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Original article

Sociodemographic Associations With Blood Pressure in 10–14-Year-Old Adolescents

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A B S T R A C T

Purpose: To determine the association between sociodemographic characteristics and blood pressure among a demographically diverse population-based sample of 10–14-year-old US adolescents.
Methods: We conducted cross-sectional analyses of data from the Adolescent Brain Cognitive Development Study (N = 4,466), year two (2018–2020). Logistic and linear regression models were used to determine the association between sociodemographic characteristics (sex, race/ethnicity, sexual orientation, household income, and parental education) with blood pressure among early adolescents.
Results: The sample was 49.3% female and 46.7% non-White. Overall, 4.1% had blood pressures in the hypertensive range. Male sex was associated with 48% higher odds of hypertensive-range blood pressures than female sex (95% confidence interval [CI], 1.02; 2.14), and Black race was associated with 85% higher odds of hypertensive-range blood pressures compared to White race (95% CI, 1.11; 3.08). Several annual household income categories less than $100,000 were associated with higher odds of hypertensive-range blood pressures compared to an annual household income greater than $200,000. We found effect modification by household income for Black adolescents; Black race (compared to White race) was more strongly associated with higher odds of hypertensive-range blood pressures in households with income greater than $75,000 (odds ratio 3.92; 95% CI, 1.95; 7.88) compared to those with income less than $75,000 (odds ratio 1.53; 95% CI, 0.80; 2.92).

IMPLICATIONS AND CONTRIBUTION

In a demographically diverse nationwide sample of 4,466 early adolescents 10–14 years old in the United States, the current study found that male sex, Black race, and low annual household income are associated with higher odds of hypertensive-range blood pressures.

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Discussion: Sociodemographic characteristics are differentially associated with higher blood pressure in early adolescents. Future research could examine potential mediating factors (e.g., physical activity, nutrition, tobacco) linking sociodemographic characteristics and blood pressure to inform targeted interventions.

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There has been a trend of increasing prevalence of childhood hypertension in recent years, with a global prevalence of 1.26% in 1990 to 6.02% observed between 2010 and 2014 [1]. In the United States, 4.6% of children aged 8–12 years in 2015–2018 had hypertension [2], with a higher mean systolic blood pressure documented in male compared with female, and in non-Hispanic Black compared with non-Hispanic White, US children. Further studies examining adolescent sociodemographic risk factors for hypertension are vital to identify potentially vulnerable population subgroups to help inform targeted public health interventions and guidelines. Although prior studies have examined adolescent hypertension [2–7], few have focused on early adolescence, which is an important period for the development of hypertension.

Social epidemiology is a field that investigates the role of demographic and socioeconomic factors on health outcomes [8–10] to better understand health disparities. Research in adults suggests the protective effects of high socioeconomic position on blood pressure typically observed in White persons may be smaller for racial and ethnic minorities [11], consistent with Minorities' Diminished Returns (MDR) theory [12]. Additional factors, such as sexual orientation, may also affect hypertension prevalence [13]; Sharma et al. found that compared with heterosexual adult participants of the same sex, bisexual women and gay men were more likely to report having been diagnosed with hypertension [14]. However, there has been a paucity of studies examining the social epidemiology of hypertension in early adolescents.

To address these research gaps, we aimed to examine the sociodemographic associations of blood pressure using extant data from a demographically diverse sample of US early adolescents. We hypothesized that male sex, Black race, sexual minority status, and lower household income would be associated with high blood pressure. As a secondary aim, we explored the effect modification of income by sociodemographic characteristics on high blood pressure. We hypothesized that income would modify the association of Black race with high blood pressure in line with MDR theory.

Methods

We conducted cross-sectional analyses of data from the Adolescent Brain Cognitive Development (ABCD) Study (4.0 release). The ABCD Study is the largest long-term longitudinal study of adolescent health, brain, and cognitive development in 11,875 children recruited from 21 sites across the United States in 2016–2018. The ABCD Study sample, recruitment, protocol, and measures have been previously described in detail [15]. Participants were 10–14 years of age during the 2-year follow-up (2018–2020), the first study year that blood pressure measures were collected. For the current analyses, only participants with complete blood pressure data were included. Of the 4,468 participants with complete blood pressure data, two were excluded due to taking antihypertensive medications, leading to a final sample size of 4,466 (See Appendix A for flow diagram showing inclusions and exclusions). Appendix B compares the sociodemographic characteristics of the early adolescents included in the study and those who were excluded. Centralized institutional review board approval was received from the University of California, San Diego. Written assent was obtained from the study participants, and written consent was obtained from their parents/guardians.

Measures and study variables

Independent variables. Sex assigned at birth (female or male), age of participant, race/ethnicity (White, Latino, Black, Asian, Native American, other), sexual minority status (yes, maybe, no, don't understand the question, decline to answer), household income (six categories), and parental education status (college education or more vs. high school education or less) were self-reported by the participants and/or their caregivers. Additional details are listed in Appendix C. All independent variables were collected at baseline, except age and sexual orientation, which were collected in year 2.

Dependent variables. Blood pressure was measured on a single day at the yearly assessment during the year two follow-up of the ABCD Study [16]. The protocol for measuring blood pressure was standardized so that all sites followed the same procedure. Research assistants were trained on the protocol and performed the assessments with an automatic sphygmomanometer (OMRON HEM 907 XL, MicroLife USA, Inc, Dunedin, FL). Blood pressure was measured using the right arm unless a condition prevented it from being used. The participant sat on a chair in a quiet environment, resting for 5 minutes before blood pressure was measured. The arm and back were supported, and the legs were uncrossed with both feet flat on the floor. Their right arm rested, palm face-up, on a table. The circumference of the mid-upper arm was measured to ensure the proper cuff size was selected (from four available cuff sizes). Three consecutive inflations (measures) were taken, with 60 seconds between inflations. The mean of the three measurements was used for analysis. Systolic and diastolic blood pressures were converted into age- and sex-specific percentiles for all ages, from which hypertensive blood pressure readings were determined based on the American Academy of Pediatrics guidelines for age and sex (Appendix D) [17]. Participants were categorized into two categories: normal blood pressure versus hypertensive-range blood pressure categories (also referred to as high blood pressure).

Statistical analysis

Data analyses were performed in Stata 18 (StataCorp, College Station, TX). Descriptive statistics were calculated by measuring the mean, standard deviation, and percentages of each category

of both the dependent and independent variables. Multivariable logistic regressions were conducted to estimate the associations between the independent variables (sex, age, race/ethnicity, sexual orientation, household income, parental education) and the binary outcome (hypertensive-range blood pressure readings), adjusting for study site. Multivariable linear regressions were conducted to estimate the associations between the exposure variables and continuous outcomes: systolic and diastolic percentile blood pressure percentiles (applied to all ages). Sensitivity analyses were conducted with systolic and diastolic blood pressures ≥ 90th percentile (Appendix E, consistent with elevated blood pressure) and ≥ 95th percentile (Appendix F, consistent with hypertensive blood pressure readings based on percentiles). We expected variations in the association between household income levels and our outcomes (hypertensive-range blood pressure readings, systolic and diastolic blood pressures) by race/ethnicity based on previously established literature demonstrating the MDR theory [18]. In exploratory analyses, we examined the association between some of the sociodemographic characteristics (race/ethnicity, sex, and sexual orientation) and hypertensive-range blood pressures, considering the potential effect modification by the binary categorical household income variable (e.g., income*race/ethnicity, income*sex, income*sexual orientation interaction term) based on previously established literature demonstrating the MDR theory [18]. We present income-stratified models where there was evidence of significant effect modification by household income. For all data analyses conducted, a two-sided alpha was set at <0.05. Propensity weights were applied to match key sociodemographic variables in the ABCD Study to the American Community Survey from the US Census [19].

Table 1
Sociodemographic and hypertension characteristics of Adolescent Brain Cognitive Development (ABCD) Study participants (N = 4,466)

Sociodemographic characteristics	Mean (SD)/%
Age (years)	11.98 (0.67)
Sex (%)	
Female	49.3%
Male	50.7%
Race/ethnicity (%)	
White	53.3%
Latino/Hispanic	17.4%
Black	17.8%
Asian	5.8%
Native American	4.0%
Other	1.7%
Sexual minority status (%)	
No	86.1%
Yes	5.0%
Maybe	4.4%
Don't understand the question	2.8%
Decline to answer	1.7%
Household income (%)	
$24,999 or less	16.8%
$25,000 to $49,999	20.8%
$50,000 to $74,999	17.8%
$75,000 to $99,999	13.7%
$100,000 to $199,999	23.4%
$200,000 and greater	7.4%
Parent's highest education	
College education or more	81.3%
High school education or less	18.7%
Blood pressure categories	
Normal	95.9%
Hypertensive-range blood pressures	4.1%
Systolic blood pressure percentile	42.29 (29.29)
Diastolic blood pressure percentile	44.48 (24.54)

ABCD propensity weights were applied based on the American Community Survey from the US Census. SD = standard deviation.

Results

Table 1 describes the sociodemographic characteristics of 4,466 participants included in this study (49.3% female, 46.7% non-White). In our analytic sample, 4.1% of the participants had hypertensive-range blood pressures, with an average systolic blood pressure percentile of 42.29 and an average diastolic blood pressure percentile of 44.48.

Table 2 shows the logistic and linear regression models examining the sociodemographic associations with hypertensive-range blood pressures and systolic and diastolic blood pressure percentile among early adolescents. Male sex was associated with hypertensive-range blood pressures (odds ratio [OR] 1.48; 95% confidence interval [CI], 1.02; 2.14) and higher systolic blood pressure percentile compared to female sex. Black race was associated with hypertensive-range blood pressures (OR 1.85; 95% CI, 1.11; 3.08) and higher systolic and diastolic percentile compared to White race. Asian race was associated with a higher diastolic blood pressure percentile compared to White race, while other race/ethnicity was associated with lower diastolic blood pressure percentile. Several annual household income categories (e.g., $24,999 or less, $50,000 to $74,999, and $75,000 to $99,999) were associated with higher odds of hypertensive-range blood pressures compared to an annual household income greater than $200,000. Parental education of high school or lower was associated with higher systolic and diastolic blood pressure percentile compared to participants with a parental education of college or higher. Sensitivity analyses with systolic and diastolic blood pressures ≥ 90th percentile (Appendix E) and ≥ 95th percentile (Appendix F) had mostly similar findings. Sexual minority adolescents had significantly higher odds of diastolic blood pressure ≥ 90th percentile compared to their heterosexual peers (Appendix E); findings were similar with continuous diastolic blood pressure percentile (Table 2) and diastolic blood pressure ≥ 95th percentile (Appendix F) but not statistically significant.

Our exploratory analyses aimed to identify potential effect modifications between sociodemographic characteristics and the binary household income variable. Among the variables tested, only race/ethnicity exhibited significant effect modification (p value for race*household income interaction = .037), whereas there was no evidence of effect modification by income for sex and sexual orientation (e.g., p value for sex*household income and sexual orientation*household income > .05). In logistic regression analyses examining racial/ethnic associations with hypertensive-range blood pressures stratified by income greater than $75,000 or less than $75,000, some notable differences by race/ethnicity and household income levels were observed (Table 3). Black participants in households with an income greater than $75,000 had higher odds of hypertensive-range blood pressures compared to their White counterparts (OR 3.92, 95% CI, 1.95; 7.88). There was not a significant association between race/ethnicity and hypertensive-range blood pressures for the other racial/ethnic minority adolescents in households with an income greater than $75,000 or less than $75,000.

Table 2
Sociodemographic associations with blood pressure in the Adolescent Brain Cognitive Development (ABCD) Study (N = 4,466)

Sociodemographic characteristics	Hypertensive-range blood pressures[a]		Systolic blood pressure percentile[b]		Diastolic blood pressure percentile[b]	
	OR (95% CI)	*p*	B (95% CI)	*p*	B (95% CI)	*p*
Age (years)	1.07 (0.84, 1.36)	.601	−0.69 (−2.21, 0.83)	.372	0.63 (−0.63, −0.63)	.327
Sex						
Female	Reference					
Male	**1.48 (1.02, 2.14)**	**.038**	**2.73 (0.71, 4.74)**	**.008**	−1.34 (−3.03, 0.35)	.119
Race/ethnicity						
White	Reference					
Latino/Hispanic	0.88 (0.44, 1.75)	.716	2.15 (−1.30, 5.60)	.222	0.18 (−2.88, 3.24)	.907
Black	**1.85 (1.11, 3.08)**	**.018**	**4.71 (1.52, 7.90)**	**.004**	**3.27 (0.55, 5.99)**	**.018**
Asian	0.46 (0.20, 1.06)	.069	0.75 (−4.39, 5.89)	.774	**4.37 (0.33, 8.40)**	**.034**
Native American	1.20 (0.53, 2.71)	.654	4.65 (−1.39, 10.70)	.131	3.42 (−1.51, 8.36)	.174
Other	Empty		0.09 (−9.71, 9.90)	.985	**−9.62 (-16.35, -2.90)**	**.005**
Sexual minority status						
No	Reference		Reference		Reference	
Yes	1.39 (0.63, 3.06)	.415	4.00 (−0.86, 8.85)	.107	3.73 (−0.32, 7.77)	.071
Maybe	0.60 (0.21, 1.71)	.344	0.82 (−4.00, 5.64)	.738	0.27 (−3.85, 4.38)	.899
Don't understand the question	0.46 (0.12, 1.72)	.248	**−7.11 (−12.01, −2.21)**	**.004**	−3.64 (−7.86, 0.59)	.091
Decline to answer	0.77 (0.13, 4.61)	.779	−3.74 (−12.28, 4.80)	.391	−2.62 (−9.88, 4.64)	.480
Household income						
$24,999 or less	**3.18 (1.38, 7.36)**	**.007**	**6.75 (2.14, 11.36)**	**.004**	**5.92 (2.00, 9.85)**	**.003**
$25,000 to $49,999	2.07 (0.87, 4.93)	.101	3.25 (−0.91, 7.41)	.125	3.43 (−0.04, 6.91)	.053
$50,000 to $74,999	**2.84 (1.28, 6.33)**	**.010**	3.15 (−0.88, 7.18)	.125	**4.05 (0.64, 7.46)**	**.020**
$75,000 to $99,999	**3.15 (1.47, 6.73)**	**.003**	3.46 (−0.42, 7.35)	.081	**3.53 (0.28, 6.79)**	**.033**
$100,000 to $199,999	1.61 (0.77, 3.36)	.203	1.41 (−1.95, 4.78)	.411	1.46 (−1.34, 4.27)	.306
$200,000 and greater	Reference		Reference		Reference	
Parent's highest education						
College education or more	Reference		Reference		Reference	
High school education or less	0.85 (0.53, 1.37)	.506	**3.64 (0.57, 6.72)**	**.020**	**2.79 (0.13, 5.44)**	**.040**

Bold indicates $p < .05$. OR = odds ratio from logistic regression model. B = coefficient from linear regression model. CI = confidence interval. Models represent the abbreviated output from the logistic and linear regression models including adjustment for age, sex, race/ethnicity, sexual orientation, household income, parent education, and study site. Propensity weights from the Adolescent Brain Cognitive Development Study were applied based on the American Community Survey from the US Census.

[a] Hypertensive-range blood pressures are based on the 2017 American Academy of Pediatrics updated definitions for pediatric blood pressure categories as described in Appendix D.

[b] Based on age- and sex-specific blood pressure percentiles for all ages.

Discussion

In this demographically diverse group of early adolescents across the United States, several sociodemographic factors were associated with high blood pressure, including male sex, Black race identity, and lower household income. An interaction effect, however, indicated that Black race was associated with higher odds of hypertensive-range blood pressure readings compared to White race only in those with higher income households, in line with MDR theory. Sexual minority status was unrelated to the risk of hypertensive-range blood pressure, although it was associated with higher diastolic blood pressure percentile. Taken together, these findings from a large, diverse, early adolescent sample highlight the prevalence of high blood pressure risk in specific sociodemographic groups, which could set the stage for lifetime risk of adverse cardiovascular health.

In a previous study utilizing the National Health and Nutrition Examination Survey (NHANES), male adolescents (13–17 years) had a higher prevalence of hypertension (11.3%) compared to female adolescents (5.7%), but there were no sex disparities in hypertension in children and early adolescents ages 8–12 years [2]. We found that male early adolescents had 1.5 times higher odds of hypertensive-range blood pressures compared to female early adolescents. Male sex is associated with a higher risk of hypertension across the lifespan [20]. Many factors could contribute to this risk, starting in childhood, including sex steroids, body composition, and heart rate regulation, in addition to a potential role of behaviors such as diet quality, physical activity, and sedentary behavior, including screen use [21].

We found that Black early adolescents had 1.85 times higher odds of hypertensive-range blood pressures compared to White early adolescents. A previous study using the NHANES had shown that Black adolescents (6.8%) between the ages 13 to 17 had a 2.9 times higher prevalence of hypertension compared to White adolescents (2.3%), but there was no difference in hypertension prevalence among those ages 8–12 years old [2]. Structural, environmental, behavioral, social, and economic factors, including systemic inequities and racism, may explain race differences [9,22]. A systematic review investigating pathways to cardiometabolic risk inequities found that racial discrimination is associated with higher cardiometabolic risk, including hypertension, by triggering a physiologic stress response [23]. Additionally, in line with MDR theory, Black adolescents in the high household income group had 3.9 times higher odds of hypertensive-range blood pressures compared with White adolescents. Racial and ethnic minorities in higher-income groups experience more health disparities compared to minorities in lower-income groups [11]. The protective effects of higher household income may be diminished by social factors and associated stressors such as structural racism. In addition, previous studies have shown that there is a higher odds of perceived racism in Black adolescents from higher-income families

Table 3
Odds of hypertensive-range blood pressures stratified by annual household income among different racial and ethnic groups in the Adolescent Brain Cognitive Development (ABCD) Study (N = 4,466)

	Hypertensive-range blood pressures	
	OR (95% CI)	*p*
Household income less than $75,000		
Race/ethnicity		
White	Reference	
Latino/Hispanic	0.92 (0.36, 2.37)	.862
Black	1.53 (0.80, 2.92)	.195
Asian	0.55 (0.15, 1.98)	.361
Native American	1.63 (0.64, 4.11)	.303
Other	Empty	
Household income greater than $75,000		
Race/ethnicity		
White	Reference	
Latino/Hispanic	0.77 (0.31, 1.91)	.569
Black	**3.92 (1.95, 7.88)**	**<.001**
Asian	0.37 (0.12, 1.13)	.081
Native American	Empty	
Other	Empty	

Bold indicates $p < .05$. OR = odds ratio from logistic regression model. CI = confidence interval. Models represent the abbreviated output from logistic regression models including adjustment for age, sex, race/ethnicity, sexual orientation, parent education, and study site. ABCD propensity weights were applied based on the American Community Survey from the US Census.

compared to those from lower-income families [24,25]. Additionally, adverse childhood experiences have been shown to have a significant impact on blood pressure and other cardiovascular disease risk factors, which may help explain the finding that high income did not protect Black adolescents from having high blood pressure [26].

In general, we found that lower-income categories were associated with higher odds of hypertensive-range blood pressures. These associations could be explained by potential mediators such as diet, physical activity, or nicotine exposure [27,28]. Adolescents from lower income backgrounds may experience food insecurity, less ability to afford nutritious foods, and fewer opportunities for physical activity, which could lead to higher body mass index and hypertension [27,28]. Adolescents with lower incomes can have a higher risk of tobacco initiation [29], which could also lead to greater hypertension risk. Lower parent education was associated with higher systolic and diastolic blood pressure percentile, similar to prior findings in adults [30].

To our knowledge, our findings are the first to investigate the association between sexual minority status and blood pressure in early adolescents. We found that sexual minority adolescents had higher odds of elevated diastolic blood pressure (≥90th percentile). These findings are in line with those in older adolescents or young adults, which found that sexual minority men had higher levels of diastolic pressure compared to their heterosexual counterparts [20,31]. Although many studies utilize systolic blood pressure as a strong predictor of hypertension, a previous national cohort study demonstrated that diastolic blood pressure is a stronger predictor of cardiovascular risk in adolescents [32]. Diastolic blood pressure disparities in sexual minority adolescents can potentially be explained by differences in physical activity or sexual minority stressors [33]. Sexual minority stressors, including discrimination and internalized heterosexism, are indirectly associated with a higher risk of hypertension in other studies [34].

Some limitations of this study should be noted. Data collection of blood pressure at year two follow-up was only possible in 4,468 participants due to limitations caused by the COVID-19 pandemic (Appendix A), which could lead to selection bias as those excluded were more likely to have lower household income and parents with lower educational attainment. Blood pressure was measured in multiple measurements on a single day, while a diagnosis of hypertension would require multiple measurements at multiple visits [17]. Furthermore, this is a cross-sectional study, so we cannot assume causality with our reported associations. Another limitation is the potential for unmeasured confounders, such as a family history of hypertension. Reporting bias is possible, especially with regard to the sexual orientation of early adolescents. Future research could investigate how neighborhood factors such as area deprivation index may be associated with early adolescent blood pressure. The strengths of this study include the sociodemographic racially/ethnically diverse and large population-based sample, even with disruptions to data collection caused by the COVID-19 pandemic. Additionally, this is the first study to our knowledge to explore sexual minority status as a risk factor for higher blood pressure in early adolescents.

Our findings explore sociodemographic differences in blood pressure among a diverse population of early adolescents that can inform clinical and public health implications to prevent hypertension. These findings may highlight vulnerable populations to target for the Life's Essential 8 campaign by the American Heart Association, which recommends eight health behaviors and factors, including managing blood pressure, to improve and maintain cardiovascular health [35]. Cardiovascular health promotion campaigns should be carefully messaged to target a diverse population of early adolescents, particularly adolescents who are male, Black, from a lower household income, and both Black and from a higher household income. School- and community-based programs can raise awareness in early adolescents and their caregivers about the importance of healthy lifestyles to promote cardiovascular health [36]. The use of digital and social media may be effective in promoting physical health in these targeted populations. Unfortunately, hypertension in early adolescents is greatly under-recognized due to difficulties in measurement, the need for multiple measurements over multiple visits, and the need to refer to detailed normative value tables, which can be a time-consuming process [6]. Therefore, there must be increased efforts to routinely assess blood pressure in early adolescents through annual physical exams and counsel caregivers when elevated blood pressure measurements are detected. These interventions are crucial for reducing the cardiovascular and renal burden associated with hypertension in adulthood [6].

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Supplementary Data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jadohealth.2023.12.015.

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