Trends in High Blood Pressure among United States Adolescents across Body Weight Category between 1988 and 2012

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Objective To examine trends in pre-high blood pressure (BP [HBP]) and HBP among US adolescents by body weight category during 1988-2012.

Study design We estimated pre-HBP and HBP prevalence among 14 844 participants aged 12-19 years using National Health and Nutrition Examination Surveys from 1988-1994, 1999-2002, 2003-2006, and 2007-2012. Pre-HBP and HBP were defined based on age-sex-height-specific BP percentiles. We examined the temporal trends in pre-HBP and HBP across category of body weight (normal weight vs overweight/obese), adjusted for potential explanatory factors, and estimated the number of adolescents with pre-HBP and HBP.

Results Between 1988 and 2012, the prevalence of HBP decreased and pre-HBP did not change. Among normal weight adolescents, multivariable adjusted pre-HBP prevalence was 11.0% during 1988-2012, and 10.9% during 2007-2012 (*P* = .923 for trend); adjusted HBP prevalence increased from 1988-1994 (0.9%) to 1999-2002 (2.3%), then declined significantly to 1.4% during 2007-2012 (*P* = .049). Among overweight/obese adolescents, adjusted pre-HBP prevalence was 17.5% during 1988-2012, and 20.9% during 2007-2012 (*P* = .323); adjusted HBP prevalence declined significantly from 7.2% during 1988-1994 to 3.2% during 2007-2012 (*P* = .018). Because of population growth, estimated number of adolescents with pre-HBP or HBP increased, from 4.18 million during 1988-1994 to 5.59 million during 2007-2012.

Conclusions Between 1988 and 2012, pre-HBP prevalence was consistently higher among overweight/obese adolescent than those of normal weight, and the pattern remain unchanged. HBP prevalence declined significantly, especially among overweight/obese adolescent that are not completely explained by sociodemographic or lifestyle characteristics. *(J Pediatr 2016;169:166-73)*.

Overweight and obesity increased significantly among US children and adolescents since the 1970s, leveling off since the mid-2000s.[1-3] Overweight and obesity are important risk factors for high blood pressure (BP [HBP]) among children and adolescents.[4] Childhood BP levels can continue to adulthood, and children with HBP are more likely to develop HBP as adults.[5] HBP is a leading risk factor for cardiovascular disease and a significant contributor to US morbidity and mortality.[6,7]

Recently, attention and research have increased on the prevention of weight-associated health outcomes in children and adolescents, including HBP.[4,8,9] Some investigators,[10-13] but not others,[8,14,15] suggest the epidemic of overweight and obesity is associated with increased average BP and HBP prevalence, and predict continuing increases in HBP prevalence with increases in overweight and obesity. A recent study examined trends in pre-HBP and HBP among US children and adolescents and found HBP prevalence declined during 1999-2012,[16] though investigators indicated that the reason for this decline merits further study. The current study extends these results by examining the interaction of body mass index (BMI) status with trends in pre-HBP and HBP during 1988-2012, adjusted for potential confounding variables.

Methods

The National Health and Nutritional Examination Survey (NHANES) is designed to represent the civilian, noninstitutionalized US population. Data for NHANES were collected by household interviews and physical examinations as described elsewhere.[17] Before 1999, NHANES surveys were periodic, but beginning that year, the survey became continuous. For the present study, we selected adolescents aged 12-19 years from NHANES 1988-1994, 1999-2002,

BMI	Body mass index
BP	Blood pressure
DBP	Diastolic BP
FDR	False discovery rate
HBP	High BP
HEI-2010	Healthy eating index-2010
MEC	Mobile examination center
NHANES	National Health and Nutritional Examination Survey
PIR	Poverty-income-ratio
PR	Prevalence ratio
SBP	Systolic BP

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2003-2006, and 2007-2012. After excluding the pregnant adolescents, our analyses included 14 844 adolescents who had BP measurements in the NHANES mobile examination centers (MECs). NHANES III and NHANES 1999-2012 underwent institutional review board approval and included written informed consent.

Measurement and Definition of Pre-HBP and HBP

Up to 3 BP measurements were taken by the certified examiners during visits to MECs after participants rested quietly in a sitting position for at least 5 minutes. In 1988-1994, 1999-2002, 2003-2006, and 2007-2012, 99%, 89%, 78%, and 92%, respectively, of adolescents had 3 BP measurements, and 0.1%, 2.4%, 8.9%, and 2.5%, respectively, had 1 BP measurement. We used averages of 2 or 3 BP measurements for those who had multiple measurements and 1 BP reading for the remaining adolescents. We classified adolescents as having normal, pre-HBP, or HBP based on age-sex-height-specific BP percentiles and the age-sex-height-specific percentiles is determined by 2000 Centers for Disease Control and Prevention growth charts.[4] For adolescents aged 12-17 years, normal was defined as systolic BP (SBP) and diastolic BP (DBP) <90th percentile for age-sex-height; pre-HBP was defined as SBP or DBP ≥90th but <95th percentile, or BP levels ≥120/80 mm Hg. HBP was defined as SBP and/or DBP ≥95th percentile. For adolescents aged 18-19 years, pre-HBP was defined as either SBP of >120 but <140 mm Hg or DBP of >80 but <90 mm Hg; HBP was defined as SBP ≥140 mm Hg, DBP ≥90 mm Hg, or taking antihypertensive medication.[18] The guidelines recommend that the multiple BP measurements at different times should be used to define persistent prehypertension and hypertension in adolescents.[4] To differentiate the BP measurements in the present study (up to 3 measurements at MECs in the same day) from the recommended definitions, we used the terms of pre-HBP and HBP with the same cut-off points that are used to define prehypertension and hypertension in the guidelines.[4]

Covariates

Age, sex, and race/ethnicity of participants were obtained from standard questionnaires. Race/ethnicity was classified as non-Hispanic white, non-Hispanic black, Mexican American, or other. BMI was calculated as measured weight (kg)/height (m^2).

We compared BMI in adolescents with age-sex-specific values from 2000 Centers for Disease Control and Prevention growth charts in order to account for variability by age and sex.[19] BMI-for-age of ≥85th to <95th percentiles was defined as overweight, and ≥95% percentile as obese. Waist-to-height ratio was calculated by dividing the waist (inches) by height (inches).[20]

For adolescents aged ≥12 years, the questions about smoking status changed substantially over time; therefore, we used the sex-race/ethnicity-specific cut-off points of cotinine concentrations to classify adolescents as current smokers vs nonsmokers.[21]

Questions to assess duration and intensity of physical activity varied substantially over time. Therefore, physical activity was classified at its most basic level: those reporting no activity vs some activities.[22]

Healthy eating index-2010 (HEI-2010) represents all major food groups, including fruits, vegetables, grains, milk, meat and beans, oils, saturated fat, sodium, and calories from solid fats, alcoholic beverages, and added sugars.[23] Food components are given maximum and minimum points per 1000 calories and total score ranges from 0-100, a higher score indicating a more healthy diet.[23]

Total annual family income, a socioeconomic status proxy, was used to calculate the poverty-income-ratio (PIR). The PIR was derived by dividing total annual family income by the established federal poverty level for the specific family size, accounting for year and state where assessment took place.[24] We defined PIR <1.0 as poor, 1.0 to <2.0 as near poor, 2.0 to <3.0 as middle income, and ≥3.0 as high income.

Statistical Analyses

We estimated the weighted prevalence and means (adjusted for age, sex, and race) of pre-HBP, HBP, BP and selected covariates by BMI status. We used linear and logistic regressions to test for temporal trends of pre-HBP and HBP prevalence, BP, and selected covariates across the 4 NHANES cycles. In the regression models, each variable of interest was the dependent variable; the independent variables included a categorical time variable corresponding to the midpoint of each survey (1991 for 1988-1994, 2001 for 1999-2002, 2005 for 2003-2006, and 2009 for 2007-2012 surveys), age, sex, and race/ethnicity. The time variable was used to assess temporal trends.

For analysis of temporal trends in prevalence, we fit logistic regression models using the Multilog procedure in SUDAAN v 10 (RTI International, Research Triangle Park, North Carolina) to estimate the adjusted pre-HBP and HBP simultaneously.[25] The adjusted prevalence was estimated by taking the predicted marginal.[26] In logistic regression analyses, we estimated the unadjusted prevalence (model 1); age-sex-race/ethnicity-adjusted prevalence (model 2); plus smoking status, physical activity, HEI-2010, PIR, waist-to-height ratio, and BMI as continuous variables (model 3). We conducted a 2-step trend test for each outcome, pre-HBP or HBP, by body weight categories (normal vs overweight/obese): first, we tested for linearity of the trends across all NHANES cycles; second, if the trends were linear, we presented the *P* values for trend during 1988-2012, and if the trends were nonlinear, with leveling off in 1999, we presented the *P* values from NHANES 1999-2012. To account for multiple comparisons, we calculated the adjusted *P* values controlling for false discovery rate (FDR) at 5.0%. The FDR represents the proportion of incorrectly rejected null hypotheses out of all rejected null hypotheses.[27] We used the SAS PROC MULTTEST with the unadjusted *P* values as input to calculate the FDR adjusted *P* values (SAS Institute, Inc, Cary, North Carolina).