Race and Obesity in Adolescent Hypertension

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abstract

BACKGROUND AND OBJECTIVES: The overall prevalence of essential hypertension in adolescents may be growing. Differences in blood pressure (BP) are well established in adults, but are less clear in adolescents. We hypothesize that the prevalence of hypertension differs by race/ethnicity among adolescents at school-based screenings.

METHODS: We performed school-based BP screening in over 20 000 adolescents from 2000 to 2015. Race/ethnicity was self-reported. Height and weight were measured to determine BMI, and BP status was confirmed on 3 occasions to diagnose sustained hypertension according to Fourth Working Group Report criteria.

RESULTS: We successfully screened 21 062 adolescents aged 10 to 19 years (mean, 13.8 years). The final prevalence of sustained hypertension in all subjects was 2.7%. Obesity rates were highest among African American (3.1%) and Hispanic (2.7%) adolescents. The highest rate of hypertension was seen in Hispanic (3.1%), followed by African American (2.7%), white (2.6%), and Asian (1.7%) adolescents ($P = .019$). However, obese white adolescents had the highest prevalence of sustained hypertension (7.4%) compared with obese African American adolescents (4.5%, $P < .001$). At lower BMI percentiles (<60th percentile), Hispanic adolescents actually had the lowest predicted prevalence of hypertension among the 4 groups.

CONCLUSIONS: The prevalence of hypertension varies among different race/ethnicities. Although obesity remains the strongest predictor of early hypertension, the strength of this relationship is intensified in Hispanic and white adolescents, whereas it is lessened in African American adolescents.

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WHAT'S KNOWN ON THIS SUBJECT: The prevalence of adolescent obesity and hypertension has seen a marked rise in the last 40 years. Surveys of the pediatric population in the United States show a disproportionate rise among minority groups.

WHAT THIS STUDY ADDS: Although an increasing BMI continues to be strongly predictive of rising hypertension prevalence across all racial and ethnic groups, we have shown that Asian, African American, Hispanic, and white children exhibit different degrees of synergism between blood pressure and BMI.

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Overweight and obesity has tripled in prevalence among children in the United States since the 1960s.[1] Currently one-third of US children are overweight or obese, with adolescent obesity exceeding 18.4% nationally.[2] Although the overweight incidence has plateaued since 2000, the rate of obesity continues to rise.[3] One consequence of rising obesity is an epidemiologic shift in pediatric hypertension.

The burden of pediatric obesity falls more often on minorities in the United States[2,3] but most of what is known about the racial/ethnic disparities in hypertension comes from studies in adults. In children, data suggest that the risk of hypertension is greater in minority groups, with Hispanic and African American children having the highest incidence, followed white children, respectively.[4–6] However, there remains a paucity of data, particularly in Asian populations, in defining the role of race/ethnicity in childhood hypertension in the context of BMI.

METHODS

Between 2000 and 2015, the Houston Pediatric and Adolescent Hypertension Program at the University of Texas McGovern Medical School at Houston completed school-based blood pressure (BP) screenings in 27 secondary education schools. Schools were selected by convenience sampling with the goal of identifying a population with similar racial/ethnic distribution as the Houston population at large. All students enrolled at selected schools were eligible to participate, with physical education classes as the primary point of contact. The screening study was performed in lieu of regular physical education activities. Our screening protocols were approved by the Committee for Protection of Human Subjects at the University of Texas Health Science Center at Houston, as well as local school district institutional review boards where required. Individual consents were obtained from each student's primary caretaker per local school district policy. In schools that did not require individual consents, all students were screened unless either the student or legal guardian declined.

Participating students completed an open-ended questionnaire that identified age, sex, racial/ethnic background, and use of antihypertensive medications. Our study personnel was composed of paramedics, medical students, pediatric residents, fellows, clinic nurses, and attending staff. All persons responsible for obtaining readings were trained in the proper use of the equipment. Study personnel then measured arm circumference (cm), height (cm), and weight (kg). A minimum of 2 oscillometric BP readings were obtained with a Spacelabs 90217 (Snoqualmie, WA) or Dinamap Critikon (Tampa, FL) monitor with at least 1 minute between measurements. All measurements were conducted while participants were seated and used an appropriately sized cuff as outlined in the Fourth Working Group Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents guidelines.[7] Our study protocol required a minimum of 2 BP readings on the initial visit. In our final data set, 3.6% of the students had only 2 BP readings, with the remaining 96% having ≥3 readings. All first BP measurements were discarded, and a mean of the remaining readings was calculated. The results were compared with the Fourth Working Group Report criteria to classify BP according to sex, age, and height for each individual student. All students with BP ≥90th percentile or ≥120/80 mm Hg were classified as having an initial abnormal BP. Students with abnormal BPs on the initial screening day subsequently had repeated measurements on up to 2 additional occasions to confirm the presence of sustained hypertension as recommended by the Fourth Working Group Report. All follow-up BP measurements were performed within 2 months of the initial screening date to reduce potential confounding from changes in body habitus. After the 3 screening sessions, subjects were classified as follows: (1) normotensive: mean systolic blood pressure (SBP) and diastolic blood pressure (DBP) <90th percentile for age, height, and sex at first screening, (2) hypertensive: mean SBP or DBP ≥95th percentile (or ≥140/90 mm Hg for subjects ≥18 years) for all 3 screenings, or (3) at risk: elevated BP at the first visit but not meeting criteria for hypertension. For the majority of the analysis, normotensive and at risk groups were collapsed into 1 category. BMI percentiles representing conventional pediatric categories (<85th percentile: normal, 85th–94th percentile: overweight, ≥95th percentile: obese) were based on the 2000 Centers for Disease Control and Prevention growth charts.

Continuous variables are reported as mean ± SD (minimum–maximum); categorical variables are reported as count (n) and/or percentage (%) and tested by χ^2 test. A binomial regression with log link was fit for the outcome of sustained hypertension with the predictors of age, sex, BMI percentile, and race/ethnicity. All main effects and pairwise interactions were tested for model inclusion in a backward stepwise fashion. Two models were fit to assess the consistency of the effect of BMI percentile as a continuous variable and categorical variable. Minimization of Bayesian information criterion was used to determine the best-fit model. The variance–covariance matrix was adjusted for intracorrelation clusters within schools. Average predicted effects from the final model are reported. A two-sided P value of .05 was used to determine statistical significance for all tests.

RESULTS

Between 2000 and 2015, 22 382 students participated in our BP screening program. Students were excluded if they were hypertensive on the first visit, but failed to complete subsequent follow-ups for confirmation (n = 825). Students were also excluded if they reported any use of antihypertensive medications or were missing sex, race/ethnicity, age, height, or weight (n = 11). Due to the small sample size, we also excluded students who self-identified as mixed race/ethnicity, Hispanic-African American, Pacific Islander, Native American, or other (n = 484). Because the vast majority of Hispanic students identified themselves as Hispanic-white, we will refer to this category as simply Hispanic for the remainder of the study. After exclusions, our final cohort consisted of 21 062 students from 27 secondary schools in the greater Houston area.

The final data set used in our analysis was composed of 21 062 students (48% boys) with a mean age of 13.8 ± 1.7 (10–19) years (Table 1). There were 6943 white students (33%), 7394 Hispanic students (35%), 5259 African American students (25%), and 1466 Asian students (7%). Approximately one-third of students were overweight (18%) or obese (19%), aligning with national estimates from NHANES.[2]

Hispanic students had the highest prevalence of overweight/obesity (20%/23%), followed by African American students (19%/21%), white students (16%/13%), and Asian students (16%/10%) (Fig 1). The largest percentage of obesity was composed of Hispanic (44%) and African American (29%) students. Similarly, Hispanic and African American students also contributed disproportionately to the overall prevalence of hypertension when compared with white and Asian students. Hispanic students made up 35% of the study population, but accounted for 40% all hypertensive students. Conversely, Asian students accounted for 7% of the student population, but only 4% of all hypertensive students.

The final prevalence of sustained hypertension was 2.7% (2% stage 1 and 0.7% stage 2) across all BMIs and races/ethnicities (Table 1). The majority of students with

TABLE 1 Cohort Characteristics

Characteristic	n = 21 062
Age, y	13.8 ± 1.7 (10–19)
Sex	
Girl	10 967 (52%)
Boy	10 095 (48%)
Race/ethnicity	
Hispanic	7394 (35%)
White	6943 (33%)
African American	5259 (25%)
Asian	1466 (7%)
Height, cm	159.7 ± 10.0 (97.5–203)
Height percentile	52.5 ± 30.5 (0–100)
Weight, kg	57.8 ± 16.6 (21–178)
Weight percentile	66.0 ± 28.6 (0–100)
BMI	22.4 ± 5.2 (9–72)
BMI percentile	67.4 ± 28.0 (0–100)
BMI category	
Normal weight for height	13 307 (63%)
Overweight	3851 (18%)
Obese	3904 (19%)
First screening SBP, mm Hg	112.2 ± 10.9 (72–168)
First screening DBP, mm Hg	61.8 ± 7.5 (36–106)
First screening SBP index	0.9 ± 0.1 (0.6–1.3)
First screening DBP index	0.8 ± 0.1 (0.4–1.3)
First screening, hypertensive after 1 screen	2189 (10.4%)
Follow-up, hypertensive after 2 screens	915 (4.3%)
Final, hypertension after 3 screens	569 (2.7%)

Continuous variables reported as mean ± SD (minimum – maximum), and categorical variables reported as n (%). BP index defined as BP/95th percentile.

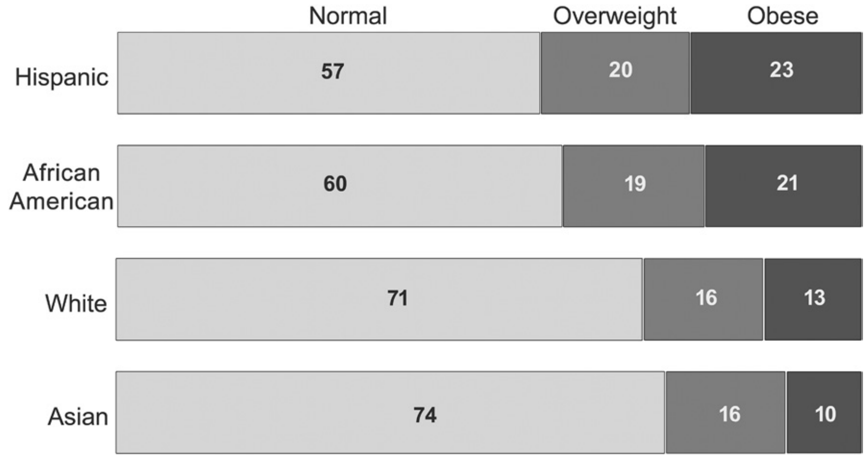

FIGURE 1
Prevalence of normal weight, overweight, and obese BMI categories within each group.

hypertension at first screening exhibited isolated systolic hypertension (2006 or 92%), followed by combined systolic/diastolic hypertension (140 or 6%) and isolated diastolic hypertensives (43 or 2%). Boys had a higher rate of hypertension (3.3%) compared with girls (2.1%). Interestingly, the rate of hypertension increased with age in boys, but decreased with age in girls. Hypertension prevalence at each screen increased with increasing BMI (Fig 2). Among students with normal BMI, 1.6% had hypertension. Overweight and obese students had a higher prevalence of hypertension at 2.6% and 6.6%, respectively ($P < .001$). Correspondingly, groups with a higher proportion of overweight or obese students were more likely to be hypertensive. The highest rate of hypertension was seen in Hispanic students (3.1%), then African American students (2.7%), white students (2.6%), and Asian students (1.7%) ($P = .019$).

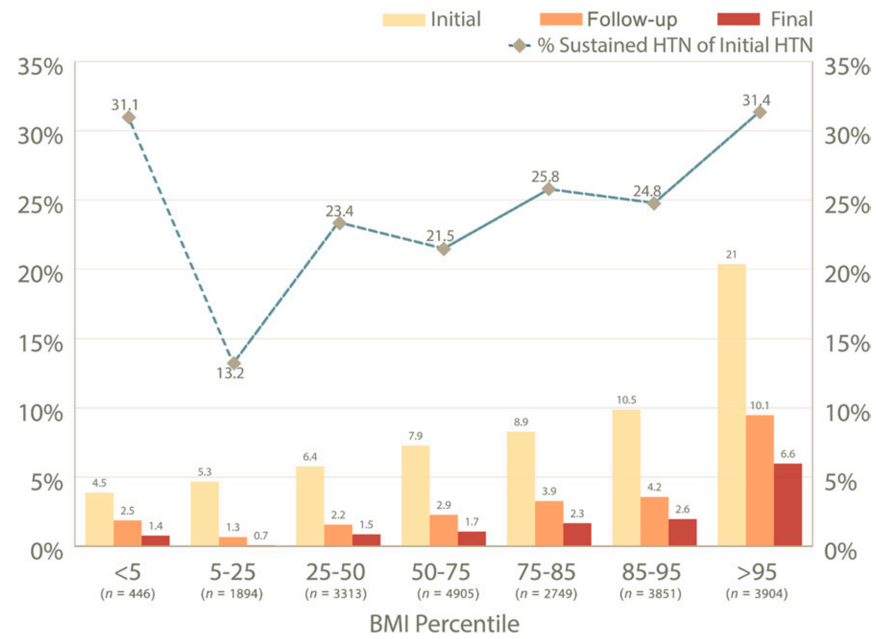

FIGURE 2
Hypertension prevalence across BMI percentiles. HTN, hypertension.

Nearly one-third of obese adolescents remained hypertensive from initial to final screen, whereas only 23% of adolescents with BMI percentiles between the 25th and 95th remained hypertensive (Fig 2). Those most likely to show normalized BPs were subjects with BMI percentiles between the fifth and 25th. Interestingly, underweight adolescents (BMI <5th percentile) with an initial high BP also exhibited a high rate of sustained hypertension (31%) similar to that seen in obese adolescents. When stratified by race/ethnicity, this finding in underweight adolescents was accounted for by the white and African American populations exclusively (41.3% and 25.5%, respectively) and was not seen in the Hispanic and Asian populations (0%).

When BMI and race/ethnicity data were compared, a disproportionate increase in the prevalence of hypertension was noted among obese Hispanic and white students (7.7% and 7.4%, respectively) (Fig 3). These high rates of hypertension seen specifically in obese Hispanic and white subjects were not seen in their nonobese counterparts. Conversely, although African American students had the highest prevalence of hypertension among normal (2%) and overweight (2.8%) subjects, they had the lowest rate of hypertension among obese subjects (4.5%). The Asian cohort exhibited a trend of lower hypertension rates across all BMI groups.

These varying relationships between BMI and BPs are obscured when we fail to account for race/ethnicity (Fig 4). Among the 4 groups sampled, the Hispanic population showed the steepest rise in hypertension prevalence when plotted against BMI percentiles. At lower BMI percentiles (<60th percentile), Hispanic adolescents actually had the lowest predicted prevalence of hypertension among the 4 groups. Similar to the white population, the Hispanic population followed a trend of slowly rising hypertension prevalence until they reached a BMI of approximately the 60th percentile, where they experienced a rapid rise. Once they reached approximately the 90th percentile for BMI, the Hispanic population transitioned from having the lowest rate of hypertension to the highest rate among the 4 groups, more than doubling the incidence of hypertension in the Asian group at BMIs >95th percentile.

This disproportionate burden of hypertension seen in obese Hispanic and white adolescents was confirmed in multivariate analysis with BMI percentile as a categorical factor. The relative risk of hypertension due to obesity varied significantly by racial/ethnic group (Fig 5). Specifically, in Hispanic adolescents, the relative risk of hypertension was 5.8 times higher in obese adolescents and 2.2 times higher in overweight adolescents compared with those with normal weights. Similarly, obese white adolescents had an increased relative risk of 4.1 and obese African American adolescents had a relative risk of 2.3

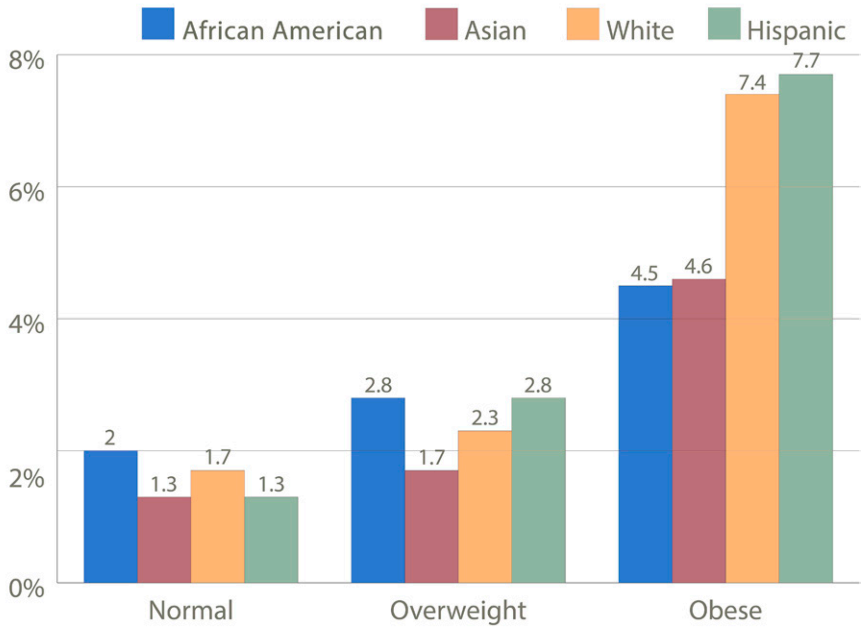

FIGURE 3
Prevalence of sustained hypertension by race/ethnicity and BMI.

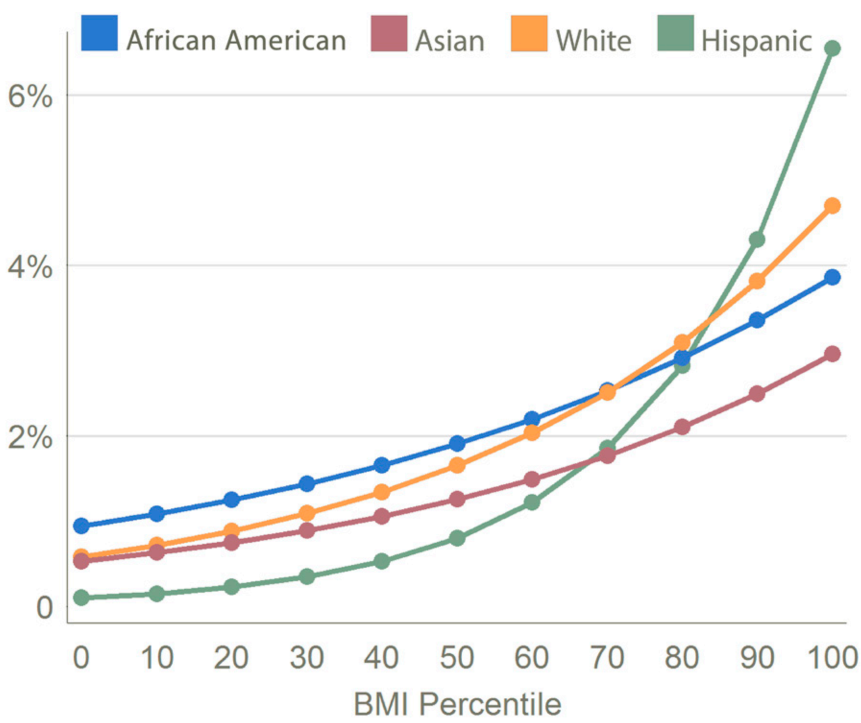

FIGURE 4
Predicted prevalence of sustained hypertension by BMI percentile.

compared with their normal weight counterparts. Although at slightly increased risk, being overweight was not a significant risk factor for hypertension in any group except for the Hispanic population.

DISCUSSION

In this study, we found 2.7% of students have sustained hypertension. Additionally, we report that the introduction of race/ethnicity significantly alters the established BMI-BP relationship. Although an increasing BMI continues to be strongly predictive of an increase in hypertension prevalence across all racial/ethnic groups, it appears to have a smaller impact on African American and Asian populations. Many studies have considered only additive effects of both race/ethnicity and BMI independently on BP. This study confirms race/ethnic-specific BMI-BP associations in a large pediatric sample.

Several of our findings have been corroborated in other studies. The excess of hypertension among normal-weight African American children compared with white children was shown by Rosner et al[8] in a large study of the US Task Force data. Rosner et al[8] and a longitudinal study of 2379 adolescent girls have also reported the blunted effect of increasing BMI on BP in African American adolescents,[9] as well as in several historical studies in African American and white adults.[10,11] Interestingly, some studies have found the opposite to be true, where the association of BMI with BP may be stronger in the Chinese-Asian population than in non-Asian populations.[12,13] It should be noted that these studies draw data from adults in mainland China, and therefore may not be analogous to the Asian-American population.

The prevalence of obesity in our study of adolescents was 19%, which is similar to the national estimate of 20.5% (95% confidence interval, 17.1%–24.4%) reported from the NHANES conducted in 2011 to 2012.[2] Given that the NHANES was designed to be a representative sample of the US population, this consistency with the NHANES demographic data suggests that our findings may be generalizable to other US regions. The prevalence of obesity was found to be highest in

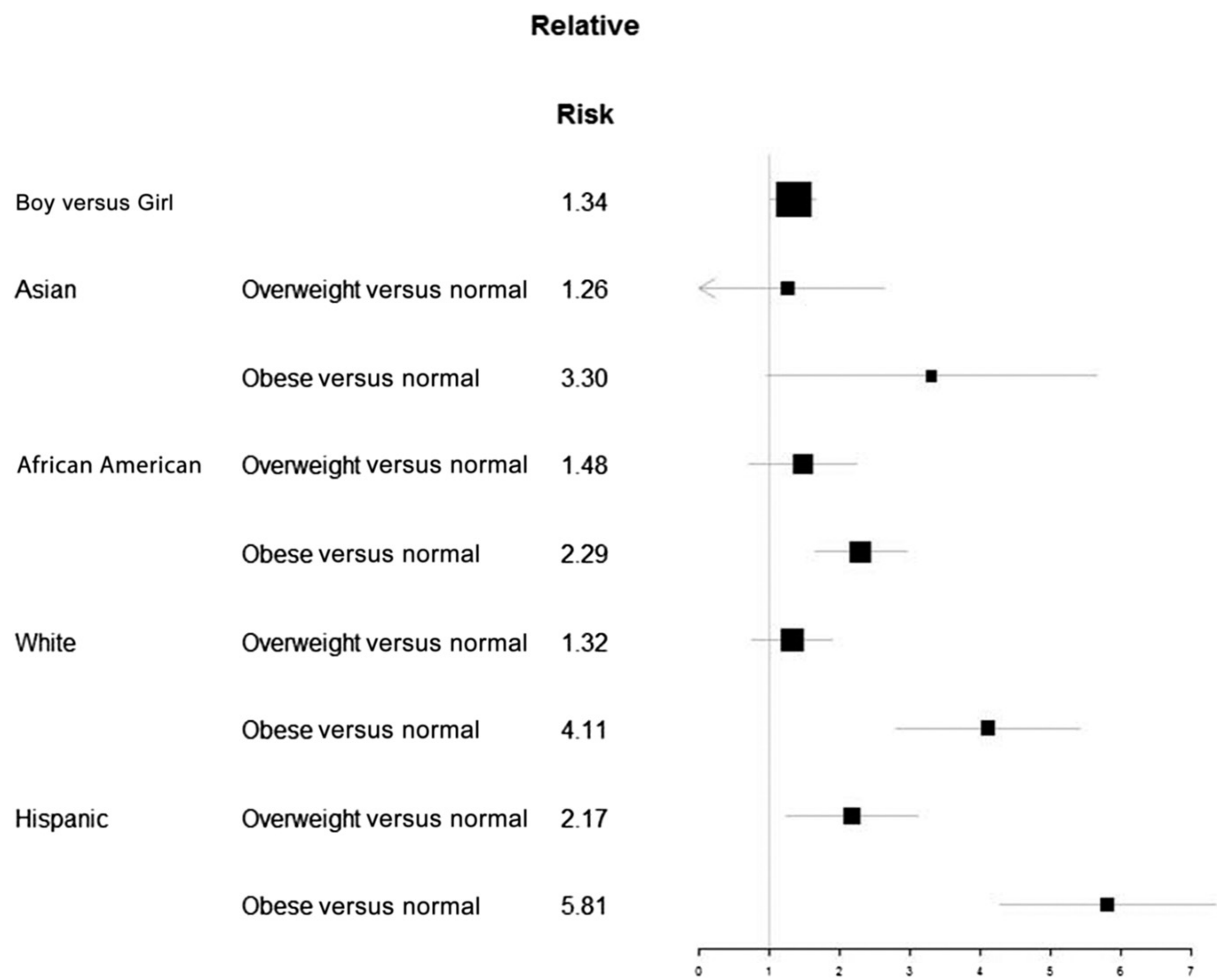

FIGURE 5
Relative risk of sustained hypertension by sample characteristics. Black boxes indicate the relative risk, with box size indicating the precision of the estimate (bigger size = more precise). Gray lines represent 95% confidence intervals. An arrow at the end of a gray line indicates that the 95% confidence interval extends beyond the range of the figure.

the Hispanic population, followed by the African American, white, and Asians populations, respectively. The Hispanic population had the highest median BMI (81st percentile), followed by the African American (78th percentile), white (67th percentile), and Asian populations (66th percentile). This pattern of obesity prevalence among the 4 groups has also been reported in a clinical electronic medical record–based study of 117 618 children between the ages of 6 and 17 years in California, Colorado, and Minnesota.[14] Other diverse cohorts have also demonstrated a higher prevalence of obesity in Hispanic and African American populations relative to the non-Hispanic white population.[15,16]

We observed a spike in sustained hypertension prevalence among adolescents with a BMI <5th percentile (Fig 2). As noted in the results, this finding is accounted for by the white and African American populations exclusively and is not seen in the Hispanic or Asian populations. Given the existing limitations of our data set, we can only speculate as to the reasons for this finding. Studies have supported the concept of the fetal origins hypothesis, which proposes that an inverse relationship exists between low birth weight and subsequent hypertension.[17,18] This finding certainly warrants additional study.

The final prevalence of sustained hypertension after 3 visits was 2.7%, higher than the 1.7% reported in the most recent NHANES data set from 2009 to 2012. The discrepancy between the studies may simply be a reflection of population characteristics unique to Houston. Alternatively, because our study was conducted from 2000 through 2015, our data may reflect a higher hypertension prevalence due to the inclusion of data earlier in the decade. NHANES has reported a significant decline in hypertension prevalence from 2.9%, to 2.7%, to 1.7% obtained from 2001 through 2004, 2005 through 2008, and 2009 through 2012, respectively.[2]

When separated by racial/ethnic group, we noted a significantly higher prevalence of hypertension among African American and Hispanic students when compared with white and Asian students, mirroring the trends mentioned earlier in average BMI. The higher risk for hypertension among minority groups (excluding the Asian population), has been demonstrated in several studies.[4,19–21] More so than height or weight, BMI has consistently been shown to be a strong independent predictor of hypertension. In the Bogalusa heart study, African American men and women who were overweight in adolescence were 52% and 62%, respectively, more likely to become obese adults.[14,22–24] These adolescents are more likely to develop hypertension, obstructive sleep apnea, diabetes mellitus, and dyslipidemia, conditions which all accelerate the onset of cardiovascular disease.[25–27]

Our data show that the relationship between BMI and hypertension differs markedly among each group. At normal weights, hypertension is most common among African American adolescents (2%), and lowest in Asian adolescents (1.3%). Although Hispanic adolescents have the lowest prevalence of hypertension among adolescents with a BMI <60th percentile, they have the highest hypertension prevalence among those with a BMI >60th percentile. Overweight and obese (BMI >85th percentile) Hispanic and white adolescents quickly surpass African American and Asian adolescents in terms of hypertension prevalence, suggesting a stronger association between BMI and BP in these 2 groups. Therefore, although African American adolescents have the highest rate of hypertension overall, obesity does not seem to affect BPs as markedly as it does in other groups.

The consideration of race/ethnicity also introduces a set of variables that extend beyond genetics. Differences in culture and social expectations exert influences on health behaviors, environmental exposures, and access to health care. All these factors may affect weight gain and, in turn, BP. As the demographics of the United States continue to evolve, studies need to account for increasingly prevalent minorities such as Hispanic and Asian people. To our knowledge, this is the first study that compares adolescent BPs in relation to BMI from 4 major racial/ethnic groups in the United States (white, African American, Hispanic, and Asian).

One limitation in our study is that the cross-sectional nature only allows us to describe differences and hypothesize causality. In addition, we relied on students to self-identify race/ethnicity. There has also been much debate regarding the effects of sexual maturation on BP.[28] Without data on pubertal status in this adolescent population, we were unable to test its effect on BMI and BP. Testing of interactions between race/ethnicity and age were not significant in the multiple logistic regression analysis.

The use of BMI in our study carries limitations as a suboptimal measure for weight classification when applied uniformly among different races/ethnicities. Race-specific body composition differences have been demonstrated in adult populations.[29–31] Such disparities may result in the over/underestimation of obesity in our African American and Asian students, respectively. In turn, this could conceivably blunt the rise of hypertension prevalence with rising BMI in African American adolescents while amplifying the prevalence among Asian adolescents.

The particular strengths of our study are its large size and diverse sampling of adolescents from all socioeconomic groups in Houston. The sample size enabled statistically powerful comparisons between several major racial/ethnic groups. Our goal was to obtain a cross-sectional survey of the adolescent population in the greater Houston area, which could be extrapolated to other population centers in the United States. We minimized the white-coat effect by screening subjects in a nonclinical setting, discarding the first BP measurement, and defining hypertension as having sustained elevations in BP over 3 consecutive screenings. By including adolescents from varied socioeconomic backgrounds, we captured populations with both regular and limited access to health care.

CONCLUSIONS

Despite the plateau seen over the last decade in the prevalence of childhood hypertension, the prevalence remains unacceptably high. In our cross-sectional analysis of adolescents in Houston, we sought to gain a better understanding of the differences in obesity and hypertension among the major racial/ethnic groups represented in the United States today. We have demonstrated that these groups clearly show different degrees of synergism between BP and BMI.

Our understanding of how race/ethnicity and BMI relate to other diagnoses remains incomplete. Additional studies are needed to evaluate the relationships of BMI with other diagnoses, such as diabetes mellitus, dyslipidemia, and obstructive sleep apnea. Because current trends only promise a new generation of young adults with early-onset cardiovascular disease, a reliable model for determining individual risk for hypertension in childhood is needed. Our findings additionally support the need for a variable approach to BMI interpretation in a racially and ethnically diverse population.

ABBREVIATIONS

BP: blood pressure
DBP: diastolic blood pressure
SBP: systolic blood pressure

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