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Trends in Prehypertension and Hypertension Risk Factors in US Adults 1999–2012

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Abstract—Prehypertension is associated with increased risk for hypertension and cardiovascular disease. Data are limited on the temporal changes in the prevalence of prehypertension and risk factors for hypertension and cardiovascular disease among US adults with prehypertension. We analyzed data from 30 958 US adults ≥20 years of age who participated in the National Health and Nutrition Examination Surveys between 1999 and 2012. Using the mean of 3 blood pressure (BP) measurements from a study examination, prehypertension was defined as systolic BP of 120 to 139 mm Hg and diastolic BP <90 mm Hg or diastolic BP of 80 to 89 mm Hg and systolic BP <140 mm Hg among participants not taking antihypertensive medication. Between 1999–2000 and 2011–2012, the percentage of US adults with prehypertension decreased from 31.2% to 28.2% (*P* trend=0.007). During this time period, the prevalence of several risk factors for cardiovascular disease and incident hypertension increased among US adults with prehypertension, including prediabetes (9.6% to 21.6%), diabetes mellitus (6.0% to 8.5%), overweight (33.5% to 37.3%), and obesity (30.6% to 35.2%). There was a nonstatistically significant increase in no weekly leisure-time physical activity (40.0% to 43.9%). Also, the prevalence of adhering to the Dietary Approaches to Stop Hypertension eating pattern decreased (18.4% to 11.9%). In contrast, there was a nonstatistically significant decline in current smoking (25.9% to 23.2%). In conclusion, the prevalence of prehypertension has decreased modestly since 1999–2000. Population-level approaches directed at adults with prehypertension are needed to improve risk factors to prevent hypertension and cardiovascular disease. **(*Hypertension*. 2017;70:275-284. DOI: 10.1161/HYPERTENSIONAHA.116.09004.)** • **Online Data Supplement**

Key Words: blood pressure ■ exercise ■ nutrition surveys ■ prehypertension ■ prevention ■ risk factors ■ trend

In 2003, the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC7) characterized adults, not taking antihypertensive medication, with systolic blood pressure (SBP) between 120 and 139 mm Hg with diastolic blood pressure (DBP) <90 mm Hg or DBP between 80 and 89 mm Hg with SBP <140 mm Hg as having prehypertension.[1] Adults with prehypertension have a high risk for developing hypertension, defined as SBP ≥140 mm Hg or DBP ≥90 mm Hg or the use of antihypertensive medication.[2–5] The risk for hypertension among people with prehypertension can be reduced through lifestyle modification and antihypertensive medication use.[1,5–7] While one goal of the JNC7 guideline was to increase awareness of the high risk for incident hypertension associated with prehypertension,[1,7] studies conducted after its publication have been cross-sectional, and there have been limited data published on the temporal changes in the prevalence of prehypertension and the risk factors for incident hypertension among those with prehypertension.[8–11]

In the current study, we determined temporal changes in the prevalence of prehypertension among US adults, overall, and within subgroups defined by age, race/ethnicity, and sex. Also, because there is an opportunity to prevent the transition to hypertension and reduce cardiovascular disease (CVD) morbidity and mortality through lifestyle modification and pharmacological antihypertensive treatment among adults with prehypertension, temporal changes in risk factors for incident hypertension, target-organ damage, and CVD were determined among this population.[12] Results from the current study may help to determine the need for interventions among adults with prehypertension and identify specific approaches that may lower blood pressure (BP) in adults at high risk for developing hypertension.

Methods

Study Population

The National Health and Nutrition Examination Survey (NHANES) is a US-based cross-sectional survey of the noninstitutionalized

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civilian population. NHANES applies a multistage, stratified, probability sampling approach to identify participants and allows the generation of nationally representative estimates. Additional information on the design and conduct of NHANES is available online.[13] In brief, NHANES has been conducted in 2-year cycles since 1999. For the current analysis, we studied seven 2-year cycles from 1999–2000 through 2011–2012.[14] During this time period, there were 30 958 participants with 3 valid clinic SBP and DBP measurements and complete information on antihypertensive medication use obtained during study visits (Figure S1 in the online-only Data Supplement). The National Center for Health Statistics Review Board governing human subjects' research approved the NHANES protocol. All participants provided written informed consent.

Data Collection

NHANES data were collected during an in-home interview and clinic examination. During the interview, trained staff administered questionnaires to collect self-reported information on sociodemographics, diet- and health-related behaviors and prior diagnosed comorbid conditions, and use of prescription antihypertensive medication. During the clinic examination, trained technicians measured height, weight, and BP and collected blood and spot urine samples.

Risk Factors for Incident Hypertension, CVD, and Target-Organ Damage

Age was categorized as <40, 40 to 59, and ≥60 years. Race/ethnicity was defined as non-Hispanic white, non-Hispanic black, and Hispanic. Heart rate, quantified in beats per minutes, was measured by palpating the radial pulse after 3 minutes of rest. Total cholesterol was categorized as normal (<200 mg/dL), borderline elevated (200–239 mg/dL), or elevated (≥240 mg/dL). Low levels of high-density-lipoprotein cholesterol were defined as <40 and <50 mg/dL in men and women, respectively. C-reactive protein was defined as normal (<1 mg/L), borderline elevated (1 to <3 mg/L), or elevated (≥3 mg/L). Participants were categorized as not having prediabetes or diabetes mellitus if they did not self-report a prior diagnosis by a physician and were not taking hypoglycemic medication, and they had a hemoglobin A1C <5.7% prediabetes if they did not self-report a history of diabetes mellitus and were not taking hypoglycemic medication and had hemoglobin A1C of 5.7% to 6.4% or diabetes mellitus if they self-reported a history of diagnosis or were taking hypoglycemic medication or had hemoglobin A1C ≥6.5%. Estimated glomerular filtration rate was calculated using the CKD-EPI (chronic kidney disease epidemiology collaboration) equation with calibrated serum creatinine.[15,16] Reduced estimated glomerular filtration rate was defined as <60 mL/min/1.73 m^2. Elevated urinary albumin-to-creatinine ratio was defined as ≥30 mg/g. High 10-year predicted atherosclerotic CVD risk was defined as ≥7.5% using the pooled cohort risk equations.[17]

Modifiable Lifestyle Risk Factors

Body mass index, calculated as weight in kilograms divided by height in meters squared, was categorized as <25, 25 to <30, and ≥30 kg/m^2. Current cigarette smoking was defined by self-reporting smoking >100 cigarettes in their lifetime and currently smoking or having quit <1 year ago. Leisure-time physical activity was calculated in minutes per week following similar methods as described by Ladabaum et al.[18] Briefly, the total minutes of physical activity per week were calculated from participants' self-reported information on the frequency, duration, and level of exertion for leisure-time activities. The ideal physical activity category included participants who self-reported at least 75 minutes of vigorous activity or at least 150 minutes of moderate or vigorous activity per week. The category for intermediate physical activity included those who had 1 to 74 minutes of vigorous activity or 1 to 149 minutes of moderate or vigorous activity per week. Poor physical activity was defined as 0 minutes of moderate or vigorous activity per week. Weekly alcohol consumption, determined by the self-reported number of drinks per week during the previous 12 months, was defined as none, moderate (men: 1–14 drinks; women: 1–7 drinks), or heavy (men: >14 drinks; women: >7 drinks). Interviewer-administered questionnaires were used to record dietary intake during two 24-hour periods. A Dietary Approaches to Stop Hypertension (DASH) adherence score was estimated similar to the studies by Fung et al[19] and Günther et al.[20] This dietary pattern is low in sodium and cholesterol, high in dietary fiber, potassium, calcium, and magnesium, and moderately high in protein content. Quintiles of the 8 DASH diet components (increased intake of fruits, vegetables, low-fat dairy products, whole grains, and nuts/seeds/legumes; reduced intake of fats/oils, sugar-sweetened beverages, and meat/poultry/fish) and reduced sodium consumption were created among all NHANES participants between 1999 and 2012. The rank scores were summed to obtain an overall DASH diet score (range: 9 [least healthy] to 45 [healthiest]). Participants were grouped into quartiles based on the distribution of DASH diet scores among all US adults ≥20 years of age (cut points [quartile 1 to quartile 4]: <25 [least healthy], 25 to <28, 28 to <31, and ≥31 [healthiest]).

Blood Pressure

BP was measured following a standardized protocol using the American Heart Association's recommendations.[13,21–23] After participants were seated for at least 5 minutes in an upright position with their back and arms supported, feet flat on the floor, and legs uncrossed, trained staff conducted 3 BP measurements in the right arm using a mercury sphygmomanometer, and appropriate cuff size determined from an arm circumference measurement. At least 30 seconds elapsed between the measurements. Quality control included quarterly recertification with retraining as needed, annually retraining of all physicians and monitoring/repairing equipment. Certification required video test recognition of Korotkoff sounds and performing measurements on volunteers. Normal BP was defined as SBP <120 and DBP <80 mm Hg without antihypertensive medication use. Prehypertension was defined by SBP of 120 to 139 mm Hg with DBP <90 mm Hg or DBP of 80 to 89 mm Hg with SBP <140 mm Hg without antihypertensive medication use. The lower range of prehypertension was defined as SBP 120 to 129 mm Hg with DBP <85 mm Hg or DBP 80 to 84 mm Hg with SBP <130 mm Hg, and the upper range of prehypertension was defined as SBP 130 to 139 mm Hg or DBP 85 to 89 mm Hg. Hypertension was defined as SBP ≥140 or DBP ≥90 mm Hg or antihypertensive medication use.

Statistical Analysis

The age-adjusted percentage of US adults ≥20 years of age with normal BP, prehypertension, and hypertension was calculated for each 2-year cycle of NHANES overall and in subgroups defined by age, race/ethnicity, and sex. Age was adjusted using 2010 US census data. Using logistic regression, the statistical significance of the linear trend in the age-adjusted prevalence of prehypertension was calculated by modeling an ordinal variable for each NHANES cycle as a continuous predictor variable of prehypertension status. Differences in linear trends in the prevalence of prehypertension over NHANES cycles across age, race/ethnicity, and sex subgroups were determined by modeling interaction terms (eg, sex×NHANES cycle). Analyses were repeated to calculate the age-adjusted prevalence of prehypertension among adults without normal BP (ie, among adults with prehypertension or hypertension) and without hypertension (ie, among adults with normal BP and prehypertension), separately. Also, multivariable adjusted prevalence ratios for prehypertension associated with NHANES cycles were calculated among adults without normal BP and without hypertension, separately, using Poisson regression. An initial model with adjustment for age, race/ethnicity, and sex was further adjusted for incident hypertension, CVD and target-organ damage, and modifiable lifestyle risk factors in 3 subsequent regression models. Pooling 2009 to 2012 NHANES data to provide stable estimates, we calculated prevalence ratios for prehypertension or hypertension comparing participants <40 and 40 to 59 years of age versus ≥60 years of age, non-Hispanic blacks and Hispanics versus non-Hispanic whites, and females versus males using log-binomial models. Prevalence ratios for prehypertension associated with age, race/ethnicity, and sex were also calculated among US adults without hypertension.

The mean or prevalence of risk factors (ie, heart rate, total cholesterol, high-density-lipoprotein cholesterol, diabetes mellitus, estimated glomerular filtration rate, urinary albumin-to-creatinine ratio, and 10-year predicted atherosclerotic CVD risk) and modifiable lifestyle factors (ie, body mass index, smoking status, physical activity level, alcohol consumption, and DASH diet adherence) was calculated in adults with prehypertension by NHANES cycle. The statistical significance of trends in the change in risk factors over NHANES cycles was calculated using linear regression or logistic regression, as appropriate. All analyses were performed accounting for the complex survey design of NHANES, and results were weighted to the noninstitutionalized civilian US adult population using SAS 9.4 (SAS Institute, Cary, NC). Two-sided P values <0.05 were considered statistically significant.

Results

Trends in Prevalent Normal BP, Prehypertension, and Hypertension

From 1999–2000 to 2011–2012, there was a nonstatistically significant increase in the age-adjusted percentage of US adults with normal BP and hypertension and a statistically significant decrease in prevalent prehypertension from 31.2% to 28.2% (Figure 1, top). The number of US adults with normal BP and hypertension increased from 1999–2000 and 2011–2012, whereas the number with prehypertension was stable (Figure 1, bottom). The prevalence of normal BP increased (Figure 2, left; Table S1, top) and prehypertension decreased in those ≥60 years of age between 1999–2000 and 2011–2012. A decrease in the age-adjusted prevalence of prehypertension occurred among men (Figure 2, middle; Table S1, middle). The prevalence of hypertension remained stable in all subgroups (Figure 2, right; Table S1, bottom).

Trends in Prevalent Prehypertension Among Adults Without Normal BP and Without Hypertension

Among US adults without normal BP, the age-adjusted prevalence of prehypertension decreased between 1999–2000 and 2011–2012. There was no change in prehypertension in any of the age categories investigated, but the prevalence of prehypertension declined in non-Hispanic whites, non-Hispanic blacks, and males (Figure 3, left; Table S2, top). The change in the prevalence of prehypertension from 1999–2000 and 2011–2012 was similar across age, race/ethnicity, and sex groups. In adults without hypertension, there was a decrease in the prevalence of prehypertension overall and among US adults ≥60 years of age and males, but no statistically significant change was present for any of the race/ethnicity groups (Figure 3, right; Table S2, bottom).

Among US adults without normal BP, there was a nonstatistically significant decrease in the prevalence ratio of prehypertension between 1999–2000 and 2011–2012 after adjustment for age, race/ethnicity, and sex (Table 1, top). There was no trend in the prevalence ratios for prehypertension after

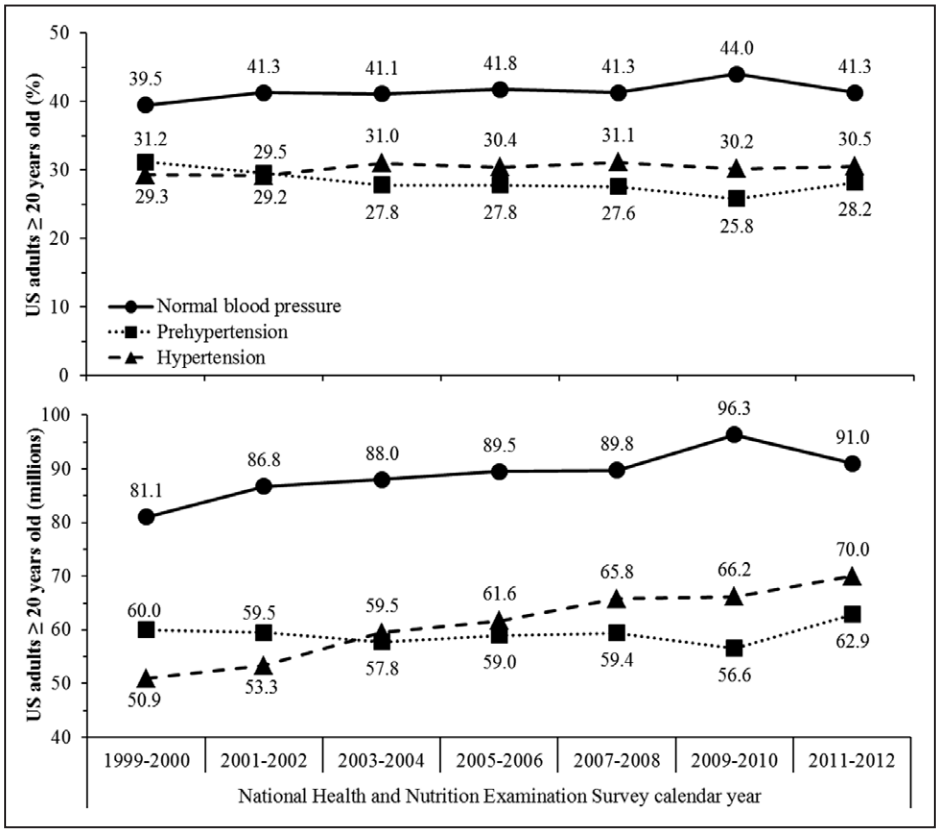

Figure 1. Age-adjusted percentage (**top**) and unadjusted number (**bottom**) of US adults ≥20 y of age with normal blood pressure, prehypertension, and hypertension by National Health and Nutrition Examination Survey by calendar year. Normal blood pressure: systolic blood pressure <120 mm Hg and diastolic blood pressure <80 mm Hg without antihypertensive medication use. Prehypertension: systolic blood pressure 120 to 139 mm Hg with diastolic blood pressure <90 mm Hg or diastolic blood pressure 80 to 89 mm Hg with systolic blood pressure <140 mm Hg without antihypertensive medication use. Hypertension: systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg and antihypertensive medication use.

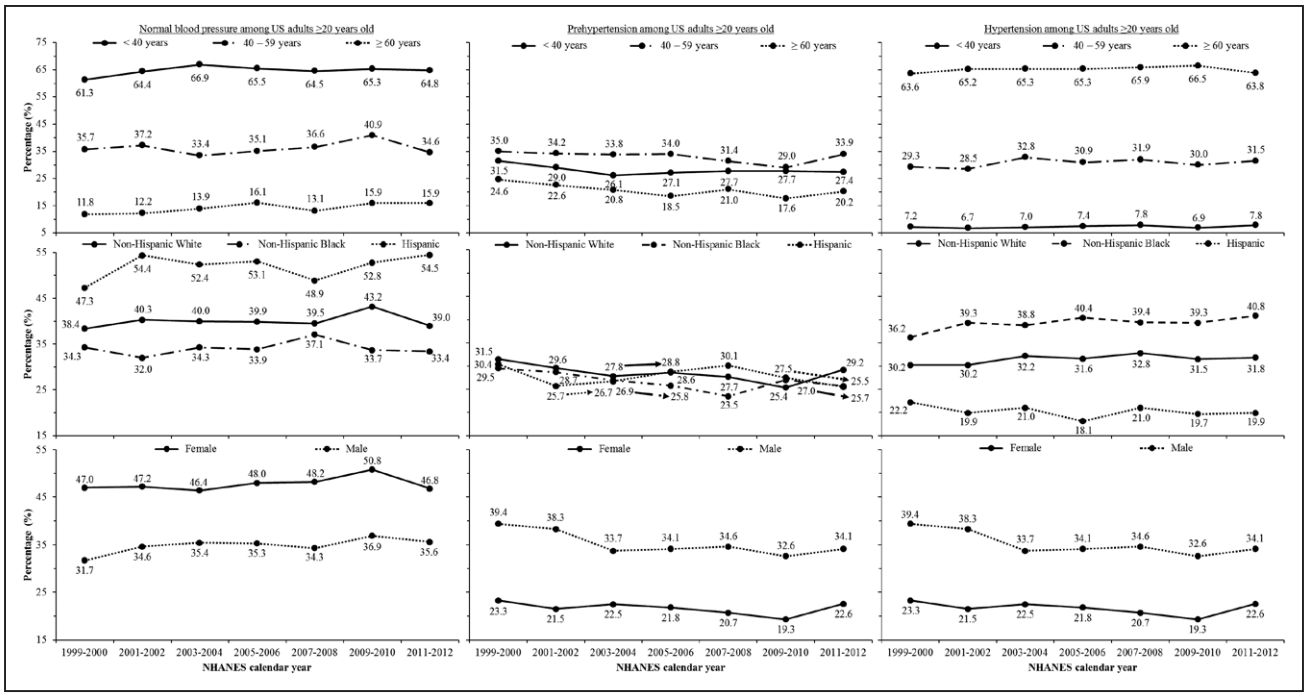

Figure 2. Age-adjusted percentage of US adults ≥20 y of age with normal blood pressure (**left**), prehypertension (**middle**), and hypertension (**right**) from 1999–2000 and 2011–2012 by age, race/ethnicity, and sex. Arrows indicate the prevalence corresponding with non-Hispanic whites, non-Hispanic blacks, or Hispanics where the plotted values for these race/ethnic groups are difficult to distinguish. The age-adjusted percentage of US adults ≥20 y of age with normal blood pressure, prehypertension, and hypertension from 1999–2000 and 2011–2012 overall is reported in Table S1. Also, the 95% confidence interval corresponding with each point estimate in the current figure, *P* trend representing the change in the prevalence over calendar period and the *P* interaction representing differences in the change in the prevalence during calendar period across age, race/ethnicity, and sex subgroups is reported in Table S1. NHANES indicates National Health and Nutrition Examination Survey.

further adjustment for risk factors for incident hypertension, CVD and target-organ damage, and modifiable lifestyle risk factors. The prevalence ratio for prehypertension decreased over calendar time among US adults without hypertension (Table 1, bottom).

Prevalence of Prehypertension and Hypertension in Subgroups of US Adults

In 2009 through 2012, after race/ethnicity and sex adjustment, US adults <40 and 40 to 59 versus ≥60 years of age were less likely to have prehypertension or hypertension versus normal BP (Table S3, middle). After age and sex adjustment, the prevalence ratio for prehypertension or hypertension versus normal BP was higher for non-Hispanic blacks versus non-Hispanic whites. After age and race/ethnicity adjustment, females were less likely to have prehypertension or hypertension compared with males. Among adults without hypertension and after race/ethnicity and sex adjustment, US adults 40 to 59 and ≥60 years of age were less likely than their counterparts <40 years of age to have prehypertension (Table S3, right). Also, non-Hispanic blacks were more likely than non-Hispanic whites, and females were less likely than males to have prehypertension.

Modifiable Risk Factors Among Adults With Prehypertension

Among US adults with prehypertension, mean heart rate and the prevalence of prediabetes and diabetes mellitus increased and elevated total cholesterol decreased between 1999–2000 and 2011–2012 (Table 2). Also, while the proportion of adults who were overweight or obese increased, DASH diet adherence decreased during the study period (Table 3). There was also a nonstatistically significant increase in poor levels of leisure-time physical activity among adults with prehypertension. In contrast, the prevalence of current smoking declined from 25.9% to 23.2% (*P* trend=0.097). Heavy alcohol intake did not change over time.

Discussion

Between 1999–2000 and 2011–2012, there was a statistically significant decrease in the age-adjusted prevalence of prehypertension and nonstatistically significant increase in normal BP and hypertension. The number of US adults with prehypertension remained stable, whereas the number with normal BP and hypertension increased during this time period because of population growth. The prevalence of normal BP increased in those ≥60 years of age; prehypertension decreased in those ≥60 years of age, non-Hispanic whites, non-Hispanic blacks, and males; and hypertension increased in non-Hispanic whites, non-Hispanic, blacks, and males. Also, among adults with prehypertension, mean heart rate and the proportion with prediabetes and diabetes mellitus and who were overweight and obese increased between 1999–2000 and 2011–2012. In contrast, adherence to the DASH diet-eating pattern decreased during this time period. There was a nonstatistically significant increase in poor levels of leisure-time physical activity and a nonstatistically significant decrease in current smoking over time.

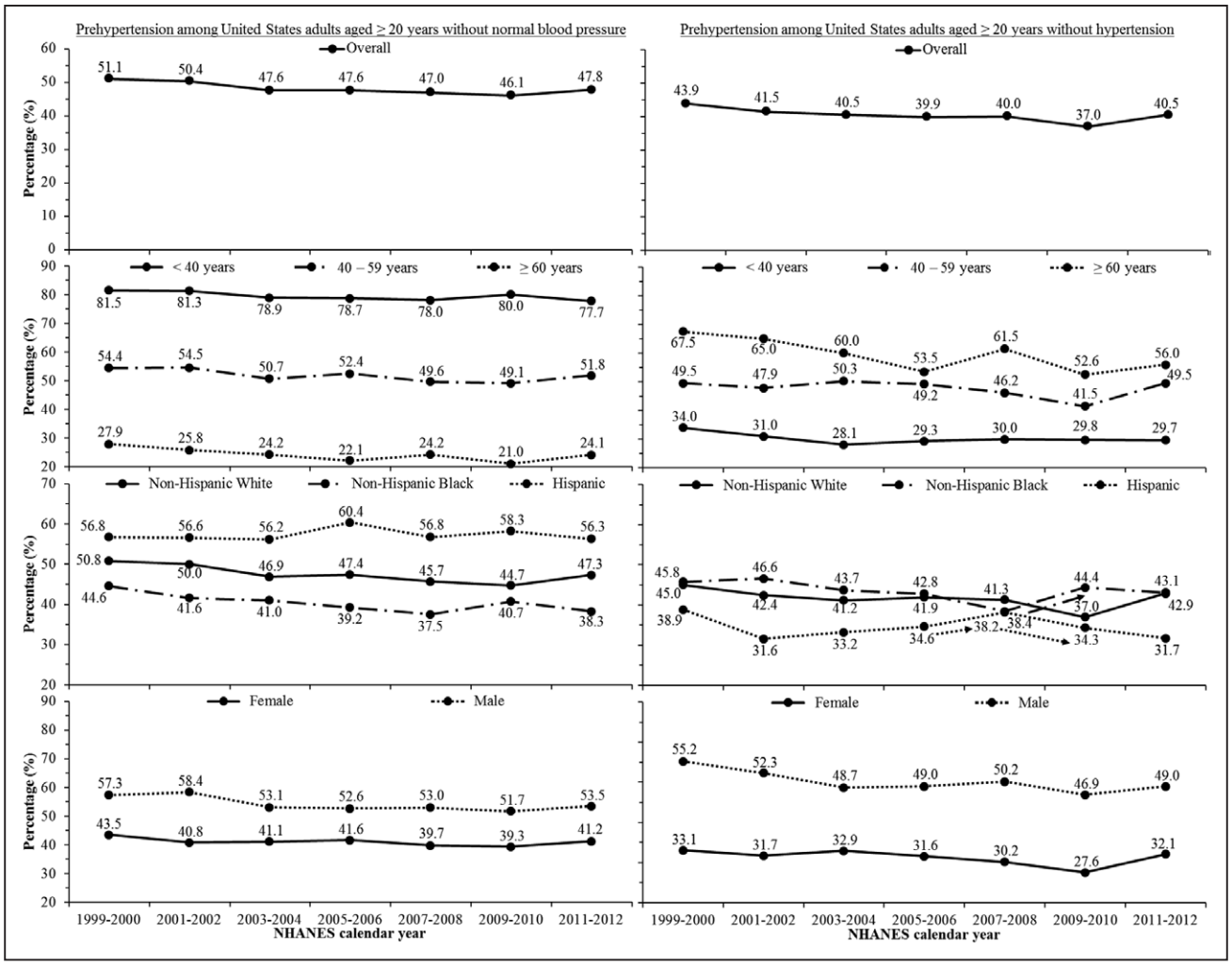

Figure 3. Age-adjusted percentage of US adults ≥20 y of age with prehypertension in US adults without normal blood pressure (**left**) and without hypertension (**right**) by National Health and Nutrition Examination Survey calendar year overall and by age, race/ethnicity, and sex. Arrows indicate the prevalence corresponding with non-Hispanic whites, non-Hispanic blacks, or Hispanics where the plotted values for these race/ethnic groups are difficult to distinguish. The 95% confidence interval corresponding with each point estimate, *P*-trend representing the change in the prevalence over calendar period and the *P* interaction representing differences in the change in the prevalence over calendar period across age, race/ethnicity, and sex subgroups is reported in Table S2. NHANES indicates National Health and Nutrition Examination Survey.

Temporal changes in the proportion of US adults with hypertension have been studied more often than prehypertension. NHANES data indicate the age-adjusted prevalence of hypertension increased from 23.9% (95% confidence interval [CI], 22.7%–25.2%) in 1988–1994 to 28.5% (95% CI, 25.9%–31.3%) in 1999–2000 and remained stable through 2007–2008 at 29.5% (95% CI, 27.6%–30.5%).[24] The results reported herein also indicate that the prevalence of hypertension has not changed substantially since 1999–2000. Because hypertension is a lifelong condition, reducing the prevalence of hypertension will require interventions to prevent its development.

A study from 1939 described SBP levels between 120 and 139 mm Hg as the "danger zone" for progressing to incident hypertension and CVD in younger individuals.[25] The goal of the JNC7 for defining prehypertension was to increase awareness so that individuals with this condition can delay or prevent incident hypertension through early adoption of healthy lifestyle interventions that lower BP levels and reduce CVD risk.[1] The range of BP levels used to define prehypertension was determined from accumulating evidence indicating that these levels were associated with traditional CVD risk factors (eg, obesity, diabetes mellitus), incident hypertension, and cardiovascular morbidity and mortality.[1,7,26–30]

While evidence from randomized controlled trials (RCTs) indicates that prophylactic antihypertensive medication reduces BP and the incidence of hypertension, the JNC7 emphasized utilization of healthy lifestyles for individuals with prehypertension.[1,31,32] The trials of hypertension prevention reported that a mean 7.7 pounds difference in weight loss during 18 months in the active intervention (ie, weight loss counseling) versus control group resulted in 5.8/3.2 mm Hg lower SBP/DBP levels.[33] A meta-analysis of 27 RCTs demonstrated that participants randomized to aerobic exercise had a 4 mm Hg (95% CI, 2.75–5.32) reduction in SBP compared with their counterparts randomized to control groups, independent of the exercise

Table 1. Multivariable Adjusted Prevalence Ratio for Prehypertension Among US Adults ≥20 Y of Age Without Normal Blood Pressure and Without Hypertension by National Health and Nutrition Examination Survey Calendar Year

Model	National Health and Nutrition Examination Survey Calendar Year							*P* Trend*
	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	
	Prevalence ratio (95% confidence interval)							
	Prehypertension among US adults ≥20 y of age without normal blood pressure							
Model 1	1 (reference)	0.99 (0.91–1.09)	0.95 (0.86–1.04)	0.95 (0.86–1.04)	0.93 (0.85–1.01)	0.92 (0.83–1.01)	0.95 (0.87–1.05)	0.052
Model 2	1 (reference)	1.00 (0.91–1.09)	0.94 (0.86–1.02)	0.95 (0.87–1.03)	0.94 (0.87–1.01)	0.92 (0.84–1.00)	0.96 (0.88–1.05)	0.087
Model 3	1 (reference)	1.01 (0.93–1.10)	0.94 (0.87–1.03)	0.97 (0.89–1.06)	0.95 (0.88–1.03)	0.96 (0.87–1.06)	0.99 (0.91–1.08)	0.474
Model 4	1 (reference)	1.02 (0.93–1.10)	0.95 (0.88–1.03)	0.98 (0.90–1.07)	0.95 (0.88–1.03)	0.98 (0.89–1.07)	1.00 (0.91–1.10)	0.678
	Prehypertension among US adults ≥20 y of age without hypertension							
Model 1	1 (reference)	0.94 (0.84–1.05)	0.91 (0.82–1.03)	0.91 (0.80–1.03)	0.91 (0.81–1.02)	0.84 (0.75–0.94)	0.92 (0.82–1.03)	0.032
Model 2	1 (reference)	0.92 (0.83–1.02)	0.89 (0.79–1.00)	0.90 (0.80–1.03)	0.89 (0.80–0.99)	0.84 (0.75–0.94)	0.92 (0.82–1.04)	0.072
Model 3	1 (reference)	0.93 (0.84–1.03)	0.88 (0.78–0.99)	0.88 (0.77–1.00)	0.85 (0.76–0.95)	0.80 (0.71–0.90)	0.90 (0.80–1.01)	0.005
Model 4	1 (reference)	0.91 (0.82–1.01)	0.84 (0.74–0.96)	0.86 (0.75–0.99)	0.83 (0.75–0.93)	0.79 (0.70–0.88)	0.89 (0.78–1.01)	0.009

Numbers in the table are prevalence ratio (95% confidence interval). Model 1: adjustment for age, race/ethnicity, and sex. Model 2: adjustment for the variables in Model 1 plus risk factors for incident hypertension, cardiovascular disease, and target-organ damage (ie, heart rate, total cholesterol, high-density lipoprotein cholesterol, diabetes mellitus, estimated glomerular filtration rate, urinary albumin-to-creatinine ratio, and 10-y predicted atherosclerotic cardiovascular disease risk). Model 3: adjustment for the variables in Model 1 plus modifiable lifestyle risk factors (ie, body mass index, smoking status, physical activity level, alcohol consumption, and Dietary Approaches to Stop Hypertension adherence). Model 4: adjustment for the variables in Model 1, Model 2, and Model 3. Normal blood pressure: systolic blood pressure <120 mm Hg and diastolic blood pressure <80 mm Hg without antihypertensive medication use. Prehypertension: systolic blood pressure 120–139 mm Hg with diastolic blood pressure <90 mm Hg or diastolic blood pressure 80–89 mm Hg with systolic blood pressure <140 mm Hg without antihypertensive medication use. Hypertension: systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg or antihypertensive medication use.

*Statistical significance of the trend in the change of the prevalence ratio over calendar period.

intensity level.[34] RCTs also provide evidence that a diet low in sodium, high in potassium, rich with fruits and vegetables, and with reduced saturated and total fat from dairy products can reduce SBP.[35,36] For example, randomization to the DASH with a low sodium level compared with a control diet with comparatively higher amounts of sodium reduced SBP by 7.1 mm Hg in adults without hypertension.[35] Furthermore, in a meta-analysis of 6 RCTs, reducing alcohol intake in adults without hypertension by 75% to 100% compared with baseline has been demonstrated to lower SBP by 3.6 (95% CI, 2.5–4.6) mm Hg and DBP by 1.8 (95% CI, 0.6–3) mm Hg.[37] While each of these interventions is beneficial for reducing BP, the PREMIER and MRFIT (Multiple Risk Factor Intervention Trial) RCTs provided evidence of an additive effect of increasing the number of lifestyle interventions to lower BP levels.[6,38,39] In the current analysis, many US adults with prehypertension had risk factors for incident hypertension, target-organ damage, and CVD and were not using lifestyle interventions. Importantly, low-cost interventions for preventing hypertension are proven in all age groups, race/ethnicities, and males and females.[6] This indicates there is a substantial opportunity to lower the incidence of hypertension and CVD through lifestyle changes. However, novel approaches for maintaining lifestyle modification may be needed because body mass index and diabetes mellitus increased, and there was a decline in adherence to the DASH diet between 1999–2000 and 2011–2012.

Few studies have reported the number of US adults with normal BP, prehypertension, and hypertension over time. In the current study, the percentage of US adults with normal BP and hypertension was stable, and the proportion who had prehypertension increased between 1999–2000 and 2011–2012. However, the number of US adults with normal BP and hypertension increased, and the number with prehypertension was stable during the time period. This suggests that the population growth has been primarily among US adults with normal BP and hypertension rather than with prehypertension.

The current study has several strengths. These include the complex sampling design of NHANES that permitted the calculation of prevalence estimates for the US population. The large sample size of NHANES facilitated subgroup analyses. Also, NHANES follows protocols that facilitate the rigorous collection of study data, including BP. However, the results should be interpreted in the context of known and potential limitations. Mean BP levels were calculated from measurements at a single examination. Average BP measured at multiple exams would provide more accurate information to categorize participants by their BP level. Participants in NHANES were not followed longitudinally, which prevented the assessment of within-person changes in BP levels, risk factors for incident hypertension, target-organ damage and CVD, and modifiable lifestyle risk factors at the individual level. Data for Asian adults, separately from other race/ethnicity groups, were not available for the NHANES calendar years of 1999–2000 through 2009–2010, and temporal changes could not be reported for this subgroup.

Perspectives

The current serial cross-sectional analysis of NHANES data reports that the age-adjusted prevalence of prehypertension decreased among US adults between 1999–2000 and 2011–2012. During this time period, the age-adjusted proportion of US adults with normal BP and hypertension remained stable. Also, there has been limited improvement in risk factors for

Table 2. Risk Factors for Incident Hypertension, Cardiovascular Disease, and Target-Organ Damage Among US Adults ≥20 Y of Age With Prehypertension by Calendar Year

	Risk Factors for Incident Hypertension, Cardiovascular Disease, and Target-Organ Damage							
	National Health and Nutrition Examination Survey Calendar Year							
Risk Factor	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	*P* Trend*
Mean heart rate, bpm	71.3 (70.5–72.1)	72.9 (71.8–74.0)	73.2 (71.8–74.6)	72.6 (71.5–73.6)	74.2 (73.0–75.4)	73.0 (72.1–73.9)	73.5 (72.3–74.7)	0.003
Systolic blood pressure, mm Hg								0.219
120–129	70.0 (64.2–75.8)	66.2 (62.9–69.4)	66.7 (62.8–70.7)	66.3 (63.1–69.5)	71.8 (69.2–74.5)	71.2 (68.2–74.3)	68.7 (64.5–72.8)	
130–139	30.0 (24.2–35.8)	33.8 (30.6–37.1)	33.3 (29.3–37.2)	33.7 (30.5–36.9)	28.2 (25.5–30.8)	28.8 (25.7–31.8)	31.3 (27.2–35.5)	
Diastolic blood pressure, mm Hg								0.715
80–84	73.3 (66.9–79.7)	70.2 (65.5–75)	67.9 (57.8–78.0)	70.4 (63.8–77.0)	78.9 (75.3–82.6)	71.0 (64.9–77.2)	67.6 (60.6–74.5)	
85–89	26.7 (20.3–33.1)	29.8 (25.0–34.5)	32.1 (22.0–42.2)	29.6 (23.0–36.2)	21.1 (17.4–24.7)	29.0 (22.8–35.1)	32.4 (25.5–39.4)	
Total cholesterol								0.018
Normal (<200 mg/dL)	44.7 (40.4–49.0)	47.1 (44.9–49.4)	47.7 (44.0–51.3)	49.6 (46.0–53.2)	49.0 (44.3–53.8)	50.2 (46.5–53.8)	48.9 (44.7–53.0)	
Borderline elevated (200–239 mg/dL)	37.0 (32.0–41.9)	34.2 (30.8–37.5)	32.3 (28.4–36.1)	32.7 (29.1–36.4)	32.0 (27.1–36.9)	34.2 (31.7–36.7)	36.4 (33.2–39.7)	
Elevated (≥240 mg/dL)	18.4 (13.7–23)	18.7 (15.0–22.4)	20.0 (15.5–24.6)	17.7 (14.6–20.7)	19.0 (14.6–23.4)	15.6 (12.9–18.4)	14.7 (11.2–18.3)	
High-density lipoprotein cholesterol								0.220
Normal (men, ≥40; women, ≥50; mg/dL)	63.8 (60.0–67.7)	69.5 (65.8–73.3)	70.1 (64.7–75.5)	72.8 (69.7–75.9)	65.2 (59.5–70.9)	68.6 (65.6–71.5)	71.7 (65.4–78.1)	
Low (men, <40; women, <50; mg/dL)	36.2 (32.3–40.0)	30.5 (26.7–34.2)	29.9 (24.5–35.3)	27.2 (24.1–30.3)	34.8 (29.1–40.5)	31.4 (28.5–34.4)	28.3 (21.9–34.6)	
C-reactive protein								0.162
Normal (<1 mg/L)	90.2 (87.4–93.1)	91.8 (89.4–94.2)	91.6 (89.1–94.2)	90.0 (87.6–92.4)	91.9 (90.0–93.7)	92.9 (91.2–94.5)	NR	
Borderline elevated (1–2.9 mg/L)	8.8 (5.4–12.3)	7 (4.5–9.4)	6.7 (4.2–9.2)	8.2 (5.9–10.5)	7.3 (5.8–8.7)	6.2 (4.8–7.6)	NR	
Elevated (≥3 mg/L)	0.9 (0.0–1.8)	1.2 (0.5–2.0)	1.7 (0.6–2.8)	1.8 (0.7–2.8)	0.9 (0.3–1.4)	0.9 (0.4–1.5)	NR	
Diabetes mellitus status								<0.001
No diabetes mellitus	84.4 (80.4–88.4)	82.1 (79.0–85.1)	81.9 (78.9–84.9)	79.3 (74.4–84.1)	70.5 (65.7–75.3)	69.4 (66.0–72.8)	69.9 (67.8–72.0)	
Prediabetes	9.6 (7.1–12.1)	11.2 (8.4–14.0)	12.9 (10.3–15.6)	13.8 (9.9–17.7)	21.3 (17.0–25.5)	24.1 (21.1–27.0)	21.6 (19.6–23.5)	
Diabetes mellitus	6.0 (4.0–7.9)	6.7 (4.8–8.7)	5.2 (3.9–6.4)	7.0 (4.7–9.2)	8.3 (6.6–9.9)	6.5 (5.2–7.8)	8.5 (7.0–10.0)	
Estimated glomerular filtration rate								0.525
Normal (≥60 mL/min/1.73 m2)	97.2 (96.2–98.2)	97.5 (96.3–98.6)	96.9 (95.7–98.0)	96.4 (94.9–97.8)	96.8 (95.4–98.2)	97.4 (96.2–98.6)	97.5 (96.5–98.5)	
Reduced (<60 mL/min/1.73 m2)	2.8 (1.8–3.8)	2.5 (1.4–3.7)	3.1 (2.0–4.3)	3.6 (2.2–5.1)	3.2 (1.8–4.6)	2.6 (1.4–3.8)	2.5 (1.5–3.5)	
Urinary albumin-to-creatinine ratio								0.938
Normal (≤30 mg/g)	92.6 (90.4–94.8)	92.7 (90.7–94.7)	93.3 (91.1–95.5)	93.9 (92–95.7)	91.6 (89.2–94)	95.0 (93.5–96.4)	91.9 (89.5–94.4)	
Elevated (>30 mg/g)	7.4 (5.2–9.6)	7.3 (5.3–9.3)	6.7 (4.5–8.9)	6.1 (4.3–8)	8.4 (6–10.8)	5.0 (3.6–6.5)	8.1 (5.6–10.5)	
10-y predicted ASCVD risk, %								0.343
<7.5	64.9 (59.7–70.1)	63.1 (58.2–68.1)	64.2 (60.8–67.6)	65.5 (59.3–71.7)	61.6 (58.2–65)	66.7 (64.5–68.9)	66.2 (60.3–72.1)	
≥7.5	35.1 (29.9–40.3)	36.9 (31.9–41.8)	35.8 (32.4–39.2)	34.5 (28.3–40.7)	38.4 (35.0–41.8)	33.3 (31.1–35.5)	33.8 (27.9–39.7)	

Numbers in the table are mean (95% confidence interval) or percentage (95% confidence interval). Standard international system conversion factors: to convert mg/dL to mmol/L, multiply values by 0.0259, and to convert mg/L to mmol/L, multiply values by 5.581. ASCVD indicates atherosclerotic cardiovascular disease; and NR, not reported because of data not being available at the time of analyses.

*Statistical significance of the trend in the change of the prevalence over calendar period.

Table 3. Modifiable Lifestyle Risk Factors for Incident Hypertension Among US Adults ≥20 Y of Age With Prehypertension by Calendar Year

Modifiable Lifestyle Risk Factor	Modifiable Lifestyle Risk Factors for Incident Hypertension							
	National Health and Nutrition Examination Survey Calendar Year							
	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	*P* Trend*
Body mass index categories								<0.001
Normal (<25 kg/m^2)	35.8 (32.2–39.5)	31.7 (28.8–34.6)	27.6 (23.2–32.0)	28.8 (23.5–31.7)	28.4 (24.1–32.8)	26.2 (21.4–31.0)	27.5 (22.9–32.2)	
Overweight (25–30 kg/m^2)	33.5 (29.4–37.7)	37.9 (34.3–41.5)	39.3 (34.2–44.4)	32.7 (30.3–35.1)	37.4 (34.4–40.4)	34.3 (29.9–38.7)	37.3 (31.2–43.4)	
Obese (≥30 kg/m^2)	30.6 (26.4–34.8)	30.3 (25.7–35.0)	33.1 (29.2–37.0)	38.4 (34.4–42.5)	34.2 (30.2–38.2)	39.5 (35.5–43.4)	35.2 (31.7–38.7)	
Smoking status								0.097
Current	25.9 (22.5–29.3)	26.8 (23.6–29.9)	27.5 (24.6–30.5)	24.7 (21.2–28.3)	25.7 (21.7–29.8)	21.4 (19.1–23.6)	23.2 (20.1–26.2)	
Former/never	74.1 (70.7–77.5)	73.2 (70.1–76.4)	72.5 (69.5–75.4)	75.3 (71.7–78.8)	74.3 (70.2–78.3)	78.6 (76.4–80.9)	76.8 (73.8–79.9)	
Physical activity (leisure time)								0.127
Ideal	38.1 (33.5–42.7)	44.8 (41.3–48.4)	39.8 (37.1–42.4)	41.4 (38.0–44.8)	35.7 (30.5–40.9)	37.9 (33.7–42.1)	39.6 (34.6–44.6)	
Intermediate	21.9 (17.0–26.9)	24.1 (21.6–26.7)	30.6 (27.6–33.6)	26.5 (22.3–30.8)	20.0 (17.0–23.0)	16.3 (14.3–18.2)	16.5 (14.1–18.8)	
Poor	40.0 (35.9–44.1)	31.0 (27.1–34.9)	29.6 (26.3–33.9)	32.0 (27.0–37.1)	44.3 (38.1–50.5)	45.8 (41.1–50.5)	43.9 (38.7–49.1)	
Alcohol consumption†								0.393
None	11.8 (8.2–15.4)	14.6 (7.8–21.4)	11.5 (9.0–14.0)	10.7 (5.8–15.7)	11.6 (9.4–13.8)	11.1 (8.5–13.6)	10.6 (7.8–13.4)	
Moderate	76.6 (73.3–80.0)	72.9 (66.4–79.3)	77.5 (74.8–80.2)	76.9 (71.5–82.2)	75.2 (72.5–77.8)	77.1 (73.3–80.8)	77.0 (73.1–80.9)	
Heavy	11.6 (9.2–14.0)	12.5 (10.9–14.1)	11.0 (8.3–13.7)	12.4 (9.8–15.0)	13.2 (10.9–15.6)	11.9 (9.8–14.0)	12.4 (8.8–16.0)	
DASH diet adherence categories								0.007
Quartile 1 (low, less healthy)	38.2 (33.7–42.8)	37.7 (32.8–42.6)	31.7 (27.8–35.5)	43.6 (38.0–49.1)	39.0 (34.0–44.0)	43.7 (39.8–47.7)	41.6 (35.1–48.1)	
Quartile 2	25.3 (21.6–29.0)	23.3 (20.4–26.2)	24.2 (21.1–27.4)	28.2 (24.6–31.8)	28.5 (25.0–31.8)	25.8 (22.0–29.5)	26.5 (22.2–30.8)	
Quartile 3	18.1 (15.0–21.1)	19.8 (16.6–23.0)	24.9 (21.5–28.3)	17.1 (14.8–19.4)	18.7 (16.1–21.2)	19.5 (17.3–21.8)	20.0 (16.8–23.1)	
Quartile 4 (high, healthier)	18.4 (16.2–20.5)	19.3 (16.9–21.6)	19.2 (17.0–21.3)	11.1 (7.9–14.4)	13.9 (10.9–16.8)	10.9 (8.9–13.0)	11.9 (8.5–15.4)	

Numbers in the table are percentage (95% confidence interval). The cut points for the DASH diet scores used to group participants into quartiles based on the distribution among US adults ≥20 y old were (quartile 1 [least healthy] to quartile 4 [healthiest]): <25, 25 to <28, 28 to <31 and ≥31). DASH indicates Dietary Approaches to Stop Hypertension.

*Statistical significance of the trend in the change of the prevalence during calendar period.

†Alcohol consumption: none, 0 drinks per wk; moderate, >0 to <8 drinks per wk for women and >0 and <15 drinks per wk for men; heavy, ≥8 drinks per wk for women and ≥15 drinks per wk for men.

incident hypertension, target-organ damage and CVD, and modifiable lifestyle risk factors in adults with prehypertension since the JNC7 characterized individuals with prehypertension as having an increased risk for transitioning to hypertension. Population-level approaches that improve CVD and lifestyle risk factors may help lower the risk for hypertension among US adults with prehypertension.

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Novelty and Significance

What Is New?

- Between 1999–2000 and 2011–2012, the age-adjusted prevalence of prehypertension decreased.
- In 2011–2012, after adjustment for age, 28.2% of US adults had prehypertension.
- Among adults with prehypertension, prediabetes, diabetes mellitus, overweight and obesity increased and Dietary Approaches to Stop Hypertension adherence decreased.
- Also, there was a nonstatistically significant increase in no physical activity each week, nonstatistically significant decrease in current smoking and alcohol consumption did not change among adults with prehypertension.

What Is Relevant?

- Population-level approaches directed at adults with prehypertension should focus on improving risk factors to prevent hypertension and cardiovascular disease.

Summary

The prevalence of prehypertension is high among US adults and many adults with prehypertension have poor levels of many modifiable risk factors for incident hypertension and cardiovascular disease.