10.7 (7.6–14.5)	8.5 (6.1–11.4)	6.6 (4.5–9.2)	6.1 (4.0–8.8)	9.0 (5.4–13.8)	.007
Low HDL-C, <40 mg/dL								
Total	17.9 (15.0–21.0)	18.7 (16.7–20.8)	11.4 (8.6–14.8)	10.6 (8.6–12.9)	15.6 (13.7–17.7)	13.8 (11.7–16.1)	12.8 (9.8–16.2)	.003
Boys	19.2 (15.7–23.1)	23.0 (19.8–26.4)	15.7 (11.3–20.9)	12.1 (9.0–15.8)	18.3 (15.8–21.1)	16.7 (14.1–19.5)	12.6 (10.3–15.2)	<.001
Girls	16.4 (11.9–21.8)	14.1 (11.8–16.7)	7.0 (4.9–9.6)	9.0 (7.0–11.4)	12.8 (9.8–16.2)	10.8 (7.2–15.5)	12.9 (8.3–18.9)	.30
High non-HDL-C, ≥145 mg/dL								
Total	13.6 (11.3–16.2)	14.6 (12.3–17.1)	10.6 (8.2–13.3)	10.6 (9.2–12.2)	10.0 (7.5–12.9)	8.5 (6.2–11.4)	8.4 (5.9–11.5)	<.001
Boys	13.1 (10.3–16.3)	15.6 (12.2–19.5)	10.4 (6.8–15.1)	10.3 (7.8–13.2)	11.5 (7.9–15.9)	9.0 (6.6–11.9)	7.5 (5.6–9.9)	<.001
Girls	14.2 (11.3–17.5)	13.5 (10.9–16.6)	10.8 (7.7–14.5)	10.9 (8.2–14.2)	8.3 (5.8–11.5)	8.0 (4.9–12.2)	9.2 (5.6–14.1)	.001
High BP								
Total	3.0 (2.0–4.3)	2.7 (1.7–4.1)	3.1 (1.9–4.8)	2.8 (1.5–4.8)	2.6 (1.8–3.5)	1.7 (1.2–2.5)	1.6 (1.0–2.4)	.003
Boys	3.3 (2.0–5.1)	3.2 (2.1–4.6)	3.1 (1.6–5.4)	2.0 (1.0–3.5)	3.2 (2.0–4.8)	1.6 (0.9–2.7)	1.8 (0.6–4.1)[b]	.03
Girls	2.7 (1.0–6.0)[c]	2.3 (1.2–4.0)	3.1 (1.5–5.7)	3.6 (1.8–6.6)	2.0 (0.7–4.2)[c]	1.9 (1.3–2.7)	1.4 (0.8–2.1)	.11
Borderline high BP								
Total	7.6 (5.8–9.8)	10.0 (8.3–11.9)	9.1 (7.4–11.1)	10.3 (7.7–13.4)	10.1 (8.3–12.2)	7.2 (5.4–9.3)	9.4 (7.2–11.9)	.90
Boys	10.0 (7.8–12.7)	14.1 (11.2–17.5)	13.2 (10.2–16.8)	13.9 (10.0–18.7)	12.5 (8.8–17.0)	10.5 (7.5–14.1)	13.7 (9.5–18.8)	.74
Girls	5.1 (2.9–8.3)	5.7 (4.1–7.7)	4.9 (3.6–6.5)	6.5 (4.2–9.5)	7.7 (5.7–10.0)	3.7 (2.2–5.9)	5.4 (3.0–9.0)	.95
High or borderline high BP								
Total	10.6 (8.4–13.1)	12.7 (10.6–15.1)	12.2 (9.8–15.0)	13.1 (9.4–17.5)	12.7 (10.6–15.0)	8.9 (7.2–10.9)	11.0 (8.8–13.4)	.26
Boys	13.3 (10.7–16.3)	17.3 (14.4–20.5)	16.3 (12.5–20.6)	15.9 (11.3–21.5)	15.6 (11.8–20.0)	12.1 (9.2–15.5)	15.4 (11.0–20.9)	.61
Girls	7.9 (4.3–12.9)	8.0 (5.8–10.7)	8.0 (5.4–11.4)	10.2 (6.7–14.6)	9.7 (7.0–12.8)	5.6 (4.3–7.3)	6.8 (4.0–10.6)	.42

Abbreviations: BP, blood pressure; HDL-C, high-density lipoprotein cholesterol; TC, total cholesterol.

SI conversion factors: To convert TC, HDL-C, and non-HDL-C to millimoles per liter, multiply by 0.0259.

[a]The National Health and Nutrition Examination Survey is the source. Prevalence estimates are weighted. Samples sizes are unweighted. Pregnant adolescents are excluded. High and borderline high BP definitions are informed by the Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents by the National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents[21] and recommendations by the Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents.[1] Unweighted sample sizes for lipid analyses in 1999–2000, 2001–2002, 2003–2004, 2005–2006, 2007–2008, 2009–2010, and 2011–2012 were 2182, 2333, 2067, 2062, 1488, 1558, and 1482 overall, respectively; 1110, 1160, 1063, 1032, 769, 817, and 757 for boys, respectively; and 1072, 1173, 1004, 1030, 719, 741, and 725 for girls, respectively. Unweighted sample sizes for BP analyses in 1999–2000, 2001–2002, 2003–2004, 2005–2006, 2007–2008, 2009–2010, and 2011–2012 were 2362, 2486, 2187, 2242, 1620, 1696, and 1665 overall, respectively; 1192, 1234, 1114, 1112, 826, 878, and 842 for boys, respectively; and 1170, 1252, 1073, 1130, 794, 818, and 823 for girls, respectively.

[b]Relative standard error of 40% or higher.

[c]Relative standard error of 30% or higher but less than 40%.