The Elusiveness of Population-Wide High Blood Pressure Control

Paul K. Whelton

Department of Epidemiology, School of Public Health and Tropical Medicine, Tulane University, New Orleans, Louisiana 70112; email: pkwhelton@gmail.com

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Abstract

High blood pressure (hypertension) is a leading risk factor for cardiovascular disease. It is highly prevalent in the US general population, especially in those who are old, African American, or socially disadvantaged. Prevalence is also high and increasing worldwide. Awareness, treatment, and control of hypertension have improved over time, but there is still considerable room for improvement. The optimal solution to this health challenge varies by country. Several nonpharmacologic and pharmacologic interventions are well proven as effective means to prevent hypertension and improve control rates in those with established hypertension. Better prevention and control of hypertension will yield substantial general population health benefits and remain high priorities in public health.

INTRODUCTION

High blood pressure (BP) is one of the most important risk factors for morbidity and mortality (63). Many reports have identified high BP as the best example of a surrogate measure for cardiovascular disease, especially for stroke (19, 26, 60, 68). A recent report from the Global Burden of Disease Study ranked high BP as the most important risk factor among 67 risk factors studied for worldwide mortality [9.4 million deaths, 95% confidence interval (CI) 8.6–10.1 million] and disability-adjusted life years (7%, 95% CI 6.2–7.7%) during 2010 (64). Nonpharmacologic treatments, especially dietary sodium reduction, have been utilized for hypertension since the early 1900s (27). Various drugs and surgical therapies were introduced shortly after World War II, but they proved to be relatively ineffective and many of the drugs produced severe side effects. The modern era of effective drug therapy started with the introduction of thiazides in the early 1960s, which was followed by conduct of the first randomized controlled trial to document the capacity of diuretics to prevent cardiovascular disease (CVD) (27). Over the next 50 years, numerous randomized controlled trials documented the effectiveness of several classes of drugs in lowering BP and preventing CVD, with few if any side effects (27, 49, 66). Likewise, several nonpharmacologic interventions including weight loss, dietary sodium reduction, potassium supplementation, physical activity, reduced alcohol consumption, and low-fat diets rich in fruits and vegetables have been effective in lowering BP and preventing hypertension (6, 96, 98). The current array of drug and nondrug therapeutic options allows for control of hypertension to currently recommended goal BP levels in all but the rarest patient and provides the capacity to reduce BP to levels much lower than current guidelines recommend (1, 5, 84). Despite this capability, the vast majority of patients with hypertension worldwide are untreated or inadequately treated. This article explores the elusiveness of high BP control in the general population of the United States and worldwide and reviews the literature related to approaches that could dramatically improve hypertension control rates in different settings. It is focused on the treatment of established hypertension rather than on the prevention of hypertension and deals mainly with issues related to pharmacologic rather than nonpharmacologic therapy.

BLOOD PRESSURE AND RISK OF CARDIOVASCULAR DISEASE

In most societies, systolic BP (SBP) rises progressively from early childhood until the seventh or eighth decade of life (95). Diastolic BP (DBP) also rises but less steeply and remains constant or declines after the fifth to sixth decade of life. Increasing levels of BP are associated with progressively higher risk of CVD (85) and renal disease (55). In both men and women, the relationship between BP and CVD risk is strong, progressive, and statistically significant throughout life, with no evidence of a threshold for BP-related risk (63, 85). Overall, a 20-mm Hg higher level of SBP is associated with a twofold increase in mortality from stroke and ischemic heart disease. Both SBP and DBP are important independent predictors of risk, but SBP is the more potent risk factor, especially at higher levels of BP (85). Accumulating evidence indicates that higher levels of variability in BP are associated with increased CVD risk (70, 78), but the magnitude of this effect is secondary to that associated with increases in BP, per se. Because of its consistent, strong relationship with vascular disease in cohort studies and clinical trials, high BP has been identified as the leading example of a valid surrogate measure for CVD, especially stroke (19, 26, 60, 68).

CLASSIFICATION OF BLOOD PRESSURE

To facilitate decision making, one can divide the distribution of BP into categories. The most basic classification system categorizes BP on the basis of the presence or absence of high BP (hypertension). This definition is often expanded to include subcategories or stages of hypertension, a high normal BP category (often called prehypertension), and a normal BP category (sometimes further classified to identify the group with the lowest or optimal BP). Hypertension is an important predictor of CVD risk. In a classic long-term follow-up study of almost 350,000 US adults, the 25% with hypertension accounted for about two-thirds of the population burden of BP-related CVD (85). Most of those categorized as being normotensive still had an average BP above the optimal level, and collectively they accounted for about one-third of the BP-related CVD population attributable risk. Much of the BP-related CVD burden in normotensives can be attributed to those with a high normal BP (35, 69, 85).

PREVALENCE OF HYPERTENSION

Prevalence estimates are greatly influenced by choice of diagnostic criteria, the methods for applying these criteria, and the population studied. In 1993, the fifth report of the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure recommended diagnosis of hypertension in adults based on the presence of an average SBP $\geq$ 140 mm Hg or DBP $\geq$ 90 mm Hg or on self-report of current treatment with BP-lowering medication (51). The core elements of this classification system are commonly used in clinical practice and population surveys. Unless otherwise specified, this definition of hypertension is employed throughout this article. Altering the BP cut-points or including self-reported history of hypertension as an additional diagnostic criterion results in a different estimate of prevalence. For example, when the definition is expanded to include individuals who do not meet the previously mentioned criteria but were previously diagnosed as having hypertension by a health professional, prevalence estimates are usually increased by 5–10%, at least in high-income countries (9, 15, 25, 58, 73). The majority of individuals added using this expanded definition of hypertension have been previously diagnosed by a health professional on more than one occasion, and many have been advised to change their lifestyle (9, 15).

Independent of diagnostic criteria, estimates of hypertension prevalence will be substantially affected by the methods used to measure BP (76, 89). BP tends to vary substantially from one reading to another owing to a combination of random and systematic errors. Some of the more common sources of systematic error include variations in the circumstances of the measurement (environment, activity, posture), selection of equipment (manual versus automated), BP measurement technique, choice of Korotkoff blood flow sounds that health care providers use to recognize SBP and DBP when taking manual blood pressure measurements with a stethoscope and sphygmomanometer, and selection of the specific BP readings to be used. Averaging BP readings is employed as a means to reduce random error. Variations in the approach to calculating the average will influence prevalence estimates. In clinical practice, use of an average value based on two or more readings on each of two or more office visits is usually recommended to reduce random error (13, 51). In most contemporary surveys, BPs are observed at only a single visit, and the average value is based on use of all readings (usually three) or all readings except the initial measurement. Use of more readings will tend to provide a slightly lower estimate of prevalence owing to regression to the mean (39).

Because BP levels and prevalence of hypertension vary with age and other demographic characteristics, choice of population can have an enormous impact on prevalence. Unless otherwise specified, this article focuses on prevalence in adult general populations. Crude or unadjusted prevalence provides the best estimate of hypertension burden in a population. It is greatly influenced by the population's demographic characteristics, especially age structure. Comparisons of hypertension prevalence from different populations and during temporal trends analysis in the same population require careful attention to the similarity of the criteria used for diagnosis, the methods used for measurement, and the populations studied. Estimates of the extent to which differences in the definition of hypertension and approaches to age adjustment affect reports of hypertension prevalence and control in general population surveillance studies have been published (15).

US General Population

Since the 1960s, the National Center for Health Statistics (NCHS) has published periodic estimates of hypertension prevalence, treatment, and control in the noninstitutionalized general population of the United States based on National Health and Nutrition Examination Survey (NHANES) study experience. These estimates provide the principal means to track progress in meeting national goals for prevention, treatment, and control of hypertension. NHANES BP measurement methods have remained fairly constant, with the exception that the number of BP readings and BP measurement occasions varied slightly until they stabilized in the 1990s to three measurements by a trained physician at a single visit. In all NHANES surveys, the prevalence of hypertension has risen progressively with increasing age. In the 2009–2012 NHANES survey, the prevalence of hypertension in US adult men and women increased from ∼10% during the second to fourth decade of life to ≥75% in those aged 75+ years (**Figure 1**). Because of this striking relationship, comparisons of prevalence rates are best conducted using age-specific or age-adjusted rates unless there is good evidence that the population age structures are similar. The absolute

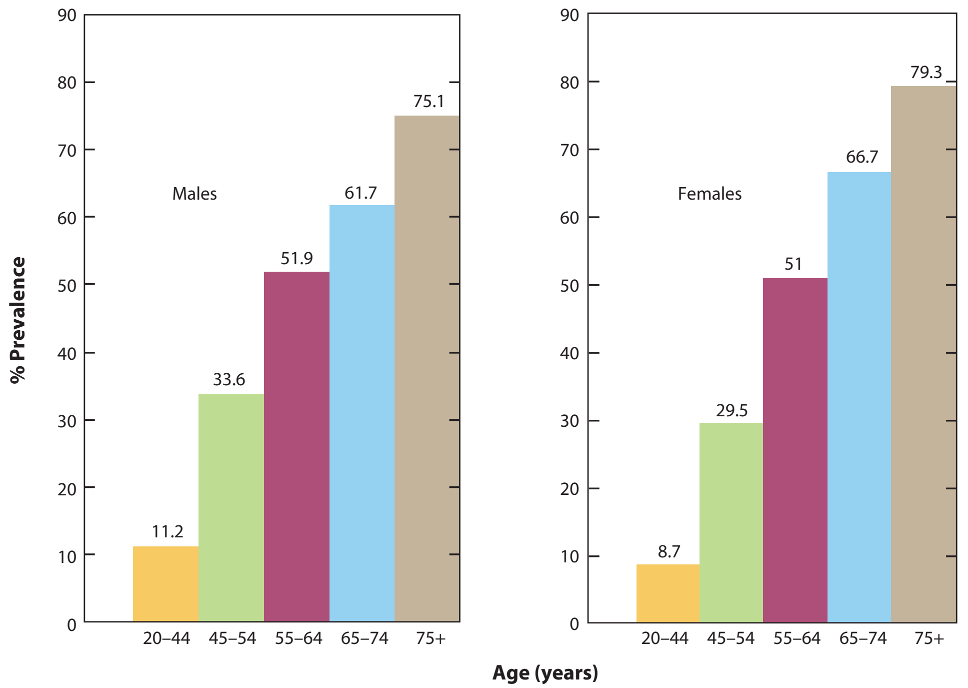

Figure 1

Age-specific prevalence of hypertension, US adults 2009–2012 (based on data from Reference 71, table 65). Hypertension was defined as the presence of an average systolic blood pressure (SBP) ≥ 140 mm Hg, an average diastolic BP (DBP) ≥ 90 mm Hg, or a self-report of current treatment with BP-lowering medication. BP averages were calculated using all available readings (three readings for 84% of the participants).

values cited in different publications that have analyzed NHANES temporal trends in prevalence rates have been based on a mix of age-specific rates and unadjusted rates (37), age-adjusted rates that employed the 2000 US standard population (18, 41, 71), or age-adjusted rates based on the 2000 US census (22). In the study by Crim et al. (15), use of crude versus age-adjusted rates in NHANES resulted in only a modest difference in prevalence estimates. In contrast, use of an expanded definition that included self-reported hypertension yielded prevalence estimates that were 5–6% higher than those accrued with the standard definition. Addressing this variance has been a high priority in NHANES, which has recognized the intrinsic challenge of maintaining constant survey methods over a prolonged period. It seems likely that the differences in hypertension prevalence noted in NHANES temporal trends analyses are real, especially those that have been relatively large and replicated in consecutive surveys. Age-adjusted prevalence of hypertension in US adults seemed to peak at slightly more than 36% in the early 1970s (8), to decline to a low of ~20–25% during the latter part of the 1980s (8, 54), and to rise again during the 1990s to its current level of slightly more than 30% by the early 2000s. Part of the latter increase could be attributed to the worsening epidemic of obesity and overweight in the United States (18, 25). Temporal trends for crude and age-adjusted rates of hypertension prevalence between 1988–1994 and 2009–2012 are displayed in **Figure 2**. Age was adjusted to the year 2000 US standard population using five

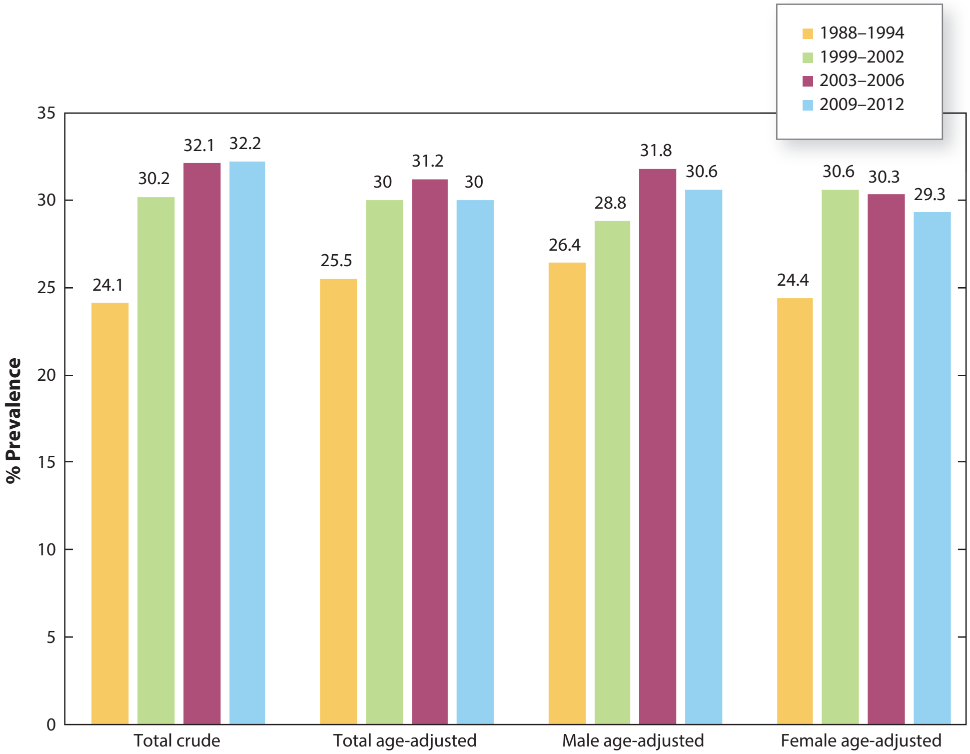

Figure 2

Age-adjusted temporal trends in prevalence of hypertension, US adults ≥20 years of age (based on data from Reference 71, table 65). Age was adjusted to the year 2000 standard population using 5 age groups: 20–34 years, 35–44 years, 45–54 years, 55–64 years, and ≥65 years. Hypertension was defined and BP averages were calculated as described in the caption for **Figure 1**.

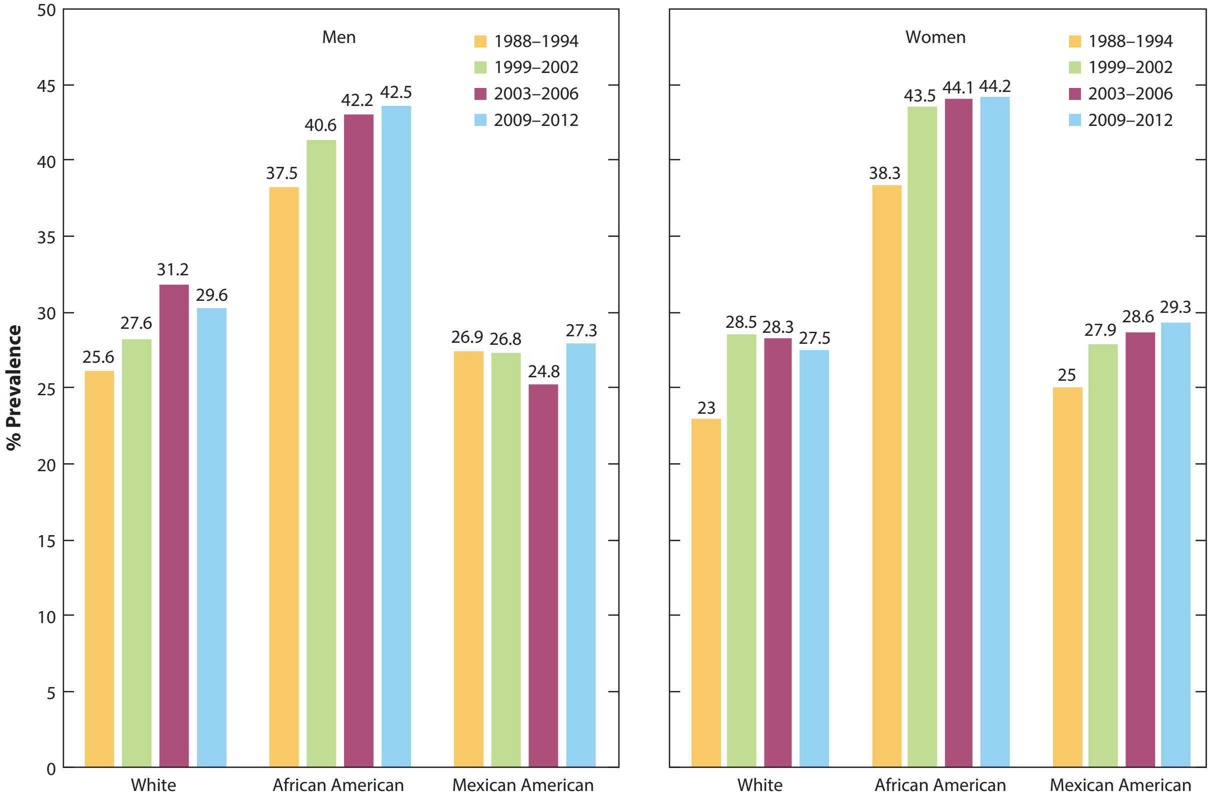

Figure 3

Age-adjusted temporal trends in prevalence of hypertension by gender and ethnicity (based on data from Reference 71, table 65). Estimates for whites and African Americans are from the non-Hispanic or Latino population. Hypertension was defined and blood pressure averages were calculated as described in the caption for **Figure 1**. Age was adjusted as described in the caption for **Figure 2**.

age groups. There was a small decline in the age-adjusted prevalence rate between 2003–2006 and 2009–2012; age-adjusted prevalence in the most recently reported 2011–2012 NHANES survey was 29.1% (72). Age-adjusted prevalence of hypertension was similar in men and women but was more than 10% higher in African Americans compared with whites and Mexican Americans, with a prevalence of 42.5% and 44.2% in African American men and women, respectively, in 2009–2012 (**Figure 3**). Prevalence of hypertension is also related to socioeconomic status. For example, age-adjusted prevalence of hypertension in the 2009–2012 NHANES survey was progressively lower for increasing categories of income, with an almost 20% difference in prevalence between those below (35%) and their counterparts with an income ≥400% above (28.9%) the US Government poverty level (71).

General Populations in Other Countries

Differences in survey methodology and sampling techniques complicate worldwide comparisons of hypertension prevalence to a much greater extent than shown in the NHANES analyses. Thus the reported estimates vary substantially by country, geographic region, socioeconomic status, and demographic profile in most reports (28, 54, 62, 100). Germany is frequently identified as the high-income country with the highest average BP and prevalence of hypertension, with an overall prevalence in adults that exceeds 40% (28, 46, 54, 58, 62, 82, 100). At the other extreme, Canada is often identified as the high-income country with the lowest prevalence of hypertension. In a comparison of unadjusted rates for adults 20–79 years in the United States (2007–2010), in Canada (2007–2009), and in England (2006), the reported prevalence of hypertension was ~10% lower in Canada (19.1%) compared with the United States (29.1%) or England (30.0%) (50). Middle- and low-income nations tend to have a lower prevalence (46), but there are exceptions to this general pattern (28, 46, 54, 62, 74). Surveys from Russia and several other northern Eastern European countries have identified a high prevalence of hypertension (46). Per capita gross national product has been directly related to prevalence of hypertension (28), and economic development has tended to be accompanied by a concurrent increase in the prevalence of hypertension and other modifiable CVD risk factors. For instance, in China the overall prevalence of hypertension was <10% in general population surveys conducted between the 1950s and early 1990s (101) but increased progressively in later years to levels closer to the prevalence of hypertension in the United States (29, 36, 102, 103). In the early 1990s, age-specific estimates of hypertension prevalence in Egypt were as high as the corresponding values in the United States (99).

Geographic Differences Within Countries and Regions

Geographic differences in the prevalence of hypertension within countries and regions have been a consistent finding worldwide. In NHANES III, SBPs and DBPs [crude and adjusted for age, ethnicity, gender, body mass index (BMI), and total energy intake] were significantly higher in the South compared with other regions of the United States (40). Olives et al. (73) used a combination of data from NHANES (average SBP > 140 mm Hg or self-reported use of BP-lowering medication) and the CDC Behavioral Risk Factor Surveillance System (self-reported hypertension) to estimate hypertension prevalence in a nationwide sample of US counties. Substantial regional differences were noted; investigators observed the highest prevalence in the southeastern "stroke belt" states, which experience unusually high stroke incidence and mortality. A similar but even more pronounced pattern was noted for prevalence of uncontrolled hypertension. National surveys in China have repeatedly identified higher average BPs and a nearly 50% higher prevalence of hypertension in northern compared with southern China (77, 86, 101, 102), with a striking geographic relationship between prevalence of hypertension and incidence of stroke (42, 43). Geographic variation has been noted in many other regions, including countries in Western Europe (20, 23), North Africa (45), sub-Saharan Africa (52, 90), and the Arabian Peninsula (2). Potential explanations for this variability include differences in demographic factors, socioeconomic status, BMI, diet, physical activity, and other environmental factors such as ambient temperature and prevalence of lead and other heavy metals. In both the United States and China, regional differences have been associated with differences in BMI, sodium and potassium intake, physical activity, and macronutrient intake (40, 105).

Global Burden

A 2002 worldwide estimate, based on application of the most representative general population survey results to country-specific census information, identified approximately one billion adults with hypertension (53). Two-thirds resided in economically developing countries. Based on demographic trends alone, the number of persons with hypertension was projected to increase to more than 1.5 billion by 2025. Using a lower SBP threshold for recognition of high BP than is typical in clinical practice (≥110–115 mm Hg), the Global Burden of Disease 2010 Study Group identified high BP as the leading risk factor of 67 risk factors studied for worldwide mortality (9.4 million, 95% CI 8.6–10.1 million) and disability-adjusted life years (7.0%, 95% CI 6.2–7.7%) in 2010 (64). In the Group's analysis, high BP was responsible for more deaths than were the second (tobacco products) and third (acute respiratory infections) most important risk factors combined.

AWARENESS, TREATMENT, AND CONTROL OF HYPERTENSION

In this article, awareness of hypertension is based on self-reported knowledge of the diagnosis in individuals who meet the standard definition for diagnosis of hypertension (average SBP ≥ 140 mm Hg, DBP ≥ 90 mm Hg, or self-report of BP-lowering medication use). The percent treated is based on use of BP-lowering medication in all persons with hypertension, and percent controlled represents the percent of all persons with hypertension who are treated with BP-lowering medication and who have an average SBP < 140 mm Hg and a DBP < 90 mm Hg, unless otherwise specified as the percent controlled in the subset being treated with BP medication. Estimates of hypertension awareness, treatment, and control in whites, blacks and Asians reflect the prevalence for these ethnic groups in non-Hispanic persons.

US General Population

Prevalence rates for hypertension awareness, treatment, and control have been improving progressively in the US general adult population for as long as NHANES surveys have been conducted (8, 18, 22). In contrast with the limited impact of age adjustment on estimation of hypertension prevalence in NHANES, use of unadjusted estimates or age-adjusted estimates based on the subpopulation with hypertension will yield a higher prevalence for hypertension awareness, treatment, and control (~2.5% different) compared with the use of the US 2000 standard population. Hypertension awareness increased from ~50% in the late 1970s (8) to ~70% by the late 1990s (18, 41) and 80% a decade later (22). The temporal trends pattern for prevalence of hypertension treatment looks similar, albeit the rates are ~5–10% lower at corresponding time points. In the most recent time trend report, the unadjusted rate of treatment among adults with hypertension increased progressively across five successive NCHS surveys from 63.5% in 2001–2002 to 77.3% in 2009–2010 (37). The percent of persons with hypertension being controlled increased from ~10% in the late 1970s (~30% in those being treated) (8) to ~50% in recent surveys (~70% in those being treated) (22, 37). The pattern for change in unadjusted prevalence of hypertension control during the past two decades is displayed in **Figure 4**. Overall, rates more than doubled between 1988–1994 and 2009–2012 from 26.1% to 52.6% of all persons with hypertension (71). A similar pattern was noted for change in hypertension control rates age-adjusted to the 2000 general US population age structure, albeit at lower absolute prevalence rates (22.8% in 1988–1994 to 44.9% in 2009–2012) (71). The overall prevalence of hypertension awareness, treatment, and control in the 2011–2012 NHANES survey is displayed in **Figure 5**, and estimates by gender, age, and race are displayed in **Figures 6**, **7**, and **9**, respectively. The overall race and gender estimates were age-adjusted using the age structure of the subpopulation with hypertension in 2011–2012 (72). The overall prevalence rates for hypertension awareness, treatment, and control were 82.7%, 75.6%, and 51.8%, respectively (**Figure 5**). Rates of awareness, treatment, and control were higher in women compared with men, with a difference in control of 5.9% (**Figure 6**). Even larger differences were noted for the comparisons of age-specific rates: The percent controlled in individuals 18–39 years was 23.4% and 16.1% lower than corresponding estimates in those 40–59

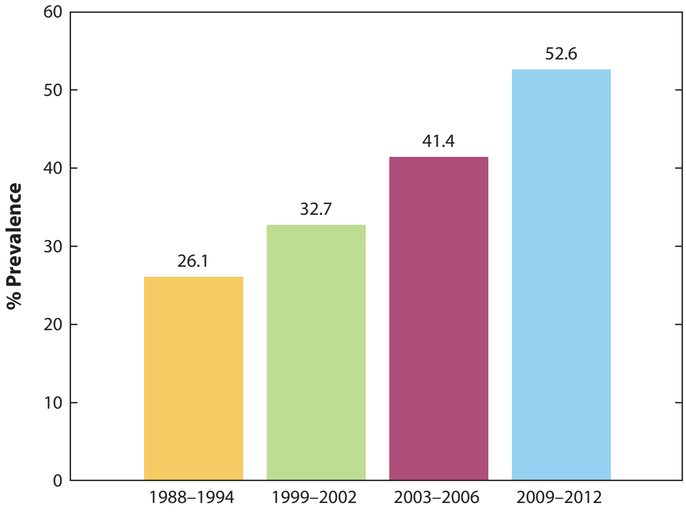

Figure 4

Temporal trends in the control of hypertension, US adults ≥20 years of age. Crude rates calculated from data in Reference 71, table 65. Control of hypertension was defined as having an average SBP < 140 mm Hg and an average DBP < 90 mm Hg in persons reporting current treatment with BP-lowering medication.

and ≥60 years, respectively (**Figure 7**). A more comprehensive exploration of rates by age and gender, using the 2009–2012 NHANES data set, is presented in **Figure 8**. It identifies far better control of hypertension in women compared with men from 20 to 64 years (23.8% difference in adults aged 20–44 years) and in men compared with women for persons ≥65 years (8.9% difference in adults aged ≥75 years). Investigators also noted differences by race/ethnicity; Asians had the

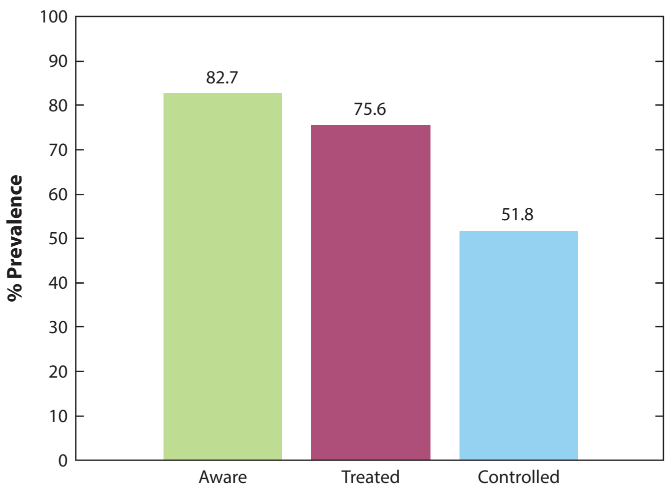

Figure 5

Prevalence of awareness, treatment, and control in the US general population, 2011–2012. Results were based on data from the 2011–2012 National Health and Nutrition Examination Survey (72, figure 2). Age was adjusted using the subpopulation of persons with hypertension in 2011–2012, as recommended by the National Surveillance Definitions for Hypertension (15). Awareness, treatment, and control were defined as in the text and in Reference 72.

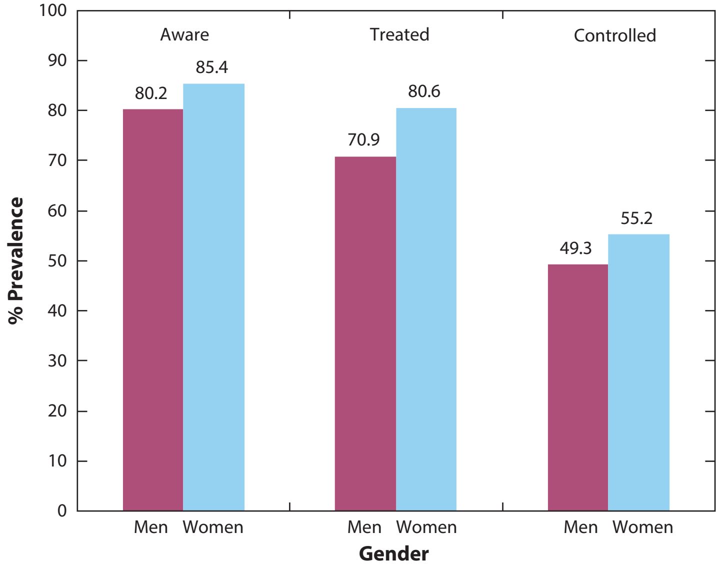

Figure 6

Age-adjusted prevalence of awareness, treatment, and control by gender, in US adults with hypertension, 2011–2012. Results were based on data from the 2011–2012 National Health and Nutrition Examination Survey (72, figures 3 and 5). Age was adjusted and awareness, treatment, and control were defined as described in the caption to **Figure 5**.

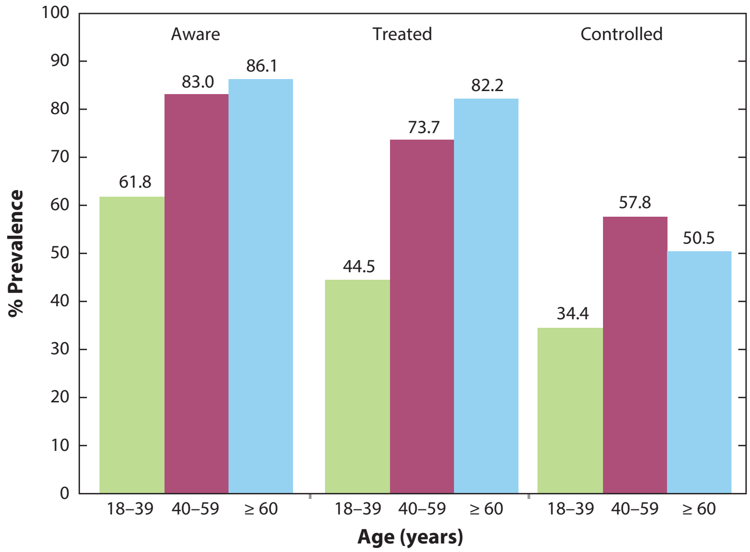

Figure 7

Age-specific prevalence of hypertension awareness, treatment, and control in US adults with hypertension, 2011–2012. Results were based on data from the 2011–2012 National Health and Nutrition Examination Survey (72, figures 3–5). Awareness, treatment, and control were defined as described in the caption to **Figure 5**.

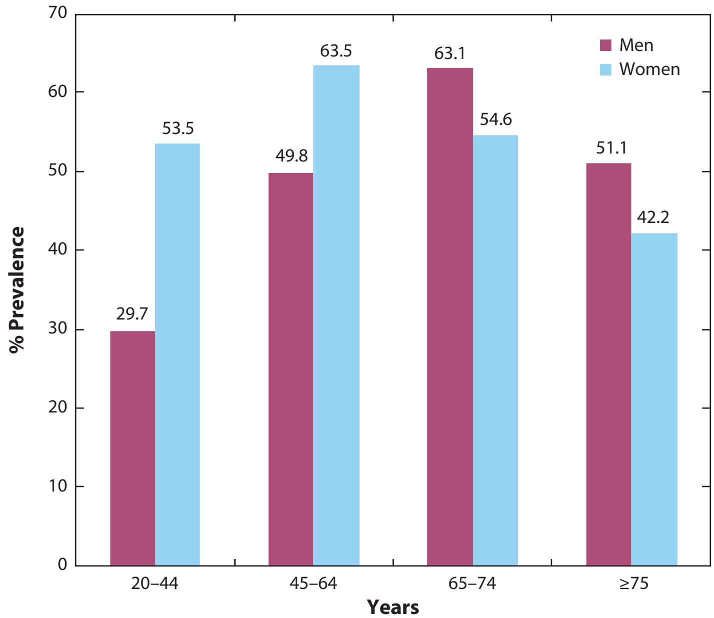

Figure 8

Age-specific prevalence of hypertension control in US adults, 2009–2012. Results were calculated from Reference 71, table 65. Control of hypertension was defined as having an average SBP $<$ 140 mm Hg and an average DBP $<$ 90 mm Hg in persons reporting current treatment with BP-lowering medication.

least favorable awareness, treatment, and control of hypertension in 2011–2012. Compared with whites, hypertension control was 7.9%, 7.4%, and 4.4% lower in Asians, Hispanics, and blacks, respectively (**Figure 9**). The relationship between income level and both prevalence of hypertension and control of hypertension in 2003–2006 NHANES participants is displayed in **Figure 10**. There was an inverse relationship between income level and prevalence of hypertension, with a 6.1% difference in prevalence between those below the poverty level (35%) and their counterparts with an income more than 4 times greater than the poverty level (28.9%). Investigators noted a strong progressive curvilinear relationship between income level and age-adjusted control rates; a 13% difference was shown between individuals below the poverty line (30.2% controlled) and those with incomes more than 4 times the poverty level (43.2% controlled) (71).

Other Countries

During recent decades, hypertension awareness, treatment, and control experiences have been made available from an increasingly large number of countries around the world. International comparisons should be interpreted with caution. In addition to the previously mentioned differences in survey methodology, formats for presentation of survey results vary considerably; most between-country contrasts are based on comparisons of crude rather than adjusted rates. In some reports, rates for treatment and control reflect experience in all adults with hypertension, whereas in others, the focus is on control rates in the subset of persons with treated hypertension. Recognizing these constraints, substantial improvements in treatment and control rates have been noted over time in all countries with temporal trends experience (24, 46). An age-adjusted comparison in 35- to 84-year-old adults in the United States, England, and Japan identified progressive

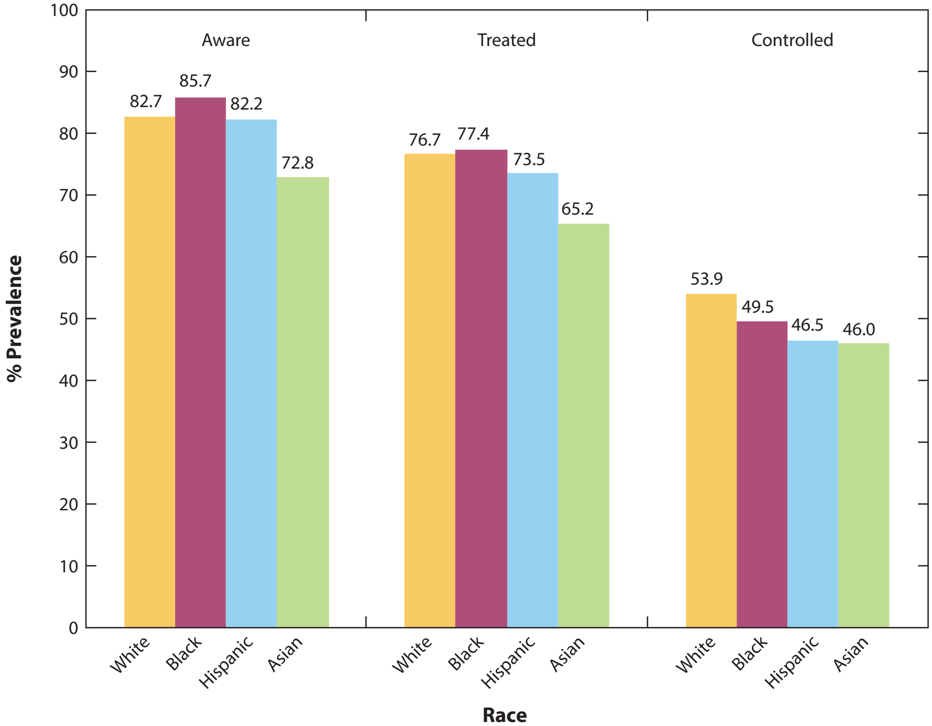

Figure 9

Age-adjusted prevalence of hypertension awareness, treatment, and control by race in US adults with hypertension, 2011–2012. Results were based on data from the 2011–2012 National Health and Nutrition Examination Survey (72, figures 3–5). Age was adjusted and awareness, treatment, and control were defined as described in the caption to **Figure 5**. Whites, blacks, and Asians were non-Hispanic.

improvements in hypertension awareness, treatment, and control rates in all three countries between 1980 and 2009 (46). In 2009, the age-adjusted percent whose hypertension was being treated and controlled in this age range was identified as 59.1%, 32.0%, and 24.8% in the United States, England, and Japan, respectively (46). Based on experience in the 1990 National Survey of Circulatory Disorders in Japan, Sekikawa & Hayakawa (80) reported much lower rates of hypertension treatment and control in Japanese adults, with the control rates in those 30–44 years, 45–64 years, and ≥65 years being 1.1%, 3.6%, and 5.1%, respectively, in men and 1.4%, 5.3%, and 7.8%, respectively, in women. A comparison of crude rates from successive national surveys of adults ≥16 years of age in England identified a progressive improvement in hypertension awareness, treatment, and control: The percent controlled increased from 11% in 1994 to 37% in 2011 (24). The highest rates of hypertension awareness, treatment, and control in general population surveys have consistently come from Canada and the United States (24, 31, 46, 50, 54, 67). In a comparison of unadjusted rates for adults 20–79 years in the United States (2007–2010), Canada (2007–2009), and England (2006), the reported prevalence of awareness was 83.4% in Canada, 81.1% in the United States, and 65.3% in England (50). The corresponding rates for treatment were 79.9%, 74%, and 51.3% and for control were 65.8%, 52.8%, and 27.3%. Numerous studies have identified Germany as a high-income country with low rates of hypertension treatment and control, with control rates less than 20% in two large, nationally representative primary care cohorts (58, 82).

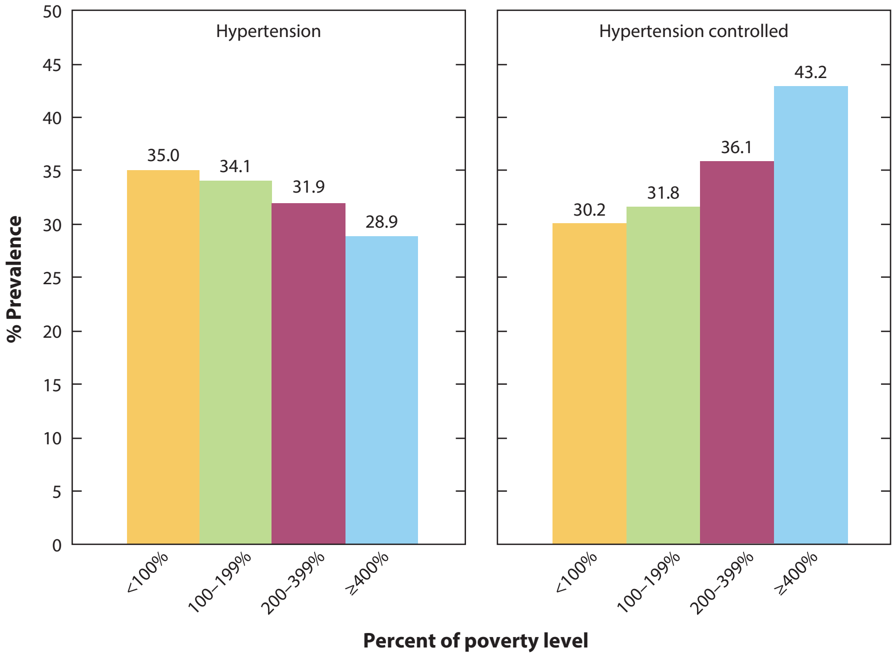

Figure 10

Age-adjusted prevalence of hypertension and percent of persons with hypertension controlled by level of poverty in US adults, 2003–2006. Results were based on data from the 2003–2006 National Health and Nutrition Examination Survey (71, table 65). Hypertension was defined as described in the caption for **Figure 1**, and age adjustment was performed as described in the caption for **Figure 2**.

National surveys from middle-income and low-income countries are less available, are more heterogeneous in their methodological rigor, and, with the exception of China, are rarely part of a continuous cycle of surveys. Despite these limitations, the available data identify a common pattern of relatively poor rates of awareness, treatment, and control (46, 54). At least three groups have conducted national general population surveys in China since 2000 (29, 36, 102). In the 2000–2001 InterASIA Study, overall awareness, treatment, and control rates were reported to be 44.7%, 28.2%, and 8.1%, respectively (36). Corresponding results from the 2002 China National Nutrition and Health Survey (NNHS) were 25%, 20%, and 5% (102) and from the 2007–2008 China National Diabetes and Metabolic Disorders Study were 45.0%, 36.2%, and 11.1% (29). Temporal trends in awareness, treatment, and control of hypertension were reported for a general population sample drawn from nine provinces in China (103). Between 1997 and 2009, awareness increased progressively from 13.0% to 26.1%, treatment increased from 9.6% to 22.8%, but control only improved from 1.7% to 6.1%. Although the absolute values varied by survey, investigators noted that an overall pattern of very inadequate awareness, treatment, and control was consistent. Likewise, the data showed a consistent pattern of undertreatment in those who were receiving BP medication. Undertreatment in low- and middle-income countries was also a prominent feature of a recently reported large cohort study (14). Poor control was more common in men and rural residents but especially a problem in those with less education and a lower income.

IMPROVING TREATMENT AND CONTROL OF HYPERTENSION

Despite the impressive gains in hypertension awareness, treatment, and control that have been noted in many countries worldwide, there is considerable room for improvement. The challenges and solutions to improving control rates vary by country. There is great heterogeneity in the conduct and quality of general population hypertension surveys. Likewise, the extent and effectiveness of health care systems vary considerably between and within countries. In most high-income countries, intervention strategies are best tailored to improving practice within the existing health care system. In many low-income countries, where the opportunities for primary care are limited, mass screening for detection of hypertension and provision of free or inexpensive BP-lowering medication are more of a priority.

The NHANES surveys provide a good mechanism to monitor hypertension control in the United States and to highlight specific groups who merit focused attention to enhance either awareness or treatment and control rates. The overall prevalence of hypertension control in the United States is still unsatisfactory and even less acceptable in subgroups such as those who are young, male, from an ethnic minority, and of lower socioeconomic status. Numerous quality-improvement strategies that target health care providers, patients, or the system of care are known to be effective in implementing hypertension treatment guidelines and improving control rates (38, 94). Prominent among these strategies are strengthening and expanding the health care management team; making control of hypertension a priority; using monitoring systems to conduct audits and provide timely feedback that includes treatment prompts for individual health care providers and data on goal achievement for those in leadership roles; empowering patients through mechanisms such as education and BP self-monitoring; using patient-friendly electronic communication systems to provide appointment reminders, treatment prompts, and encouragement; enhancing treatment adherence by simplifying the regimen and providing free or discounted medication; and providing lifestyle counseling or promoting public policies aimed at achieving optimal weight, being physically active, reducing dietary sodium intake, enhancing potassium intake, and moderating alcohol consumption.

Structured, Team-Based Interventions

Research studies have repeatedly demonstrated that structured, goal-oriented BP treatment initiatives with feedback and provision of free medication result in a substantial improvement in BP control. For example, control rates in the Antihypertensive and Lipid Lowering Treatment to Prevent Heart Attack Trial (ALLHAT) increased rapidly from ~27% at baseline to ~50% at 6 months and more than 70% by the end of the trial (16, 17). In the Action to Control Cardiovascular Risk in Diabetes (ACCORD) Blood Pressure Trial, SBP in the intensive treatment arm was reduced from an average of 139 mm Hg at baseline to 119 mm Hg within 4 months and was successfully maintained at a similar level for up to 8 years of follow-up (1). Structured, goal-oriented approaches that utilize a strong motivated team with electronic monitoring and feedback of target achievement have also been successful in clinical practice. The Kaiser Permanente Northern California (KPNC) program experience provides a good example of this approach in the setting of a large, integrated health care system (48). The program's five major elements were creation of a hypertension registry to facilitate tracking and performance progress, use of a standardized approach for identification and reporting of control rates, dissemination of evidence-based practice guidelines within KPNC, implementation of medical assistant follow-up visits 2–4 weeks after a medication adjustment to inform decisions by primary care physicians, and promotion of a single-pill combination therapy. Healthcare Effectiveness Data and Information Set (HEDIS) reports were used to compare the KPNC experience with that of others in a standardized manner.

At the outset of the program in 2001, KPNC and national HEDIS hypertension control rates were 43.6% and 55.4%, respectively. However, by 2009 the corresponding rates were 80.4% and 64.1%. Differences in demography, insurance coverage, and selection of BPs (the HEDIS BP readings were based on automated oscillometric measurements of the best BP of the day) preclude direct comparisons of the KPNC and NHANES control rates.

Many studies have demonstrated the value of strengthening the hypertension treatment team by enhancing the role of pharmacists, nurse practitioners, medical assistants, and community health care workers (3, 11, 34). Team-based care interventions have produced sizable SBP reductions, typically between 5 and 10 mm Hg (11, 93).

Self-Monitoring of Blood Pressure Levels

Meta-analyses of randomized controlled trials that have investigated the usefulness of home BP monitoring (HBPM) have identified a SBP intervention effect of ~2 mm Hg (10, 32). This approach may be less valuable when other more effective strategies are already in place (34). In a 2004–2005 survey of 530 patients from 24 practices in North Carolina, 35.2% reported that their doctor had recommended HBPM and 43.1% reported current use of HBPM (91). HBPM was used more commonly by older patients, those with CVD, and patients with a greater level of hypertension knowledge.

Treatment Regimen

With the exception of heart failure and, in African-Americans, stroke, morbidity and mortality trials suggest that BP-lowering medications from different drug classes are similarly effective in CVD risk reduction (4, 7, 61). However, most patients need to take more than one BP medication to control their hypertension. In ALLHAT, only 26% of the participants had their BP controlled with a single medication at the fifth-year visit, and ~30% required 3 or more BP-lowering drugs (17). In most countries, various single-pill drugs with logical, complementary pharmacological combinations that provide additive BP-lowering effects are available. Use of combination agents provides an efficient and patient-friendly means to improve adherence and achieve therapeutic goals (83). A nonconcurrent prospective analysis in 1,762 patients with hypertension suggested that initial combination therapy, compared with monotherapy followed by combination therapy, resulted in more rapid achievement of therapeutic goals and significantly fewer CVD complications and less mortality (33). Recognition and management of other barriers to medication adherence, including depression, psychosocial stress, substance abuse, and cognitive impairment, may also be important, especially in seniors, minorities, and socially disadvantaged patients (12, 56, 57). Fixed-dose combinations have been advocated as a means to provide an inexpensive, patient-friendly polypill designed to combat several CVD risk factors at the same time (44, 59, 65, 92). Use in patients with CVD or at high risk for CVD and in resource-poor countries has been a principal focus. Most polypill formulations include one or more BP-lowering medications, a statin and aspirin. To date, trials have suggested that polypills are well tolerated (47, 88, 104), improve adherence (88), and may provide modest benefits in risk factor control compared with usual care (88). However, a benefit of polypill therapy compared with usual care in reducing CVD complications has yet to be proven (30).

Financial Incentives

It seems likely that financial incentives can improve control rates; however, most randomized controlled trials suggest only a modest benefit (75), and an interrupted time series analysis in

470,725 patients with hypertension in the United Kingdom showed no discernible effect of a sizable physician pay-for-performance financial incentive (81). The impact of financial incentives seems to depend on the specific type of incentive, payer mix, and preexisting level of quality care (21).

Nonpharmacologic Interventions

Abundant evidence indicates that nonpharmacologic interventions such as weight loss and sodium reduction are effective in additional lowering of BP and reducing the need for drug treatment in patients with hypertension (79, 97). In the randomized controlled trial with the largest sample size ($n = 975$ adults, aged 60–80 years) and longest follow-up (median = 29 months), behavior counseling aimed at reducing dietary sodium intake and weight loss in the overweight participants were effective both in lowering BP and in reducing the need for antihypertensive medication (97). The combination of weight loss and sodium reduction counseling was more effective than either component on its own, yielding an additional 5.3 mm Hg reduction in SBP from a baseline value of 127.6 mm Hg and hypertension control following withdrawal of BP medication in 71.4% (compared with 39.5% in the nonintervention control group) at 6 months. The challenge in this and other trials has been maintenance of the intervention over longer periods of time. In the United States and many Western countries, most dietary sodium comes from additions during food processing and restaurant food preparation. This information provides the potential for a potent public health intervention that would require little or no effort on the part of the individual. Various combinations of active campaigns to achieve voluntary reductions in the addition of sodium during food processing and public policy requirements for food labeling and mandatory reductions in the addition of sodium to specific food products have resulted in sizable declines in sodium intake in countries such as Finland, the United Kingdom, and Turkey (96). Federal, state, and city agencies as well as voluntary nonprofit organizations such as the American Heart Association are actively pursuing approaches to achieve corresponding reductions for US adults and children.

CONCLUSIONS

Various nonpharmacological interventions provide the capacity to prevent and treat hypertension. In addition, medications from several drug classes, alone or in combination, provide an effective means to treat established hypertension and prevent CVD. Use of these therapeutic options provides a cost-effective means to avoid the huge burden of high-BP-related illness, social disruption, and expenditure for individuals and societies worldwide. Over recent decades, the prevalence of hypertension has declined but remains high in most economically developed nations. Concurrently, awareness, treatment, and control of hypertension have improved progressively but remain unsatisfactory. In many middle- and low-income countries, the prevalence of hypertension has been increasing rapidly, but awareness, treatment, and control have been very limited and ineffective. Proven solutions to the challenges of high BP can be tailored to meet the needs of individuals and communities with different health care infrastructures and resources. Enhanced efforts to prevent and treat high BP are feasible, and pursuit of cost-effective approaches that will yield substantial health benefits should be a very high priority for societies and the public health community.

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