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Prevalence and trends of isolated systolic hypertension among untreated adults in the United States

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Abstract

The prevalence and long-term trends of isolated systolic hypertension (ISH) among untreated adults have not been reported. Data from 24,653 participants aged 18 years were selected from the National Health and Nutrition Examination Survey 1999–2010. The prevalence and 95% confidence intervals (CIs) of untreated ISH were estimated by conducting the independent survey *t*-test. The prevalence of untreated ISH was 9.4% and decreased from 10.3% in 1999–2004 to 8.5% in 2005–2010 ($P = .00248$). Old persons, females, and non-Hispanic blacks had higher prevalence of untreated ISH. Compared with 1999–2004, the prevalence of untreated ISH in 2005–2010 decreased among older (33.6%; 95% CI, 30.9%–36.3% vs. 25.1%; 95% CI, 22.7%–27.5%) and female individuals (8.3%; 95% CI, 7.5–9.2% vs. 11.4%; 95% CI, 10.4–12.3%). The stratified prevalence of untreated ISH declined in 2005–2010 (vs. 1999–2004) for older non-Hispanic whites (24.6% vs. 32.8%; $P < .0001$) and blacks (27.7% vs. 40.8%; $P = .0013$), non-Hispanic white females (7.5% vs. 10.8%; $P < .0001$), older individuals with higher education (21.0% vs. 30.6%; $P = .0024$), and females with lower education (10.1% vs. 13.1%; $P = .006$). Untreated ISH is more prevalent in older adults and females. Significant decreases in untreated ISH prevalence over time among these groups suggest that public health measures and/or treatment patterns are trending in the right direction.

Keywords

Blood pressure; hypertension; isolated systolic hypertension; prevalence

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Supplementary Data

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Introduction

Isolated systolic hypertension (ISH) is an important hypertension subtype. It is defined as a systolic blood pressure (SBP) of ≥ 140 mm Hg and a diastolic blood pressure (DBP) of <90 mm Hg.¹ ISH is often characterized as a phenomenon of aging as SBP increases as a reflection of increasing arterial stiffness and losses in arterial compliance with age.^{2,3} After age 50, ISH becomes the major form of hypertension.⁴ Elevated SBP has been thought to be more important than elevated DBP as a risk factor for adverse cardiovascular and renal outcomes.^{5–8} With increasing age, there is a gradual shift from DBP to SBP as predictors of cardiovascular risk.⁹ When combined with other risk factors such as poor diet and lack of exercise, untreated ISH can lead to serious health problems, such as stroke, heart disease, chronic kidney disease, and dementia.^{10–13}

Although the prevalence of ISH has been reported in the untreated adult populations from several international studies, inconsistent age selections between studies have limited available data on untreated ISH, and made comparison across studies difficult.^{14–16} The existing studies of pattern changes in rates of ISH in the US adult population focus on uncontrolled hypertension subtypes among individuals with uncontrolled blood pressure, and the prevalence and changes of untreated ISH in the general population was not the main focus.^{3,17} In addition, the studies were based on the data collected two decades ago (the third National Health and Nutrition Examination Survey [NHANES III], 1988–1994). More recent prevalence estimates and long-term changes of ISH among US untreated adults are needed to fill the gap in the hypertension literature.

In this study, we used available data from NHANES 1999–2010 to estimate the prevalence of untreated ISH, identify the long-term trends in the ISH prevalence, and determine whether these trends reflect recent changes in the prevalence or distribution of correlated risk factors (eg, obesity and smoking). Specific attention was directed toward estimating the prevalence of untreated ISH in the subpopulations of adults stratified by age, gender, race/ethnicity, and education.

Methods

Study Design and Population

Public-use data from the continuous NHANES program 1999–2010 (including demographic questionnaire and examination files) were built up for this study. The continuous NHANES included a series of 2-year cross-sectional stratified multistage surveys designed to assess the health and nutrition status among children and adults in the US.¹⁸ In each 2-year cycle of the survey, a nationally representative sample (approximately 10,000 people) of the US civilian non-institutionalized population was selected from 30 counties across the country through a stratified multistage probability clustered sampling design. All surveys consisted of two sections: interviews and examination. Interviews were performed in the participants' home to obtain information for sociodemographic characteristics and history of diseases. Examination was conducted in the Mobile Examination Center to obtain measurements about examination and clinical/laboratory factors. All participants provided informed

consent and the data were approved by the Centers for Disease Control and Prevention Institutional Review Board to ensure confidentiality.

We analyzed data from six cycles of NHANES surveys from 1999 to 2010 to have adequate sample sizes and power for subgroup analyses. The sample from each survey was weighted to the US population corresponding to the respective time periods during which the surveys were 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.

There were 62,160 individuals interviewed or examined in NHANES 1999–2010. The participants aged <18 years ($n = 26,781$) were excluded from this study. We also excluded those persons who only participated in the interview or examination but not both ($n = 1819$), who had incomplete SBP or DBP measurements ($n = 1691$), or who were taking antihypertensive medications for hypertension when being interviewed ($n = 7216$). Finally, a total of 24,653 untreated adults were available in the continuous NHANES for further study, among which 12,018 persons were from NHANES 1999–2004 and 12,635 persons from NHANES 2005–2010.

Blood Pressure and Isolated Systolic Hypertension Assessment

Blood pressure was measured by certified physician examiners using mercury sphygmomanometers in accordance with a standardized procedure.¹⁹ Up to four SBP and DBP readings on each participant were recorded for accuracy consideration after the participant had rested quietly in a sitting position for 5 minutes and the examiner determined the maximum inflation level. The average SBP and DBP were calculated for each participant based on individual readings according to the NHANES specifications. Consistent with the Seventh Joint National Commission guidelines,¹² hypertension was defined as SBP ≥ 140 mm Hg or DBP ≥ 90 mm Hg. A participant was considered to have isolated systolic hypertension if his/her SBP ≥ 140 mm Hg and DBP was <90 mm Hg.

Cross Factors of Interest

Four demographic characteristics (age, gender, race, and education) were selected to see differences in the prevalence of untreated ISH across the factors. Sociodemographic information on age, gender, race, and education were assessed through questionnaire files of NHANES. Participants were divided into three groups in terms of age: young adults (aged 18 and <40 years), middle-aged adults (aged 40 and <60 years), and old adults (aged ≥ 60 years). The survey population included four races of people: Hispanic (including non-Mexican Hispanic and Mexican American), non-Hispanic white, non-Hispanic black, and other race (including American Indian, Alaskan Native, Asian or Pacific Islander, and other race not specified for sufficient number of individuals and meaningful analyses). The

participant's level of education was classified as high school or below and college or above, based on the number of years in school.

Statistical Analysis

NHANES report and analysis guidelines were followed for data analyses.²⁰ The study sample with a stratified multistage sampling design was obtained by combining six 2-year cycles of continuous NHANES to estimate overall prevalence of untreated ISH from 1999 to 2010. The 6-year prevalence of untreated ISH was also estimated to examine differences/changes in the prevalence during 2005–2010 versus 1999–2004. 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, Hispanics, and individuals aged 60 years or more in the NHANES survey.

Since 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 Taylor series standard errors. Independent *t*-test was used to compare means of continuous characteristics, and χ^2 and the Cochran–Mantel–Haenszel tests were used for categorical survey data. We calculated age-adjusted descriptive statistics for subject characteristics using PROC SURVEYMEANS for continuous variables and PROC SURVEYREG for categorical values. The prevalence estimates of untreated ISH (unadjusted or age-adjusted) were calculated using PROC SURVEYREG. Ninety-five percent confidence intervals (CIs) were reported to examine the differences of characteristics and untreated ISH prevalence over the 6-year lapse of time. Statistical analyses were performed using SAS statistical software (SAS version 9.2, SAS Institute Inc, Cary, NC).

Results

In the present study, data on 24,653 adults (12,018 from NHANES 1999–2004 and 12,635 from NHANES 2005–2010) were included. Average age of participants in the study sample was 41.6 years. A total of 50.7% were female, 13.6% were Hispanic, 71.3% were non-Hispanic white, and 9.7% were non-Hispanic black. Of all the participants, 45.0% received a high school education or below. There were no significant differences in socio-demographic characteristics between NHANES 1999–2004 and NHANES 2005–2010 (Table 1).

The overall prevalence of ISH among untreated adults in 1999–2010 was 9.4%. The prevalence of untreated ISH decreased significantly from 10.3% in 1999–2004 (95% CI, 9.4%–11.1%) to 8.5% in 2005–2010 (95% CI, 7.7%–9.3%; *P* = .003; Figure 1). Prevalence and changes of untreated ISH by age, gender, race, and education in NHANES 1999–2010 are presented in Table 2. The prevalence of untreated ISH increased with increasing age; older adults had a higher ISH prevalence than middle-aged adults whose prevalence was higher than young adults. Non-Hispanic blacks had a higher prevalence of untreated ISH

than non-Hispanic whites ($P = .006$). Adults who attained high school education or below had higher prevalence than those with higher levels of education ($P = .01$). Compared with 1999–2004, the prevalence of untreated ISH in 2005–2010 declined significantly among older adults (25.1% vs. 33.6%; $P < .0001$), females (8.3% vs. 11.4%; $P < .0001$), and non-Hispanic whites (8.1% vs. 9.9%; $P = .0319$). There were no significant differences in the prevalence over other races or education levels between 1999–2004 and 2005–2010.

Prevalence estimates and changes of untreated ISH stratified by the combination of age and other characteristics are listed in Table 3. The prevalence of untreated ISH decreased significantly in 2005–2010 versus 1999–2004 for older females (39.2% vs. 27.7%; $P = .001$), older non-Hispanic whites (32.8% vs. 24.6%; $P < .0001$), and blacks (40.8% vs. 27.7%; $P = .001$), as well as older adults with higher education (30.6% vs. 21.0%; $P = .002$). Although the prevalence of untreated ISH was lower in younger females compared with young males (0.7% vs. 2.9%; $P < .0001$), ISH was higher in older females than in older males (33.5% vs. 24.7%; $P < .0001$). Non-Hispanic blacks had higher prevalence of untreated ISH than Hispanics and non-Hispanic whites among young adults and middle-aged adults (black 11.0% vs. Hispanic 6.1%, white 5.3%, other race 5.9%). Compared with adults with higher education, adults with lower education (high school or below) had a higher prevalence of untreated ISH in both middle-aged (8.0% vs. 4.7%; $P = .00923$) and older groups (32.8% vs. 25.4%; $P = .003$). Further analysis on the prevalence of ISH reconsidered the age categories as <60 years and ≥60 years, and are shown in Supplemental Tables 1 and 2.

Prevalence estimates and changes of untreated ISH stratified by gender and race, gender and education, and education and race are presented in Table 4. Although the stratified prevalence of untreated ISH in 2005–2010 tended to decrease, it was not shown to be significantly different from the prevalence in 1999–2004 except for non-Hispanic white females (7.5% in 2005–2010 vs. 10.8% in 1999–2004; $P < .0001$) and females who did not attend college (10.1% in 2005–2010 vs. 13.1% in 1999–2004; $P = .006$). Non-Hispanic black males had higher prevalence of untreated ISH than other males (black males 12.2% vs. white males 8.7%, Hispanic males 8.4%, other males 6.3%; $P < .0001$), and non-Hispanic black females had a higher prevalence than non-Hispanic white females (black females 13.4% vs. white females 9.2%; $P = .005$). Adults with lower education levels had higher prevalence of untreated ISH than adults with higher education in both males and females (10.0% vs. 7.9%; $P = .046$ for males; 11.7% vs. 8.0%; $P = .0079$ for females). Stratification analysis by education and race indicated that the prevalence of untreated ISH was higher in low-educated non-Hispanic blacks (14.4%; 95% CI, 12.8–16.0%) than in low-educated non-Hispanic whites (14.4% vs. 10.5%; $P = .002$) and Hispanics (14.4% vs. 11.3%; $P = .03$).

Discussion

The NHANES data are valuable for the study of the prevalence and trends in the health status of a population because of its large sample size, complex sampling design, good quality control, and comprehensive content.¹⁸ It has been used to study the pattern of hypertension subtypes^{3,17} and racial disparity in cardiovascular risk factors,²¹ as well as the

prevalence, awareness, treatment, and control of hypertension in the United States.^{22–24} Our analysis estimates the prevalence and changes of untreated ISH over time in the population of US adults and in the subpopulations of adults stratified by age, gender, race/ethnicity, and education. The overall prevalence of ISH among untreated adults has decreased significantly from 1999–2004 to 2005–2010. This trend is supported by a study of stroke mortality showing that mean SBP has declined in the last few decades.²⁵ The prevalence of untreated ISH in 2005–2010 also decreased significantly in old and female adults compared with 1999–2004. Our analyses indicated that the prevalence of untreated ISH in 2005–2010 was not significantly different from the prevalence in 1999–2004 except for older females, older non-Hispanic whites and older blacks, all non-Hispanic white females, as well as older adults with higher educational attainment and all females with lower education.

The prevalence estimate of untreated ISH among adults aged 18–39 years was 1.62% during 1999–2004 in the present study. The result is consistent with the estimate ($1.57\% \pm 0.23\%$) from a previous study about ISH among young adults, considering minor difference in exclusion criteria between studies.¹ A separate analysis was performed to estimate the prevalence of untreated ISH among adults aged 18–39 years in NHANES III (1988–1994). The prevalence of untreated ISH among young adults has more than doubled between the NHANES III and 1999–2004 surveys (0.66% vs. 1.62%) and tends to increase from 1999–2004 to 2005–2010 among young adults (although statistically not significant).

ISH is the most common hypertension subtype in participants aged 60 years or older, and the decreased prevalence of untreated ISH in the old adults in this study may have significant clinical relevance. Every 20 mm Hg 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.¹ The absolute risk of cardiovascular (CV) 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, and extend the overall life expectancy and life expectancy free of CV disease in the old adults. The potential reason for the lowered prevalence in the recent 6 years compared with 1999–2004 may be due to an increased awareness of hypertension, greater concerns in health status, improved lifestyles in older people, and changing treatment patterns.^{23,27}

Elevated SBP has been shown to be a stronger risk factor of myocardial infarction for women compared with men.²⁸ Among women aged 65–84 years, the hazard of death significantly increased with increase in SBP.²⁹ In this study, the decreased prevalence of untreated ISH in females, particularly in older females in 2005–2010, may help to reduce the risk of myocardial infarction and CV-related mortality in the future. One likely reason for the decline in untreated ISH is that more ISH is being treated. The percentage of treated hypertensive patients (including all hypertension subtypes) aged 60 years or above increased from 67.9% in 1999–2004 to 79.6% in 2005–2010 ($P < .0001$), and the percentage of treated hypertensive females increased from 65.1% to 77.8% ($P < .0001$; See Supplemental Table 3). This potential explanation is also supported by the finding from another study recently published in *Circulation*.³⁰ Other possible reasons may include a greater awareness of hypertension and the lack of increase in body mass index (BMI) in females, particularly in older females.^{24,31} Those aware of their hypertension are more likely to be treated than

those unaware of their hypertension; thus potentially those participants would not be accounted for in our ISH prevalence rates. Increased BMI is a known risk factor for development of ISH; then potentially ISH can be less likely to develop if BMI has not increased over time. The lack of increased prevalence of untreated ISH in other categories of characteristics may be because of the lack of a further increase in BMI in the population, although there was an increase in waist circumference (results not shown). Better publicity and education and effort from health professionals may be another reason for this.

According to the national goal of Healthy People 2020, the proportion of adults with hypertension should be reduced to 26.9%.³² Since NHANES did not capture the detailed information on hypertension subtypes for treated hypertensive individuals, only the individuals with untreated ISH could be identified and hence included for further analysis. This may cause a major concern that the decline in untreated ISH is due to more treatment of hypertension and cannot be used as solid evidence to support the promising goal of Healthy People 2020. The higher prevalence of untreated ISH in young males than in young females and the increased trend in the prevalence in young males necessitates the escalation of efforts to prevent ISH in this subpopulation. The prevalence of untreated ISH was relatively high and did not decline from 1999–2004 to 2005–2010 among old males, old Hispanics, and old persons with a high school education or below. To meet Healthy People 2020, greater attention must be paid to these groups in the United States.

NHANES is a large national survey of civilian non-institutionalized representative individuals in the US. Our prevalence estimates of untreated ISH are representative and can be generalized to the entire non-institutionalized population in the US. However, there are several limitations in our study. NHANES is a cross-sectional survey without follow-up, and hence the selected data could not be used for the causal effects of risk factors on the reduction of SBP. Hypertensive individuals who took prescribed medications for treatment were not included in the study because once treated within the NHANES dataset, we could not determine their hypertension subtypes (ISH, diastolic/systolic hypertension vs. isolated diastolic hypertension) due to the effects of antihypertensive drug therapy. Exclusion of these hypertensive persons under drug treatment might underestimate the prevalence of ISH in the general US population. A few individuals who were diagnosed to have hypertension may have used non-pharmacological techniques for BP control. The information on hypertension subtypes among hypertensive patients who were successfully controlled by physical activity, weight control, and other non-pharmacological techniques was not available. Our definition of ISH treated these individuals as normotensive persons, and this might also underestimate the prevalence of ISH in our study.

Conclusions

Our study indicated that there were no significant changes in the prevalence of ISH in young and middle-aged individuals and males from 1999–2004 to 2005–2010. However, ISH was more prevalent in old people and females, and there were significant improvements over time among these groups. These findings suggest that public health measures or changes in clinical practice are trending in the right direction. The higher prevalence of ISH in non-

Hispanic blacks compared with other races and no significant reductions over time reveal that more attention should be paid to this racial population in the future.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Grebla RC, Rodriguez CJ, Borrell LN, Pickering TG. Prevalence and determinants of isolated systolic hypertension among young adults: the 1999–2004 US National Health and Nutrition Examination Survey. *J Hypertens*. 2010; 28:15–23. [PubMed: 19730124]
2. Franklin SS, Jacobs MJ, Wong ND, L'Italien GJ, Lapuerta P. Predominance of isolated systolic hypertension among middle-aged and old US hypertensives: analysis based on National Health and Nutrition Examination Survey (NHANES) III. *Hypertension*. 2001; 37:869–74. [PubMed: 11244010]
3. Nichols, WW.; O'Rourke, MF., editors. McDonald's blood flow in arteries: theoretical, experimental and clinical principles. 5th ed. Hodder Headline Group; London, UK: 2005.
4. Chobanian AV. Isolated systolic hypertension in the elderly. *N Engl J Med*. 2007; 357:789–96. [PubMed: 17715411]
5. Izzo JL, Levy D, Black HR. Importance of systolic blood pressure in older Americans. *Hypertension*. 2000; 35:1021–4. [PubMed: 10818056]
6. Forette F, Seux M-L, Staessen JA, Thijs L, Birkenhäger WH, Babarskiene MR, et al. Prevention of dementia in randomized double-blind placebo-controlled Systolic Hypertension in Europe (Syst-Eur) trial. *Lancet*. 1998; 352:1347–51. [PubMed: 9802273]
7. Wright JT Jr, Fine LJ, Lackland DT, Ogedegbe G, Himmelfarb CRD. Evidence supporting a systolic blood pressure goal of less than 150 mm hg in patients aged 60 years or older: the minority view. *Ann Intern Med*. 2014; 160:499–503. [PubMed: 24424788]
8. James PA, Oparil S, Carter BL, Cushman WC, Dennison-Himmelfarb C, Handler J, et al. 2014 evidence-based guideline for the management of high blood pressure in adults: report from the panel members appointed to the Eighth Joint National Committee (JNC 8). *JAMA*. 2014; 311:507–20. [PubMed: 24352797]
9. Franklin SS, Larson MG, Khan SA, Wong ND, Leip EP, Kannel WB, et al. Does the relation of blood pressure to coronary heart disease risk change with aging?: the Framingham Heart Study. *Circulation*. 2001; 103:1245–9. [PubMed: 11238268]
10. Qureshi AI, Suri MFK, Mohammad Y, Guterman LR, Hopkins LN. Isolated and borderline isolated systolic hypertension relative to long-term risk and type of stroke: a 20-year follow-up of the National Health and Nutrition Survey. *Stroke*. 2002; 33:2781–8. [PubMed: 12468770]
11. Ekundayo OJ, Allman RM, Sanders PW, Aban I, Love TE, Arnett D, et al. Isolated systolic hypertension and incident heart failure in older adults: a propensity-matched study. *Hypertension*. 2009; 53:458–65. [PubMed: 19188527]
12. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL Jr, et al. 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; 289:2560–72. [PubMed: 12748199]

13. Neaton JD, Wentworth D. Serum cholesterol, blood pressure, cigarette smoking, and death from coronary heart disease. Overall findings and differences by age for 316,099 white men. Multiple Risk Factor Intervention Trial Research Group. *Arch Intern Med.* 1992; 152:56–64. [PubMed: 1728930]
14. Huang J, Wildman RP, Gu D, Muntner P, Su S, He J. Prevalence of isolated systolic and isolated diastolic hypertension subtypes in China. *Am J Hypertens.* 2004; 17:955–62. [PubMed: 15485760]
15. Clara JG, De Macedo ME, Pego M. Prevalence of isolated systolic hypertension in the population over 55 years old: results from a national study. *Rev Port Cardiol.* 2007; 26:11–7. [PubMed: 17427833]
16. Antikainen RL, Jousilahti P, Tuomilehto J. Trends in the prevalence of isolated systolic hypertension in the middle-aged population in 1972–1992. *J Hum Hypertens.* 1999; 13:485–91. [PubMed: 10449214]
17. Joffres MR, Hamet P, MacLean DR, L'Italien GJ, Fodor G. Distribution of blood pressure and hypertension in Canada and the United States. *Am J Hypertens.* 2001; 14:1099–105. [PubMed: 11724207]
18. National Center for Health Statistics. [Accessed January 16, 2012] Distribution of blood pressure and hypertension in Canada and the United States. Available at: http://www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm
19. National Health and Nutrition Examination Survey. [Accessed February 5, 2012] Physician examination procedures manual. Aug. 2009 Available at: http://www.cdc.gov/nchs/data/nhanes/nhanes_09_10/physician.pdf
20. [Accessed April 7, 2012] The National Health and Nutrition Examination Surveys: analytic and reporting guidelines. Available at: http://www.cdc.gov/nchs/data/nhanes/nhanes_03_04/nhanes_analytic_guidelines_dec_2005.pdf
21. Liu XF, Liu M, Tsilimingras D, Schiffrin EL. Racial disparities in cardiovascular risk factors among diagnosed hypertensive subjects. *J Am Soc Hypertens.* 2011; 5:239–48. [PubMed: 21524638]
22. Hajjar I, Kotchen TA. Trends in prevalence, awareness, treatment and control of hypertension in the United States, 1988–2000. *JAMA.* 2003; 290:199–206. [PubMed: 12851274]
23. Ong KL, Cheung BM, Man YB, Lau CP, Lam KSL. Prevalence, awareness, treatment and control of hypertension among United States adults, 1999–2004. *Hypertension.* 2007; 49:69–75. [PubMed: 17159087]
24. Egan BM, Zhao Y, Axon RN. US trends in prevalence, awareness, treatment, and control of hypertension, 1988–2008. *JAMA.* 2010; 303:2043–50. [PubMed: 20501926]
25. Lackland DT, Roccella EJ, Deutsch AF, Fornage M, George MG, Howard G, et al. Factors influencing the decline in stroke mortality: a statement from the American Heart Association/American Stroke Association. *Stroke.* 2014; 45:315–53. [PubMed: 24309587]
26. Lewington S, Clarke R, Qizilbash N, Peto R, Collins R. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *Lancet.* 2002; 360:1903–13. [PubMed: 12493255]
27. Roger VL, Go AS, Lloyd-Jones DM, Adams RJ, Berry JD, Brown TM, et al. Heart disease and stroke statistics–2011 update: a report from the American Heart Association. *Circulation.* 2011; 123:e18–209. [PubMed: 21160056]
28. Jonsdottir LS, Sigfusson N, Gudnason V, Sigvaldason H, Thorgeirsson G. Do lipids, blood pressure, diabetes, and smoking confer equal risk of myocardial infarction in women as in men? The Reykjavik Study. *J Cardiovasc Risk.* 2002; 9:67–76. [PubMed: 12006913]
29. Satish S, Freeman DH Jr, Ray L, Goodwin JS. The relationship between blood pressure and mortality in the oldest old. *J Am Geriatr Soc.* 2001; 49:367–74. [PubMed: 11347778]
30. Egan BM, Li J, Shatat IF, Fuller JM, Sinopoli A. Closing the gap in hypertension control between younger and older adults: National Health and Nutrition Examination Survey (NHANES) 1988 to 2010. *Circulation.* 2014; 129:2052–61. [PubMed: 24733570]
31. Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999–2010. *JAMA.* 2012; 307:491–7. [PubMed: 22253363]

32. US Department of Health and Human Services. [Accessed August 24, 2012] Healthy People 2020: Topics and Objectives. Available at: <http://www.healthypeople.gov/2020/topicsobjectives2020/default.aspx>

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Figure 1.

Prevalence and 95% confidence intervals of isolated systolic hypertension (ISH) among untreated adults by survey cycles in National Health and Nutrition Examination Survey (NHANES) 1999–2010, United States. $P = .00248$ indicates the significant difference in the prevalence of untreated ISH between periods 1999–2004 and 2005–2010).

Table 1

Characteristics of participants in the National Health and Nutrition Examination Survey (NHANES) 1999–2010, United States

Characteristics	Overall	Mean or Percentage (95% CI)		
		NHANES 1999–2004	NHANES 2005–2010	P Values
Age, y	41.6 (41.3, 42.0)	41.6 (41.1, 42.2)	41.6 (41.1, 42.2)	.97
Gender				
Female, %	50.7 (50.2, 51.3)	50.8 (49.9, 51.7)	50.7 (49.9, 51.5)	.94
Race				
Hispanic, %	13.6 (11.7, 15.6)	13.4 (10.3, 16.5)	13.9 (11.3, 16.4)	.79
Non-Hispanic white, %	71.3 (69.0, 73.7)	72.5 (69.2, 75.7)	70.3 (66.7, 73.8)	.34
Non-Hispanic black, %	9.7 (8.5, 10.8)	9.5 (7.7, 11.2)	9.9 (8.2, 11.5)	.74
Other race, %	5.4 (4.7, 6.1)	4.7 (3.8, 5.7)	6.0 (5.0, 7.1)	.07
Education				
High school or below, %	45.0 (43.4, 46.5)	47.0 (44.7, 49.2)	43.0 (40.8, 45.2)	.06

CI, confidence interval.

Notes: Data were age-adjusted (except for age-specific estimates) by direct standardization to the 2000 projected US population.

P value indicates the significance of the difference in means or percentages of characteristics between periods 1999–2004 and 2005–2010.

Table 2

Prevalence and changes of isolated systolic hypertension (ISH) by age, gender, race, and education among untreated adults in the National Health and Nutrition Examination Survey (NHANES) 1999–2010, United States

Characteristics	Overall, %	Prevalence (95% CI)		
		NHANES 1999–2004, %	NHANES 2005–2010, %	P Values
Age, y				
18–39	1.8 (1.4, 2.1)	1.6 (1.1, 2.1)	1.9 (1.4, 2.4)	.41
40–59	6.0 (5.2, 6.8)	5.9 (4.7, 7.2)	6.0 (5.0, 7.0)	.91
60	29.4 (27.6, 31.2)	33.6 (30.9, 36.3)	25.1 (22.7, 27.5)	<.0001
Gender				
Male	8.9 (8.1, 9.6)	9.0 (8.0, 10.1)	8.7 (7.6, 9.8)	.74
Female	9.9 (9.2, 10.5)	11.4 (10.4, 12.3)	8.3 (7.5, 9.2)	<.0001
Race				
Hispanic	10.4 (8.9, 11.9)	11.1 (8.7, 13.6)	9.5 (8.0, 10.9)	.45
Non-Hispanic white	9.0 (8.3, 9.6)	9.9 (8.9, 10.8)	8.1 (7.2, 9.0)	.0319
Non-Hispanic black	12.8 (11.5, 14.0)	13.9 (12.1, 15.7)	11.6 (9.8, 13.4)	.59
Other race	8.8 (6.6, 10.9)	9.1 (5.4, 12.8)	8.5 (6.0, 11.0)	.84
Education				
High school or below	11.0 (10.3, 11.8)	11.8 (10.6, 13.0)	10.1 (9.1, 11.0)	.37
College or above	8.0 (7.2, 8.7)	8.8 (7.9, 9.8)	7.2 (6.2, 8.3)	.06

CI, confidence interval.

Note: The prevalence estimates of ISH were age-adjusted (except for the age-specific estimates) by direct standardization to the 2000 projected US population.

P value indicates the significance of the difference in the prevalence of untreated ISH between periods 1999–2004 and 2005–2010.

Table 3

Prevalence and changes of isolated systolic hypertension (ISH) stratified by age and gender, age and race, and age and education among untreated adults in the National Health and Nutrition Examination Survey (NHANES) 1999–2010, United States

Characteristics	Overall, %	Stratified Prevalence (95% CI)		
		NHANES 1999–2004, %	NHANES 2005–2010, %	P Values
Stratified by age and gender				
Age 18–39 y				
Male	2.9 (2.2, 3.5)	2.4 (1.5, 3.4)	3.3 (2.4, 4.3)	.15
Female	0.7 (0.4, 0.9)	0.9 (0.5, 1.3)	0.5 (0.2, 0.8)	.15
Age 40–59 y				
Male	6.1 (5.0, 7.1)	5.5 (3.9, 7.0)	6.6 (5.2, 8.1)	.28
Female	5.9 (4.9, 6.9)	6.4 (4.9, 7.9)	5.4 (4.1, 6.7)	.31
Age 60 y				
Male	24.7 (22.5, 26.9)	27.2 (24.1, 30.4)	22.1 (19.0, 25.3)	.0532
Female	33.5 (31.2, 35.8)	39.2 (35.6, 42.7)	27.7 (24.6, 30.9)	.0014
Stratified by age and race				
Age 18–39 y				
Hispanic	1.6 (1.0, 2.1)	1.8 (0.8, 2.8)	1.3 (0.8, 1.9)	.37
Non-Hispanic white	1.6 (1.2, 2.1)	1.3 (0.7, 1.9)	1.9 (1.2, 2.7)	.22
Non-Hispanic black	3.0 (2.2, 3.8)	3.2 (1.8, 4.5)	2.8 (2.0, 3.6)	.66
Other race	1.6 (0.4, 2.8)	1.1 (0.0, 2.5)	2.0 (0.1, 3.8)	.46
Age 40–59 y				
Hispanic	6.1 (4.6, 7.5)	5.3 (3.3, 7.3)	6.7 (4.6, 8.8)	.33
Non-Hispanic white	5.3 (4.4, 6.3)	5.6 (4.1, 7.1)	5.1 (3.9, 6.3)	.62
Non-Hispanic black	11.0 (9.1, 12.8)	9.8 (7.4, 12.2)	12.0 (9.2, 14.8)	.23
Other race	5.9 (3.0, 8.8)	5.4 (0.9, 10.0)	6.2 (2.5, 10.0)	.79
Age 60 y				
Hispanic	33.8 (28.0, 39.6)	38.1 (28.7, 47.4)	29.2 (24.2, 34.2)	.08
Non-Hispanic white	28.8 (26.8, 30.7)	32.8 (30.0, 35.7)	24.6 (21.9, 27.3)	<.0001
Non-Hispanic black	34.2 (29.9, 38.4)	40.8 (34.9, 46.6)	27.7 (22.2, 33.2)	.0013
Other race	27.0 (19.3, 34.8)	30.3 (16.9, 43.7)	24.3 (15.5, 33.1)	.44
Stratified by age and education				
Age 18–39 y				
High school or below	2.0 (1.5, 2.6)	2.4 (1.4, 3.4)	1.7 (1.1, 2.2)	.17
College or above	1.6 (1.1, 2.0)	0.9 (0.5, 1.4)	2.1 (1.4, 2.8)	.0048
Age 40–59 y				
High school or below	8.0 (6.8, 9.2)	7.9 (6.0, 9.9)	8.0 (6.5, 9.6)	.93
College or above	4.7 (3.7, 5.6)	4.6 (3.4, 5.9)	4.7 (3.2, 6.2)	.92
Age 60 y				
High school or below	32.8 (30.4, 35.2)	35.7 (31.9, 39.5)	29.3 (26.3, 32.3)	.07
College or above	25.4 (22.9, 27.8)	30.6 (27.2, 33.9)	21.0 (17.6, 24.4)	.0024

CI, confidence interval.

Notes: *P* value indicates the significance of the difference in the prevalence of untreated ISH between periods 1999–2004 and 2005–2010.

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Table 4

Prevalence and changes of isolated systolic hypertension (ISH) stratified by gender and race, gender and education, and education and race among untreated adults in the National Health and Nutrition Examination Survey (NHANES) 1999–2010, United States

Characteristics	Overall, %	Stratified Prevalence (95% CI)		
		NHANES 1999–2004, %	NHANES 2005–2010, %	P Values
Stratified by gender and race				
Male				
Hispanic	8.4 (7.0, 9.9)	8.6 (6.1, 11.2)	8.2 (6.7, 9.8)	.97
Non-Hispanic white	8.7 (7.8, 9.6)	8.7 (7.5, 9.9)	8.7 (7.3, 10.0)	.77
Non-Hispanic black	12.2 (10.7, 13.6)	13.6 (11.8, 15.5)	10.9 (8.7, 13.1)	.75
Other race	6.3 (3.8, 8.8)	5.5 (1.6, 9.4)	7.0 (3.7, 10.3)	.25
Female				
Hispanic	12.1 (10.2, 14.0)	13.2 (10.5, 16.0)	10.7 (8.5, 12.9)	.20
Non-Hispanic white	9.2 (8.5, 9.8)	10.8 (9.8, 11.9)	7.5 (6.6, 8.4)	<.0001
Non-Hispanic black	13.4 (11.4, 15.4)	14.2 (12.0, 16.5)	12.5 (9.1, 15.8)	.66
Other race	11.0 (8.0, 14.0)	11.7 (6.7, 16.7)	10.2 (6.6, 13.9)	.52
Stratified by gender and education				
Male				
High school or below	10.0 (9.0, 10.9)	10.0 (8.4, 11.6)	9.9 (8.7, 11.1)	.72
College or above	7.9 (7.0, 8.9)	8.2 (7.1, 9.4)	7.7 (6.3, 9.1)	.38
Female				
High school or below	11.7 (10.8, 12.7)	13.1 (11.7, 14.5)	10.1 (8.8, 11.5)	.006
College or above	8.0 (7.1, 9.0)	9.5 (8.1, 10.9)	6.8 (5.6, 8.1)	.11
Stratified by education and race				
High school or below				
Hispanic	11.3 (9.8, 12.7)	12.0 (9.7, 14.3)	10.5 (8.9, 12.0)	.24
Non-Hispanic white	10.5 (9.6, 11.5)	11.4 (9.9, 12.9)	9.5 (8.3, 10.6)	.08
Non-Hispanic black	14.4 (12.8, 16.0)	15.1 (13.3, 17.0)	13.6 (10.9, 16.2)	.59
Other race	9.8 (6.1, 13.4)	9.8 (4.2, 15.5)	9.9 (5.4, 14.3)	.57
College or above				
Hispanic	7.2 (4.8, 9.7)	8.2 (3.8, 12.5)	6.4 (3.9, 9.0)	.72
Non-Hispanic white	7.8 (7.0, 8.6)	8.7 (7.7, 9.7)	7.1 (5.9, 8.3)	.25
Non-Hispanic black	10.4 (8.5, 12.2)	12.3 (8.8, 15.7)	9.2 (7.2, 11.2)	.84
Other race	8.1 (5.7, 10.6)	8.4 (4.2, 12.6)	8.0 (5.0, 11.0)	.90

CI, confidence interval.

Notes: The stratified prevalence estimates of ISH were age-adjusted by direct standardization to the 2000 projected US population.

P value indicates the significance of the difference in the prevalence of untreated ISH between periods 1999–2004 and 2005–2010.