RACE/ETHNIC AND SEX DIFFERENTIALS IN PULSE PRESSURE AMONG US ADULTS

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The prevalence of high blood pressure in the United States is a public health concern. This study uses the Third National Health and Nutrition Examination Survey (1988–1994) and linear regression to document variations in pulse pressure by race/ethnicity and sex in the United States. We find higher pulse pressures among racial and ethnic minorities than among non-Hispanic Whites and among males than females. The results indicate that the effect of race on pulse pressure decreases with the inclusion of various controls; nevertheless, African Americans maintain higher pulse pressures than non-Hispanic White Americans, even net of controls. Compared to females, males exhibit higher pulse pressures. Moreover, this sex gap progressively increases with controls for socioeconomic status and physical activity. Given the known health consequences associated with high pulse pressure, these results highlight the importance of better understanding and addressing the risk of high pulse pressure among demographic subpopulations in the United States. (*Ethn Dis*. 2005;15:601–606)

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INTRODUCTION

The prevalence of high blood pressure and the associated health disparities among US adults is a pressing public health concern. Various demographic subpopulations, including non-Hispanic Blacks and males experience higher levels of risk for elevated blood pressure and subsequent poor health. To better document at-risk subpopulations, this article reveals the relationship between race/ethnicity, sex, and pulse pressure (PP) among US adults.

Pulse pressure (PP), the difference between the systolic (SBP) and diastolic blood pressure (DBP), possesses a number of physiological and methodological characteristics that contribute to its increased use as an indicator of risk for increased morbidity and mortality.[1–4] Importantly, high PP increases the risk of circulatory disease and mortality primarily because it is a marker for atherosclerosis.[1] PP is a parsimonious continuous measure that incorporates important information from both systolic blood pressure (SBP) and diastolic blood pressure (DBP) and independently affects health outcomes.[1,3,5]

Pulse pressure (PP) varies by race/ethnicity. But few studies have found clear relationships between PP and race in the examination of cardiovascular disease (CVD) deaths.[6] Thus, it is important to document differences in PP by race/ethnicity.

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In examining PP, assessing body mass is important because increases in body mass increase the prevalence of elevated blood pressures among a variety of populations.[7–10] Obesity is positively associated with future risk of high blood pressure,[11–13] and increasing body mass is shown to specifically increase PP.[14,15] Moreover, substantial race/ethnic differences in body mass index (BMI) exist. For instance, compared to non-Hispanic Whites, Mexican Americans and non-Hispanic Blacks, especially non-Hispanic Black women, have higher levels of obesity.[16]

Behavioral and health factors influence conduit vessel stiffness. For example, research has shown that engaging in exercise increases vascular compliance.[17] Additionally, healthy eating, specifically focusing on a low sodium diet, has positive effects on conduit vessel stiffness.[18] Blood pressure levels also reflect cumulative socioeconomic factors that operate over the course of a person's life. Therefore, socioeconomic factors and health behaviors must be incorporated to adequately explain PP prevalence in subpopulations.

AIMS

Although extensive studies have reported PP for various subpopulations, including women and the elderly, few studies document PP variations in racial/ethnic subpopulations. We examine racial/ethnic and sex variations in PP, adjusting for sociodemographic characteristics, socioeconomic variables, and behavioral factors.

METHODS

We employed the Third National Health and Nutrition Examination

Survey (NHANES III) to examine racial/ethnic, sex, and body mass differences in PP. NHANES III, conducted by the National Center for Health Statistics (NCHS), is a nationally representative survey of 33,199 noninstitutionalized adults aged 17–90. Data were collected from 1988 through 1994 and the survey is the seventh in a series of surveys based on a multistate sample plan.[19] This dataset is especially suitable for addressing our research questions because it was designed to collect information about the health and nutritional status of the United States population and includes detailed information from physical examinations.

Pulse pressure (PP) was measured as the difference between SBP and DBP. The SBP and DBP measures were derived as an average of a potential six separate measurements: the interviewer took the initial three blood pressure measurements; the examining physician took the remaining three measurements during a full medical examination administered in a mobile examination center. The SBP and DBP measurements were obtained from the arm of the seated subject after five minutes of quiet rest with a mercury-column sphygmomanometer with cuff-size adjustment for arm diameter.[20] The use of multiple measurements in different settings by health professionals ensures accurate and precise measures, reduces digit preferences, reduces the variability of blood pressure, and reduces elevated blood pressure associated with the presence of a medical professional. Pulse pressure (PP) – measured as a continuous linear variable – was normally distributed within the sample, with a range of 15 to 175 and a median of 45.

Race/ethnicity included non-Hispanic Whites, non-Hispanic Blacks, and Mexican Americans, with non-Hispanic Whites serving as the reference category (this category is henceforth specified as "referent"). Sex was coded as male or female (referent). Age was categorized into three groups: 17–44 years of age (referent), 45–64 years of age, and 65–90 years of age. Marital status included individuals who were currently married (referent), who had been previously married, and who had never married. We controlled for region with Midwest (referent), Northeast, South, and Western regions of the country.

Family income was measured with four categories: <\$20,000 a year (referent), \$20,000–\$29,999, \$30,000–\$39,999, and ≥\$40,000. Education was coded as more than a high school education (referent), high school degree, and less than a high school education. Employment status included employed (referent), unemployed, and not currently in the labor force. Walking as a physical activity, included in the models as a behavioral control, was coded as either walking at least one mile per month, or walking less than one mile per month (referent).

Body mass index (BMI) was calculated according to the World Health Organization (WHO) guidelines as weight in kilograms/height in meters squared.[21] Height and weight were collected through physical examinations administered through NHANES III. The WHO categorizes BMI as normal ($18.5 \leq \text{BMI} < 25.0$), overweight ($25.0 \leq \text{BMI} < 30.0$), and obese class I ($30.0 \leq \text{BMI} < 35.0$).[21] We combined obese classes II ($35.0 \leq \text{BMI} < 40.0$) and III ($\text{BMI} \geq 40.0$) because of small numbers of cases in the latter category. Because being underweight can adversely affect PP and CVD in a different manner than increasing weight, we excluded underweight individuals ($\text{BMI} < 18.5$) from the analysis.

Ancillary analyses (results not shown) controlled for a number of physical activity behaviors, which did not substantially affect the results presented. The presence of individuals currently taking hypertension medication, and various hypertension practices (ie, dieting) were limited by a small number of cases and did not show any improvements or changes to the models. Similarly, religious affiliation and smoking behaviors did not add any new information to the models and were therefore excluded for parsimony. Given our focus on demographic subpopulations, we include respondents regardless of preexisting conditions with the recognition that the exclusion of various groups differentially affects subpopulations and could potentially confound the results with PP.

We examined racial/ethnic and sex variations in PP with ordinary least squares analyses with the SAS 8.2 statistical package[22] and used progressive model adjustment to control for covariates associated with elevated blood pressure. Results are given as unstandardized regression coefficients; a positive coefficient indicates a positive effect on the dependent variable, and a negative coefficient indicates an inverse relationship.[23] We began with 20,050 records that contained both laboratory values and interview information and then excluded 461 individuals who had missing values on either SBP or DBP, 2,286 underweight individuals, and 771 individuals who were not classified as non-Hispanic White, non-Hispanic Black, or Mexican-American, which resulted in a final sample of 16,532 individuals. Auxiliary analyses demonstrated that these exclusions did not significantly affect the results. Our analyses incorporated sample weights to accurately represent the US non-institutionalized population and to produce accurate estimates of the coefficients and standard errors.

RESULTS

Table 1, which presents descriptive statistics, shows that Mexican Americans had lower PPs than non-Hispanic Whites, who in turn had lower PPs than non-Hispanic Blacks. Compared to females, males had a higher mean PP; and compared to the youngest age category, the two oldest age categories showed higher pulse pressures. The remaining control variables showed the expected relationships with income, education, and employment status inversely related to PP. Behavioral controls showed that, compared to more inactive individuals, those who regularly walk more than a mile in a month have lower PP. The BMI categories indicated a gradual increase in pulse pressure with increasing body mass. Although these descriptive results are informative and can be used to show the different means of various groups, they do not simultaneously adjust for demographic composition or other risk factors. Therefore, Table 2 employs a multivariate model to elucidate PP relationships with demographic subpopulations.

Table 1. Frequencies and mean pulse pressure for variables, US Adults 1988–1994

	%	Mean PP
Sociodemographic factors		
Race/Ethnicity		
Non-Hispanic White	81.35	47.94
Non-Hispanic Black	12.64	48.30
Mexican-American	6.01	46.79
Sex		
Female	51.56	47.42
Male	48.44	47.93
Age		
17–44	59.96	42.19
45–64	25.14	67.72
65+	14.9	67.07
Marital status		
Currently married	64.35	47.03
Previously married	16.39	53.69
Never married	19.26	44.80
Region		
Midwest	19.37	48.76
Northeast	25.67	47.25
South	35.13	47.37
West	19.83	47.61
Socioeconomic controls		
Family income		
<$20,000	35.89	50.31
$20,000–29,999	15.62	48.21
$30,000–39,999	13.62	45.91
$40,000+	34.87	45.16
Education		
More than high school	40.21	45.03
High school degree	34.73	47.54
Less than high school	25.06	51.82
Employment status		
Employed	37.95	44.53
Unemployed	32.82	53.91
Not in labor force	29.23	55.15
Behavioral controls		
Walks		
Less than 1 mile per month	48.54	48.99
At least 1 mile per month	51.46	46.41
Health status		
BMI		
Normal	44.74	46.17
Over	32.79	48.48
Class I	14.43	49.99
Class II+III	8.04	50.17

Source: Third National Health and Nutrition Examination Survey, 1988–1994 (NHANES III).

Table 2 presents the unstandardized ordinary least squares coefficients for sex and racial/ethnic differences on PP while including sociodemographic, socioeconomic, and behavioral controls. Model 1 examined the effect of race/ethnicity, sex, and age on PP. Compared to non-Hispanic Whites, non-Hispanic Blacks had a 2.3-point and Mexican Americans had a 2.1-point greater PP,* controlling for age and sex. Specifically, this shows that the average PP is 41.6 for non-Hispanic Whites, 43.9 for non-Hispanic Blacks (or 41.64+2.28), and 43.7 for Mexican Americans (or 41.64+2.08), controlling for age and sex. Compared to females, males had a 0.68-point greater PP, controlling for age and race/ethnicity. Age also exerted a significant and strong direct effect on PP.

Model 2 additionally controls for marital status and region. The race/ethnicity coefficients remained relatively stable, with a slight decrease for African Americans and a slight increase for Mexican Americans. The addition of the new controls had a suppressor effect on males: compared to females, male PP increased from 0.68 to 0.78. Model 3 included a control for family income. The effect for males again increased. The control for family income also decreased the importance of race/ethnicity, particularly for Mexican Americans. Controlling for education (Model 4) did not have a strong effect on sex, but decreased the race/ethnic effect for Mexican Americans, and slightly decreased the race/ethnic effect for non-Hispanic Blacks. Controlling for labor force involvement and physical activity (Model 5) increased male PP, and attenuated PP for non-Hispanic Blacks and Mexican Americans.

The effects of body mass categories, presented in Model 6, showed an increase in PP for males. The inclusion of BMI in this model further attenuated the effects of race/ethnicity on PP, showing that part of the difference between non-Hispanic Whites and non-Hispanic Blacks and Mexican Americans was attributed to unequal distribution in body mass categories. Indeed, PP differences between non-Hispanic Whites and Mexican Americans drops from statistical significance. Increasing weight increases PP: compared to normal-weight individuals, individuals who are in the heaviest weight class (BMI≥35.0) can expect a 3.0-point higher PP.

The final model, which included the interaction between sex and BMI, further decreased PP differences between non-Hispanic Whites and both non-Hispanic Blacks and Mexican Americans. This model also indicated that increases in body mass differentially affect the sexes. The increase for males was more gradual than for females. Compared to females, males started with a higher PP, but increasing body mass had a smaller effect. For example, an average normal-weight, middle-aged male would maintain a PP of 50.1, whereas an average normal-weight, mid-

* Compared to non-Hispanic Whites, Mexican Americans had the lowest PP in Table 1, but significantly higher PP in Table 2. This discrepancy is due to differential age compositions: compared to non-Hispanic Whites, Mexican Americans are younger. A separate model examining Mexican Americans without controlling for age revealed that Mexican Americans had lower PP than non-Hispanic Whites. Such differences highlight the need to examine PP within a multivariate framework.

Table 2. Unstandardized OLS Regression Coefficients of Covariates and Pulse Pressure, U.S. Adults 1988–1994

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Sociodemographic Factors							
Race/Ethnicity [N.H. White]							
N.H. Black	2.28†	1.71†	1.37†	1.21†	1.14†	0.95†	0.89†
Mexican American	2.08†	2.23†	1.63†	0.84*	0.79*	0.71	0.69
Sex [female]	0.68†	0.78†	0.81†	0.80†	0.99†	1.09†	1.96†
Age [19–44]							
45–65	7.52†	7.96†	7.97†	7.76†	7.59†	7.39†	7.36†
65+	24.91†	25.07†	24.69†	24.26†	23.50†	23.52†	23.53†
Marital Status [currently married]							
Previously married		1.69†	1.19†	1.27†	1.32†	1.37†	1.34†
Never married		2.46†	2.14†	2.17†	2.22†	2.40†	2.35†
Region [Midwest]							
Northeast		−1.64†	−1.63†	−1.68†	−1.73†	−1.74†	−1.77†
South		−0.77†	−0.86†	−1.01†	−1.07†	−1.05†	−1.08†
West		−1.15†	−0.99†	−0.83†	−0.89†	−0.88†	−0.91†
Socioeconomic Controls							
Family Income [<$20,000]							
$20,000–29,999			−0.60*	−0.36	−0.28	−0.20	−0.17
$30,000–39,999			−1.01†	−0.63*	−0.52	−0.54	−0.50
$40,000+			−1.80†	−1.00†	−0.86†	−0.77†	−0.73†
Education [More than high school]							
High school degree				1.43†	1.33†	1.23†	1.22†
Less than high school				2.69†	2.41†	2.33†	2.31†
Employment status [employed]							
Unemployed					0.12	0.07	0.05
Not in labor force					0.97	0.95	0.94
Physical Activity							
Walks [less than 1 mile per month]							
More than 1 mile per month					−0.73†	−0.66†	−0.64†
Body Mass							
BMI [Normal]							
Over						0.28	1.24†
Class I						1.57†	2.09†
Class II+III						2.97†	3.56†
Interactions							
Male*overweight							−1.86†
Male*class I							−1.13*
Male* class II+III							−1.47*
Constant	41.64	41.70	42.81	41.48	41.66	41.09	40.74
R-Square	0.35	0.36	0.36	0.37	0.37	0.37	0.37

* $P \leq .05$, † $P \leq .01$.
Note: The referent for each variable is listed in brackets
Source: Third National Health and Nutrition Examination Survey, 1988–1994 (NHANES III).

dle-aged female would maintain a PP of 48.1. At the extreme weight category, an average obese class II or III, middle-aged male would have a PP of 52.2 whereas a female in the same weight class would have a PP of 51.7. This finding demonstrates that while the PP of males and females both rise with increasing body mass, compared to males, female PP is proportionately greater at higher body mass levels. Although the sex gap in PP attenuates with increasing body mass, a significant difference remained at all times, with males maintaining higher PP than females at all weight categories (individual *t* tests show that significant differences remain in each category, $P \leq .001$).

DISCUSSION

This study employs a large nationally representative sample based on medical examinations to document how PP varies by race/ethnicity and sex, net of other risk factors. The examination of racial/ethnic characteristics suggests that whereas socioeconomic, demographic, and health controls explain some of the variation among non-Hispanic Blacks, Mexican Americans, and non-Hispanic Whites, non-Hispanic Blacks maintain higher PP levels. For example, non-Hispanic Black males will have a PP of 43.6

compared to 42.7 for comparable non-Hispanic Whites, net of other factors (see Model 7).

Pulse pressure (PP) differences by racial/ethnic groups are due in part to socioeconomic disadvantage. The effects of these socioeconomic variables on PP indicate that social advancement through income and education will benefit the health of both non-Hispanic Blacks and Mexican Americans. Thus, PP differences should close as racial/ethnic groups converge in their socioeconomic status and health behaviors, as demonstrated by the 33% reduction in PP for non-Hispanic Blacks after controlling for socioeconomic status and physical activity (compare Models 2 and 5). Nevertheless, current racial/ethnic disparities persist, albeit attenuated, even with controls for socioeconomic, demographic, and behavioral factors.

Racial/ethnic differences in PP suggest that social policies may be most effective if they incorporate messages and interventions that appeal to various subpopulations. While the diminishing significance of race with the inclusion of control variables suggests the potential for increased health among racial minorities, underserved racial groups need to be readily informed about the risks of and viable ways to prevent or reduce high PP.

Compared to females, males are more likely to have higher PP levels, even after controlling for important covariates. For example, a young White male will have a PP of 42.7 compared to the PP of 40.7 for a comparable female (see Model 7). Males are more likely than females to be socioeconomically advantaged, enjoying higher levels of education, income, and employment, which in turn masks their higher PP. Thus, if the sex gap in socioeconomic status closes further, we may witness greater overall sex disparity in PP.

Increasing BMI leads to greater increases in PP for females than it does for males. Although males maintain higher levels of PP given the various controls, females are more strongly affected by increasing BMI. This research suggests that women need to become informed of their increasing risks with increases in BMI. Although we did not find a significant interaction between BMI and race, given the relationship between BMI and PP, all racial/ethnic groups need to be aware of the detrimental effects of obesity.

Our research suggests that therapies that improve arterial compliance and that encourage weight loss among those who are overweight may help in the treatment of patients with elevated PP, especially for women and non-Hispanic Blacks. Given that the treatment of elevated blood pressure over a long period of time is expensive,[24] and compliance is often overstated,[25] risk assessment and preventative measures become more crucial. Individuals must recognize that a healthy diet and regular physical activity can reduce the risks of obesity and high PP. Indeed, clinical research demonstrates that short-term weight loss reduces blood pressure in persons with high-normal blood pressure.[26–28] Furthermore, the association of demographic factors with risk of high levels of PP must be understood to determine whether weight loss could be one way to more effectively prevent elevated PP in population subgroups.

Future research could build upon our findings by replicating our results with other datasets, expanding the number of ethnic groups, examining different measures of high blood pressure, disaggregating by specific diseases, and linking to overall and cause-specific mortality. Because comorbidity confounds the effects of PP, future studies could examine racial/ethnic PP among different diseases, particularly circulatory diseases and diabetes.[5] Innovative analyses could gain additional insight by disaggregating PP into groups according to diastolic decline or systolic increase.[4,29] Whereas we focused on Mexican Americans and non-Hispanic Blacks and Whites, using other datasets, including the Hispanic NHANES, could extend these results to other racial/ethnic groups such as Cubans, Puerto Ricans, Asians, and Native Americans.

Thus, PP differences should close as racial/ethnic groups converge in their socioeconomic status and health behaviors, as demonstrated by the 33% reduction in PP for non-Hispanic Blacks . . .

Overall, our results from a nationally representative dataset underscore the importance of better understanding and addressing the risk of high PP among demographic subpopulations in the United States. By reducing risky PP among all racial/ethnic and sex subpopulations, we can contribute to further gains in the quality and length of life within the United States.

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Data analysis and interpretation: Rogers, Saint Onge
Manuscript draft: Rogers, Saint Onge
Statistical expertise: Rogers
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