Published in final edited form as:
Am J Hypertens. 2010 June ; 23(6): 620–626. doi:10.1038/ajh.2010.40.

The Impact of Differences in Methodology and Population Characteristics on the Prevalence of Hypertension in US Adults in 1976–1980 and 1999–2002

Jacqueline D. Wright[1], **June Stevens**[2,3], **Charles Poole**[3], **Katherine M. Flegal**[1], and **Chirayath Suchindran**[4]

[1]National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, Maryland, USA

[2]Department of Nutrition, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA

[3]Department of Epidemiology, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA

[4]Department of Biostatistics, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA

Abstract

BACKGROUND—Results from the National Health and Nutrition Examination Survey (NHANES) indicate that hypertension prevalence declined by 9% points from 34% in 1976–1980 to 25% in 1999–2002 in adults 20–74 years. The purpose of this study was to estimate the impact on hypertension prevalence of measurement error and selected risk factors.

METHODS—Using cross-sectional survey data from NHANES, we estimated the effect on hypertension of incorrect blood pressure (BP) cuff size and zero end-digit preference and the effect of changes in the distribution of age, body mass index (BMI), sex, race-ethnicity, smoking, and education. The analytic sample of persons 20–74 years consisted of 11,563 from 1976–1980 and 7,901 from 1999–2002 NHANES. Covariate-adjusted prevalences were calculated using log-linear regression models to produce predictive margins.

RESULTS—After adjustment to age, BMI, sex, race-ethnicity, smoking, and education, the prevalence difference became higher, changing from -9% (95% confidence interval (CI): −11, −6) to −14% (95 CI: −17, −11). After adjustment to these risk factors and correction for measurement error the prevalence difference was −9% (95 CI: −11, −6).

CONCLUSIONS—Measurement error, mainly from cuff size differences, inflated the temporal decline in hypertension prevalence. The results indicate that age, sex, race-ethnicity, smoking, or education did not fully explain the lower prevalence of measured hypertension in all BMI groups and suggest that a change in some unmeasured factor or factors contributed to the decline.

Correspondence: Jacqueline D. Wright (jwright@cdc.gov).
Disclosure: The authors declared no conflict of interest.

Keywords

blood pressure; blood pressure determination; body mass index; cross-sectional studies; hypertension; nutrition surveys; prevalence

Over the same period that saw the doubling of prevalence of obesity, the prevalence of hypertension in US adults declined from 34 to 25% (age-adjusted to the 2000 US population).[1–3] For the purpose of tracking prevalence, hypertension is defined to include persons currently taking antihypertensive medication or having measured blood pressure (BP) above recommended levels thus the increased use of medication over this period does not explain the observed decline in hypertension prevalence.[4–6] These trends emphasize the multifactorial nature of hypertension etiology and highlight the necessity of an evaluation of differences in measurement methods and changes in population distribution of demographic and behavioral factors. A trend analysis of hypertension in the National Health and Nutrition Examination Survey (NHANES) up through 1991, was more detailed than other trends analyses and included documentation of several important differences but did not include an analysis of the effect of differences on estimates.[2] Ostchega and coauthors detailed training procedures in NHANES 1999–2000 and evaluated the effect of measurement error on mean BP.[7] Subsequent analysis of trends in hypertension in NHANES did not include evaluation of methods differences.[8]

The goal of this work is to gain a more complete understanding of the trends in hypertension, using data from the NHANES surveys in 1976–1980 and 1999–2002. Previous work documented methodologic differences in BP determination which may have contributed to the observed decline in hypertension.[2] The methods used in the 1976–1980 survey were different from the most recent survey with more thorough training and more accurate methods being used in the 1999–2002 survey. We first estimated the impact of two sources of error in BP measurement for which methods differed between surveys: incorrect cuff size and zero end-digit preference. We then considered whether differences in hypertension- related factors between the surveys may have contributed to differences in the prevalence of hypertension in US adults in 1976–1980 compared to 1999–2002. The factors examined included age, sex, race-ethnicity, cigarette smoking, and body mass index (BMI).

METHODS

Study population

The NHANES used a cross-sectional design with nationally representative samples with interview and examination. The 1976–1980 sample included 27,801 eligible persons 6 months–74 years, of whom 20,322 (73%) were interviewed and examined (11,864 adults 20–74 years). A detailed description of the survey design and operation has been published elsewhere.[9] The 1999–2002 sample included 25,316 eligible persons of all ages, of whom 19,759 (78%) were interviewed and examined (8,817 adults 20–74 years). Detailed information on the survey design and operation is available at the NHANES website http://www.cdc.gov/nchs/nhanes.htm.[10,11] The analyses in the present study were restricted to adults 20–74 years, an age range covered in both surveys. Informed consent was obtained from all participants and the protocols were approved by the NCHS Ethics Review Board for both surveys.

Measurements

More specific information was collected on Mexican, Hispanic, or Latino ancestry in 1999–2002 but available information in 1976–1980 was used to create categories similar to those available in the 1999–2002 survey, namely non-Hispanic whites, non-Hispanic blacks, and other race-ethnicities.[12,13]

In both surveys mid-arm circumference and body weight and height were measured similarly following standardized procedures with calibrated equipment.[9–11,14] BMI was calculated as weight in kg divided by height in m^2. The following categories of BMI were used: underweight (BMI < 18.5), normal weight (BMI 18.5–22.9 and 23.0–24.9), overweight or preobese (BMI 25.0–27.4 and 27.5–29.9), and obese class I (BMI 30.0–32.4 and 32.5–34.9), obese class II (35.0–37.4 and 37.5–39.9) and obese class III (BMI ≥ 40.0).[15]

In 1976–1980 two seated measurements were taken and in 1999–2002, three seated measurements were taken. In both surveys BP was measured using a mercury sphygmomanometer by physicians to the nearest two mm Hg. For this analysis, hypertension was defined using the current definition of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC): systolic pressure of 140 mm Hg or higher or diastolic pressure of 90 mm Hg or higher or current treatment with antihypertensive medicine.[16] This definition was applied to the mean of the two measurements in 1976–1980 and the mean of two or three measurements in 1999–2002.

In 1976–1980, the proportion of zero end digits was higher than the expected 20% in a uniform distribution of the five possible end digits.[2] In 1999–2000 the percent of measurements ending in zero was close to the expected 20%.[7] We adjusted BP for zero end-digit preference using an algorithm to impute values. In each survey the mean and s.d. of the first systolic measurement was used to calculate the expected relative frequency of observations at 140 and 138 mm Hg assuming a log-normal distribution (Table 1). The observed data were imputed so that the relative frequency of observations at 140 and 138 mm Hg was equal to that expected in a log-normal distribution. We randomly selected observations at 140 mm Hg to impute to 138 mm Hg. Diastolic pressures were adjusted in a similar fashion.

The definition of diastolic BP used in 1976–1980 was the level “at the point of complete cessation of Korotkoff sounds (fifth sound) or if no cessation occurred, at the point of muffling (fourth sound)” (p. 4).[17] Unfortunately the data files do not include an indicator of whether Korotkoff V (K5) or Korotkoff IV (K4) was recorded. In contrast in 1999–2002 the diastolic pressure was recorded as K5. The effect of this difference is that some individuals in 1976–1980 might have been classified as hypertensive using K4 but would not using K5, thus 1976–1980 prevalence might be higher because of this. Lack of data on whether K4 or K5 was recorded complicates any attempt to model the effect of this difference on the hypertension prevalence difference. Given that hypertension is the outcome in this study, the effect of the use of K4 instead of K5 is only relevant at the cutpoint of 90 mm Hg. We conducted a sensitivity analysis similar to that done for the effect of zero end-digit preference. We changed all diastolic BP observations at 90–88 mm Hg and calculated the prevalence of hypertension after imputation, modeling the effect of an extreme assumption that all diastolic measurements recorded as 90 mm Hg were measurements of K4 and the corresponding level of K5 would have been <90 mm Hg. The prevalence of hypertension in 1976–1980 showed a moderate decrease from 33.9 to 32.0% and in 1999–2002 from 25.3 to 24.5%.

The 1988 American Heart Association recommendations for BP measurement included corrections for BP not measured with appropriate cuff size based on a study by Maxwell and coauthors.[18,19] They developed correction equations for measurements by three cuffs: 12-cm, 15-cm, and 18-cm. In 1999–2002, five cuffs were available: 6-cm, 9-cm, 12-cm, 15-cm, and 18-cm. In 1976–1980 only two cuffs were used: 9-cm and 12-cm. In 1976–1980, 32.4% of participants had arm circumferences >33 cm, the upper acceptable circumference for a 12-cm cuff according to the 1988 American Heart Association recommendations, and thus should be corrected. Larger cuffs were available in 1999–2002 and Ostchega and coauthors reported that correct cuff sizes were used on over 86% of participants in 1999–2000.[7] We used Maxwell's equations to correct all observed measurements in the 1976–1980 survey. Although the frequency of incorrect cuff size use is less in the 1999–2002 survey, we applied the same corrections to make the data more comparable.

For each cuff size the equation is based on ideal arm circumference, for example for the 12-cm cuff an arm circumference of 30 cm is the ideal size and for a circumference of 32 cm the systolic BP correction would be −2 mm Hg. The majority of participants had nonzero corrections in both surveys; for obese persons in 1976–1980, 99.0% of systolic readings were corrected and 98.6% of diastolic readings; and for 1999–2002, 83.4% of systolic and 75.2% of diastolic readings.

In 1976–1980, 26 participants were measured with the 9-cm cuff. In 1999–2002 for the one participant measured with the 6-cm cuff and 217 measured with the 9-cm cuff, corrections were made using the equation for a 12-cm cuff since the study by Maxwell and coauthors did not include cuffs smaller than 12-cm.

Exclusions

In 1976–1980 of the 11,864 examined adults 20–74 years old, 15 (0.1%) were missing both BP measurements and medication information, 33 (0.3%) were missing BMI, four (0.03%) were missing information on cigarette smoking, and 249 (2.1%) were missing information on education level. The analytic sample consisted of 11,563 participants with complete data. In 1999–2002 of the 8,817 examined adults 20–74 years old, 720 (8.2%) failed to complete the BP component, 171 (1.9%) were missing BMI, 11 (0.1%) were missing information on cigarette smoking, and 14 (0.2%) were missing information on education level. The analytic sample consisted of 7,901 participants with complete data.

Statistical methods

Analyses were conducted using SAS (version 9.1.3; SAS Institute, Cary, NC) and SUDAAN (version 9.0.1; Research Triangle Institute, Research Triangle Park, NC) with examined sample weights and sample design variables to account for the clustered design and produce nationally representative estimates.[20–22] Previous papers on trends in hypertension reported declines adjusted only for age. One of our purposes was to explore whether changes in the distribution of other measured characteristics explained the observed decline. Because age-adjusted estimates formed the basis of our questions we used similarly age-adjusted estimates as our starting point so as not to attribute any part of the observed decline to the aging of the population. For both surveys, estimates were adjusted by the direct method to the 2000 US population using the 20-year intervals: 20–39 years, 40–59 years, and 60–74 years. Differences between surveys in demographic characteristics were tested for statistical significance using *t*-tests, with Bonferroni adjustment for multiple comparisons.[23]

We modeled the association of hypertension with selected risk factors and present model results as predicted prevalences and differences. Log-linear regression models were used to calculate predictive margins with data from the two surveys combined. Predictive margins provide predicted prevalences based on the estimated model coefficients adjusted to the distribution of the covariates included in the model.[8,24–27] The predicted values for each survey were adjusted to the combined sample distribution of covariates and adjustments were model-specific. The predicted values for each survey-BMI category were calculated using the same approach. Previous papers on trends in hypertension that reported a decline used estimates standardized for age with 20-year age intervals.[2,8,28,29] Given that our purpose was to consider possible explanations for this reported decline we used similar 20-year age-adjusted estimates as the base for comparisons.

To evaluate the effect of measurement error, we created separate models using hypertension status corrected for cuff size, corrected for zero end-digit preference, and using hypertension status corrected for both sources of measurement error; these models included age defined using 20-year intervals as the independent variable. We estimated predicted prevalences and differences after adjustment for measured risk factors with and without measurement error corrections. In order to examine possible variation in the prevalence difference by BMI category, we produced estimates by BMI for hypertension as observed and after measurement error correction and with adjustment for age, sex, race-ethnicity, smoking, and education.

RESULTS

There were differences between the two populations in some demographic characteristics associated with hypertension (Table 2).[30] The percent of 20–29 decreased ($P < 0.01$), the percent of 40–49-year olds and 60–69-year olds increased ($P < 0.01$ for both comparisons), the percent of non-Hispanic whites decreased ($P < 0.01$), the percent of persons with more than high-school education increased ($P < 0.01$), and the percent of never smokers increased ($P < 0.01$). The previously noted doubling in the prevalence of obesity is reflected in the increases between the two populations in the two higher BMI categories (BMI ≥ 30.0). This change in the BMI distribution of the population might be expected to result in an increase in hypertension prevalence assuming the association was the same in 1999–2002 as in 1976–1980.

After adjusting to the age distribution of the combined survey population the difference in the predicted hypertension prevalence was −8.6% points (95% confidence interval (CI): −11.4, −5.7) and decreased after correction for measurement error (Figure 1). After correction for cuff size, the age-adjusted difference decreased to a difference of −5.0% points (95% CI: −7.8, −2.3). Correction for zero end-digit preference in both surveys reduced the difference to −7.3% points (95% CI: −10.1, −4.4). After correction for both sources of measurement error, the estimated age-adjusted difference was −4.8% points, 95% CI: −7.5, −2.0).

The decrease in the predicted prevalence difference after correction for cuff size was primarily due to a lowering of the predicted prevalence estimate for 1976–1980 (Table 3). The larger cuff size corrections seen for the 1976–1980 estimates were because of unavailability of larger cuff sizes. Arm circumference was correlated with BMI and thus the corrections for incorrect cuff size were larger for overweight and obese persons measured with an incorrect cuff. For adults 20–74 years, the mean arm circumference was 31.3 cm in 1976–1980 and 33.0 cm in 1999–2002 and increased with BMI level in both surveys.

The observed prevalence difference was larger after adjustment for BMI and age (−14.7 points, 95% CI: −17.6, −11.7) than after adjustment for age alone (Figure 2). This was primarily due to a rise in the predicted prevalence for 1976–1980 from 33.9 to 37.7% (Table 3). This result was in contrast to what one might have expected after adjustment for BMI and age and suggests that the association of obesity and hypertension was different in 1976–1980 and in 1999–2002. The interaction of survey and BMI was tested using the Satterwaite-adjusted *F*-test with models using hypertension before and after correction for measurement error and produced *P* values of 0.01 and 0.45, respectively. This indicates that after correction for measurement error the association of obesity and hypertension did not differ between surveys. Adjustment for sex, race-ethnicity, and education level made little difference in the prevalence or prevalence differences compared to the age-adjusted rates.

After adjustment for all the putative risk factors combined (BMI, age, sex, race-ethnicity, smoking, and education) the predicted difference in hypertension prevalence between surveys was larger than after adjustment for age alone but similar to the adjustment for BMI and age (−14.0 points, 95% CI: −16.9, −10.9). This increase in the predicted difference was also seen when using hypertension prevalence corrected for measurement error (−8.0 points, 95% CI: −10.8, −5.1).

Given our a priori interest in understanding the trends in hypertension with the increase in obesity prevalence across surveys, we estimated the predicted prevalence of hypertension within the five BMI categories after adjusting for sex, race-ethnicity, age, education, and smoking (Table 4). We found that the prevalence of hypertension increased with increasing BMI category in both surveys before and after correction for measurement error. Without measurement error corrections the difference in hypertension prevalence between surveys tended to be larger in overweight and obese subjects than in those who were underweight or normal weight. After correction for measurement error the difference between surveys was more similar between overweight and obese subjects and normal weight subjects.

DISCUSSION

The decline in the prevalence of hypertension was only partially explained by measurement error due to cuff size or end-digit preference and by differences in the distribution of BMI, sex, age, race-ethnicity, education, or smoking between surveys. The decline in hypertension reported from the NHANES has been reported in other studies as well. A decline in hypertension was reported between 1980–1982 and 1985–1987 in the Minnesota Heart Survey and similar trends in BP in Finland were reported between 1982 and 1987.[31,32] In Australia, the prevalence of hypertension decreased between 1980 and 1989 primarily due to a decrease in undiagnosed hypertension.[33]

Unmeasured or unidentified changes in the US population between the two time periods may further explain the decline in the prevalence of hypertension. Dietary intake is one behavior that was measured in the surveys, but differences in the methodologies used made standardization across surveys difficult. [34] Beneficial changes in diet are not likely given analysis of NHANES trends reported for 1971–2000 for the total US population of increased sodium intake and no increase in intake of fruits, vegetables, or low-fat dairy foods.[34] In addition, recent analysis of NHANES data from 1988 to 1994 and 1999 to 2004 suggest that the percentage of hypertensive persons following a Dietary Approaches to Stop Hypertension trail (DASH)-accordant diet has decreased.[35] In addition, a decline in the proportion of adults with no leisure-time physical activity was reported for the time period from 1988 to 2000.[36]

Limitations of this study include inability to adjust for several methodologic differences between the surveys. More intensive and frequent training for BP measurement was conducted in 1999–2002 than in 1976–1980. The most recent recommendations for BP measurement from the American Heart Association identified end-digit preference as a commonly used indicator of measurement quality.[37] The high prevalence of zero end digits in the 1976–1980 data suggest the amount and quality of training during that survey was less than subsequent NHANES surveys which included improved standardization of training reflected in lower proportions of zero end digits.[2,7] The prevalence differences were attenuated after correction for cuff size, due to lowering of the 1976–1980 estimates. This underscores the importance of the use of appropriate techniques and equipment in measuring BP. It is possible that the correction equations were not appropriate. The study by Maxwell and coauthors was based on BP measured in a sample of 1,240 obese patients enrolled in a rapid weight loss study.[19] As far as we are aware the equations have not been validated elsewhere. In addition our corrections did not take into account the variability of the equations. The adjustment equations developed by Maxwell and coauthors have been applied in recent NHANES analyses and confirmation of these adjustment equations would be an important contribution.[38,39]

We found that adjusting for the distribution of BMI in the combined survey population increased the difference in the prevalence of hypertension between the two surveys. This was true even after correction for measurement error. This indicates that obese persons (BMI ≥30.0) in 1999–2002 had a lower rate of hypertension than obese persons in 1976–1980. The similarity in the decline in hypertension in normal weight and obese persons after correction for measurement error suggests a change in some factor or factors that affected all persons regardless of BMI. Furthermore, we found that the observed prevalence difference increased with increasing BMI, however after adjustment for measurement error the differences were more similar.

Acknowledgments

We thank the staff of the NHANE S program for their dedication to high-quality data collection and we thank the survey participants for their willingness to provide information that is widely used for research to improve the public's health. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention. Each of the authors participated in the conceptual design of the study, statistical analysis and interpretation of the data, and the preparation of the manuscript.

References

1. Ogden C, Fryar C, Carroll MD, Flegal KM. Mean Body Weight, Height, and Body Mass Index, United States1960–2002. Adv Data. 2004:347.
2. Burt VL, Cutler JA, Higgins M, Horan MJ, Labarthe D, Whelton P, Brown C, Roccella EJ. Trends in the prevalence, awareness, treatment, and control of hypertension in the adult US population. Data from the health examination surveys, 1960 to 1991. Hypertension. 1995; 26:60–69. [PubMed: 7607734]
3. Flegal KM, Carroll MD, Kuczmarski RJ, Johnson CL. Overweight and obesity in the United States: prevalence and trends, 1960–1994. Int J Obes Relat Metab Disord. 1998; 22:39–47. [PubMed: 9481598]
4. Gross TP, Wise RP, Knapp DE. Antihypertensive drug use. Trends in the United States from 1973 to 1985. Hypertension. 1989; 13:I113–I118. [PubMed: 2577455]
5. Manolio TA, Cutler JA, Furberg CD, Psaty BM, Whelton PK, Applegate WB. Trends in pharmacologic management of hypertension in the United States. Arch Intern Med. 1995; 155:829–837. [PubMed: 7717791]
6. Nelson CR, Knapp DA. Trends in antihypertensive drug therapy of ambulatory patients by US office-based physicians. Hypertension. 2000; 36:600–603. [PubMed: 11040242]
7. Ostchega Y, Prineas R, Paulose-Ram R, Grim C, Willard G, Collins D. National Health and Nutrition Examination Survey 1999–2000: effect of observer training and protocol standardization on reducing blood pressure measurement error. J Clin Epidemiol. 2003; 56:1–7. [PubMed: 12589864]
8. 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]
9. U.S. Department of Health and Human Services National Center for Health Statistics. Plan and operation of the second National Health and Nutrition Examination Survey, United States: 1976–1980. National Center for Health Statistics; Hyattsville, MD: 1981.
10. Centers for Disease Control and Prevention National Center for Health Statistics. NHANES 1999–2000 Procedures Manuals. Centers for Disease Control and Prevention; Hyattsville, MD: 2000.
11. Centers for Disease Control and Prevention National Center for Health Statistics. NHANES 2001–2002 Procedures Manuals. Centers for Disease Control and Prevention; Hyattsville, MD: 2002.
12. Chang VW, Lauderdale DS. Income disparities in body mass index and obesity in the United States, 1971–2002. Arch Intern Med. 2005; 165:2122–2128. [PubMed: 16217002]
13. Hitchcock, D. NHANES II Comparison Data for HHANES Analysis and PIR Definition. National Center for Health Statistics; Hyattsville, MD: 1985. pp. memorandum
14. Kuczmarski RJ, Flegal KM, Campbell SM, Johnson CL. Increasing prevalence of overweight among US adults. The National Health and Nutrition Examination Surveys, 1960 to 1991. JAMA. 1994; 272:205–211. [PubMed: 8022039]
15. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet. 2004; 363:157–163. [PubMed: 14726171]

16. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL Jr, Jones DW, Materson BJ, Oparil S, Wright JT Jr, Roccella EJ. Joint National Committee on Prevention, Detection Evaluation, and Treatment of High Blood Pressure, National Heart, Lung, and Blood Institute; National High Blood Pressure Education Program Coordinating Committee. Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. Hypertension. 2003; 42:1206–1252. [PubMed: 14656957]
17. Drizd T, Dannenberg AL, Engel A. Blood pressure levels in persons 18–74 years of age in 1976–80, and trends in blood pressure from 1960 to 1980 in the United States. Vital Health Stat. 1986; 11:1–68.
18. Frohlich ED, Grim C, Labarthe DR, Maxwell MH, Perloff D, Weidman WH. Recommendations for human blood pressure determination by sphygmomanometers: report of a special task force appointed by the Steering Committee, American Heart Association. Circulation. 1988; 77:501A–514A.
19. Maxwell MH, Waks AU, Schroth PC, Karam M, Dornfeld LP. Error in blood-pressure measurement due to incorrect cuff size in obese patients. Lancet. 1982; 2:33–36. [PubMed: 6123760]
20. National Center for Health Statistics. Analytic and Reporting Guidelines: The Third National Health and Nutrition Examination Survey, NHANES III (1988–94). Centers for Disease Control and Prevention; Hyattsville, MD: 1996.
21. National Center for Health Statistics. NHANES 1999–2000 Addendum to the NHANES III Analytic Guidelines. Centers for Disease Control and Prevention; Hyattsville, MD: 2002.
22. National Center for Health Statistics. NHANES 2001–02 Analytic Guidelines. Centers for Disease Control and Prevention; Hyattsville, MD: 2004.
23. Neter, J., Wasserman, W., Kutner, M. Applied Linear Statistical Models. 2. Richard D. Irwin; Homewood, IL: 1985.
24. Breslow RA, Guenther PM, Smothers BA. Alcohol drinking patterns and diet quality: the 1999–2000 National Health and Nutrition Examination Survey. Am J Epidemiol. 2006; 163:359–366. [PubMed: 16394204]
25. Gregg EW, Gu Q, Williams D, de Rekeneire N, Cheng YJ, Geiss L, Engelgau M. Prevalence of lower extremity diseases associated with normal glucose levels, impaired fasting glucose, and diabetes among U.S. adults aged 40 or older. Diabetes Res Clin Pract. 2007; 77:485–488. [PubMed: 17306411]
26. Kim SY, Breslow RA, Ahn J, Salem N Jr. Alcohol consumption and fatty acid intakes in the 2001–2002 National Health and Nutrition Examination Survey. Alcohol Clin Exp Res. 2007; 31:1407–1414. [PubMed: 17561920]
27. Valdez R, Yoon PW, Liu T, Khoury MJ. Family history and prevalence of diabetes in the U.S. population: the 6-year results from the National Health and Nutrition Examination Survey (1999–2004). Diabetes Care. 2007; 30:2517–2522. [PubMed: 17634276]
28. Glover M, Greenlund K, Ayala C, Croft J. Racial/ethnic disparities in prevalence, treatment, and control of hypertension – United States, 1999–2002. MMWR. 2005; 54:7–9. [PubMed: 15647724]
29. Hajjar I, Kotchen JM, Kotchen TA. Hypertension: trends in prevalence, incidence, and control. Annu Rev Public Health. 2006; 27:465–490. [PubMed: 16533126]
30. Labarthe, D. Epidemiology and prevention of cardiovascular diseases: a global challenge. Aspen Publishers; Gaithersburg, MD: 1998.
31. Kastarinen MJ, Nissinen AM, Vartiainen EA, Jousilahti PJ, Korhonen HJ, Puska PM, Tuomilehto JO. Blood pressure levels and obesity trends in hypertensive and normotensive Finnish population from 1982 to 1997. J Hypertens. 2000; 18:255–262. [PubMed: 10726710]
32. Sprafka JM, Burke GL, Folsom AR, Luepker RV, Blackburn H. Continued decline in cardiovascular disease risk factors: results of the Minnesota Heart Survey, 1980–1982 and 1985–1987. Am J Epidemiol. 1990; 132:489–500. [PubMed: 2389753]
33. Bennett SA, Magnus P. Trends in cardiovascular risk factors in Australia. Results from the National Heart Foundation’s Risk Factor Prevalence Study, 1980–1989. Med J Aust. 1994; 161:519–527. [PubMed: 7968750]

34. Briefel RR, Johnson CL. Secular trends in dietary intake in the United States. Annu Rev Nutr. 2004; 24:401–431. [PubMed: 15189126]
35. Mellen PB, Gao SK, Vitolins MZ, Goff DC Jr. Deteriorating dietary habits among adults with hypertension: DASH dietary accordance, NHANES 1988–1994 and 1999–2004. Arch Intern Med. 2008; 168:308–314. [PubMed: 18268173]
36. Centers for Disease Control and Prevention. Prevalence of no leisure-time physcial activity – 35 states and the District of Columbia, 1988–2002. MMWR. 2004; 53:82–86. [PubMed: 14762333]
37. Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN, Jones DW, Kurtz T, Sheps SG, Roccella EJ. Recommendations for blood pressure measurement in humans and experimental animals: part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. Circulation. 2005; 111:697–716. [PubMed: 15699287]
38. Gregg EW, Cheng YJ, Cadwell BL, Imperatore G, Williams DE, Flegal KM, Narayan KM, Williamson DF. Secular trends in cardiovascular disease risk factors according to body mass index in US adults. JAMA. 2005; 293:1868–1874. [PubMed: 15840861]
39. Kanjilal S, Gregg EW, Cheng YJ, Zhang P, Nelson DE, Mensah G, Beckles GL. Socioeconomic status and trends in disparities in 4 major risk factors for cardiovascular disease among US adults, 1971–2002. Arch Intern Med. 2006; 166:2348–2355. [PubMed: 17130388]

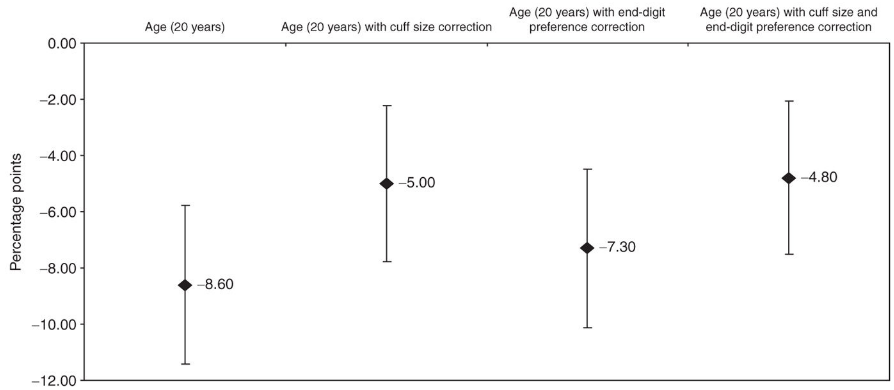

Figure 1.
Predicted prevalence difference between 1999–2002 and 1976–1980 (95% confidence interval) for hypertension in adults 20–74 years with corrections for measurement error.

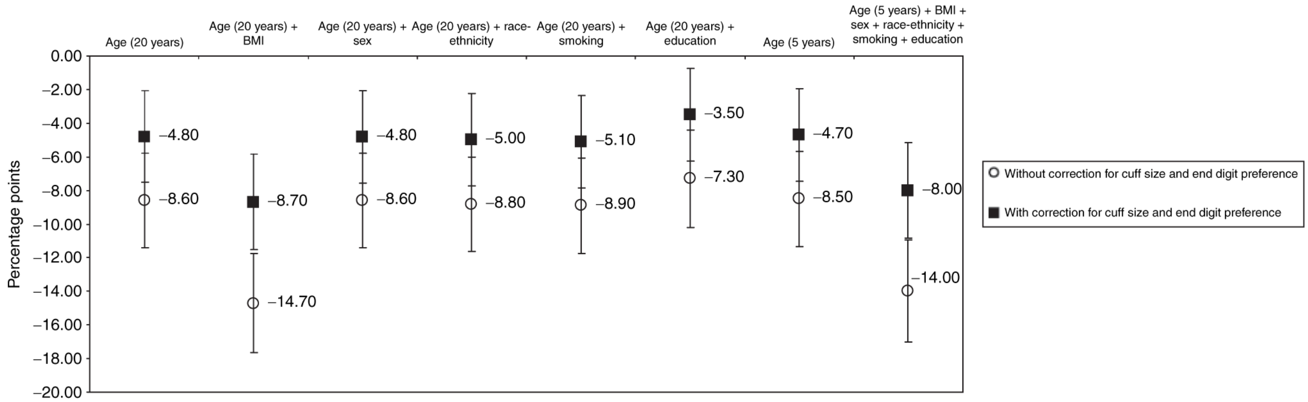

Figure 2.

Predicted prevalence difference between 1999–2002 and 1976–1980 (95% confidence interval) for hypertension in adults 20–74 years with corrections for measurement error and adjustment for age, body mass index (BMI), sex, race-ethnicity, smoking, and education.

Table 1

Relative frequency (%) of observations at hypertension cutpoints in the National Health and Nutrition Examination Survey, 1976–1980 and 1999–2002

	1976–1980 measurements			1999–2002 measurements			
	First	**Second**	**Expected[a]**	**First**	**Second**	**Third**	**Expected[a]**
Systolic pressure (mm Hg)							
140	69.1	76.6	48.5	57.5	47.0	55.4	48.6
138	30.9	23.4	51.5	42.5	53.0	44.6	51.4
Diastolic pressure (mm Hg)							
90	74.6	68.8	47.6	54.3	54.4	48.2	41.9
88	25.4	31.2	52.4	45.7	45.6	51.8	51.8

[a]Expected frequencies assuming a log-normal distribution.

Table 2

Percent (s.e.) with selected demographic characteristics

	1976–1980	1999–2002
Age in years		
20–29	27.8 (0.65)	20.3 (0.79)[a]
30–39	20.5 (0.55)	22.9 (0.91)
40–49	16.8 (0.42)	23.5 (0.75)[a]
50–59	16.7 (0.45)	17.2 (0.65)
60–69	13.6 (0.38)	11.3 (0.53)[a]
70–74	4.6 (0.28)	4.8 (0.25)
Body mass index		
<18.5	3.3 (0.16)	2.0 (0.18)[a]
18.5–24.9	50.8 (0.81)	33.0 (0.75)[a]
25.0–29.9	31.4 (0.62)	34.2 (0.85)
30.0–34.9	10.1 (0.36)	17.9 (0.57)[a]
≥35.0	4.4 (0.16)	13.0 (0.68)[a]
Sex		
Male	47.6 (0.50)	48.5 (0.49)
Female	52.4 (0. 50)	51.5 (0.49)
Race-ethnicity		
Non-Hispanic white	82.6 (1.40)	70.4 (1.78)[a]
Non-Hispanic black	10.0 (1.25)	11.2 (1.23)
Other	7.3 (0.98)	18.4 (2.11)[a]
Cigarette smoking[b]		
Never	40.0 (0.64)	50.3 (1.23)[a]
Former	22.9 (0.46)	24.0 (0.87)
Current	37.1 (0.62)	25.7 (0.90)[a]
Education		
<High school	32.7 (0.97)	23.5 (1.25)[a]
High school	35.6 (0.83)	25.8 (1.92)[a]
>High school	31.6 (1.08)	50.7 (2.22)[a]

All estimates other than age-specific estimates were adjusted by the direct method to the 2000 US population using the following age groups: 20–39 years, 40–59 years, and 60–74 years.

[a]Differences between 1976–1980 and 1999–2002 were statistically significant at $P < 0.01$, the α-level reflecting adjustment for multiple comparisons.

[b]In both surveys smoking status was categorized as never smokers (defined as persons who reported not smoking at least 100 cigarettes in their life), former smokers (defined as persons who reported smoking at least 100 cigarettes in their life but were not currently smoking), and current smokers (defined as persons who reported smoking at least 100 cigarettes in their life and were currently smoking).

Author Manuscript

Author Manuscript

Author Manuscript

Table 3

Predicted prevalence of hypertension in adults 20–74 years with corrections for measurement error and adjustment for age, sex, race-ethnicity, education, smoking, and body mass index (BMI)

	Predicted prevalence[a] of hypertension (s.e.)			
	Without adjustment for cuff size and end-digit preference		With adjustment for cuff size and end-digit preference	
Model	**1999–2002**	**1976–1980**	**1999–2002**	**1976–1980**
Age (in 20-year intervals)	25.3 (0.91)	33.9 (1.12)	25.5 (0.88)	30.3 (1.08)
Age (in 20-year intervals) + sex	25.3 (0.91)	33.9 (1.12)	25.5 (0.88)	30.3 (1.09)
Age (in 20-year intervals) + race-ethnicity	25.2 (0.92)	34.0 (1.10)	25.4 (0.90)	30.4 (1.07)
Age (in 20-year intervals) + education	25.7 (0.90)	33.0 (1.16)	25.9 (0.87)	29.4 (1.11)
Age (in 20-year intervals) + sex + race-ethnicity + education	25.4 (0.91)	33.5 (1.16)	24.3 (0.84)	32.3 (1.19)
Age (in 20-year intervals) + smoking	25.2 (0.92)	34.1 (1.12)	25.4 (0.89)	30.5 (1.09)
Age (in 20-year intervals) + BMI	23.0 (0.84)	37.7 (1.24)	24.1 (0.82)	32.8 (1.19)
Age (in 5-year intervals) + sex + race-ethnicity + education + smoking + BMI	23.2 (0.84)	37.2 (1.30)	24.3 (0.84)	32.3 (1.19)

[a]All differences between 1976–1980 and 1999–2002 were statistically significant at $P < 0.01$.

Table 4

Predicted prevalence (percent) of hypertension in adults 20–74 years by body mass index (BMI) category with corrections for measurement error and adjustment for age, sex, race-ethnicity, education, and smoking

	Without adjustment for cuff size and end-digit preference		**With adjustment for cuff size and end-digit preference**	
	1999–2002	**1976–1980**	**1999–2002**	**1976–1980**
BMI				
<18.5	15.9 (3.54)	11.8 (2.38)	17.4 (3.86)	16.9 (2.66)
18.5–24.9	13.1 (0.97)	20.7 (1.07)	15.0 (1.06)	21.5 (1.07)
25.0–29.9	25.5 (1.49)	41.3 (1.66)	26.0 (1.26)	34.6 (1.51)
30.0–34.9	35.6 (1.40)	55.4 (2.23)	35.2 (1.40)	42.7 (1.91)
≥35.0	44.7 (2.37)	67.2 (2.64)	43.8 (2.06)	52.5 (2.10)

Separate models for each BMI group included adjustment for age, sex, race-ethnicity, education, and smoking. All differences between 1976–1980 and 1999–2002 were statistically significant at $P < 0.01$.