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ORIGINAL RESEARCH ARTICLE

Forty-Year Shifting Distribution of Systolic Blood Pressure With Population Hypertension Treatment and Control

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BACKGROUND: Hypertension awareness, treatment, and control programs were initiated in the United States during the 1960s and 1970s. Whereas blood pressure (BP) control in the population and subsequent reduced hypertension-related disease risks have improved since the implementation of these interventions, it is unclear whether these BP changes can be generalized to diverse and high-risk populations. This report describes the 4-decade change in BP levels for the population in a high disease risk southeastern region of the United States. The objective is to determine the magnitude of the shift in systolic BP (SBP) among Blacks and Whites from the Southeast between 1960 and 2005 with the assessment of the unique population cohorts.

METHODS: A multicohort study design compared BPs from the CHS (Charleston Heart Study) and ECHS (Evans County Heart Study) in 1960 and the REGARDS study (Reasons for Geographic and Racial Differences in Stroke) 4 decades later. The analyses included participants ≥45 years of age from CHS (n=1323), ECHS (n=1842), and REGARDS (n=6294) with the main outcome of SBP distribution.

RESULTS: Among Whites 45 to 54 years of age, the median SBP was 18 mm Hg (95% CI, 16–21 mm Hg) lower in 2005 than 1960. The median shift was a 45 mm Hg (95% CI, 37–51 mm Hg) decline for those ≥75 years of age. The shift was larger for Blacks, with median declines of 38 mm Hg (95% CI, 32–40 mm Hg) at 45 to 54 years of age and 50 mm Hg (95% CI, 33–60 mm Hg) for ages ≥75 years. The 95th percentile of SBP decreased 60 mm Hg for Whites and 70 mm Hg for Blacks.

CONCLUSIONS: The results of the current analyses of the unique cohorts in the Southeast confirm the improvements in population SBP levels since 1960. This assessment provides new evidence of improvement in SBP, suggesting that strategies and programs implemented to improve hypertension treatment and control have been extraordinarily successful for both Blacks and Whites residing in a high-risk region of the United States. Severe BP elevations commonly observed in the 1960s have been nearly eliminated, with the current 75th percentile of BP generally less than the 25th percentile of BP in 1960.

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Clinical Perspective

What Is New?

- Analyses of data from 2 unique population-based cohorts from the southeastern coastal plain of the United States—the CHS (Charleston Heart Study) and ECHS (Evans County Heart Study)—in 1960 and the REGARDS study (Reasons for Geographic and Racial Differences in Stroke) 4 decades later identified decreases in blood pressure (BP) levels for Blacks and Whites.
- Although there were consistent and similar systolic BP reductions, the changes were greater for Blacks compared with Whites at different age categories.
- Shifts in BP distributions were detected for both Whites and Blacks, with the severe values common in 1960 practically eliminated over the 45-year period.

What Are the Clinical Implications?

- The clinical strategies of high BP detection, treatment, and control implemented in the later part of the last century are effective in all patients including Blacks and Whites residing in high-risk and socioeconomically disadvantaged geographic areas.
- Primordial and primary prevention activities implemented at the clinical setting can have impact on BP levels for Blacks and Whites in vulnerable areas.
- Early detection of hypertension using proper BP measurement and prompt appropriate treatment can be effective in high BP control for all patients regardless of population social determinants.

The excess mortality associated with elevated blood pressure (BP) has been recognized for nearly 100 years, beginning with quantified risk reporting from actuaries in the 1920s.[1] In the current era of intensive pharmacologic treatment of hypertension, there is considerably less awareness of the extreme BPs that were prevalent in the past, such as the values of Franklin D. Roosevelt progressing from 162/98 mm Hg at age 54 in 1938 to 300/190 mm Hg in 1945.[2] High BP detection and control efforts have shifted from these extreme values, where mild benign hypertension was defined as BP up to 200/100 mm Hg, to the current definition of hypertension as levels >130/80 mm Hg.[3,4] In the late 1960s, a landmark clinical trial raised awareness of the need for diagnosis and treatment of elevated BP.[5] In 1969, the Framingham Study provided epidemiologic evidence that hypertension is a major contributor to coronary heart disease morbidity and mortality and is readily controlled by "hygienic and pharmacologic measures."[6] The benefits of hypertension detection, treatment, and control with subsequent risk reduction prompted the implementation of the High Blood Pressure Education Program in 1972.[7]

An analysis of virtual birth cohorts compiled from multiple National Health and Nutrition Examination Survey examinations spanning 1960 to 1994 indicated a decline in population distribution of systolic BP (SBP) over the decades.[8] A recent review by Fuchs and Whelton[9] identified elevated BP as the predominant risk factor for cardiovascular disease (CVD), and proposed that CVD is caused by the rightward shift in the distribution of BP above biologically normal levels. The authors concluded that pharmacologic interventions could have shifted the higher percentiles of the BP distribution downward, and that population-based changes could have contributed to a downward shift in the entire distribution, including lower percentiles, of BP. It remains unclear whether the changes in BP levels during this period are consistent in high-risk geographic areas and can be generalized to multiracial, economically disadvantaged, and rural populations with high disease risk. The southeastern region of the United States is one such area with an excess burden of hypertension-related outcomes including stroke.[10–12] In 1960, Georgia and South Carolina had high-risk populations of low socioeconomic status with per capita income in the lower fifth of the nation, rural health characteristics including low access to health care, and high racial diversity with a substantial proportion of Blacks.[13] The goal of this report is to use data from the unique historical CHS (Charleston Heart Study) and ECHS (Evans County Heart Study) with the REGARDS study (Reasons for Geographic and Racial Differences in Stroke) to compare the BP levels in the early 1960s (immediately before the implementation of population hypertension control programs) with those in the 2000s.

METHODS

The data used in these analyses include potentially identifying participant information and therefore are not publicly available because of legal and ethical restrictions. Qualified investigators may request access from the University of Alabama at Birmingham (regardsadmin@uab.edu) to obtain deidentified data.

Study Cohorts

The Black Pooling Project included 2 population cohorts from the Southeast in the 1960s. The CHS included a random sample of 2181 Black and White participants ≥35 years of age recruited in the early 1960s. The study cohort represented an overall response rate of 84% to the population-based sampling plan. Details of the sampling procedure and other procedures have been published previously.[14] In summary, a cross-sectional population-based sample was drawn using the 1950 census. The expected yield was 2500 persons ≥35 years of age within this age group, which constituted a 3.825% sampling rate. A stratified sampling (with a shared sampling rate) was used based on social density: city proper, the urban fringe, the open country, and rural settlements. These areas were then subdivided into units of 12 households each with units selected by a random sample. Variables measured at baseline included the first BP measurement taken in the seated position (5th phase) with use of a frequently standardized aneroid manometer with a standard cuff; 99% of all readings were taken by the same observer, on whom repeated audiometric examinations were made. To harmonize with age strata data available from the REGARDS study (which recruited participants ≥45 years of age), only 1323 participants ≥45 years of age were included in these analyses.

The ECHS also recruited Black and White participants in 1960 through 1962. All noninstitutionalized residents of Evans County and 5 districts in adjacent Bulloch County, Georgia, ≥40 years of age and 50% of those 15 to 39 years of age were invited to participate. Details of the methodology have been reported previously.[15] The study population for the ECHS was selected from the census list and consisted of the entire Evans County population 40 to 74 years of age, plus the 5 enumeration districts in the Bulloch County population. As indicated, a randomly selected 50% sample of the Evans County population 15 to 39 years of age was also included. The initial BP measurement recorded during the 1960 to 1962 baseline assessment used mercury sphygmomanometers with standard cuffs, with subjects seated and assessment using the left arm. Participants were not medically treated for high BP at baseline. To harmonize with age data available from the REGARDS study, only 1842 participants ≥45 years of age were included in these analyses.

REGARDS is an ongoing population-based national study that recruited 30 239 Black and White participants ≥45 years of age between 2003 and 2007. Participants were recruited from the 48 contiguous US states, with oversampling of Blacks and residents of the stroke belt (North Carolina, South Carolina, Georgia, Tennessee, Alabama, Mississippi, Louisiana, and Arkansas). REGARDS used a stratified random sample based on 12 strata: 3 regions (buckle of stroke belt, rest of stroke belt, rest of the nation), 2 races (Black and White), and sex (men and women). This report uses only data from within the stroke buckle and is stratified by race; hence no adjustment is needed for these 2 factors. The recruitment goal by sex was 50:50 and 55:45 (female:male) was achieved. Adjustment for sex is not needed given that the distribution of sex is similar to that in the general population and sex differences are small compared with the differences between cohorts. SBP was defined as the mean of 2 seated measures taken after a 5-minute rest. Details of study design and sample selection have been reported.[16] To harmonize with CHS and ECHS for age and geography, only 6294 participants from the southeastern coastal plain region (the region where CHS and ECHS were conducted) were included in these analyses. The geographic locations of the 3 cohorts are presented in Figure 1.

The protocol was approved by the relevant health authorities and institutional review boards. Written informed consent was required from all participants.

Statistical Analysis

The focus of statistical analysis was a description of the distribution of SBP as characterized by the 5th, 25th, 50th, 75th, and 95th percentiles. The percentiles of SBP and their 95% CIs were calculated using the univariate procedure from SAS 13.1 (Cary, NC). The difference between the percentiles was calculated by simple subtraction of the CHS/ECHS percentiles from REGARDS percentiles, with the 95% confidence bounds for this difference calculated using bootstrap techniques with 5000 replications. These percentiles were displayed graphically using box and whisker plots and provided in tabular format (along with their 95% confidence bounds and differences between studies/periods with their 95% confidence bounds).

RESULTS

Table 1 presents the numbers of participants in each era (CHS/ECHS in 1960 versus REGARDS in 2005), race (Black and White), and age stratum (45 to 54, 55 to 64, 65 to 74, and ≥75 years). The analytic database provides essential numbers for each race–age category for both study eras.

The percentiles of SBP are shown graphically in Figure 2 and numerically (with 95% confidence bounds and differences between eras with 95% confidence bounds) for Whites and Blacks in Table 2. Overall, the percentiles of SBP were strikingly lower in 2005 compared with 1960, with a number of notable patterns.

1. The magnitude of the difference in BP between eras was substantially larger for Blacks than for Whites. The differences between eras were approximately twice as large for Blacks as Whites between the ages of 45 and 54 years. For example, the difference in the 50th percentile was 18 mm Hg (95% CI, 16–21 mm Hg) for Whites, but 38 mm Hg (95% CI, 32–40 mm Hg) for Blacks. With increasing age, the Black–White difference in the magnitude of the decrease became smaller.
2. The magnitude of the difference in BP between eras was larger at older ages for Blacks and Whites. For example, for Blacks, the median difference between eras increased from 18 mm Hg (95% CI, 16–21 mm Hg) for participants 45 to 54 years of age to 29 mm Hg (95% CI, 25–31 mm Hg) for those 55 to 64 years of age to 36 mm Hg (95% CI, 34–40 mm Hg) for those 65 to 74 years of age and to 45 mm Hg (95% CI, 37–51 mm Hg) for those ≥75 years of age. Similarly, for Whites, the increase was from 38 mm Hg (95% CI, 32–40 mm Hg) for participants 45 to 54 years of age to 43 mm Hg (95% CI, 38–48 mm Hg) for those 55 to 64 years of age to 51 mm Hg (95% CI, 43–55 mm Hg) for those 65 to 74 years of age and to 50 mm Hg (95% CI, 33–60 mm Hg) for those ≥75 years of age.
3. The magnitude of the difference between eras was substantially larger for the higher percentiles. For example, at age 65 to 74 years for Whites,

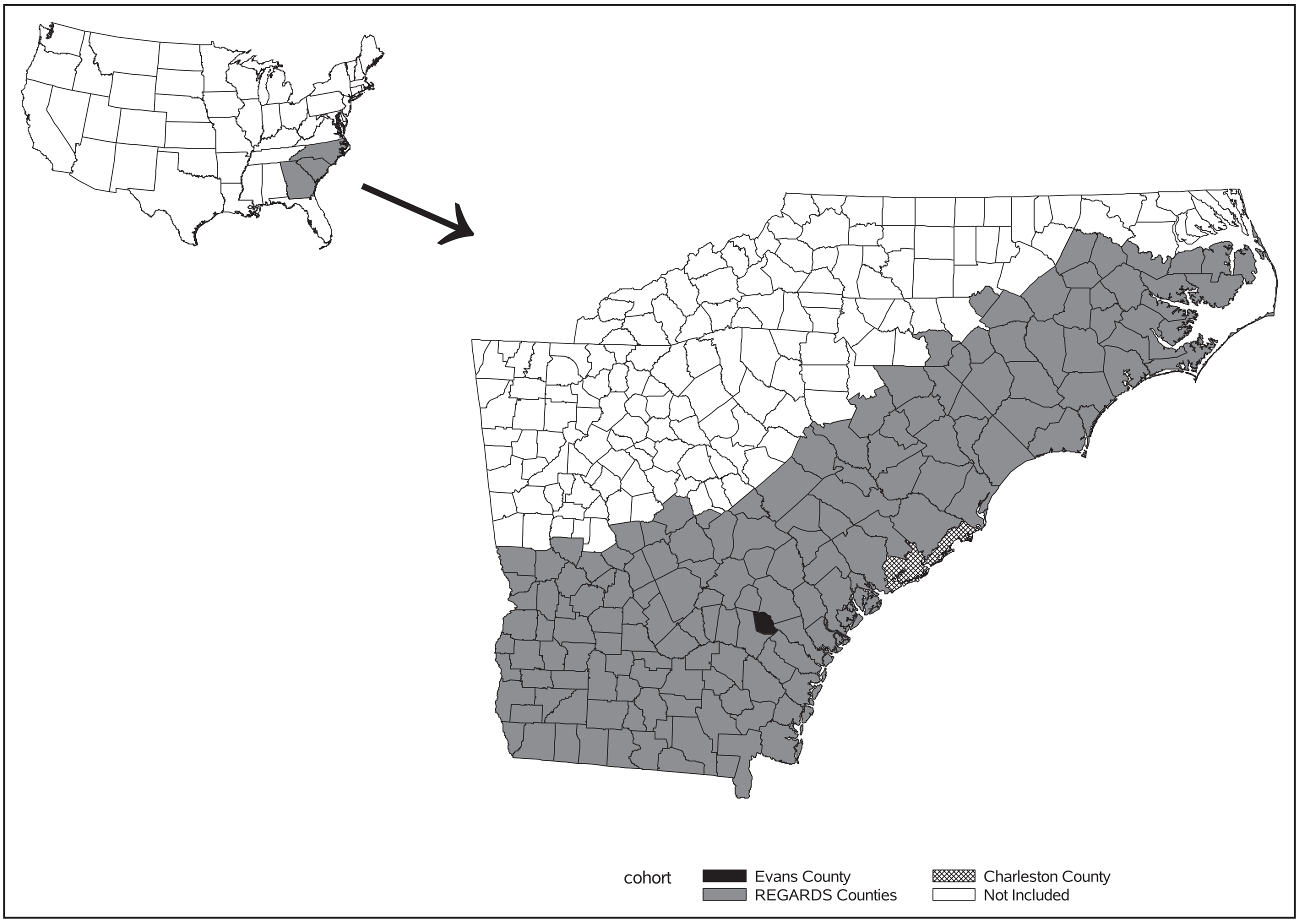

Figure 1. Geographic locations of ECHS (Evans County Heart Study), CHS (Charleston Heart Study), and REGARDS (Reasons for Geographic and Racial Differences in Stroke) cohorts inset in the United States.

there was a 16 mm Hg (95% CI, 12–22 mm Hg) difference at the 5th percentile, a 26 mm Hg (95% CI, 22–31 mm Hg) difference at the 25th percentile, a 36 mm Hg (95% CI, 34–40 mm Hg) difference at the 50th percentile, a 47 mm Hg (95% CI, 41–53 mm Hg) difference at the 75th percentile, and a 63 mm Hg (95% CI, 41–68 mm Hg) difference at the 95th percentile.

Cumulatively, these changes have contributed to the dramatic shift in SBP levels shown in Figure 3. In 1960, SBPs were generally >150 mm Hg for Blacks and >130 mm Hg for Whites, with few individuals having SBP levels <120 mm Hg or >225 mm Hg. In contrast, by 2005, the SBP levels for both Blacks and Whites were generally <130 mm Hg, with SBP levels <120 mm Hg and >180 mm Hg occurring in only a few individuals.

Table 1. Number of Participants in the Analyses From the ECHS (Evans County Heart Study), CHS (Charleston Heart Study), and REGARDS Study (Reasons for Geographic and Racial Differences in Stroke) by Age Strata and Race

	White		Black	
Age Group, y	ECHS/CHS	REGARDS	ECHS/CHS	REGARDS
45 to 54	950	543	526	423
55 to 64	606	1467	360	909
65 to 74	366	1339	245	648
75+	66	708	41	257

DISCUSSION

In the years after the implementation of high BP detection, treatment, control, and prevention programs, there has been an immense decline in the distribution of SBP in the general population. Improvement in hypertension treatment and control and subsequent shifts in BP have been reported recently from national population surveys,[17] as well as global pooled analyses from the Noncommunicable Disease Risk Factor Collaboration.[18,19] These reports provide consistent evidence of improvements in population BP levels, but it remains unclear whether the changes in SBP levels can be generalized to high-risk and vulnerable populations. The CHS/ECHS and REGARDS data and analyses provide a unique resource to assess BP changes in a high-risk geographic area with an economically disadvantaged and diverse population. Consistent with the higher cardiovascular and cerebrovascular disease rates, the BPs in CHS/ECHS were substantially higher in 1960

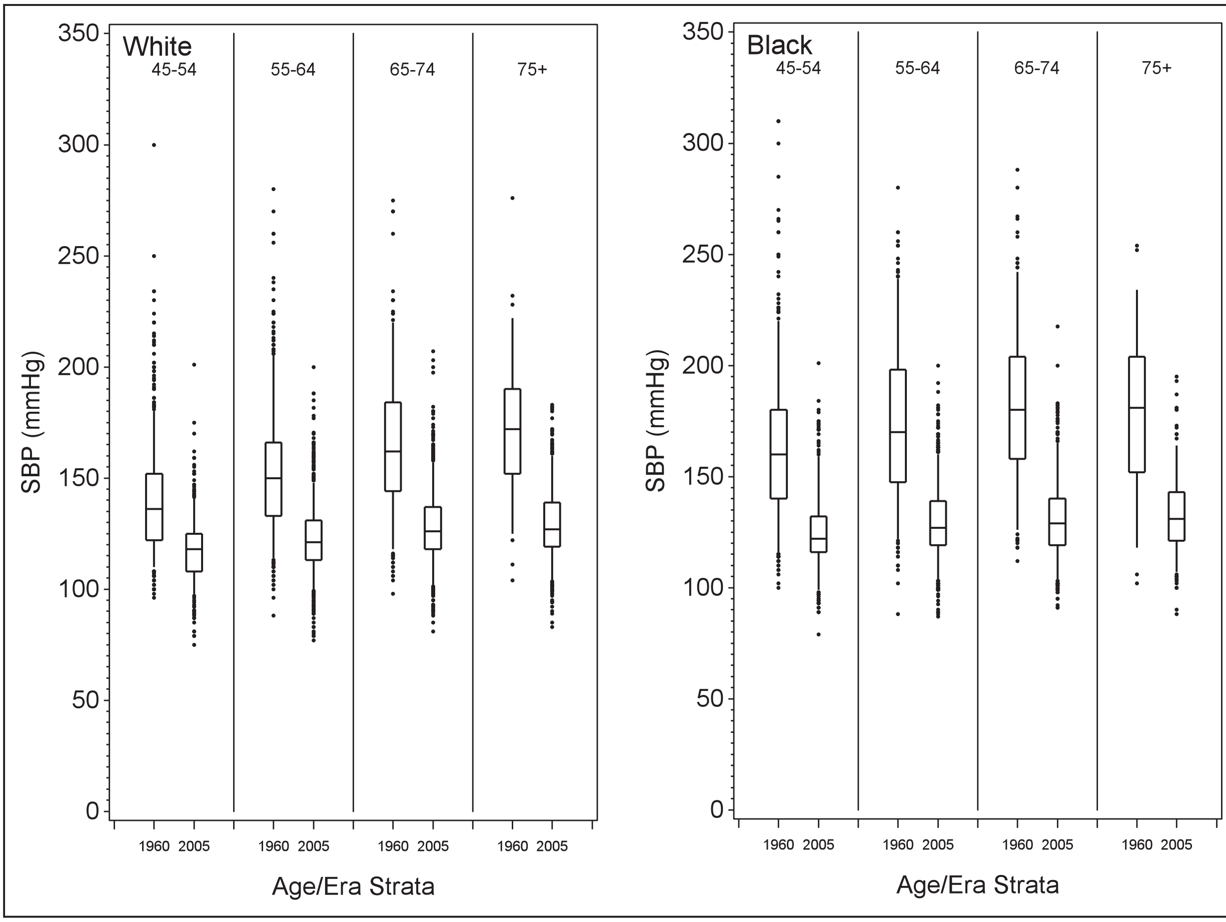

Figure 2. Box and whisker plot showing the distribution of systolic blood pressure (SBP) by race, age strata (45 to 54, 55 to 64, 65 to 74, and ≥75 years), and study (CHS [Charleston Heart Study]/ECHS [Evans County Heart Study] circa 1960 and REGARDS [Reasons for Geographic and Racial Differences in Stroke] circa 2005).
The box represents the 25th, 50th, and 75th percentiles of the distribution, the whiskers the 5th and 95th percentiles of the distribution, and the individual data points the observations below the 5th or about the 95th percentile.

compared with values in the Framingham Study[20,21] and the 1960 National Health and Nutrition Examination Survey.[17] In the 1960s, SBP levels of 160 to 220 mm Hg were not unusual, falling between the 75th and 95th percentiles of SBP reported for that period in this high-risk population. After 4 decades, these severely elevated BPs have become much rarer, with even the 95th percentile values being lower than 160 mm Hg. With the exception of only one race–age stratum in this analysis, the 75th percentile of SBP in 2005 was below the 25th percentile in 1960. The exception was Whites 45 to 54 years of age, in whom the 25th percentile in 1960 (122 mm Hg) and the 75th percentile in 2005 (125 mm Hg) were nearly identical. Between 1960 and 2000, there were dramatic reductions in both heart disease and stroke mortality, and the declines in SBP were a major contributor.[22]

These results confirm previous reports of declines across the entire BP distribution.[17–19] Clearly, introduction of pharmacologic antihypertensive treatment is a major contributor to the temporal decline in the distribution of BP at the higher percentiles. However, the finding of decreases at the lower percentiles (even the 5th percentile) suggests that population-wide changes in lifestyle and other factors may have played a role. Thus the current study provides new evidence suggesting both the medical treatment and control of hypertension as well as lifestyle modifications have made an impact in high-risk populations.

In the previous report using virtual cohorts, there was an estimated change of 1.19 mm Hg per decade at the 10th percentile, 2.40 mm Hg per decade at the 50th percentile, and 4.62 mm Hg per decade at the 90th percentile of the BP range.[7] Hence a 9.6 mm Hg decline might have been expected over 40 years at the 50th percentile. The declines using the actual cohorts in the current report are dramatically larger. For example, there was a 36 mm Hg (95% CI, 34–40 mm Hg) decline in the 50th percentile for Whites 65 to 74 years of age, and a 51 mm Hg (95% CI, 43–55 mm Hg) decline for Blacks in the same age strata. This corresponds to decreases of approximately 10 mm Hg per decade. This larger decline could reflect the temporal positioning of the cohorts used in this report, where the CHS/ECHS

Table 2. Age-Specific Percentiles (95% CI) of Systolic Blood Pressure for White and Black Participants in the Combined CHS (Charleston Heart Study) and ECHS (Evans County Heart Study) Conducted in the Early 1960s and the REGARDS Study (Reasons for Geographic and Racial Differences in Stroke) Conducted in the Early 2000s With the Difference (95% CI) Between the 2 Time Periods

Race and Age, y	Percentile									
	5		25		50		75		95	
	CHS/ECHS	REGARDS	CHS/ECHS	REGARDS	CHS/ECHS	REGARDS	CHS/ECHS	REGARDS	CHS/ECHS	REGARDS
White										
45 to 54										
Estimate	110 (108–112)	98 (92–99)	122 (122–124)	108 (106–110)	136 (134–138)	118 (116–119)	152 (150–155)	125 (123–127)	180 (176–186)	141 (139–144)
Difference	12 (9–17)		14 (12–17)		18 (16–21)		27 (25–31)		39 (33–44)	
55 to 64										
Estimate	114 (111–118)	100 (99–101)	133 (130–136)	113 (111–115)	150 (146–152)	121 (121–122)	166 (164–170)	131 (130–132)	205 (196–213)	148 (146–150)
Difference	14 (12–18)		20 (17–23)		29 (25–31)		35 (33–39)		57 (47–64)	
65 to 74										
Estimate	118 (114–123)	102 (100–104)	144 (140–148)	118 (116–119)	162 (160–166)	126 (125–127)	184 (178–190)	137 (136–138)	220 (210–224)	157 (152–160)
Difference	16 (12–22)		26 (22–31)		36 (34–40)		47 (41–53)		63 (41–68)	
75+										
Estimate	125 (104–134)	104 102–105)	152 (140–162)	119 (118–120)	172 (164–178)	127 (125–128)	190 (178–210)	139 (137–140)	222 (215–276)	160 (157–163)
Difference	21 (6–34)		33 (21–43)		45 (37–51)		51 (39–62)		62 (49–75)	
Black										
45 to 54										
Estimate	116 (114–120)	99 (94–101)	140 (136–142)	116 (113–118)	160 (154–162)	122 (121–123)	180 (175–184)	132 (130–134)	220 (214–230)	159 (150–171)
Difference	17 (14–23)		24 (20–28)		38 (32–40)		48 (42–53)		61 (49–75)	
55 to 64										
Estimate	122 (118–124)	104 (102–107)	148 (142–152)	119 (118–120)	170 (165–174)	127 (125–128)	198 (190–204)	139 (138–140)	239 (230–243)	160 (158–163
Difference	18 (13–21)		29 (23–34)		43 (38–48)		59 (51–65)		79 (69–82)	
65 to 74										
Estimate	126 (120–135)	104 (101–105)	158 (150–160)	119 (118–120)	180 (173–184)	129 (128–130)	204 (200–212)	140 (139–141)	242 (236–260)	165 (161–170)
Difference	22 (17–34)		39 (31–43)		51 (43–55)		64 (59–71)		77 (67–85)	
75+										
Estimate	118 (102–128)	107 (103–110)	152 (128–166)	121 (119–122)	181 (164–192)	131 (128–135)	204 (190–224)	143 (141–148)	234 (190–254)	164 (160–180)
Difference	11 (–7 to 36)		31 (20–47)		50 (33–60)		61 (43–74)		70 (46–93)	

cohorts were nearly ideally positioned to collect data immediately before the growth in the recognition of the importance of BP control. Nonetheless, these declines in the median SBP levels of 10 mm Hg per decade are remarkable population health achievements.

The larger decreases in SBP observed at higher percentiles of the BP range are associated with a near elimination of critically high BPs requiring immediate medical attention. In the 1960s, 25% of the Black population 55 to 64 years of age had SBPs >198 mm Hg, and 5% had SBP levels ≥239 mm Hg. In 2005, only 7% of the Black population had values >198 mm Hg and 1% had values >239 mm Hg. Hence, although very high levels of SBP persisted, the proportion of the population affected was much smaller.

Mortality from hypertension-related conditions, such as stroke, has been declining rapidly from the 1960s to the 2000s.[22] This decline in mortality was more rapid in Whites than Blacks.[17] Thus the current finding that declines in hypertension and SBP levels were strikingly larger in Blacks than their White counterparts are new and unpredicted. The Black–White differences in the magnitude of the decline in SBP were larger at younger ages, with both Blacks and Whites having larger but approximately equal declines at older ages. Thus the finding that racial differences were diminished at older

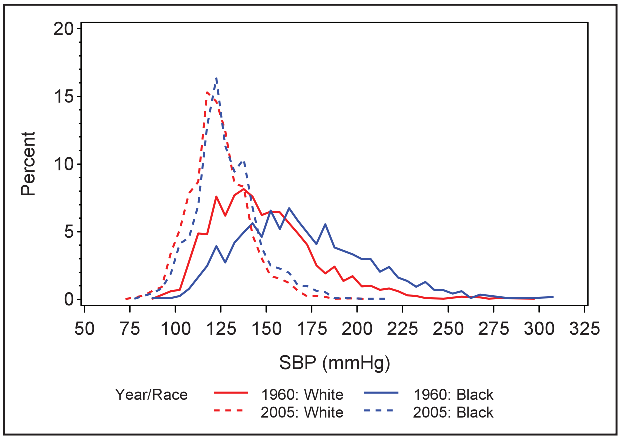

Figure 3. Histogram of systolic blood pressure for Blacks and Whites in 1960 (CHS [Charleston Heart Study] and ECHS [Evans County Heart Study]) and 2005 (REGARDS [Reasons for Geographic and Racial Differences in Stroke]).

ages where stroke events are more prevalent may underlie the smaller declines in stroke mortality in Blacks.

There are several limitations that should be considered when interpreting our results. The REGARDS 2005 comparison metrics might be considered dated, but the analytic design identified substantial improvements in the SBP distributions in the high-risk region in the early phases of population high BP control. Data from current population assessments suggest that the improvements in SBP have been sustained.[23] The measurements of BP were not standardized among the different cohorts, but were consistent with the protocols of the era. As BP measurement was relatively new for the CHS/ECHS participants in 1960, it is reasonable to consider a white coat effect.[24] Although the cohorts did not include indicators of white coat hypertension, the magnitude of the SBP values are much greater than the 10 mm Hg reported with those with the white coat effect.[24] Furthermore, the SBP levels in the CHS/ECHS were considerably greater than other cohorts of the era. However, the high SBP values are consistent with the higher prevalence of hypertension-related outcomes for the geographic region, suggesting validity of the measurements. In addition, because of the stronger association of SBP (relative to diastolic BP) with health outcomes, these analyzes focus solely on SBP. The study also includes many strengths, the largest being the use of 3 large high-quality studies nearly perfectly temporally positioned to assess the change in BP levels from before to after the widespread acceptance of the need for control of BP. An additional strength is inclusion of participants who were all residents of the historically high-risk coastal plain region of the Southeast.

This article provides new evidence that SBP levels were reduced over a 40-year period in high-risk populations geographically disadvantaged by social determinants of disease. Specifically, the analyses quantify and document the magnitude in the decline in the distribution of SBP in the southeastern United States over the past 40 years after widespread acceptance of the importance of BP control. These reductions were particularly evident at the higher end of the SBP distribution, with decreases of ≥50 mm Hg in the 95th percentile of SBP. Whereas the results confirm and reinforce the findings of other studies demonstrating the successful lowering of elevated BP in the United States, the SBP reductions described were even larger in this high-risk population of the Southeast and Blacks. The results provide an indication of the potential population impact of structured hypertension awareness, treatment, control, and prevention programs for all populations, including areas of high risk such as areas with diverse demographics, rural, economically disadvantaged populations, and geographies with excess disease burden.

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