

ORIGINAL ARTICLE

Prevalence and changes of untreated isolated systolic hypertension among non-Hispanic black adults in the United States

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Isolated systolic hypertension (ISH) is a growing health concern in the United States (US) black population. The stratified prevalence of untreated ISH has not been fully investigated in non-Hispanic blacks. Cross-sectional data on 4625 non-Hispanic blacks aged ≥ 18 years were collected from the National Health and Nutrition Examination Survey 1999–2010, representing a probability sample of the US civilian noninstitutionalized black population. The 6-year prevalence of ISH and 95% confidence intervals (CIs) were estimated by conducting weighted frequency and logistic procedures. The prevalence of untreated ISH was 11.2% among non-Hispanic black adults in 1999–2010. Individuals who received lower education (high school or below) had higher prevalence of untreated ISH than those with higher education (12.8% (95% CI: 11.3–14.2%) vs. 9.0% (95% CI: 7.5–10.6%)). The prevalence of untreated ISH was higher in young men than in young women (4.3% (95% CI: 3.3–5.4%) vs. 1.8% (95% CI: 0.9–2.7%)), and higher in middle-aged adults with lower education than in middle-aged adults with higher education (14.1% (95% CI: 11.4–16.7%) vs. 7.7% (95% CI: 5.5–9.8%)). Compared with 1999–2004, the prevalence of untreated ISH in 2005–2010 decreased for old individuals (27.7% vs. 40.8%), old men (24.4% vs. 40.0%) and old individuals who received higher education (21.4% vs. 40.7%). Untreated ISH is more prevalent in old blacks, and significant reduction of the prevalence in this group suggests that public health interventions, lifestyle modifications or health awareness are in the right direction.

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INTRODUCTION

According to the American Heart Association, more than 40% of non-Hispanic black adults have hypertension in the United States (US).¹ The excess of hypertension has been recognized for a long time and accounts for substantial adverse cardiovascular events in blacks.² Hypertension has three hemodynamic subtypes: isolated systolic hypertension (ISH), systolic and diastolic hypertension and isolated diastolic hypertension.³ ISH is defined as values of systolic blood pressure (SBP) greater than or equal to 140 mm Hg and values of diastolic blood pressure (DBP) less than 90 mm Hg. It becomes a dominant form of hypertension as age increases.⁴ Although the existing studies of ISH examine pattern changes in rates of uncontrolled ISH with age in the general population of adults,^{5,6} the prevalence and change patterns of untreated ISH have not been reported in US non-Hispanic blacks.

Elevated SBP has been thought to be more important than elevated DBP as a risk factor for adverse cardiovascular and renal outcomes.⁷

When combined with other risk factors (for example, smoking, obesity, poor diet and lack of exercise), untreated ISH may lead to serious health problems, such as stroke, heart disease, chronic kidney disease and dementia,^{8–11} particularly in the black population.

Given the importance of ISH for cardiovascular and renal diseases and the little information for the change pattern in the prevalence of ISH in the black population, we analyzed data from the continuous National Health and Nutrition Examination Survey (NHANES). The objective of this study was to estimate the prevalence of untreated ISH and identify the trends in the corresponding prevalence of untreated ISH among non-Hispanic black adults aged 18 years or above, following the advisory guidelines from the National High Blood Pressure Education Program with the expressed purpose of further characterizing high SBP.¹² Specific attention was directed toward estimating the prevalence and changes of untreated ISH in the subpopulations of non-Hispanic black adults stratified by age, sex and education. The findings from the present study would be crucial

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for the better understanding of the distribution and pattern of untreated ISH among US non-Hispanic adults. As the population is aging and ISH becomes more significant, this would allow targeting specific black subpopulations in an effort to better control BP and thereby reduce the risk of cardiovascular-related morbidities and mortality among non-Hispanic black adults in the US.

METHODS

Study design and population

Cross-sectional demographic and examination data on non-Hispanic blacks from the continuous NHANES program 1999–2010 were collected and analyzed for this study. The continuous NHANES, beginning in 1999, included a series of 2-year stratified multistage surveys designed to assess the health and nutrition status among children and adults in the US.¹³ Each survey investigated ~10 000 people who were selected from 30 counties across the country through a stratified multistage probability clustered sampling design, and represented the US civilian noninstitutionalized population. Complete descriptions of the continuous NHANES and sampling designs have been reported in the previous study.^{14–16} All participants signed informed consent forms and the data were approved by the Centers for Disease Control and Prevention Institutional Review/Ethic Board.

We pooled data from recent six cycles of NHANES surveys conducted from 1999 to 2010 to obtain adequate sample size and power for unbiased estimation of the prevalence of untreated ISH in non-Hispanic blacks. The sample from each survey was weighted to the US population corresponding to the respective time period during which the survey was performed. The stratified multistage probability clustered sampling design was similar from NHANES 1999–2000 to NHANES 2009–2010. We compared the prevalence of untreated ISH in 1999–2004 with the prevalence in 2005–2010. For the 6-year prevalence estimate of untreated ISH in NHANES 1999–2004, a 6-year weight was created by assigning two-thirds of the 4-year weight for NHANES 1999–2002 and one-third of the 2-year weight for NHANES 2003–2004; for the prevalence estimate in NHANES 2005–2010, a 6-year weight was created by assigning one-third of the 2-year weight for NHANES 2005–2006, 2007–2008 and 2009–2010, respectively.

NHANES 1999–2000, NHANES 2001–2002, NHANES 2003–2004, NHANES 2005–2006, NHANES 2007–2008 and NHANES 2009–2010 examined a total of 9777, 10 897, 9971, 10 198, 10 001 and 10 425 individuals who participated in both demographic component survey and BP examination or questionnaire, respectively. Out of 61 269 individuals included in the sample from NHANES 1999–2010, there were 33 560 individuals aged 18 years or above who participated in both interview and examination, of which 6950 individuals were non-Hispanic blacks. In these non-Hispanic black adults, 332 individuals with incomplete SBP or DBP measurements and 1993 individuals who reported antihypertensive medication use were excluded from the final analysis. Finally, we had a total of 4625 non-Hispanic blacks aged 18 years or above available in the continuous NHANES for further study, among which 2251 individuals were collected from NHANES 1999–2004 and 2374 individuals from NHANES 2005–2010. To examine the changes in the prevalence of untreated ISH over time, estimates from NHANES 2005–2010 data were compared with estimates from NHANES 1999–2004 data.

Blood pressure and ISH

SBP and DBP measurements were collected by certified physician examiners using mercury sphygmomanometer in accordance with a standardized protocol.¹⁷ Mid-arm circumference was measured to determine the selection of sphygmomanometer with appropriate cuff size for each participant before BP examination. Up to four SBP and DBP readings on each participant were recorded for accuracy after the subject has rested quietly in a sitting position for 5 min and the examiner determined the maximum inflation level. The average SBP and DBP was calculated on the basis of the individual readings according to the NHANES specifications.¹⁷ The SBP and DBP values recorded in this study represented averages of the SBP and DBP readings. According to the seventh Joint National Commission guidelines,¹⁸ a participant was considered to have hypertension if values of average SBP were ≥ 140 mm Hg

or values of average DBP were ≥ 90 mm Hg. ISH was one of the hypertension subtypes and defined as average SBP ≥ 140 mm Hg and average DBP < 90 mm Hg.

Information on demographic factors

Race/ethnicity was self-reported in the NHANES demographic survey component. As the objective of this study was to investigate the prevalence of untreated ISH among non-Hispanic blacks, other race/ethnicity categories (including Mexican Americans, other Hispanics, non-Hispanic whites and other race) were excluded from the total sample analyses. Three demographic characteristics (age, sex and education) were selected as stratified factors to see differences in the prevalence of untreated ISH across all factors. Demographic information on age, sex and education were assessed through questionnaire of NHANES. Non-Hispanic black adults were divided into three groups in terms of age: young adults if their ages were greater than or equal to 18 years and less than 40 years, middle-aged adults if ages were greater than or equal to 40 years and less than 60 years, and old adults if ages were 60 years or above. The participant's level of education was classified as high school or less and college or above, based on the number of years in school.

Statistical analysis

We followed NHANES report and analysis guidelines for data analyses in the present study.¹⁹ The 6-year prevalence of untreated ISH was presented to examine differences/changes in the prevalence in non-Hispanic black adults during 1999–2004 vs. 2005–2010. To reflect unequal probabilities of selection, non-response adjustments and post-stratification adjustments, examination sampling weights were incorporated into the data analysis to get bias-reduced estimates and sampling errors of estimates. Sampling weights were also used to adjust for the impact of oversampling non-Hispanic blacks and individuals aged 60 years or above in the NHANES survey.

Independent *t*-test was used for continuous characteristics, and χ^2 and the Cochran–Mantel–Haenszel tests were used for categorical data to examine the differences in means or percentages of characteristics between 1999–2004 and 2005–2010. As continuous NHANES was a national survey with a multistage clustered probability sampling design, conventional statistical analyses with underlying distributional assumptions were not appropriate for variance estimation and statistical testing. Survey procedures were used to compute estimates of Taylor series s.e. and conduct statistical significance tests. We calculated age-adjusted descriptive statistics for subject's demographic characteristics using PROC SURVEYMEANS for continuous variables and PROC SURVEYFREQ for categorical values. The crude prevalence of untreated ISH by age, sex and education was calculated using PROC SURVEYFREQ. 95% confidence intervals (CIs) were calculated to examine the differences in untreated ISH prevalence over the 6-year period of time. All statistical analyses were performed on a PC with Microsoft Window 7 operating system, using SAS statistical software (SAS version 9.2, SAS Institute, Cary, NC, USA).

RESULTS

Demographic characteristics of participants

In the present study, data on 4625 non-Hispanic black adults aged 18 years or above were included; 2251 adults were from NHANES 1999–2004 and 2374 adults from NHANES 2005–2010. Average age of participants in the study sample was 37.7 years. In total, 52.2% of participants were women; 53.8% received a high school education or below. Compared with the period 1999–2004, the percentage of non-Hispanic black adults who received a high school education or below decreased significantly (57.6% vs. 50.3%, $P = 0.0004$) in the period of 2005–2010. There were no significant differences in mean age and percentage of men or women between NHANES 1999–2004 and NHANES 2005–2010 (Table 1).

Overall prevalence of untreated ISH

Figure 1 shows the overall prevalence of untreated ISH in the general US population of non-Hispanic blacks aged 18 years or above

Table 1 Characteristics of non-Hispanic blacks aged 18 years or above in NHANES 1999–2010, United States

Characteristics	Mean or percentage (95% CI)			P-values ^a
	Overall	1999–2004	2005–2010	
Age, years	37.7 (37.1, 38.2)	37.7 (37.1, 38.2)	37.6 (36.7, 38.5)	0.96
18–39, %	56.0 (57.1, 60.8)	59.3 (57.3, 61.4)	58.6 (55.6, 61.6)	0.73
40–59, %	33.2 (31.5, 35.0)	32.7 (30.8, 34.7)	33.7 (30.9, 36.5)	
≥60, %	7.8 (7.0, 8.7)	7.9 (6.5, 9.3)	7.7 (6.7, 8.7)	
Sex				
Men, %	47.8 (46.3, 49.4)	47.4 (45.3, 49.4)	48.3 (46.1, 50.5)	0.55
Women, %	52.2 (50.7, 53.7)	52.7 (50.6, 54.7)	51.7 (49.5, 53.9)	
Education				
High school or below, %	53.8 (51.7, 56.0)	57.6 (54.5, 60.6)	50.3 (47.6, 53.1)	0.0004 ^b
College or above, %	46.2 (44.0, 48.3)	42.4 (39.4, 45.5)	49.7 (47.0, 52.4)	

Abbreviations: CI, confidence interval; NHANES, National Health And Nutrition Examination Survey.
^aP-value is used to test the significance for the difference in mean or percentage of each characteristic over time 1999–2004 vs. 2005–2010.
^bIndicates the significant difference in the mean or percentage of a characteristic over 1999–2004 vs. 2005–2010.

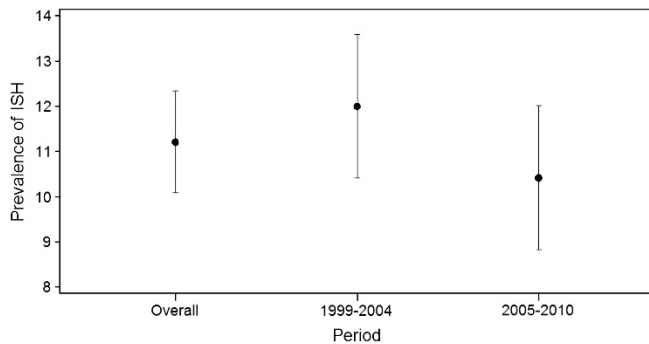


Figure 1 Prevalence and 95% confidence intervals of isolated systolic hypertension among non-Hispanic blacks in 1999–2010, United States. (The prevalence of untreated ISH is age adjusted by direct standardization to the NHANES 1999–2010 non-Hispanic black population). ISH, isolated systolic hypertension; NHANES, National Health and Nutrition Examination Survey.

between 1999 and 2010 and the 6-year prevalence of untreated ISH in 1999–2004 and in 2005–2010. The overall prevalence of untreated ISH in 1999–2010 was 11.2% (95% CI: 10.1–12.3%). The prevalence of untreated ISH was 12.0% (95% CI: 10.4–13.9%) over 1999–2004 and 10.4% (95% CI: 8.8–12.0%) over 2005–2010. There was no significant decrease in the prevalence of untreated ISH from 1999–2004 to 2005–2010. Compared with non-Hispanic whites, non-Hispanic blacks had higher prevalence of untreated ISH; the prevalence did not decrease significantly from 1999–2004 to 2005–2010 for each of racial groups (Supplementary Table).

Prevalence and changes of untreated ISH by age, sex and education

The overall prevalence of untreated ISH was 34.2% in old non-Hispanic blacks aged 60 years or above. Compared with the prevalence in 1999–2004, the prevalence of untreated ISH in 2005–2010 decreased significantly from 40.8% (95% CI: 35.0–46.5%) to 27.7% (95% CI: 22.3–33.1%) in old individuals. There were no significant changes in the prevalence of untreated ISH in young and middle-aged adults between periods 1999–2004 and 2005–2010. In addition, the differences in the prevalence of untreated

ISH over categories of sex (men, women) and education (high school or below, college or above) were not significant from 1999–2004 to 2005–2010.

The prevalence of untreated ISH increased with age in non-Hispanic adults; old adults had higher prevalence than middle-aged individuals whose prevalence was higher than in young adults (34.2, 11.0 and 3.0% for old, middle-aged and young adults, respectively) during 1999–2010. This pattern of observation remained similar in period 1999–2004 and 2005–2010. During 1999–2010, after adjusting for age, individuals who received a high school education or below had higher prevalence of untreated ISH than those with higher education (12.8% (95% CI: 11.3–14.2%) vs. 9.0% (95% CI: 7.5–10.6%)). The prevalence of untreated ISH in non-Hispanic black women was similar to the prevalence in non-Hispanic black men (Table 2).

Prevalence and changes of untreated ISH stratified by age–sex, age–education and sex–education

The prevalence and changes of untreated ISH stratified by age–sex, age–education and sex–education in non-Hispanic black adults were presented in Table 3. The prevalence of untreated ISH decreased significantly from 40.0% (95% CI: 32.4–47.6%) in 1999–2004 to 24.4% (95% CI: 17.9–30.9%) in 2005–2010 ($P=0.0023$) among old men, and from 40.7% (95% CI: 27.8–53.6%) in 1999–2004 to 21.4% (95% CI: 13.6–29.2%) in 2005–2010 among old individuals who received a college education or above ($P=0.0095$). Although the prevalence of untreated ISH was lower in young women (1.8% (95% CI: 0.9–2.7%)) than in young men (4.3% (95% CI: 3.3–5.4%)), there was no significant difference between middle-aged men and women or old men and women. The prevalence analysis stratified by age and education showed that middle-aged adults with a high school education or below had higher prevalence of untreated ISH than those who received a college education or above (14.1% (95% CI: 11.4–16.7%) vs. 7.7% (95% CI: 5.5–9.8%)), whereas the prevalence of untreated ISH did not differ by levels of education in both young and old adults. Further analysis stratified by sex and education showed that the prevalence of untreated ISH did not differ significantly by levels of education in both non-Hispanic black men and non-Hispanic black women.

Table 2 Prevalence and changes of isolated systolic hypertension by age, sex and education among non-Hispanic blacks aged 18 years or above in 1999–2010, United States

Characteristics	Prevalence (95% CI)			
	Overall, %	1999–2004, %	2005–2010, %	P-values ^a
Age				
18–39	3.0 (2.2, 3.7)	3.2 (1.8, 4.5)	2.8 (2.1, 3.5)	0.65
40–59	11.0 (9.1, 12.8)	9.8 (7.5, 12.2)	12.0 (9.3, 14.7)	0.23
≥60	34.2 (30.0, 38.4)	40.8 (35.0, 46.5)	27.7 (22.3, 33.1)	0.0012 ^b
Sex				
Men	10.8 (9.5, 12.0)	11.8 (10.2, 13.4)	9.9 (8.0, 11.9)	0.75
Women	11.7 (10.0, 13.4)	12.2 (10.3, 14.2)	11.0 (8.2, 13.9)	0.66
Education				
High school or below	12.8 (11.3, 14.2)	13.3 (11.7, 14.9)	12.2 (9.8, 14.6)	0.66
College or above	9.0 (7.5, 10.6)	10.3 (7.5, 13.1)	8.3 (6.5, 10.0)	0.67

Abbreviation: CI, confidence interval.

Note: The prevalence of isolated systolic hypertension is age adjusted by direct standardization to the National Health and Nutrition Examination Survey 1999–2010 non-Hispanic black population, except for age-specific estimates.

^aP-value is used to test the significance for the difference in the prevalence of isolated systolic hypertension over 1999–2004 vs. 2005–2010.

^bIndicates the significant difference in the prevalence of isolated systolic hypertension over 1999–2004 vs. 2005–2010.

DISCUSSION

The NHANES is a remarkable series of national probability surveys carried out by the National Center for Health Statistics for comparative estimates of the prevalence and trends in health status by sociodemographic and other factors.¹³ It has been used to provide a comprehensive description of the prevalence of hypertension,^{20–22} explore the pattern of uncontrolled hypertension subtypes^{5,6} and examine racial disparity in cardiovascular risk factors.²³ We used data from the continuous NHANES to estimate the prevalence and changes of untreated ISH in the general US population of non-Hispanic black adults, and the prevalence and pattern changes in the subpopulations of non-Hispanic black adults stratified by age, sex and education. The overall prevalence of untreated ISH was 11.2% among non-Hispanic black adults in 1999–2010. There was no significant change in the prevalence of untreated ISH from 1999–2004 to 2005–2010. The prevalence of untreated ISH was higher in young men (vs young women) and middle-aged adults with a high school education or below (vs. middle-aged adults with higher education). Compared with 1999–2004, the prevalence of untreated ISH in 2005–2010 reduced for all old individuals, old men and old individuals who received at least a college education.

Non-Hispanic blacks have been shown to have higher prevalence of untreated ISH than non-Hispanic whites.²⁴ In our study, the prevalence estimate of untreated ISH among non-Hispanic black adults was 11.2% in 1999–2010, which is consistent with the prevalence estimate from a previous study on ISH among adults,²⁴ considering differences between studies in the exclusion criteria and the US population on which the age adjustment for the prevalence estimate was based. Nonsignificant change in the prevalence of untreated ISH between 1999–2004 and 2005–2010 among non-Hispanic blacks may mostly be contributed by young and middle-aged blacks, as they accounted for ~92.2% of the study sample, and the prevalence of untreated ISH among them did not have a significant change over time in this study. Although the prevalence of untreated ISH is relatively low in young and middle-aged non-Hispanic black adults, a large proportion of the black population between ages of 18–59 years warrants the necessities of the application

of further preventive health care and strategies for prevention of ISH in this age population to significantly reduce the prevalence of untreated ISH in the general US non-Hispanic black population.

ISH is the most common hypertension subtype in individuals aged 60 years or above. Our study indicates that improvement of the untreated ISH prevalence among old non-Hispanic blacks is attributed to the decreased untreated ISH prevalence in old men and old individuals who received at least a college education. The decreased prevalence of untreated ISH in the categories of other characteristics may be due to the lack of a further increase in body mass index in the population. Better health awareness, health education and lifestyle modifications as well as effort from health care professionals may also explain the reduction in prevalence of untreated ISH. The significantly decreased prevalence of untreated ISH among old non-Hispanic blacks in the present study may have significant clinical indications. Every 20 mmHg increase in SBP is associated with doubling of mortality from both coronary heart disease and stroke in people between the ages of 40 and 89 years.²⁵ The absolute risk of cardiovascular mortality for any given increase in SBP is much more pronounced in the older population.²⁶ The significant decrease in the prevalence of untreated ISH may lower the risks of coronary heart disease and stroke, improve quality of life from cardiovascular disease standpoint and extend overall life expectancy in US old non-Hispanic blacks. Data from within black and African populations show striking BP gradients (rural and urban) that predictably track directly with Western lifestyles.²⁷ Over the past two decades, the number of Americans aware of their hypertension has increased particularly in non-Hispanic black women.^{22,28} The decreased prevalence in recent years among old non-Hispanic blacks may be attributed to the increased awareness of hypertension, greater concerns in health status and improved lifestyles.^{22,27,28}

The prevalence of untreated ISH decreased by 15.6% and 18.6%, respectively, in old men and old individuals with higher education (college or above). SBP has been shown to be a strong risk factor of stroke, heart disease, myocardial infarction and cardiovascular death^{8,9,25,26,29} in older populations. In this study, the decreased prevalence of untreated ISH among old black men and old blacks

Table 3 Prevalence and changes of isolated systolic hypertension stratified by characteristics among non-Hispanic blacks in 1999–2010, United States

Characteristics	Stratified prevalence (95% CI)			P-values ^a
	Overall, %	1999–2004, %	2005–2010, %	
<i>Age 18–39 years</i>				
Men	4.3 (3.3, 5.4)	4.1 (2.4, 5.8)	4.5 (3.3, 5.8)	0.69
Women	1.8 (0.9, 2.7)	2.4 (0.8, 3.9)	1.3 (0.4, 2.1)	0.18
<i>Age 40–59 years</i>				
Men	9.2 (7.1, 11.3)	8.4 (5.6, 11.3)	10.0 (7.0, 13.0)	0.45
Women	12.6 (9.8, 15.5)	11.3 (7.6, 14.9)	13.9 (9.7, 18.1)	0.35
<i>Age ≥ 60 years</i>				
Men	31.6 (26.3, 37.0)	40.0 (32.4, 47.6)	24.4 (17.9, 30.9)	0.0023 ^b
Women	36.6 (29.7, 43.5)	41.4 (32.9, 50.0)	31.3 (20.6, 42.1)	0.16
<i>Age 18–39 years</i>				
High school or below	3.2 (2.3, 4.2)	3.6 (2.0, 5.2)	2.8 (1.8, 3.8)	0.42
College or above	2.7 (1.7, 3.7)	2.6 (1.0, 4.2)	2.8 (1.5, 4.1)	0.85
<i>Age 40–59 years</i>				
High school or below	14.1 (11.4, 16.7)	13.1 (10.5, 15.7)	15.1 (10.4, 19.8)	0.44
College or above	7.7 (5.5, 9.8)	5.9 (2.8, 9.0)	9.1 (6.1, 12.0)	0.17
<i>Age ≥ 60 years</i>				
High school or below	36.0 (31.0, 40.9)	40.1 (33.7, 46.6)	31.3 (24.4, 38.3)	0.07
College or above	29.2 (22.1, 36.2)	40.7 (27.8, 53.6)	21.4 (13.6, 29.2)	0.0095 ^b
<i>Men</i>				
High school or below	11.9 (10.4, 13.3)	12.9 (11.1, 14.6)	10.9 (8.5, 13.3)	0.50
College or above	8.6 (6.7, 10.5)	9.7 (6.5, 12.9)	8.1 (5.6, 10.6)	0.62
<i>Women</i>				
High school or below	13.8 (11.4, 16.3)	13.8 (11.3, 16.3)	13.7 (9.4, 18.1)	0.91
College or above	9.6 (7.3, 11.9)	10.9 (7.0, 14.8)	8.7 (6.0, 11.3)	0.82

Abbreviation: CI, confidence interval.

Note: The prevalence of isolated systolic hypertension is age adjusted by direct standardization to the National Health and Nutrition Examination Survey 1999–2010 non-Hispanic black population, except for age-specific estimates.

^aP-value is used to test the significance for the difference in the prevalence of isolated systolic hypertension over 1999–2004 vs. 2005–2010.

^bIndicates the significant difference in the prevalence of isolated systolic hypertension over 1999–2004 vs. 2005–2010.

with higher education in 2005–2010 may reduce the risk of cardiovascular disease and cardiovascular mortality in these subpopulations of non-Hispanic blacks in the future. The causes of the decreased prevalence of untreated ISH in these groups remain unclear and need to be further investigated. The possible reasons may include the increased awareness of hypertension and relatively stable body mass index in old people, particularly in those with higher education.^{22,30}

ISH is a predominant type of hypertension in old people. The prevalence of untreated ISH increased with age, and was the highest in old non-Hispanic blacks (60 years or above) and the lowest in young blacks (18–39 years) in the present study. Changes in the mechanical properties of large vessels, such as the decrease in arterial compliance and increase in stiffness, may be responsible for the increase in SBP.³¹ Aging is associated with deterioration in arterial compliance through both structural and functional changes in large arteries.^{32,33} Structural changes result in a decrease in the lumen-to-wall ratio, the overall lumen cross-sectional area and an increase in arterial stiffness, which involves the aorta and other elastic arteries.

Functional changes result in the baroreceptor dysfunction or lower sensitivity of beta-receptors and increased sympathetic activity. All these changes may raise the level of SBP and cause the higher prevalence of untreated ISH in the old black population. A recent study has linked education to BP in African Americans. The results reveal that higher education is associated with lower adjusted SBP and each increasing year of education is associated with a 0.51 mm of mercury decrease in SBP.³⁴ The findings provide evidence to support the observation in our study that the adults who received a high school education or below had higher prevalence of untreated ISH than the adults who received a college education or above. As our stratification analyses show that education was only significantly associated with the prevalence of untreated ISH in middle-aged adults (not in young or old adults), the higher prevalence of untreated ISH in non-Hispanic blacks with lower education may be largely attributed to middle-aged non-Hispanic blacks who receive a high school education or below.

NHANES is a national comprehensive survey of civilian non-institutionalized representative individuals in the US. A complex

stratified multistage probability sampling design is used to select participants. Oversampling of certain population subgroups (for example, non-Hispanic blacks and Mexican Americans) is performed to increase the reliability and precision of health status indicator estimates for these groups. To account for the NHANES design, we incorporated sampling weights and sampling design variables into data analyses. Our prevalence estimates of untreated ISH are representative at the national level and can be generalized to the entire noninstitutionalized population of US non-Hispanic blacks. However, there are several limitations in our study. Hypertensive individuals who took prescribed medications for treatment were not included in the study because we could not determine what types of hypertension they had (ISH, isolated diastolic hypertension or systolic and diastolic hypertension) due to antihypertensive drug therapy. Exclusion of these hypertensive persons under drug treatment underestimated the prevalence of ISH in the general US population; the results in this study really reflect the prevalence and changes of untreated ISH. A few non-Hispanic black individuals who were diagnosed to have hypertension used non-pharmacological techniques to control hypertension. The information for hypertension subtypes in the hypertensive individuals whose SBP was successfully controlled by increased physical activity, weight loss and other non-pharmacological approach (for example, low-salt diet) was not available. Our definition of ISH treated them as normotensive individuals, and this might also underestimate the prevalence of ISH. The decline in untreated ISH prevalence among older non-Hispanic blacks may have been attributed to increased antihypertensive medication over time. However, the information for the dose and duration of drug use was not captured by NHANES data and thus the change in drug administration could not be evaluated in the present study.

Perspectives

Our study indicates that there were no significant changes in the prevalence of untreated ISH in young and middle-aged non-Hispanic blacks from 1999–2004 to 2005–2010. However, untreated ISH was more prevalent in old non-Hispanic blacks, and significant reduction in the prevalence of untreated ISH in 2005–2010 was found in older individuals. These findings suggest that public health interventions, lifestyle modifications or increased health awareness are probably in effect or changes in clinical practice are in the right direction. The higher prevalence of untreated ISH and no significant reductions over time in non-Hispanic blacks who receive a high school education or below indicate that more attention should be paid to this special population by encouraging them for higher education and educating them on healthy lifestyles. Non-Hispanic blacks with untreated hypertension will benefit from lifestyle modifications (for example, smoking cessation, low-salt diet and graded exercise), pharmacologic therapy for controlling SBP and aggressive treatment of major cardiovascular risk factors such as diabetes and hyperlipidemia by full implementation of seventh Joint National Commission guidelines.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Supplementary Information accompanies the paper on Hypertension Research website (<http://www.nature.com/hr>)