ORIGINAL RESEARCH

Cumulative Incidence of Hypertension by 55 Years of Age in Blacks and Whites: The CARDIA Study

S. Justin Thomas, PhD; John N. Booth III, PhD; Chen Dai, MS; Xuelin Li, PhD; Norrina Allen, PhD; David Calhoun, MD; April P. Carson, PhD; Samuel Gidding, MD; Cora E. Lewis, MD; James M. Shikany, DrPH; Daichi Shimbo, MD; Stephen Sidney, MD; Paul Muntner, PhD

***Background*—**Blacks have higher blood pressure levels compared with whites beginning in childhood. Few data are available on racial differences in the incidence of hypertension from young adulthood through middle age.

***Methods and Results*—**We calculated the cumulative incidence of hypertension from age 18 to 55 years among participants in the CARDIA (Coronary Artery Risk Development in Young Adults) study. Incident hypertension was defined by the first visit with mean systolic blood pressure ≥130 mm Hg, mean diastolic blood pressure ≥80 mm Hg, or self-reported use of antihypertensive medication. Among 3890 participants without hypertension at baseline (aged 18–30 years), cumulative incidence of hypertension by age 55 years was 75.5%, 75.7%, 54.5%, and 40.0% in black men, black women, white men, and white women, respectively. Among participants with systolic blood pressure/diastolic blood pressure <110 and 70, 110 to 119/70 to 74, and 120 to 129/75 to 79 mm Hg at baseline, blacks were more likely than whites to develop hypertension: multivariable-adjusted hazard ratios 1.97 (95% confidence interval, 1.65, 2.35), 1.80 (95% confidence interval, 1.52, 2.14), and 1.59 (95% confidence interval, 1.31, 1.93), respectively. Parental history of hypertension and higher body mass index, serum uric acid, and systolic blood pressure/diastolic blood pressure categories were associated with a higher risk for hypertension among blacks and whites. A higher Dietary Approaches to Stop Hypertension diet adherence score was associated with a lower risk for hypertension in blacks and whites.

***Conclusions*—**Regardless of blood pressure level in young adulthood, blacks have a substantially higher risk for hypertension compared with whites through 55 years of age. **(*J Am Heart Assoc*. 2018;7:e007988. DOI: 10.1161/JAHA.117.007988.)**

Key Words: hypertension • incidence • race

There is evidence that blacks have higher blood pressure (BP) levels and increased risk for hypertension compared with whites beginning in childhood.[1–3] Cross-sectional studies using data from the National Health and Nutrition Examination Survey (NHANES) have consistently reported a higher prevalence of hypertension in blacks compared with whites beginning at a young age.[4–8] However, few studies have used longitudinal data to quantify the cumulative incidence of hypertension from young adulthood through middle age among blacks and whites. Also, there are few data on racial differences in hypertension according to the definition in the 2017 American College of Cardiology (ACC)/American Heart Association (AHA) BP guideline.[9] Determining the magnitude of racial differences in the cumulative incidence of hypertension in young adulthood through middle age may help determine the need for primordial prevention and interventions aimed at maintaining optimal BP levels across the life span, particularly among blacks. Therefore, the goal of the current study was to determine the cumulative incidence of hypertension in black and white adults aged 18 to 30 years who have been followed until age 55 years. Because there are limited data on the percentage of young adults with normal BP (systolic BP [SBP] <120 mm Hg and diastolic BP [DBP] <80 mm Hg) and elevated BP who develop hypertension, cumulative incidence of hypertension was calculated by baseline levels of SBP and DBP. An additional goal was to identify risk factors associated

From the Department of Epidemiology (C.E.L., J.N.B., A.P.C., P.M.) and Division of Preventive Medicine, School of Medicine (C.D., X.L., J.M.S.), Department of Psychiatry (S.J.T.), Department of Medicine (D.C.), University of Alabama at Birmingham, AL; Department of Preventive Medicine, Northwestern University, Chicago, IL (N.A.); Nemours Cardiac Center, DuPont Hospital for Children, Wilmington, DE (S.G.); Department of Medicine, Columbia University, New York, NY (D.S.); Division of Research, Kaiser Permanente Northern California, Oakland, CA (S.S.).

Accompanying Tables S1 through S6 and Figures S1, S2 are available at http://jaha.ahajournals.org/content/7/14/e007988/DC1/embed/inline-supplementary-material-1.pdf

Correspondence to: S. Justin Thomas, PhD, Department of Psychiatry, University of Alabama at Birmingham, SC 1010, 1720 2nd Ave S, Birmingham, AL 35294-0017. E-mail: sjthomas@uab.edu

Received January 22, 2018; accepted May 23, 2018.

Clinical Perspective

What Is New?

- Using the 2017 American College of Cardiology/American Heart Association blood pressure guideline definition, cumulative incidence of hypertension by age 55 years was 75.5%, 75.7%, 54.5%, and 40.0% in black men, black women, white men, and white women, respectively.
- Blacks had 1.5 to 2 times higher risk for hypertension after multivariable adjustment, regardless of baseline blood pressure level.
- Body mass index and adherence to Dietary Approaches to Stop Hypertension diet were modifiable risk factors associated with hypertension in blacks and whites.

What Are the Clinical Implications?

- Given that racial differences in hypertension emerged before 30 years of age, primordial prevention should be considered for blacks at a young age.
- Among potential risk factors for racial disparities in hypertension, a focus on maintaining optimal body mass index may be particularly effective.

with a higher risk for hypertension that could serve as targets for primordial prevention.

Methods

Data used in this analysis are available to the scientific community through the National Heart, Lung, and Blood Institute's Biological Specimen and Data Repository Information Coordinating Center (BioLINCC), and the analytical methods are described below.

Study Population

Detailed methods for the CARDIA (Coronary Artery Risk Development in Young Adults) study have been published previously.[10] Briefly, in 1985–1986, 5115 black and white men and women aged 18 to 30 years were enrolled in the CARDIA study from 4 field centers in the United States (Birmingham, AL; Chicago, IL; Minneapolis, MN; and Oakland, CA). Enrollment was performed to provide approximately equal numbers of participants by sex, self-reported race (black or white), age (18–24 or 25–30 years), and education (less than or equal to high school or greater than high school) at each site. The baseline clinic visit was completed in 1985–1986 (Exam Year 0). The current analyses included data from clinic visits that were completed at baseline and during 8 follow-up visits that occurred 2, 5, 7, 10, 15, 20, 25, and 30 years following the baseline examination. Participation rates at follow-up visits ranged from 90% (Year 2 follow-up) to 71% (Year 30 follow-up) of the surviving cohort. Institutional review boards at the participating sites approved the human subjects protocol at each examination. All participants provided written informed consent at each study visit.

We restricted the analytical sample to participants with valid clinic BP measurements at the baseline examination and during at least 1 follow-up examination (n=4961). Participants with SBP ≥130 mm Hg, DBP ≥80 mm Hg, self-reported use of antihypertensive medications, or a self-reported previous diagnosis of hypertension (n=911) at baseline were excluded. Participants who were missing baseline covariate data relevant to the analyses (n=159; described below) were also excluded. One additional participant withdrew their consent and was not included. After these exclusions, 3890 participants (795 black males, 1124 black females, 854 white males, and 1117 white females) were included in the current analyses.

Covariates

Age, sex, self-reported race, highest level of education achieved, alcohol use, cigarette smoking (current, former, or never), and parental history of hypertension were collected using an interviewer-administered questionnaire during the baseline examination. All covariates were measured at the baseline study visit (Exam Year 0), except for highest level of education, which was defined as the highest number of years of education reported at any study visit. Alcohol use was categorized as nondrinker, moderate (men/women: >0–14/>0–7 drinks per week), or heavy (men/women: >14/>7 drinks per week). A graded, symptom-limited maximal exercise treadmill test that involved a multistaged protocol with progressive difficulty of walking and running was performed at baseline.[11] Duration, in minutes, of the treadmill tests was used to assess physical fitness, with longer durations indicative of better physical fitness. Height and weight were measured, and body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Adherence to the Dietary Approaches to Stop Hypertension (DASH) diet was calculated using the methods described by Chang et al.[12] Eight dietary components comprise the DASH adherence score. In brief, each dietary component was assigned a score between 0 (poor adherence) and 3 (high adherence). Dietary component scores were summed to create an overall DASH diet adherence score ranging from 0 (poor adherence) to 24 (high adherence). Serum uric acid was measured using the uricase method from an overnight fasting blood sample collected between 7 and 10 AM.[3]

Clinic BP Measurements

At each visit, clinic SBP and DBP were measured following a standardized protocol by trained and certified staff. During the baseline and Year 2, 5, 7, 10, and 15 study visits, BP was measured using a Hawksley random-zero sphygmomanometer (W.A. Baum Co., Copiague, NY). During the Year 20, 25, and 30 study visits, BP was recorded using a standard automated BP measurement monitor (Omron model HEM907XL; Omron Healthcare, Inc, Lake Forest, IL). To ensure comparability between the 2 methods, BP measurements at the Year 20 and 25 study visits were calibrated to random-0 sphygmomanometer values based on simultaneous readings from both devices using a Y connector on a subset (n=906) of CARDIA participants.[13] At all study visits, each participant's arm circumference was measured at the midpoint between the acromion and olecranon of the right arm to determine the appropriate cuff size. Participants were asked to sit quietly in a comfortable posture with feet flat on the floor for at least 5 minutes before having their BP measured. Three readings, each separated by at least 30 seconds, were performed with the participant's right arm positioned at heart level. Each BP measurement was rounded to the nearest even number and recorded. The average of the second and third readings was used to define BP at each visit. Incident hypertension was defined by the first visit at which a participant had mean SBP ≥130 mm Hg, mean DBP ≥80 mm Hg or self-reported use of antihypertensive medication. Incident elevated BP or hypertension was defined by the first visit at which a participant had mean SBP ≥120 mm Hg, mean DBP ≥80 mm Hg, or self-reported use of antihypertensive medication.

Statistical Analyses

Baseline characteristics were calculated for the overall population and for blacks and whites, separately. Statistical significance of differences in participant characteristics across race was determined using *t* tests and chi-square tests, as appropriate. Cumulative incidence of hypertension from age 18 through 55 years was calculated by race/sex groups (ie, black males, black females, white males, and white females) using the practical incidence estimator accounting for the competing risk of death.[14] This method is a modified Kaplan–Meier approach that estimates incidence of disease using age as the time scale. Specifically, we estimated age-specific incidence of hypertension up to 55 years of age. If a participant did not develop hypertension, they were included in analyses through age 55 years, at which time they were censored. We did not calculate cumulative incidence of hypertension beyond age 55 years because there were insufficient data for participants of both race/sex groups beyond this age. Cumulative incidence of hypertension through age 55 years was also calculated by race within categories of baseline SBP (ie, <110, 110–119, and 120–129 mm Hg), DBP (ie, <70, 70–74 and 75–79 mm Hg), and SBP/DBP (ie, SBP/DBP <110/70, 110–119/70–74, and 120–129/75–79 mm Hg). For analysis of SBP/DBP categories, participants with BP in 2 categories (eg, SBP <110 mm Hg and DBP between 70 and 74 mm Hg) were designated into the higher category. Cumulative incidence of elevated BP or hypertension from age 18 through 55 years was calculated by race/sex groups using the practical incidence estimator by race/sex groups, overall, and within categories of baseline SBP, DBP, and SBP/DBP. A log-rank test was used to determine the statistical significance of differences in cumulative incidence of elevated BP or hypertension between groups.

Interval-censored Weibull regression models were used to calculate the hazard ratio for incident hypertension comparing blacks with whites within categories of baseline SBP, DBP, and SBP/DBP. Model 1 included adjustment for age and sex. Model 2 included adjustment for factors included in the FHS (Framingham Heart Study) hypertension risk score: age, sex, BMI, SBP, DBP, cigarette smoking, and parental history of hypertension. Model 3 included adjustment for the variables in model 2 and the highest level of education obtained, physical fitness, serum uric acid level, alcohol consumption, and the DASH diet adherence score. Values of covariables were not updated following baseline because we were interested in analyzing incidence over a long time horizon. Multivariable-adjusted hazard ratios for incident hypertension associated with risk factors at baseline were calculated using interval-censored Weibull regression for blacks and whites, separately, and within categories of SBP/DBP (ie, SBP <110 and DBP <70, 110–119 or 70–74, and 120–129 or 75–79 mm Hg). Continuous variables were modeled so that prevalence ratios represent 1 standard deviation difference in risk factor level (eg, 5 kg/m^2 for BMI). All models that were stratified by SBP/DBP categories included adjustment for SBP and DBP as continuous variables to account for potential residual confounding. The above analyses were repeated to calculate multivariable-adjusted hazard ratios for incident elevated BP or hypertension as the outcome for blacks and whites, separately, and within categories of SBP/DBP. We conducted a sensitivity analysis among participants with valid clinic BP measurements at the baseline examination and during at least 4 follow-up examinations (n=3341). Analyses were conducted using SAS software (version 9.4; SAS Institute, Cary, NC).

Results

At baseline, the mean age of participants was 24.7 years, 42.4% were men, and 49.3% were black. Compared with

whites, blacks were younger, had fewer years of education, were less physically fit, and were less likely to consume moderate-to-heavy amounts of alcohol and adhere to the DASH diet and more likely to smoke cigarettes and have a parental history of hypertension. Blacks also had a higher mean BMI and SBP and lower mean serum uric acid level compared with whites (Table 1).

Over 30 years of follow-up, 2040 participants developed hypertension. Among these participants, 1050 (51.4%) met SBP and/or DBP criteria alone (ie, SBP ≥130 mm Hg or DBP ≥80 mm Hg, but not taking antihypertensive medication), 150 (7.4%) met the antihypertensive medication criterion alone (ie, SBP <130 mm Hg and DBP <80 mm Hg and reported taking antihypertensive medication), and 840 (41.2%) met both SBP and/or DBP and antihypertensive medication criteria (ie, SBP ≥130 mm Hg or DBP ≥80 mm Hg and reported taking antihypertensive medication). Among the 1050 participants identified as developing hypertension based on high BP alone and who attended a subsequent visit (n=739), 713 (96.5%) had SBP ≥130 mm Hg or DBP

Table 1. Characteristics of the Study Participants Overall and by Race

	Overall (n=3890)	Black (n=1919)	White (n=1971)	*P* Value
Age, y	24.7±3.7	24.1±3.8	25.3±3.4	<0.001
Male, n (%)	1649 (42.4)	795 (41.4)	854 (43.3)	0.230
Highest level of education, y	15.3±3.2	14.5±3.5	16.1±2.7	<0.001
Exercise test duration, min	9.7±3.0	8.9±2.9	10.5±2.9	<0.001
Alcohol use, n (%)				<0.001
Nondrinker	1549 (39.8)	927 (48.3)	622 (31.6)	
Moderate	1879 (48.3)	827 (43.1)	1052 (53.4)	
Heavy	462 (11.9)	165 (8.6)	297 (15.1)	
Current cigarette smoking, n (%)	1172 (30.1)	648 (33.8)	524 (26.6)	<0.001
DASH diet*	12.1±4.1	10.7±3.6	13.5±4.1	<0.001
Parental history of hypertension, n (%)	1853 (47.6)	1030 (53.7)	823 (41.8)	<0.001
Body mass index, kg/m^2	24.0±4.5	24.8±5.1	23.3±3.7	<0.001
Serum uric acid, mg/dL	5.1±1.3	5.0±1.3	5.2±1.3	<0.001
Systolic blood pressure, mm Hg	107.8±9.0	108.8±8.9	106.8±9.1	<0.001
Diastolic blood pressure, mm Hg	66.0±7.6	66.0±7.9	66.0±7.3	0.829
Systolic blood pressure, n (%)				<0.001
<110 mm Hg	2267 (58.3)	1040 (54.2)	1227 (62.3)	
110 to 119 mm Hg	1202 (30.9)	636 (33.1)	566 (28.7)	
120 to 129 mm Hg	421 (10.8)	243 (12.7)	178 (9.0)	
Diastolic blood pressure, n (%)				0.171
<70 mm Hg	2574 (66.2)	1250 (65.1)	1324 (67.2)	
70 to 74 mm Hg	785 (20.2)	396 (20.6)	389 (19.7)	
75 to 79 mm Hg	531 (13.7)	273 (14.2)	258 (13.1)	
Systolic/diastolic blood pressure, n (%)				<0.001
<110/70 mm Hg	1814 (46.6)	817 (42.6)	997 (50.6)	
110 to 119/70 to 74 mm Hg	1271 (32.7)	665 (34.7)	606 (30.7)	
120 to 129/75 to 79 mm Hg	805 (20.7)	437 (22.8)	368 (18.7)	
Follow-up duration, y	25.5 (8.3)	24.7 (8.7)	26.3 (7.7)	<0.001
Follow-up visits completed	6.3 (2.1)	6.0 (2.3)	6.7 (2.0)	<0.001

Numbers in the table are mean±SD or numbers and percentages. All variables in the table are from baseline (exam year 0) except for highest level of education, which was defined as the highest level of education reported at any study visit. Nondrinker is defined as 0 drinks per week for men and women. Moderate drinker is defined as 1 to 14 drinks per week for men and 1 to 7 drinks per week for women. Heavy drinker is defined as greater than 14 drinks per week for men and greater than 7 drinks per week for women. *P* value is for the comparison of blacks and whites. DASH indicates Dietary Approaches to Stop Hypertension.

*DASH scores have a range from 0 to 24, with scores of 0 indicating the lowest adherence to the DASH diet.

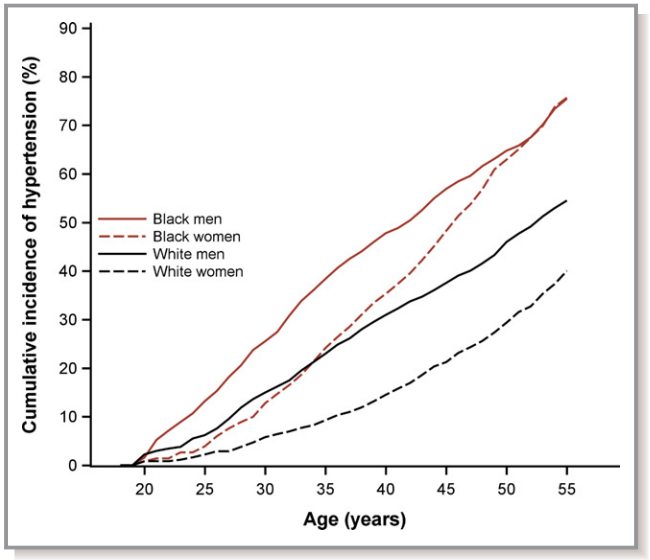


Figure 1. Cumulative incidence of hypertension between ages 18 and 55 years by race and sex using the previous and current definitions of hypertension. Incident hypertension was defined as systolic blood pressure ≥130 mm Hg, diastolic blood pressure ≥80 mm Hg, or reported use of antihypertensive medication. Cumulative incidence of hypertension was calculated adjusting for the competing risk of death. *P* value was <0.001 for race and sex group differences in incident hypertension.

≥80 mm Hg or were taking at least 1 antihypertensive medication at a subsequent visit. By age 55 years, cumulative incidence of hypertension was 75.5% in black men, 75.7% in black women, 54.5% in white men, and 40.0% in white women (Figure 1 and Table S1). Black men and women developed hypertension at younger ages compared with white men and women (Table 2). There was a graded increase in cumulative incidence of hypertension with higher baseline SBP/DBP levels in blacks and whites (Figure 2 and Table S2). The subgroups with the highest cumulative incidence of hypertension between 18 and 55 years of age were blacks with SBP/DBP 120 to 129/75 to 79 mm Hg (cumulative incidence, 88.1%) and SBP/DBP 110 to 119/70 to 74 mm Hg (79.7%) followed by whites with SBP/DBP 120 to 129/75 to 79 mm Hg (71.5%) and blacks with SBP/DBP <110/70 mm Hg (64.0%). The subgroups with the lowest cumulative incidence of hypertension between 18 and 55 years of age were whites with SBP/DBP of 110 to 119/70 to 74 mm Hg (52.6%) and <110/70 mm Hg (32.7%). Cumulative incidence of elevated BP or hypertension by race and sex and by baseline category of BP level is presented in Figures S1 and S2. The number and percentage of individuals who developed hypertension in each baseline BP category are presented in Table S3.

After adjustment for age and sex and within each baseline SBP, DBP, and SBP/DBP category, risk for hypertension was ≈2 times higher for blacks compared with whites (Table 3).

Table 2. Age in Years at Which 10% Through 50% of Participants in Each Race/Sex Group Developed Hypertension

	Age in Years at Which 10% Through 50% of Participants Developed Hypertension					
Percent developing hypertension	10%	15%	20%	30%	40%	50%
Black male (n=795)	27	29	32	35	40	46
Black female (n=1124)	30	33	35	39	44	48
White male (n=854)	31	34	37	44	51	N/A
White female (n=1117)	39	43	46	53	N/A	N/A

Incident hypertension was defined as systolic blood pressure ≥130 mm Hg, diastolic blood pressure ≥80 mm Hg, or reported use of antihypertensive medication. N/A: The specified percentage of participants who developed hypertension was not reached for this race/sex group (eg, 40% of white women did not develop hypertension by age 55 years).

There were statistically significant differences in the black-white hazard ratio for hypertension across SBP and SBP/DBP levels with higher hazard ratios at lower BP levels (*P* values for interaction, <0.05). After full multivariable adjustment, blacks had 1.5 to 2 times the risk for hypertension compared with whites within each baseline BP category. Differences in the black-white hazard ratio for hypertension across baseline SBP, DBP, or SBP/DBP levels were not statistically significant after multivariable adjustment (all *P* values for interaction, >0.2).

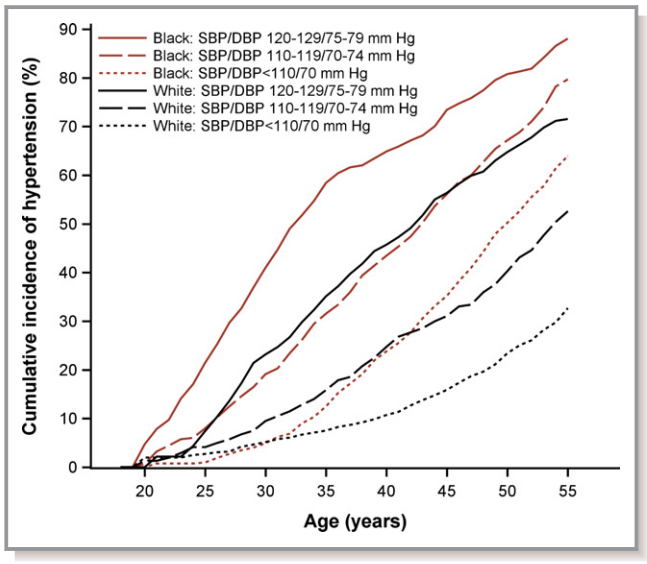


Figure 2. Cumulative incidence of hypertension between ages 18 and 55 years by race and baseline category of blood pressure level. Incident hypertension was defined as SBP ≥130 mm Hg, DBP ≥80 mm Hg, or reported use of antihypertensive medication. Cumulative incidence of hypertension was calculated adjusting for the competing risk of death. *P* value was <0.001 for race and blood pressure category group differences in incident hypertension. DBP indicates diastolic blood pressure; SBP, systolic blood pressure.

Table 3. Hazard Ratios for Incident Hypertension Comparing Black and White Participants Within Blood Pressure Categories

	Black-White Hazard Ratio (95% Confidence Interval)		
	Model 1	Model 2	Model 3
Systolic blood pressure, mm Hg			
<110	2.52 (2.21, 2.87)	2.18 (1.91, 2.49)	1.90 (1.64, 2.19)
110 to 119	2.13 (1.84, 2.47)	1.98 (1.70, 2.29)	1.81 (1.55, 2.12)
120 to 129	1.82 (1.44, 2.30)	1.64 (1.30, 2.08)	1.49 (1.16, 1.91)
P interaction*	0.036	0.110	0.247
Diastolic blood pressure, mm Hg			
<70	2.60 (2.31, 2.94)	2.24 (1.98, 2.53)	1.92 (1.68, 2.19)
70 to 74	2.10 (1.75, 2.53)	1.76 (1.46, 2.12)	1.59 (1.32, 1.93)
75 to 79	2.07 (1.70, 2.54)	1.81 (1.47, 2.21)	1.73 (1.39, 2.16)
P interaction*	0.057	0.048	0.260
Systolic/diastolic blood pressure, mm Hg			
<110/70	2.59 (2.23, 3.02)	2.31 (1.98, 2.69)	1.97 (1.65, 2.35)
110 to 119/70 to 74	2.27 (1.96, 2.64)	2.02 (1.74, 2.36)	1.80 (1.52, 2.14)
120 to 129/75 to 79	1.92 (1.62, 2.26)	1.71 (1.44, 2.02)	1.59 (1.31, 1.93)
P interaction*	0.030	0.033	0.268

Model 1 included adjustment for age and sex. Model 2 included adjustment for age, sex, body mass index, systolic blood pressure, diastolic blood pressure, cigarette smoking, and parental history of hypertension. Model 3 included adjustment for the model 2 variables plus highest level of education obtained, physical fitness, serum uric acid level, alcohol consumption, and Dietary Approaches to Stop Hypertension adherence score. Incident hypertension was defined as systolic blood pressure ≥130 mm Hg, diastolic blood pressure ≥80 mm Hg, or reported use of antihypertensive medication.

**P* interaction is testing whether the hazard ratio for incident hypertension for blacks compared with whites differs across blood pressure category.

After full multivariable adjustment, blacks also had ≈1.5 to 2 times the risk for elevated BP or hypertension compared with whites within each baseline BP category (Table S4).

Parental history of hypertension and higher BMI, serum uric acid, and baseline SBP/DBP categories were each associated with an increased risk for hypertension in blacks and whites (Table 4). A higher DASH diet adherence score was associated with a lower risk for hypertension in blacks and whites. Female sex and higher levels of physical fitness were associated with a lower risk for hypertension in whites, but not blacks. Older age was associated with a higher risk for hypertension in blacks, but not whites. Risk factors associated with incident elevated BP or hypertension in blacks and whites are presented in Table S5.

Black race and higher BMI were associated with a higher risk for hypertension within each SBP/DBP category (Table 5). Adherence to the DASH diet was associated with a lower incidence of hypertension within each SBP/DBP category. Older age and parental history of hypertension were associated with a higher risk for hypertension among participants with SBP/DBP <110/70 mm Hg and 110 to 119/70 to 74 mm Hg. Higher serum uric acid was associated with a higher risk for hypertension among participants with SBP/DBP <110/70 mm Hg and 120 to 129/75 to 79 mm Hg. Higher physical fitness was associated with a lower incidence of hypertension among participants with SBP/DBP <110/70 mm Hg and 110 to 119/70 to 74 mm Hg. The results did not change when restricting the sample to 3341 participants who had valid clinic BP measurements at the baseline examination and during at least 4 follow-up examinations (data not shown). Risk factors associated with incident elevated BP or hypertension within each SBP/DBP category are presented in Table S6.

Discussion

In the current study, the cumulative incidence of hypertension by age 55 years was substantially higher for black men and women compared with white men and women. Using the 2017 ACC/AHA BP guideline definition,[9] 75.5% of black men and 75.7% of black women developed hypertension compared with 54.5% of white men and 40.0% of white women by 55 years of age. Within subgroups of baseline SBP/DBP, cumulative incidence of hypertension was higher among blacks compared with whites. After multivariable adjustment, blacks had 1.5 to 2 times higher risk for hypertension compared with whites, even among participants with SBP/DBP <110/70 mm Hg at baseline. Parental history of hypertension and higher levels of BMI, serum uric acid, and baseline

Table 4. Adjusted Hazard Ratios (95% Confidence Interval) for Incident Hypertension Associated With Risk Factors Measured at Baseline in Blacks and Whites

Risk Factor	Hazard Ratio (95% Confidence Interval)		Interaction *P* Value
	Black	White	
Age, per 5 y	1.27 (1.17, 1.37)	1.09 (0.99, 1.21)	0.024
Sex, female vs male	1.10 (0.91, 1.33)	0.79 (0.64, 0.98)	0.024
Highest level of education, per 1 y	0.98 (0.96, 1.00)	0.97 (0.94, 1.00)	0.713
Physical fitness, per 1 min	0.98 (0.95, 1.01)	0.93 (0.90, 0.96)	0.039
Alcohol use			
Nondrinker	1 (ref)	1 (ref)	0.366
Moderate	0.97 (0.86, 1.11)	1.10 (0.93, 1.30)	
Heavy	1.04 (0.84, 1.29)	1.27 (1.02, 1.57)	
Current cigarette smoking, yes vs no	1.12 (0.98, 1.28)	1.02 (0.86, 1.20)	0.378
DASH diet, per 4 units higher score	0.91 (0.86, 0.98)	0.85 (0.79, 0.92)	0.165
Parental history of hypertension, yes vs no	1.24 (1.10, 1.39)	1.24 (1.07, 1.42)	0.993
Body mass index, per 5 kg/m^2	1.12 (1.06, 1.19)	1.24 (1.13, 1.37)	0.080
Serum uric acid, per 1 mg/dL	1.12 (1.06, 1.19)	1.07 (1.00, 1.15)	0.327
SBP/DBP, mm Hg			
<110/70	1 (ref)	1 (ref)	0.274
110 to 119/70 to 79	1.61 (1.41, 1.85)	1.72 (1.46, 2.04)	
120 to 139/80 to 89	2.39 (2.05, 2.78)	2.90 (2.41, 3.50)	

Nondrinker is defined as 0 drinks per week for men and women. Moderate drinker is defined as 1 to 14 drinks per week for men and 1 to 7 drinks per week for women. Heavy drinker is defined as greater than 14 drinks per week for men and greater than 7 drinks per week for women. Incident hypertension was defined as SBP ≥130 mm Hg, DBP ≥80 mm Hg, or reported use of antihypertensive medication. *P* value is the interaction of race and risk factors. Hazard ratios were calculated from models that included age, sex, highest level of education, physical fitness, alcohol use, current cigarette smoking, DASH adherence score, parental history of hypertension, body mass index, serum uric acid, and SBP and DBP categories. DASH indicates Dietary Approaches to Stop Hypertension; DBP, diastolic blood pressure; SBP, systolic blood pressure.

SBP/DBP were associated with a higher incidence of hypertension in blacks and whites. Higher adherence to the DASH diet was associated with a lower incidence of hypertension in blacks and whites.

The higher incidence of hypertension in blacks compared with whites in the current study is consistent with previous cross-sectional and longitudinal studies.[3–8,15,16] In a previous analysis of the CARDIA study, 10-year incidence of hypertension was 16.4% in black men, 13.1% in black women, 7.8% in white men, and 3.2% in white women.[3] Additionally, in the NHANES I Epidemiologic Follow-up Study, 10-year incidence of hypertension in blacks was more than 2 times higher than that of whites.[16] Among adults free of hypertension at age 45 years in the MESA (Multi-Ethnic Study of Atherosclerosis), a higher cumulative incidence of hypertension in blacks compared with whites was also present through 75 years of age.[15] These studies used the 7th report of the Joint National Committee (JNC7) definition of hypertension (ie, SBP ≥140 mm Hg or DBP ≥90 mm Hg or antihypertensive medication use). The current study extends previous research by reporting the incidence of hypertension following young black and white adults from 18 through 55 years of age using the 2017 ACC/AHA BP guideline definition of hypertension (ie, SBP ≥130 mm Hg or DBP ≥80 mm Hg or antihypertensive medication use). Racial differences in incident hypertension emerged before 30 years of age, a finding that is consistent with the AHA Scientific Statement on Cardiovascular Health in African Americans, and suggests that primordial prevention should be considered for blacks at a young age.[17]

It has been hypothesized that blacks have a higher incidence of hypertension compared with whites attributed to higher BP beginning in childhood.[18] However, studies have consistently reported a stronger progression to hypertension in blacks compared with whites.[19–21] A meta-analysis of 50 cohort studies reported stronger tracking of BP from childhood into adulthood for blacks.[19] A recent cross-sectional study using Markov modeling of NHANES data indicated that transitions from lower to higher BP categories occur at a young age, particularly among blacks.[20] Additionally, a prospective cohort study using electronic health record data reported that progression from prehypertension is accelerated in blacks.[21] Risk for hypertension in the current study

Table 5. Adjusted Hazard Ratios (95% Confidence Interval) for Incident Hypertension Associated With Risk Factors Measured at Baseline in Clinic Blood Pressure Categories

Risk Factors	Hazard Ratio (95% Confidence Interval) Systolic Blood Pressure/Diastolic Blood Pressure, mm Hg <110/70	110 to 119/70 to 74	120 to 129/75 to 79	Interaction *P* Value
Race, black vs white	1.97 (1.65, 2.35)	1.80 (1.52, 2.14)	1.59 (1.31, 1.93)	0.268
Age, per 5 y older	1.24 (1.11, 1.38)	1.16 (1.04, 1.29)	1.11 (0.99, 1.25)	0.396
Sex, female vs male	1.18 (0.92, 1.52)	0.83 (0.65, 1.05)	0.95 (0.72, 1.25)	0.123
Highest level of education, per 1 y	0.97 (0.94, 1.00)	0.99 (0.97, 1.01)	0.96 (0.92, 1.00)	0.387
Physical fitness, per 1 min	0.95 (0.92, 0.98)	0.94 (0.91, 0.97)	0.98 (0.94, 1.02)	0.308
Alcohol use				
Nondrinker	1 (ref)	1 (ref)	1 (ref)	0.272
Moderate	1.01 (0.85, 1.19)	1.05 (0.89, 1.25)	0.92 (0.77, 1.11)	
Heavy	1.16 (0.89, 1.50)	1.38 (1.08, 1.76)	0.89 (0.67, 1.18)	
Current cigarette smoking, yes vs no	1.19 (1.00, 1.41)	1.10 (0.92, 1.30)	1.09 (0.90, 1.34)	0.746
DASH diet, per 4 units higher score	0.89 (0.82, 0.96)	0.86 (0.80, 0.94)	0.90 (0.82, 0.99)	0.797
Parental history of hypertension, yes vs no	1.33 (1.15, 1.55)	1.34 (1.15, 1.55)	1.02 (0.86, 1.21)	0.032
Body mass index, per 5 mg/kg^2	1.17 (1.07, 1.27)	1.14 (1.05, 1.23)	1.14 (1.03, 1.27)	0.924
Serum uric acid, per 1 mg/dL	1.11 (1.03, 1.19)	1.07 (0.99, 1.15)	1.10 (1.02, 1.19)	0.760
Systolic blood pressure, per 5 mm Hg	1.13 (1.05, 1.22)	1.13 (1.04, 1.23)	1.13 (1.05, 1.22)	1.000
Diastolic blood pressure, per 5 mm Hg	1.11 (1.03, 1.19)	1.14 (1.06, 1.22)	1.22 (1.13, 1.33)	0.195

Nondrinker is defined as 0 drinks per week for men and women. Moderate drinker is defined as 1 to 14 drinks per week for men and 1 to 7 drinks per week for women. Heavy drinker is defined as greater than 14 drinks per week for men and greater than 7 drinks per week for women. Incident hypertension was defined as systolic blood pressure ≥130 mm Hg, diastolic blood pressure ≥80 mm Hg, or reported use of antihypertensive medication. *P* value is the interaction of clinic blood pressure and risk factors. Hazard ratios were calculated from models that included race, age, sex, highest level of education, physical fitness, alcohol use, current cigarette smoking, DASH adherence score, parental history of hypertension, body mass index, serum uric acid, and systolic and diastolic blood pressure. DASH indicates Dietary Approaches to Stop Hypertension.

was 1.5 to 2 times higher in blacks than whites after multivariable adjustment, a disparity that was present at all BP levels investigated. The finding that blacks with SBP/DBP <110/70 mm Hg at baseline (ie, when participants were aged 18–30 years) have a higher risk for developing hypertension than their white counterparts suggests that racial disparities in hypertension are not solely attributed to higher BP levels beginning in childhood. Racial differences in factors, including the maintenance of health behaviors, may also play an important role in the higher incidence of hypertension in blacks compared with whites.[21–23]

Higher BMI, cigarette smoking, parental history of hypertension, lower level of education, higher alcohol use, and higher serum uric acid level are well-established risk factors for hypertension.[24–29] Most of these risk factors are more common among blacks compared with whites. Also, higher levels of physical fitness and adherence to DASH diet have been associated with reductions in BP and lower risk for hypertension among blacks and whites.[30,31] In the JHS (Jackson Heart Study), a cohort comprised exclusively of blacks, higher BMI and physical inactivity and a less heart healthy diet were all modifiable health behaviors associated with an increased risk for incident hypertension.[32] In the current study, parental history of hypertension and higher BMI, serum uric acid level, and baseline SBP/DBP were each associated with developing hypertension in blacks and whites. A higher DASH diet adherence score was associated with a lower risk for hypertension in blacks and whites. Also, higher levels of physical fitness were associated with a lower risk for developing hypertension in whites, but not blacks. Given the steep increase in weight occurring among black young adults as they grew older, previously reported in the CARDIA study, and the association between BMI and incident hypertension in the JHS, primordial prevention aimed at reducing BMI may be particularly effective.[32,33]

A National Heart, Lung, and Blood Institute advisory on Primary Prevention of Hypertension and the Lancet Commission on Hypertension has identified the promotion of a healthy lifestyle in childhood and young adulthood, with a particular focus on lowering caloric intake combined with an increase in physical activity, as critical in the prevention of hypertension.[34,35] The current study supports these recommendations and suggests that primordial prevention beginning at a young age may be effective in preventing

hypertension in some young adults, but may not fully eliminate disparities in hypertension incidence by race. Risk for developing hypertension was much higher in blacks compared with whites, regardless of baseline BP level, even after multivariable adjustment. Given the interaction of genetic and environmental factors in determining one's risk for hypertension,[36] more-detailed genotyping, as well as phenotyping of risk factors associated with the development of hypertension, may help identify the reasons underlying this racial disparity in hypertension.

The strengths of this study include the use of a large, population-based cohort with representation from 4 US cities and collection of data beginning in early adulthood with 30 years of follow-up. CARDIA collected data in a comprehensive fashion, which allowed for the investigation of risk factors for hypertension. This study also used the 2017 ACC/AHA BP guideline definitions of elevated BP and hypertension. Despite these strengths, the current results should be interpreted in the context of known and potential limitations. Several covariates, including diet and alcohol use, were self-reported. Data on dietary sodium intake were not available. Also, clinic BP was taken 3 times at each study visit, whereas the recommendations for diagnosing hypertension are often based on the average BP at 2 or more visits.[37] BP was measured using different devices over the study follow-up; however, we were able to calibrate measurements to account for this protocol change. CARDIA only enrolled white and black adults, and future studies are needed to determine the cumulative incidence of hypertension from young adulthood through middle age among other racial and ethnic groups.

In conclusion, blacks have a substantially higher risk for hypertension compared with whites from young adulthood through middle age. Racial differences in incident hypertension became apparent before 30 years of age. By 55 years of age, 75% of black men and women in the current study developed hypertension compared with 54% of white men and 40% of white women. The increased risk for hypertension in blacks was present at all baseline BP levels, suggesting that higher BP in childhood does not fully explain racial disparities in hypertension. These findings also underscore the importance of focusing on modifiable risk factors, including BMI and adherence to a DASH diet, at an early age for the prevention of hypertension.

Sources of Funding

The Coronary Artery Risk Development in Young Adults Study (CARDIA) is conducted and supported by the National Heart, Lung, and Blood Institute (NHLBI) in collaboration with the University of Alabama at Birmingham (HHSN268201300025C & HHSN268201300026C), Northwestern University (HHSN-268201300027C), University of Minnesota (HHSN-268201300028C), Kaiser Foundation Research Institute (HHSN268201300029C), and Johns Hopkins University School of Medicine (HHSN268200900041C). CARDIA is also partially supported by the Intramural Research Program of the National Institute on Aging (NIA) and an intra-agency agreement between NIA and NHLBI (AG0005). This article has been reviewed by CARDIA for scientific content. This analysis was supported by grant R01 HL117323 and K24-HL125704 from the National Heart, Lung, and Blood Institute and grant 15SFRN2390002 from the American Heart Association.

Disclosures

None.

References

1. Voors AW, Foster TA, Frerichs RR, Webber LS, Berenson GS. Studies of blood pressures in children, ages 5-14 years, in a total biracial community: the Bogalusa Heart Study. *Circulation*. 1976;54:319–327.
2. Berenson GS, Wattigney WA, Webber LS. Epidemiology of hypertension from childhood to young adulthood in black, white, and Hispanic population samples. *Public Health Rep*. 1996;111:3–6.
3. Dyer AR, Liu K, Walsh M, Kiefe C, Jacobs DR Jr, Bild DE. Ten-year incidence of elevated blood pressure and its predictors: the CARDIA study. Coronary Artery Risk Development in (Young) Adults. *J Hum Hypertens*. 1999;13:13–21.
4. Burt VL, Whelton P, Roccella EJ, Brown C, Cutler JA, Higgins M, Horan MJ, Labarthe D. Prevalence of hypertension in the US adult population. Results from the Third National Health and Nutrition Examination Survey, 1988–1991. *Hypertension*. 1995;25:305–313.
5. Muntner P, He J, Cutler JA, Wildman RP, Whelton PK. Trends in blood pressure among children and adolescents. *JAMA*. 2004;291:2107–2113.
6. Hertz RP, Unger AN, Cornell JA, Saunders E. Racial disparities in hypertension prevalence, awareness, and management. *Arch Intern Med*. 2005;165:2098–2104.
7. Cutler JA, Sorlie PD, Wolz M, Thom T, Fields LE, Roccella EJ. Trends in hypertension prevalence, awareness, treatment, and control rates in United States adults between 1988–1994 and 1999–2004. *Hypertension*. 2008;52:818–827.
8. Guo F, He D, Zhang W, Walton RG. Trends in prevalence, awareness, management, and control of hypertension among United States adults, 1999 to 2010. *J Am Coll Cardiol*. 2012;60:599–606.
9. Whelton PK, Carey RM, Aronow WS, Casey DE Jr, Collins KJ, Dennison Himmelfarb C, DePalma SM, Gidding S, Jamerson KA, Jones DW, MacLaughlin EJ, Muntner P, Ovbiagele B, Smith SC Jr, Spencer CC, Stafford RS, Taler SJ, Thomas RJ, Williams KA Sr, Williamson JD, Wright JT Jr. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertension*. 2018;71:1269–1324.
10. Friedman GD, Cutter GR, Donahue RP, Hughes GH, Hulley SB, Jacobs DR Jr, Liu K, Savage PJ. CARDIA: study design, recruitment, and some characteristics of the examined subjects. *J Clin Epidemiol*. 1988;41:1105–1116.
11. Sidney S, Haskell WL, Crow R, Sternfeld B, Oberman A, Armstrong MA, Cutter GR, Jacobs DR, Savage PJ, Van Horn L. Symptom-limited graded treadmill exercise testing in young adults in the CARDIA study. *Med Sci Sports Exerc*. 1992;24:177–183.
12. Chang A, Van Horn L, Jacobs DR Jr, Liu K, Muntner P, Newsome B, Shoham DA, Durazo-Arvizu R, Bibbins-Domingo K, Reis J, Kramer H. Lifestyle-related factors, obesity, and incident microalbuminuria: the CARDIA (Coronary Artery Risk Development in Young Adults) study. *Am J Kidney Dis*. 2013;62:267–275.
13. Gunderson EP, Chiang V, Lewis CE, Catov J, Quesenberry CP Jr, Sidney S, Wei GS, Ness R. Long-term blood pressure changes measured from before to after pregnancy relative to nonparous women. *Obstet Gynecol*. 2008;112:1294–1302.
14. Beiser A, D'Agostino RB Sr, Seshadri S, Sullivan LM, Wolf PA. Computing estimates of incidence, including lifetime risk: Alzheimer's disease in the

Framingham Study. The Practical Incidence Estimators (PIE) macro. *Stat Med*. 2000;19:1495–1522.

15. Carson AP, Howard G, Burke GL, Shea S, Levitan EB, Muntner P. Ethnic differences in hypertension incidence among middle-aged and older adults: the Multi-Ethnic Study of Atherosclerosis. *Hypertension*. 2011;57:1101–1107.
16. Cornoni-Huntley J, LaCroix AZ, Havlik RJ. Race and sex differentials in the impact of hypertension in the United States. The National Health and Nutrition Examination Survey I Epidemiologic Follow-up Study. *Arch Intern Med*. 1989;149:780–788.
17. Carnethon MR, Pu J, Howard G, Albert MA, Anderson CAM, Bertoni AG, Mujahid MS, Palaniappan L, Taylor HA Jr, Willis M, Yancy CW; American Heart Association Council on Epidemiology and Prevention; Council on Cardiovascular Disease in the Young; Council on Cardiovascular and Stroke Nursing; Council on Clinical Cardiology; Council on Functional Genomics and Translational Biology; and Stroke Council. Cardiovascular health in African Americans: a scientific statement from the American Heart Association. *Circulation*. 2017;136:e393–e423.
18. Chen W, Srinivasan SR, Ruan L, Mei H, Berenson GS. Adult hypertension is associated with blood pressure variability in childhood in blacks and whites: the Bogalusa Heart Study. *Am J Hypertens*. 2011;24:77–82.
19. Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: a systematic review and meta-regression analysis. *Circulation*. 2008;117:3171–3180.
20. Hardy ST, Holliday KM, Chakladar S, Engeda JC, Allen NB, Heiss G, Lloyd-Jones DM, Schreiner PJ, Shay CM, Lin D, Zeng D, Avery CL. Heterogeneity in blood pressure transitions over the life course: age-specific emergence of racial/ethnic and sex disparities in the United States. *JAMA Cardiol*. 2017;2:653–661.
21. Selassie A, Wagner CS, Laken ML, Ferguson ML, Ferdinand KC, Egan BM. Progression is accelerated from prehypertension to hypertension in blacks. *Hypertension*. 2011;58:579–587.
22. Andrew ME, Jones DW, Wofford MR, Wyatt SB, Schreiner PJ, Brown CA, Young DB, Taylor HA. Ethnicity and unprovoked hypokalemia in the Atherosclerosis Risk in Communities Study. *Am J Hypertens*. 2002;15:594–599.
23. King DE, Mainous AG III, Carnemolla M, Everett CJ. Adherence to healthy lifestyle habits in US adults, 1988–2006. *Am J Med*. 2009;122:528–534.
24. Gelber RP, Gaziano JM, Manson JE, Buring JE, Sesso HD. A prospective study of body mass index and the risk of developing hypertension in men. *Am J Hypertens*. 2007;20:370–377.
25. Niskanen L, Laaksonen DE, Nyyssonen K, Punnonen K, Valkonen VP, Fuentes R, Tuomainen TP, Salonen R, Salonen JT. Inflammation, abdominal obesity, and smoking as predictors of hypertension. *Hypertension*. 2004;44:859–865.
26. Friedman GD, Selby JV, Quesenberry CP Jr, Armstrong MA, Klatsky AL. Precursors of essential hypertension: body weight, alcohol and salt use, and parental history of hypertension. *Prev Med*. 1988;17:387–402.
27. Levenstein S, Smith MW, Kaplan GA. Psychosocial predictors of hypertension in men and women. *Arch Intern Med*. 2001;161:1341–1346.
28. Fuchs FD, Chambless LE, Whelton PK, Nieto FJ, Heiss G. Alcohol consumption and the incidence of hypertension: the Atherosclerosis Risk in Communities Study. *Hypertension*. 2001;37:1242–1250.
29. Sundstrom J, Sullivan L, D'Agostino RB, Levy D, Kannel WB, Vasan RS. Relations of serum uric acid to longitudinal blood pressure tracking and hypertension incidence. *Hypertension*. 2005;45:28–33.
30. Berlin JA, Colditz GA. A meta-analysis of physical activity in the prevention of coronary heart disease. *Am J Epidemiol*. 1990;132:612–628.
31. Sacks FM, Svetkey LP, Vollmer WM, Appel LJ, Bray GA, Harsha D, Obarzanek E, Conlin PR, Miller ER III, Simons-Morton DG, Karanja N, Lin PH; DASH-Sodium Collaborative Research Group. Effects on blood pressure of reduced dietary sodium and the Dietary Approaches to Stop Hypertension (DASH) diet. *N Engl J Med*. 2001;344:3–10.
32. Booth JN III, Abdalla M, Tanner RM, Diaz KM, Bromfield SG, Tajeu GS, Correa A, Sims M, Ogedegbe G, Bress AP, Spruill TM, Shimbo D, Muntner P. Cardiovascular health and incident hypertension in blacks: JHS (The Jackson Heart Study). *Hypertension*. 2017;70:285–292.
33. Dutton GR, Kim Y, Jacobs DR Jr, Li X, Loria CM, Reis JP, Carnethon M, Durant NH, Gordon-Larsen P, Shikany JM, Sidney S, Lewis CE. 25-year weight gain in a racially balanced sample of U.S. adults: the CARDIA study. *Obesity (Silver Spring)*. 2016;24:1962–1968.
34. Whelton PK, He J, Appel LJ, Cutler JA, Havas S, Kotchen TA, Roccella EJ, Stout R, Vallbona C, Winston MC, Karimbakas J; National High Blood Pressure Education Program Coordinating Committee. Primary prevention of hypertension: clinical and public health advisory from the National High Blood Pressure Education Program. *JAMA*. 2002;288:1882–1888.
35. Olsen MH, Angell SY, Asma S, Boutouyrie P, Burger D, Chirinos JA, Damasceno A, Delles C, Gimenez-Roqueplo AP, Hering D, Lopez-Jaramillo P, Martinez F, Perkovic V, Rietzschel ER, Schillaci G, Schutte AE, Scuteri A, Sharman JE, Wachtell K, Wang JG. A call to action and a lifecourse strategy to address the global burden of raised blood pressure on current and future generations: the Lancet Commission on hypertension. *Lancet*. 2016;388:2665–2712.
36. Levy D, Ehret GB, Rice K, Verwoert GC, Launer LJ, Dehghan A, Glazer NL, Morrison AC, Johnson AD, Aspelund T, Aulchenko Y, Lumley T, Kottgen A, Vasan RS, Rivadeneira F, Eiriksdottir G, Guo X, Arking DE, Mitchell GF, Mattace-Raso FU, Smith AV, Taylor K, Scharpf RB, Hwang SJ, Slijbrands EJ, Bis J, Harris TB, Ganesh SK, O'Donnell CJ, Hofman A, Rotter JI, Coresh J, Benjamin EJ, Uitterlinden AG, Heiss G, Fox CS, Witteman JC, Boerwinkle E, Wang TJ, Gudnason V, Larson MG, Chakravarti A, Psaty BM, van Duijn CM. Genome-wide association study of blood pressure and hypertension. *Nat Genet*. 2009;41:677–687.
37. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL Jr, Jones DW, Materson BJ, Oparil S, Wright JT Jr, Roccella EJ; National Heart, Lung and Blood Institute Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; National High Blood Pressure Education Program Coordinating Committee. The seventh report of the Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure: the JNC 7 report. *JAMA*. 2003;289:2560–2572.

SUPPLEMENTAL MATERIAL

Table S1. Cumulative incidence of hypertension between ages 18 and 55 years of age by race and sex.

	Age, years							
	20	25	30	35	40	45	50	55
Black men (n=795)	1.6%	13.2%	25.5%	38.4%	47.8%	56.9%	64.8%	75.5%
Black women (n=1,124)	0.8%	3.9%	12.8%	24.2%	35.3%	48.3%	63.0%	75.7%
White men (n=854)	2.3%	6.2%	15.0%	23.0%	31.0%	37.6%	46.0%	54.5%
White women (n=1,117)	0.9%	2.2%	5.8%	9.3%	14.5%	21.3%	29.4%	40.0%

SBP: Systolic blood pressure.

DBP: Diastolic blood pressure.

Incident hypertension was defined as systolic blood pressure ≥130 mm Hg, diastolic blood pressure ≥80 mm Hg, or reported use of antihypertensive medication.

Table S2. Cumulative incidence of hypertension between ages 18 and 55 years by race and baseline category of blood pressure level.

	Age, years							
	20	25	30	35	40	45	50	55
	SBP/DBP < 110/70 mmHg							
Black	0%	1.0%	4.9%	12.5%	23.8%	35.2%	50.2%	64.0%
White	2.0%	2.7%	5.2%	7.5%	10.7%	15.9%	23.4%	32.7%
	SBP/DBP 110-119/70-74 mmHg							
Black	0.7%	8.0%	19.1%	31.6%	43.5%	56.1%	67.2%	79.7%
White	1.3%	4.1%	9.5%	15.8%	24.7%	31.1%	40.3%	52.6%
	SBP/DBP 120-129/75-79 mmHg							
Black	4.7%	21.4%	41.0%	58.4%	64.9%	73.4%	80.80%	88.1%
White	0%	7.4%	23.2%	35.1%	45.7%	56.4%	64.8%	71.5%

SBP: Systolic blood pressure.

DBP: Diastolic blood pressure.

Incident hypertension was defined as systolic blood pressure ≥130 mm Hg, diastolic blood pressure ≥80 mm Hg, or reported use of antihypertensive medication.

Table S3. Number and percentage of participants who developed hypertension in each baseline blood pressure category.

SBP/DBP, mmHg	Overall	Black	White
<110/70	716 (39.5%)	428 (52.4%)	288 (28.9%)
110-119/70-74	739 (58.1%)	457 (68.7%)	282 (46.5%)
120-129/75-79	585 (72.7%)	344 (78.7%)	241 (65.5%)

SBP: Systolic blood pressure.

DBP: Diastolic blood pressure.

Incident hypertension was defined as systolic blood pressure ≥130 mm Hg, diastolic blood pressure ≥80 mm Hg, or reported use of antihypertensive medication.

Table S4. Adjusted hazard ratios for incident elevated blood pressure or hypertension comparing black and white participants within blood pressure categories.

	Black-White hazard ratio (95% confidence interval)		
	Model 1	Model 2	Model 3
Systolic blood pressure, mmHg			
<110	2.43 (2.13, 2.77)	2.13 (1.86, 2.44)	1.91 (1.64, 2.21)
110-119	1.96 (1.70, 2.26)	1.80 (1.56, 2.09)	1.64 (1.40, 1.91)
P interaction†	0.027	0.089	0.154
Diastolic blood pressure, mmHg			
<70	2.48 (2.19, 2.81)	2.12 (1.87, 2.41)	1.90 (1.66, 2.19)
70-79	2.00 (1.71, 2.33)	1.76 (1.50, 2.06)	1.59 (1.35, 1.88)
P interaction†	0.031	0.065	0.092
Systolic/diastolic blood pressure, mmHg			
<110/70	2.52 (2.16, 2.93)	2.24 (1.91, 2.61)	2.02 (1.69, 2.42)
110-119/70-79	2.03 (1.79, 2.30)	1.82 (1.60, 2.07)	1.64 (1.42, 1.88)
P interaction†	0.031	0.040	0.066

Model 1 included adjustment for age and sex.

Model 2 included adjustment for age, sex, body mass index, systolic blood pressure, diastolic blood pressure, cigarette smoking, and parental history of hypertension.

Model 3 included adjustment for the Model 2 variables plus highest level of education obtained, physical fitness, serum uric acid level, alcohol consumption, and Dietary Approaches to Stop Hypertension adherence score.

Incident elevated blood pressure or hypertension was defined as systolic blood pressure ≥120 mm Hg, diastolic blood pressure ≥80 mm Hg, or reported use of antihypertensive medication.

†P interaction is testing whether the hazard ratio for incident hypertension for blacks compared with whites differs across blood pressure category.

Table S5. Adjusted hazard ratios (95% confidence interval) for incident elevated blood pressure or hypertension associated with risk factors measured at baseline in blacks and whites.

	Hazard ratio (95% confidence interval)		
Risk factor	Black	White	Interaction p-value
Age, per 5 years	1.19 (1.09, 1.30)	1.10 (0.98, 1.23)	0.262
Sex, female versus male	0.78 (0.63, 0.97)	0.62 (0.50, 0.78)	0.143
Highest level of education, per 1 year	0.97 (0.95, 1.00)	0.98 (0.95, 1.01)	0.877
Physical fitness, per 1 minute	0.96 (0.93, 0.99)	0.95 (0.92, 0.98)	0.857
Alcohol use			
Non-drinker	1 (ref)	1 (ref)	0.190
Moderate	0.99 (0.86, 1.13)	1.21 (1.01, 1.45)	
Heavy	1.22 (0.97, 1.55)	1.33 (1.06, 1.68)	
Current cigarette smoking, yes versus no	1.15 (1.00, 1.33)	1.05 (0.88, 1.25)	0.398
DASH diet, per 4 units higher score	0.91 (0.85, 0.97)	0.90 (0.84, 0.97)	0.907
Parental history of hypertension, yes versus no	1.33 (1.17, 1.51)	1.25 (1.08, 1.45)	0.534
Body mass index, per 5 kg/m^2	1.09 (1.02, 1.16)	1.21 (1.08, 1.34)	0.104
Serum uric acid, per 1 mg/dL	1.11 (1.04, 1.17)	1.05 (0.98, 1.13)	0.311
SBP/DBP, mm Hg			
<110/70	1 (ref)	1 (ref)	0.154
110-119/70-79	1.90 (1.67, 2.16)	2.20 (1.88, 2.57)	

SBP: Systolic blood pressure.

DBP: Diastolic blood pressure.

DASH: Dietary Approaches to Stop Hypertension.

Non-drinker is defined as 0 drinks per week for men and women.

Moderate drinker is defined as 1-14 drinks per week for men and 1-7 drinks per week for women.

Heavy drinker is defined as greater than 14 drinks per week for men and greater than 7 drinks per week for women.

Incident elevated blood pressure or hypertension was defined as systolic blood pressure ≥120 mm Hg, diastolic blood pressure ≥80 mm Hg, or reported use of antihypertensive medication.

P-value is the interaction of race and risk factors.

Hazard ratios were calculated from models that included age, sex, highest level of education, physical fitness, alcohol use, current cigarette smoking, Dietary Approaches to Stop Hypertension adherence score, parental history of hypertension, body mass index, serum uric acid, and systolic and diastolic blood pressure categories.

Table S6. Adjusted hazard ratios (95% confidence interval) for incident elevated blood pressure or hypertension associated with risk factors measured at baseline in blood pressure categories.

	Hazard ratio (95% confidence interval)		
	Systolic Blood Pressure/Diastolic Blood Pressure, mmHg		
Risk factors	<110/70	110-119/70-79	Interaction p-value
Race, black versus white	2.02 (1.69, 2.42)	1.64 (1.42, 1.88)	0.066
Age, per 5 years older	1.26 (1.13, 1.40)	1.07 (0.98, 1.17)	0.029
Sex, female versus male	0.88 (0.69, 1.12)	0.67 (0.55, 0.82)	0.089
Body mass index, per 5 kg/m^2	1.11 (1.01, 1.22)	1.11 (1.03, 1.19)	0.983
Highest level of education, per 1 year	0.98 (0.95, 1.01)	0.98 (0.95, 1.00)	0.816
Physical fitness, per 1 year	0.95 (0.92, 0.99)	0.95 (0.93, 0.98)	0.887
Alcohol use			
Non-drinker	1 (ref)	1 (ref)	0.973
Moderate	1.07 (0.90, 1.26)	1.04 (0.90, 1.20)	
Heavy	1.27 (0.97, 1.66)	1.25 (1.01, 1.54)	
Current cigarette smoking, yes versus no	1.13 (0.95, 1.34)	1.14 (0.99, 1.31)	0.969
DASH diet, per 4 units higher score	0.93 (0.86, 1.00)	0.88 (0.82, 0.94)	0.271
Parental history of hypertension	1.40 (1.20, 1.63)	1.25 (1.11, 1.42)	0.272
Serum uric acid, per 1 mg/dL	1.08 (1.00, 1.17)	1.05 (0.99, 1.11)	0.513
Systolic blood pressure, per 5 mm Hg	1.24 (1.15, 1.35)	1.25 (1.17, 1.33)	0.963
Diastolic blood pressure, per 5 mm Hg	1.10 (1.02, 1.18)	1.14 (1.08, 1.20)	0.371

DASH: Dietary Approaches to Stop Hypertension.

Non-drinker is defined as 0 drinks per week for men and women.

Moderate drinker is defined as 1-14 drinks per week for men and 1-7 drinks per week for women.

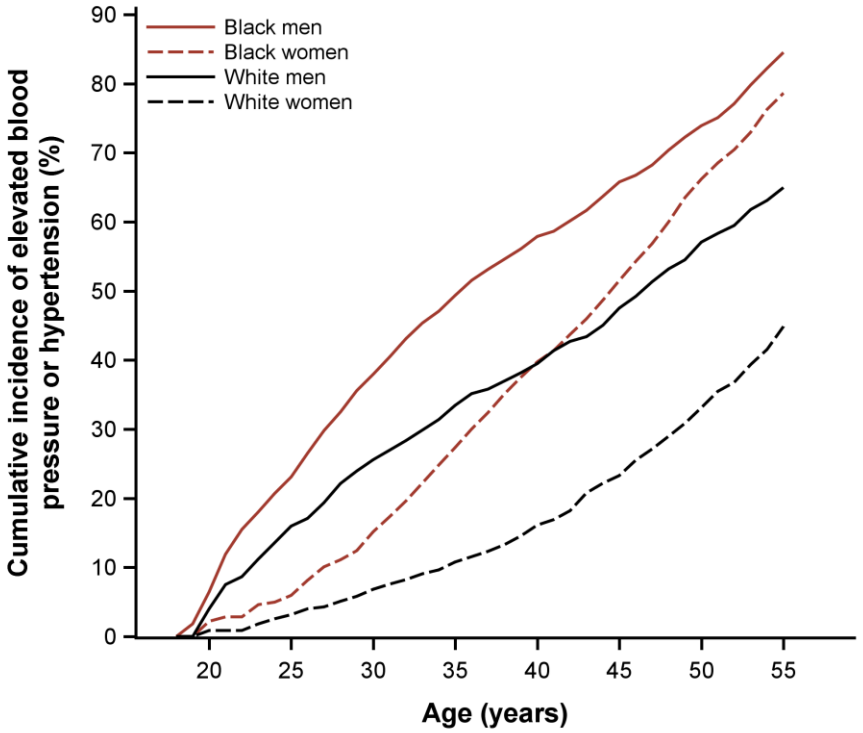
Heavy drinker is defined as greater than 14 drinks per week for men and greater than 7 drinks per week for women.

P-value is the interaction of clinic blood pressure and risk factors.

Incident elevated blood pressure or hypertension was defined as systolic blood pressure ≥120 mm Hg, diastolic blood pressure ≥80 mm Hg, or reported use of antihypertensive medication.

Hazard ratios were calculated from models that included race, age, sex, highest level of education, physical fitness, alcohol use, current cigarette smoking, Dietary Approaches to Stop Hypertension adherence score, parental history of hypertension, body mass index, serum uric acid, and systolic and diastolic blood pressure.

Figure S1. Cumulative incidence of elevated blood pressure or hypertension between ages 18 and 55 years by race and sex.

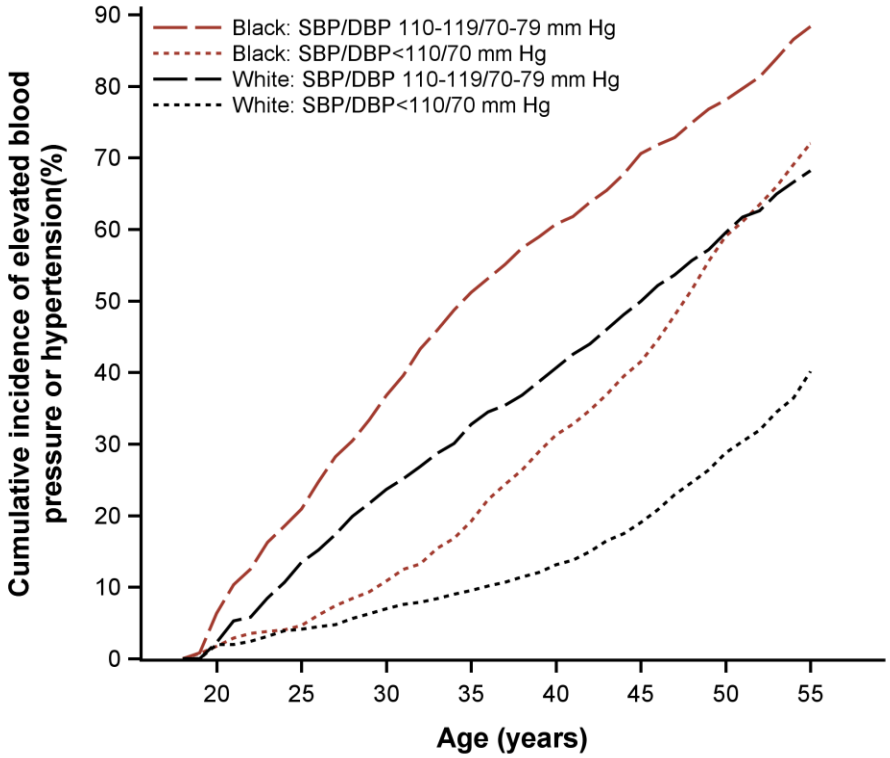


Incident elevated blood pressure or hypertension was defined as systolic blood pressure ≥120 mm Hg, diastolic blood pressure ≥80 mm Hg, or reported use of antihypertensive medication.

The cumulative incidence of hypertension was calculated adjusting for the competing risk of death.

The P-value was <0.001 for race and sex group differences in incident elevated blood pressure or hypertension.

Figure S2. Cumulative incidence of elevated blood pressure or prehypertension between ages 18 and 55 years by race and baseline category of blood pressure level.



SBP: Systolic blood pressure.

DBP: Diastolic blood pressure.

Incident elevated blood pressure or hypertension was defined as systolic blood pressure ≥120 mm Hg, diastolic blood pressure ≥80 mm Hg, or reported use of antihypertensive medication.

The cumulative incidence of hypertension was calculated adjusting for the competing risk of death.

The P-value was <0.001 for race and blood pressure category group differences in incident elevated blood pressure or hypertension.