EPIDEMIOLOGY AND PREVENTION OF HYPERTENSION

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Hypertension is an important public health challenge in the United States because of its high prevalence and the concomitant increase in risk of cardiovascular-renal disease. As many as 43 million Americans have hypertension, defined as having a systolic blood pressure 140 mm Hg or greater, and/or having diastolic blood pressure 90 mm Hg or greater, and/or taking antihypertensive medications.[11] More than $10 billion is spent annually for medications, office visits, and laboratory tests related to treatment of hypertension in Americans.[66] Moreover, hypertension is the most important modifiable risk factor for coronary heart disease (the leading cause of death in the U.S. population), stroke (the third leading cause of death), congestive heart failure, end-stage renal disease, and peripheral vascular disease.[35, 39, 44, 65]

DISTRIBUTION OF HYPERTENSION IN POPULATIONS

Classification of Hypertension

The Fifth Report of the U.S. Joint National Committee for Detection, Evaluation, and Treatment of High Blood Pressure recommended a new classification system for hypertension (Table 1). In this system, optimal

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Table 1. CLASSIFICATION OF BLOOD PRESSURE FOR ADULTS AGE 18 YEARS OR OLDER*

Category	Systolic BP (mm Hg)	Diastolic BP (mm Hg)
Optimal	<120	<80
Normal	120–129	80–84
High normal	130–139	85–89
Hypertension		
Stage 1 (mild)	140–159	90–99
Stage 2 (moderate)	160–179	100–109
Stage 3 (severe)	180–209	110–119
Stage 4 (very severe)	≥210	≥120

*Based on the average of two or more readings taken at each of two or more visits in individuals not taking antihypertensive drugs and not acutely ill. When systolic and diastolic blood pressure (BP) fall into different categories, the higher category should be selected to classify the individual's BP status. Isolated systolic hypertension is defined as systolic BP ≥140 mm Hg and diastolic BP <90 mm Hg and staged appropriately.

Based on recommendations of Fifth Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure.[34]

Data from Arch Intern Med 153:154–183, 1993.

blood pressure is defined as a systolic blood pressure less than 120 mm Hg and a diastolic blood pressure less than 80 mm Hg. Those with a systolic blood pressure between 130 and 139 mm Hg or diastolic blood pressure between 85 and 89 mm Hg are designated as having a high normal blood pressure. Hypertension is characterized by a confirmed elevation of systolic (≥140 mm Hg) or diastolic (≥90 mm Hg) blood pressure. Hypertension is further characterized into four stages according to the patient's level of systolic and diastolic blood pressure. Stage 1 is the mildest (systolic 140 to 159 mm Hg and diastolic <100 mm Hg or diastolic 90 to 99 mm Hg and systolic <160 mm Hg) and most common form of hypertension, and stage 4 is the most severe (systolic blood pressure ≥210 mm Hg or diastolic blood pressure ≥120 mm Hg) and least common category of hypertension.[34]

Age and Hypertension

With the exception of a few relatively isolated societies, average blood pressure tends to rise progressively with increasing age in almost every population.[77] As a consequence, the prevalence and incidence of hypertension also increase with age. The relationship between age and hypertension has been consistently demonstrated in cross-sectional surveys as well as in longitudinal cohort studies conducted in Western populations.[15, 18, 33, 45, 70, 71] The age-related increase in risk of hypertension, however, varies considerably depending on an individual's stage of life, gender, race, initial level of blood pressure, and exposure to environmental factors.[77]

In the Third National Health and Nutrition Examination Survey (NHANES III), which was conducted in a representative sample of

9901 noninstitutionalized U.S. civilians 18 years of age and older, the prevalence of hypertension rose with increasing age in every gender-race group (Table 2). For example, the age-specific prevalence was 3.3% in white men aged 18 to 29 years. It increased to 13.2% in the group aged 30 to 39 years. The prevalence of hypertension increased even more dramatically in middle age and in older age groups, from 22.0% in the group aged 40 to 49 years to 37.5% in the group aged 50 to 59 years and 51.1% in the group aged 60 to 74 years. Age-related increases in hypertension prevalence have also been reported in numerous other national surveys conducted in different countries at various stages of economic development.[31, 33, 45, 53, 67, 70, 71] In general, the rise in hypertension prevalence with age is steeper in populations in which hypertension is more common.[77]

The incidence of hypertension also tends to rise with increasing age. In the Framingham Heart Study, the incidence of hypertension was measured over 30 years of follow-up in 5209 adults.[18] The biennial incidence of hypertension (systolic blood pressure ≥160 mm Hg, diastolic blood pressure ≥95 mm Hg, or use of antihypertensive medications) increased with age in men from 3.3% at ages 30 to 39 to 6.2% at ages 70 to 79 and in women from 1.5% at ages 30 to 39 to 8.6% at ages 70 to 79.[18] In the NHANES I Epidemiologic Follow-up Study, the incidence of hypertension increased approximately 5% for each 10-year interval of age for a medium 9.5-year follow-up period.[15]

The age-related rate of rise in blood pressure is consistently greater for systolic than for diastolic blood pressure. Systolic blood pressure tends to rise until the 70s or 80s, whereas diastolic blood pressure tends to remain constant or decline after the 40s. As a consequence, risk of isolated systolic hypertension increases progressively with advancing age and is a common type of hypertension in the elderly.[3, 77]

Table 2. PREVALENCE (%) OF HYPERTENSION BY AGE, GENDER, AND ETHNICITY AMONG ADULT RESIDENTS OF THE UNITED STATES, 1988–1991, AGED 18–74 YEARS*

	Males			Females		
Age (y)	African-American	White	Mexican-American	African-American	White	Mexican-American
18–29	6.4	3.3	3.4	2.3	1.0	0.9
30–39	22.5	13.2	7.6	11.2	6.9	4.4
40–49	35.2	22.0	24.8	33.2	11.3	10.5
50–59	53.3	37.5	38.4	47.8	33.0	28.8
60–74	71.2	51.1	44.3	73.9	50.0	53.0

*Hypertension was defined as an average systolic blood pressure ≥140 mm Hg, and/or diastolic blood pressure ≥90 mm Hg, and/or current antihypertensive drug treatment.

Data from the Third National Health and Nutrition Examination Survey, Phase I, 1988–1991.[10, 53]

Gender and Hypertension

Overall the prevalence and incidence of hypertension are slightly higher in men compared to women.[11, 15] In NHANES III, the age-adjusted prevalence of hypertension was 34.0%, 25.4%, and 23.2% for men and 31.0%, 21.0%, and 21.6% for women among African-Americans, whites, and Mexican-Americans (Fig. 1). The relationship between gender and hypertension, however, is modified by age. In young adults, systolic and diastolic blood pressure tends to be higher in men than in women. As a consequence, the prevalence and incidence of hypertension are higher in men than in women. For example, in NHANES III, the prevalence of hypertension was 12% for white men and 5% for white women at age 18 to 49 years.[11] The age-related rise in blood pressure during adulthood is, however, steeper for women than for men. Thus, by the 60s, women tend to have levels of blood pressure that equal or exceed those seen in men. Consequently the prevalence of hypertension is higher in women than in men late in life. For example, the prevalence of hypertension was 50% for white men and 55% for white women aged 70 years and older in NHANES III.[11] In the NHANES I Epidemiologic Follow-up Study, hypertension incidence was 11.9% for men and 8.1%

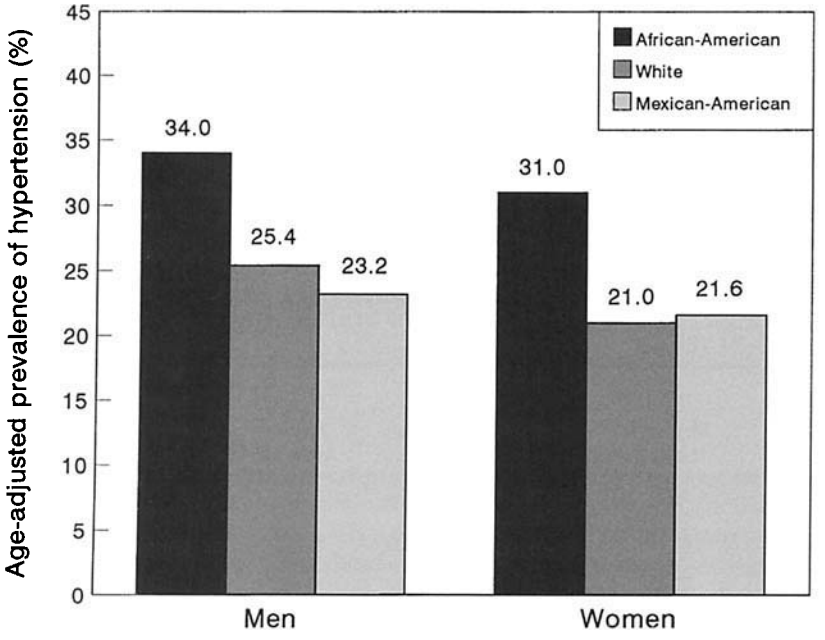

Figure 1. Age-adjusted prevalence of hypertension in African-American, white, and Mexican-American men and women. (*Data from* the Third National Health and Nutrition Examination Survey, 1988–91. Hypertension 25:305–313, 1995.)

for women at age 25 to 34 years and 41.8% for men and 43.3% for women at age 55 years or older over an average of 9.5 years of follow-up.[15] In the Framingham Heart Study cohort, women had a higher incidence of hypertension compared to men after age 50 years.[18] Part of this gender-related difference in the risk of hypertension may reflect selective survivorship. Longitudinal analysis of data from the Framingham Cohort, however, suggests that selective survivorship explains only a portion of these age-related trends.[36]

Ethnicity and Hypertension

African-Americans have a higher prevalence and incidence of hypertension compared to whites. This has been well documented in national surveys of U.S. residents conducted by the National Center for Health Statistics as well as in other studies.[10, 11, 29] In most studies, the prevalence of hypertension was increased about 50% in African-Americans compared to whites. Few studies have compared the incidence of hypertension between African-Americans and whites.[15, 38, 46] On average, African-Americans have about a twofold higher incidence of hypertension compared to whites. Racial differences in the prevalence and incidence of hypertension are modified by age. For example, in the NHANES I Epidemiologic Follow-up Study, the incidence ratio of hypertension for African-Americans compared to whites who were 25 to 34 years old was 2.29 in men and 2.91 in women. In contrast, the incidence ratio in those who were 55 years or older was 1.10 in men and 1.00 in women.[15]

The prevalence and incidence of hypertension is similar or lower in Mexican-Americans than in non-Hispanic whites.[11, 22] In NHANES III, the age-adjusted prevalence of hypertension was 22.6% in Mexican-Americans and 23.3% in non-Hispanic whites.[11] In the San Antonio Heart Study cohort, the 8-year incidence of hypertension was 9.1% in Mexican-Americans and 9.2% in non-Hispanic whites.[22]

Asian-Americans have a substantially lower prevalence of hypertension compared to other ethnic groups.[40] The prevalence of hypertension varies greatly in Native Americans. For example, in the Strong Heart Study, the prevalence of hypertension in South Dakota and North Dakota Native Americans was lower, but in Arizona and Oklahoma Native Americans it was higher, than in the overall U.S. population estimate from NHANES III.[72]

Secular Trends in Prevalence and Incidence of Hypertension

The prevalence of hypertension from repeated independent cross-sectional surveys is available for a variety of regional and national samples.[10, 21, 27, 42, 70] The largest and most extensive body of information

comes from observations collected in the United States by the National Center for Health Statistics. Similar methods were used for collecting blood pressure measurements and for estimating the prevalence of hypertension during the First National Health Examination Survey in 1960–1962 and the three subsequent Health and Nutrition Examination Surveys conducted in 1971–1974, 1976–1980, and 1988–1991.[10] Based on data collected in these surveys, the prevalence of hypertension has decreased progressively for every gender-race group over the past 20 years (Fig. 2).

It is more difficult to observe secular trends in hypertension incidence because it requires follow-up of a large population for a long period. In the Framingham Heart Study, 5209 study participants were observed for more than 30 years. Blood pressure was measured every other year. In this cohort, no consistent secular trend in hypertension incidence was evident for either sex from the 1950s through the 1970s.[18]

HYPERTENSION AND RISK OF CARDIOVASCULAR-RENAL DISEASE

Most evidence regarding the effects of blood pressure on the risks of cardiovascular-renal disease derives from two principal sources:

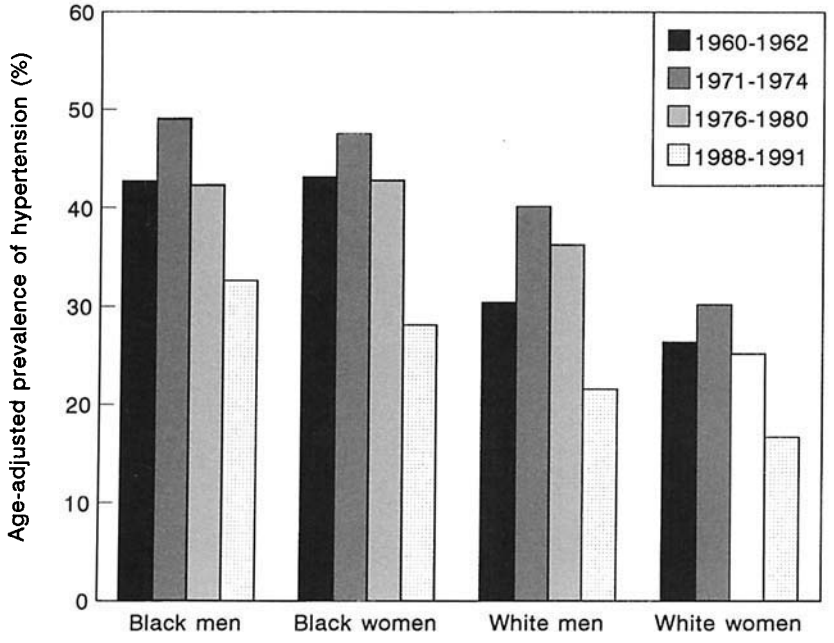

Figure 2. Age-adjusted prevalence of hypertension in black men, black women, white men, and white women: 1960–1990. (*Data from* the National Health Examination Surveys 1960–1991. Hypertension 26:60–69, 1995.)

(1) prospective observational studies of the incidence of or mortality from stroke, coronary heart disease, congestive heart failure, and end-stage renal disease and (2) randomized trials of antihypertensive therapy.

Prospective studies have repeatedly identified an increasing risk of cardiovascular disease, stroke, and renal insufficiency with progressively higher levels of both systolic and diastolic blood pressure.[35, 39, 44, 65, 75] MacMahon and colleagues[44] conducted a pooled analysis of nine prospective observational studies with 418,343 participants aged 25 to 84 years. None of the study participants had clinical evidence of coronary heart disease or stroke at baseline, and they were followed for an average of 10 years. The combined results demonstrated a positive, continuous, and independent association between blood pressure and the incidence of coronary heart disease and stroke. There was no evidence of a J-shaped relationship or a *threshold* below which lower levels of blood pressure were not associated with a lower risk of stroke and coronary heart disease. After correction for *regression dilution* bias, prolonged differences in usual diastolic blood pressure of 5, 7.5, and 10 mm Hg were associated with at least a 34%, 46%, and 56% lower incidence of stroke and at least a 21%, 29%, and 37% lower incidence of coronary heart disease.[44]

The relation between blood pressure and risk of congestive heart failure and renal disease in observational studies has been equally impressive.[35, 39] In the Framingham Heart Study, the age-adjusted risk of congestive heart failure was 2.3-fold higher in men and 3.0-fold higher in women for those in the highest compared to those in the lowest quintile of systolic blood pressure at baseline during a 34-year period of follow-up.[35] Klag and colleagues[39] studied the relation of blood pressure to incidence of end-stage renal disease in 332,544 men, 35 to 57 years of age, who were screened for entry into the Multiple Risk Factor Intervention Trial (MRFIT). During an average of 16 years of follow-up, 814 subjects either died of end-stage renal disease or were treated for that condition. A strong, graded relation between both systolic and diastolic blood pressure and end-stage renal disease was identified, independent of age, race, income, use of medication for diabetes mellitus, history of myocardial infarction, serum cholesterol concentration, and cigarette smoking. Among those who survived the first 10 years of follow-up without suffering from end-stage renal disease, the relative risks of eventually developing the condition were 2.8, 5.0, 8.4, and 12.4 fold higher for those with hypertension of stage 1, 2, 3, or 4 at baseline, compared to their counterparts without hypertension.[39]

In clinical trials, antihypertensive drug therapy reduces the risk of cardiovascular disease and stroke.[13, 28, 74] Most trials have demonstrated a statistically significant and impressive reduction in stroke rates. The impact on coronary heart disease event rates has been less striking, and, in most studies, the reduction has not been statistically significant. The failure to recognize a statistically significant reduction in coronary heart disease event rates in individual trials may result from a lack of sufficient power. To overcome this problem, data from individual trials have been

pooled to obtain more precise estimates of the effect of treatment. In one of the most recent analyses, results from 17 trials with a combined sample size of 47,653 were pooled.[28, 74] The average weighted difference in diastolic blood pressure between active and control therapy in this analysis was 5 to 6 mm Hg. The corresponding reductions in total and fatal event rates were 38% (95% confidence interval [CI], 31% to 45%) and 40% (95% CI, 26% to 51%) for stroke and 16% (95% CI, 8% to 23%) and 16% (95% CI, 5% to 26%) for coronary heart disease.

Population Attributable Risk

The burden of hypertension-related disease in the community depends on the prevalence of hypertension as well as on its importance as a predictor of risk in the individual. Figures 3 and 4 show the relative risk and population attributable risk of hypertension on coronary heart disease and stroke. These estimates were derived from a 15-year follow-up experience among 347,978 men who were screened for inclusion in

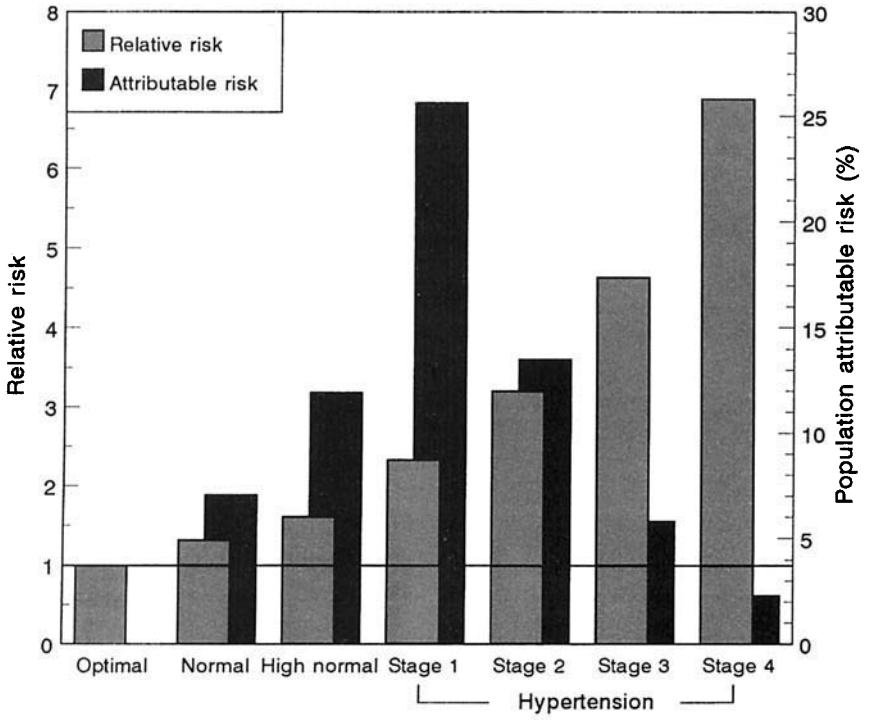

Figure 3. The relative risk and population attributable risk of hypertension on coronary heart disease. (*Data from* the 15-year follow-up of the 347,978 MRFIT screenees. Stamler J: The intersalt study: background, methods, findings, and implications. Am J Clin Nutr 65:265–425, 1997.)

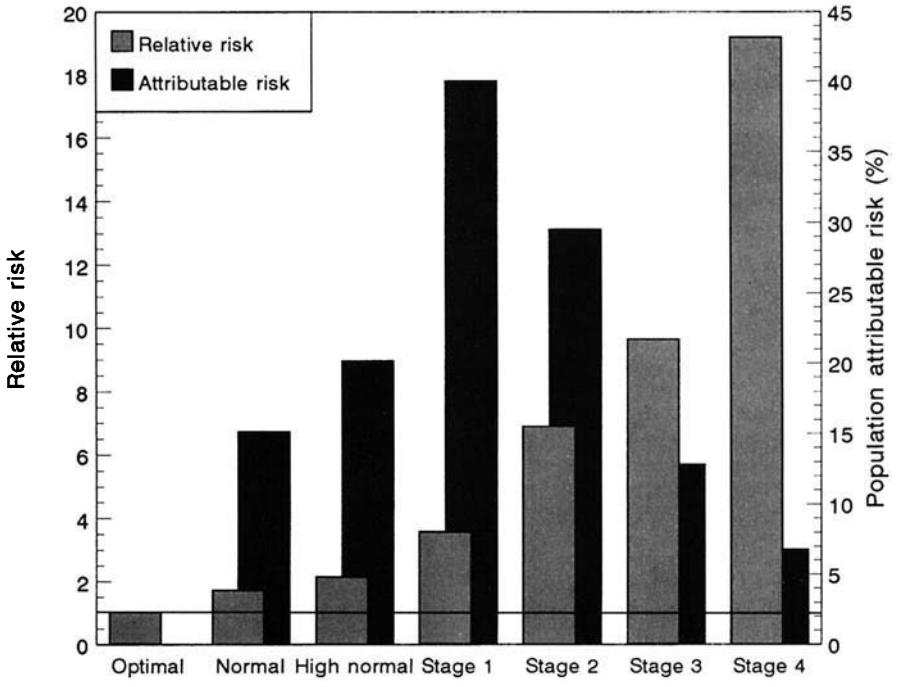

Figure 4. The relative risk and population attributable risk of hypertension on stroke. (*Data from* the 15-year follow-up of the 347,978 MRFIT screenees. Stamler J: The intersalt study: background, methods, findings, and implications. Am J Clin Nutr 65:265–425, 1997.)

MRFIT.[63] After adjustment for age, race, income, serum cholesterol, cigarettes smoked, and use of medication for diabetes, the relative risks of coronary heart disease mortality were 2.3, 3.2, 4.6, and 6.9 fold higher for those with hypertension of stage 1, 2, 3, or 4 at baseline compared to their counterparts with optimal blood pressure. The prevalence of stage 1 and stage 2 hypertension was more common than stage 3 and stage 4 hypertension in the general population. Therefore, the population attributable risks were greater for stage 1 (25.6%) and stage 2 (13.5%) hypertension compared to stage 3 (5.8%) and stage 4 (2.3%) hypertension. Although stroke is a somewhat more blood pressure–dependent disease, the overall pattern for blood pressure–related population attributable risk appears to be quite similar. For example, the relative risks of stroke were 3.6, 6.9, 9.7, and 19.2, and the population attributable risks of stroke were 40.0%, 29.5%, 12.8%, and 6.8% for stage 1, 2, 3, and 4 hypertension in the MRFIT cohort.

These data and similar findings for other blood pressure–related complications[35, 39] have important implications for prevention of blood pressure–related disease. First, they provide a strong rationale for detection, treatment, and control of hypertension in the community. Second,

they underscore the importance of treating those with the least severe stage of hypertension because most hypertension-related coronary heart disease and stroke occur within this range of blood pressure. Finally, the data indicate that treatment of hypertension represents only a partial response to the overall burden of blood pressure–related cardiovascular disease in the general population. Even under optimum conditions, treatment and control of hypertension influence no more than 50% of blood pressure–related coronary heart disease in the community.

TREATMENT AND CONTROL OF HYPERTENSION IN THE COMMUNITY

Over the past 30 years, awareness, treatment, and control of hypertension have improved progressively.[73] For example, data from sequential National Center for Health Statistics Surveys indicate that hypertension (blood pressure ≥160/95 mm Hg or on treatment with antihypertensive medications) awareness increased from 53% in 1960–1962 to 89% in 1988–1991.[10] During the same interval, the corresponding percentages for hypertension treatment increased from 35% to 79%, and control (blood pressure <160/95 mm Hg) of those with hypertension increased from 16% to 64%. Using the currently recommended definition of hypertension (140/90 mm Hg), the percentages for awareness, treatment, and control of hypertension were 69%, 53%, and 24% in the general U.S. population in 1988–1991.[11] The estimates vary by gender and ethnicity (Fig. 5). African-American women had the highest percentages of hypertension awareness (79%), treatment (65%), and control (29%), whereas Mexican-American men had the lowest percentages of hypertension awareness (44%), treatment (28%), and control (11%). These data might underestimate the extent to which hypertension is being treated because they do not reflect the use of nonpharmacologic therapy. Nonetheless, they suggest that efforts aimed at detection, treatment, and control of hypertension should not be relaxed.

PRIMARY PREVENTION OF HYPERTENSION

To accomplish the broad goal of eliminating all blood pressure–related diseases in the community, the detection and treatment of hypertension must be complemented by prevention strategies.[79] This prevention includes a population strategy to achieve a slight downward shift in the entire distribution of blood pressure in the community and a more intensive targeted strategy to lower blood pressure in those who are at greater risk of hypertension. The latter includes persons with a high normal blood pressure, family history of hypertension, African-American ancestry, overweight, excess consumption of sodium, physical inactivity, and alcohol consumption.[79] Because most persons in the general population are candidates for primary prevention interventions,

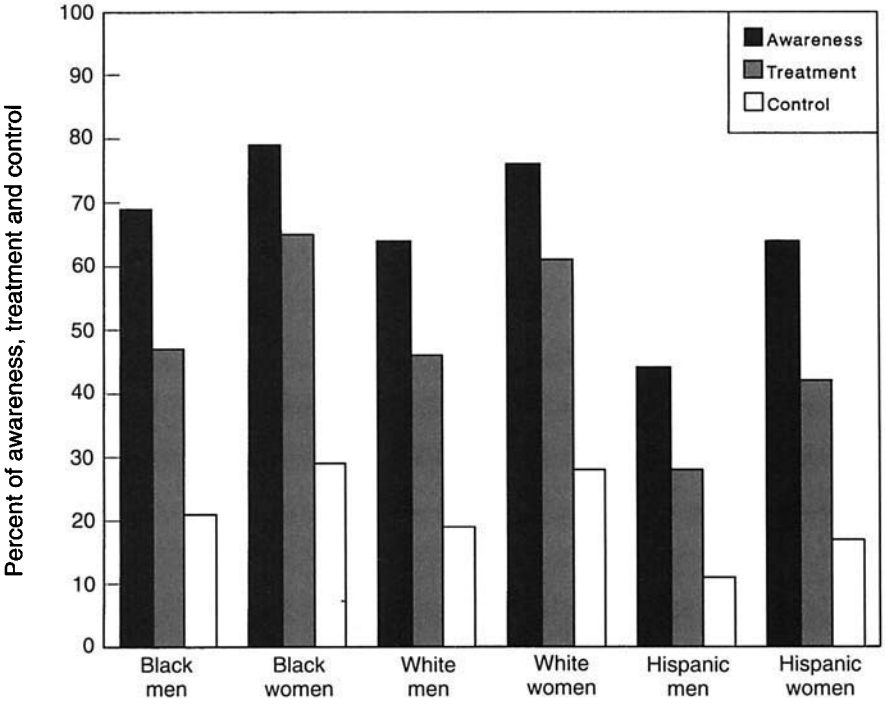

Figure 5. The percentages of hypertension awareness, treatment, and control in US populations: 1988–1991. (*Data from* the Third National Health and Nutrition Examination Survey, 1988–91. Hypertension 25:305–313, 1995.)

small changes in blood pressure are likely to yield substantial health benefits in reducing the prevalence of hypertension as well as the associated risk of cardiovascular disease. It is estimated that a population-wide reduction in diastolic pressure of as little as 2 mm Hg would result in a 17% reduction in the prevalence of hypertension as well as a 15% reduction in the risk of stroke and transient ischemic attacks and a 6% reduction in the risk of coronary heart disease.[14] This blood pressure reduction would likely prevent 93% as many strokes and transient ischemic attacks and approximately the same number of incident coronary heart disease events as would be prevented by treatment of all hypertensive patients with antihypertensive drug therapy.[14] The interventions recommended for primary prevention of hypertension are the same as those already being used for nonpharmacologic treatment of hypertension (Table 3).

Weight Loss

For more than 70 years, there has been interest both in the role of obesity in the cause of hypertension and in the effects of weight loss on

Table 3. EFFICACY OF LIFESTYLE MODIFICATIONS ON PRIMARY PREVENTION OF HYPERTENSION

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blood pressure.[41, 43] These issues have been investigated in many large epidemiologic studies and a smaller number of clinical trials of weight reduction. Both cross-sectional and longitudinal studies have consistently identified an association between overweight and hypertension, independent of age.[43] Several clinical trials have also shown a blood pressure–lowering effect of weight loss.[30, 62, 68, 69] In the Trials of Hypertension Prevention (TOHP), Phase I, weight loss intervention produced an average weight loss of −3.9 kg, systolic blood pressure reduction of −2.9 mm Hg, and diastolic blood pressure reduction of −2.3 mm Hg (all $P<.01$) over 18 months of follow-up in a group of men and women with high normal blood pressure. Weight loss intervention also produced a 34% (95% CI, 6% to 54%) reduction in the incidence of hypertension.[68] Weight loss intervention was associated with a 21% reduction ($P=.02$) in the incidence of hypertension over 36 months in the TOHP-II.[69] These data indicate that weight loss is an important intervention for primary prevention of hypertension.

Dietary Sodium Reduction

Evidence relating dietary sodium and blood pressure comes from a variety of sources: animal experiments, observational epidemiologic studies, migration studies, and randomized controlled trials.[25] Results from both observational epidemiologic studies and randomized controlled trials have identified a dose-response association between dietary sodium and blood pressure in human populations. In the INTERSALT study, a cross-sectional study of 10,074 participants from 52 populations in 32 countries, a 100-mmol higher 24-hour urinary sodium was associated with a 4.3-mm Hg increase in systolic and 1.8-mm Hg increase in diastolic blood pressure in within-population analyses after adjustment for age and sex and correction for regression dilution bias.[20] During the

past 30 years, more than 60 randomized controlled trials have been conducted in hypertensive or normotensive participants. Several meta-analyses were conducted to pool the results from these trials.[17, 50] Midgley and colleagues[50] identified 28 trials conducted in normotensive participants (n = 2374) that met their inclusion criteria. For the trials conducted in normotensive participants, the mean reduction (95% CI) in daily urinary sodium excretion, a proxy measure of dietary sodium intake, was 125 mmol (95 to 156 mmol). Because of significant heterogeneity in the effect size among trials, the random-effects model provided the most valid estimates of pooled effect size. Compared to the control group, the mean reduction (95% CI) was −1.6 (−2.4 to −0.9) mm Hg for systolic and −0.5 (−1.2 to 0.1) mm Hg for diastolic pressure in trials of normotensive persons. In another meta-analysis by Cutler and associates,[17] the pooled estimates of blood pressure reduction for 12 trials conducted in normotensive persons (n = 1689) were −1.9 (95% CI, −1.2 to −2.6) mm Hg for systolic and −1.1 (−0.6 to −1.6) mm Hg for diastolic blood pressure. These data provide strong support for recommendations to reduce sodium intake in the general population for primary prevention of hypertension.

Moderation in Alcohol Consumption

An association between alcohol consumption and blood pressure levels has been observed in more than 60 population studies worldwide. The relationship is generally linear, but within some studies there has been a threshold effect at an intake of around two to three standard drinks a day.[7] In the INTERSALT study, after adjustment for age, body mass, smoking, and 24-hour urinary sodium and potassium excretion, men who consumed three to five drinks of alcohol per day had systolic and diastolic pressures that were, on average, 2.7 and 1.6 mm Hg higher than those in their counterparts who were nondrinkers. Men who consumed more than five drinks of alcohol per day had blood pressures that were, on average, 4.6 and 3.0 mm Hg higher than those in nondrinkers. For women, heavy alcohol consumption (>5 drinks/day) was associated with blood pressures that were, on average, higher by 3.9 and 3.1 mm Hg than those in nondrinkers.[49] Cushman and colleagues[16] summarized 10 randomized controlled trials of the effect of alcohol reduction on blood pressure. With a median intervention period of 5 weeks, systolic blood pressure was reduced by −2.1 to −8 mm Hg and diastolic blood pressure by −1.4 to −6 mm Hg. In a randomized controlled cross-over trial, Puddey and co-workers[56] found that an average reduction in alcohol consumption of four drinks per day for 6 weeks was associated with a −3.8 mm Hg ($P<.001$) reduction in systolic and −1.4 mm Hg ($P<.05$) reduction in diastolic blood pressure among 46 normotensive men. Modification of alcohol consumption, especially among heavy drinkers, should be recommended as an important means for primary prevention of hypertension.

Potassium Supplementation

Results from both observational epidemiologic studies and randomized controlled trials suggest an inverse relationship between potassium intake and blood pressure in human populations.[56] Data from the INTERSALT study indicate that a 50 mmol/day higher level of urinary potassium excretion was associated with a −3.4 (95% CI, −1.5 to −5.2) mm Hg lower level of systolic blood pressure and −1.9 (95% CI, −0.7 to −3.0) mm Hg lower level of diastolic blood pressure.[24] Whelton and colleagues[76] conducted a meta-analysis of 33 randomized controlled trials published between 1981 and 1995. Twenty-one trials were conducted in hypertensives (n = 1560) and 12 in normotensives (n = 1005). The weighted mean net change in urinary potassium excretion for intervention versus control was 53 mmol/24 hours in the 31 trials with available urinary electrolyte excretion information. Overall, potassium supplementation was associated with a mean systolic blood pressure reduction of −3.1 (95% CI, −1.9 to −4.3) mm Hg and diastolic blood pressure reduction of −2.0 (95% CI, −0.5 to −3.4) mm Hg.[76] In normotensives, the mean reduction was −1.8 (95% CI, −0.6 to −2.9) mm Hg for systolic blood pressure and −1.0 (95% CI, 0.0 to −2.1) mm Hg for diastolic blood pressure. Subgroup analysis suggested the treatment effects were enhanced in African-Americans and in participants consuming a high intake of sodium. These data indicate that potassium supplementation should be included as part of the recommendations for primary prevention of hypertension, especially in African-Americans and those with difficulty reducing dietary intake of sodium.

Physical Activity

Observational epidemiologic studies have identified a significant inverse association between physical activity and blood pressure or risk of hypertension.[8, 55, 57] Occupational or leisure-time physical activity or both were used as the predicted variable in most of these studies. Physical fitness was also used in some studies.[8] The inverse association between habitual physical activity and hypertension has been noted in both sexes and at all ages and has been independent of body weight. Arroll and Beaglehole[5] reviewed 22 published clinical trials of physical activity as a means of reducing blood pressure. Virtually all of these trials have had one or more major limitations in study design. Overall, blood pressure was reduced by physical activity in both hypertensive and normotensive persons. This effect was independent of weight loss, and in some studies blood pressure reduction occurred in the presence of weight gain. The average reduction in blood pressure in the trials with the best study design was approximately 6 to 7 mm Hg for both systolic and diastolic blood pressure.[5] Although recognizing the need for additional information, the existing body of evidence favors the

notion that physical activity should be recommended as a means of primary prevention of hypertension.

Calcium Supplementation

In a review, Cappuccio and colleagues[12] identified 63 published observational studies that investigated the association between dietary calcium intake and blood pressure. Of studies, 23 were suitable for a quantitative overview (n = 38,950). For a 100-mg higher intake of calcium, the unadjusted regression coefficients ranged between −9.40 and 1.63 mm Hg for systolic blood pressure and between −4.90 and 0.47 mm Hg for diastolic blood pressure. In those studies that used the 24-hour recall method for assessment of calcium intake, the pooled regression coefficients were −0.06 and −0.09 mm Hg per 100 mg calcium ($P<.005$ and $P=.07$), whereas in those that used the food frequency questionnaire, they were −0.15 and −0.05 mm Hg per 100 mg calcium ($P<.001$ and $P<.03$).[12] Results from at least 56 randomized trials that studied the effect of calcium supplementation on blood pressure have been published during the past 30 years.[9] Bucher and colleagues[9] conducted a meta-analysis using results from 33 trials (n = 2412) that met the eligibility criteria for inclusion in their study. The overall pooled estimates for reduction in systolic and diastolic blood pressure were −1.27 (95% CI, −2.25 to −0.29) mm Hg for systolic and −0.24 (95% CI, −0.92 to 0.44) mm Hg for diastolic. Among the six trials conducted in normotensive persons, the pooled estimates were −0.27 (95% CI, −1.80 to 1.27) mm Hg for systolic blood pressure and −0.33 (95% CI, −1.56 to 0.90) mm Hg for diastolic blood pressure.[9] A meta-analysis by Allender and colleagues[2] produced similar results. These studies indicate that the effect of calcium supplementation on blood pressure is too small to support a recommendation for its general use in primary prevention of hypertension.

Magnesium Supplementation

Mizushima and colleagues[51] reviewed observational studies on the relation between dietary magnesium intake and blood pressure. Of 88 published observational studies, 27 provided some quantitative information on the relation between magnesium and blood pressure. The majority of these studies reported an inverse association between dietary magnesium intake and blood pressure. Randomized controlled trials of magnesium supplementation have indicated a nonsignificant reduction in blood pressure among hypertensives.[79] In TOHP-I, oral magnesium supplementation (340 mg/day) resulted in only a −0.2 and −0.1 mm Hg reduction in systolic and diastolic blood pressure.[68] At present, there is not enough evidence to recommend magnesium supplementation for primary prevention of hypertension.

Fish Oil Supplementation

Most of the evidence suggesting that supplementation of diet with ω-3 polyunsaturated fatty acids, commonly referred to as fish oils, may reduce blood pressure mainly comes from clinical trials. In a meta-analysis of 17 controlled trials (n = 1019) of fish oil supplementation, Appel and colleagues[4] reported an average reduction in systolic blood pressure of −1.5 (95% CI, −0.6 to −2.4) mm Hg and in diastolic blood pressure of −1.0 (95% CI, −0.4 to −1.6) mm Hg. In the 11 trials that enrolled normotensive individuals (n = 728), the pooled estimates of systolic and diastolic blood pressure reductions were −1.0 (95% CI, 0.0 to −2.0) mm Hg and −0.5 (95% CI, −1.2 to 0.2) mm Hg.[4] Overall the results from this meta-analysis and others[52] do not provide sufficient evidence for a general recommendation to use fish oil supplements as a means to prevent hypertension.

Dietary Fiber Supplementation

Cross-sectional and prospective studies have demonstrated an inverse relation between dietary fiber intake and blood pressure.[6, 23, 78] During the past several decades, at least 47 trials of the effect of fiber supplementation on blood pressure have been conducted. In a meta-analysis of fiber supplementation in 12 randomized trials, He and colleagues[26] reported that the overall reduction in blood pressure was −1.2 (95% CI, −0.1 to −2.4) mm Hg for systolic and −1.8 (95% CI, −0.7 to −2.8) mm Hg for diastolic, both $P<.05$. Trial duration ranged from 3 weeks to 1 year, and the median dose of dietary fiber supplementation was 14 g/day.[26] Only three of the trials were conducted in normotensives, and they provided inconsistent results. Additional studies, especially randomized controlled trials using well-characterized water-soluble fiber, are needed to clarify the efficacy of dietary fiber supplementation in primary prevention of hypertension.

Modification of Other Dietary Macronutrients

Observational and cross-cultural studies of vegetarian diets have consistently shown a significant inverse relation with blood pressure.[23, 58, 60] Vegetarian diets are lower in total and saturated fats and higher in polyunsaturated fats than the usual Western diet. Dietary total and saturated fats have been positively, and polyunsaturated fats inversely, associated with blood pressure in several studies.[23, 61, 64] In general, randomized intervention trials have failed to show a significant effect of dietary total, saturated, monounsaturated, or polyunsaturated fats on blood pressure.[47, 59]

Obarzanek and colleagues[54] reviewed the evidence for a relation between dietary protein intake and blood pressure. Observational stud-

ies conducted in the United States and elsewhere have found an inverse relationship between dietary protein intake and blood pressure. Most intervention studies, however, have failed to identify a significant effect of protein on blood pressure. Because of insufficient data and limitations in the design and statistical power of previous investigations, better controlled and adequately powered observational and experimental studies in human populations are needed to assess the effect of dietary protein on blood pressure.

Moderation in Consumption of Caffeine

Jee and colleagues[32] conducted a meta-analysis of 23 controlled clinical trials studying the effect of coffee consumption on blood pressure. A majority of the trial participants were normotensive, and most of the trials were of short duration. Among the 11 trials that had a duration longer than 2 weeks, the median intake of 3.3 cups of coffee per day was associated with a 2.4 (95% CI, 1.0 to 3.7) mm Hg increase in systolic blood pressure and 1.2 (95% CI, 0.4 to 2.1) mm Hg increase in diastolic blood pressure. Future long-term trials to investigate the effect of coffee cessation on blood pressure are needed.

Stress Management

The role of psychological stress as a cause of hypertension has long been debated. An early psychosomatic hypothesis put forth by Alexander[1] stated that feelings of anxiety may lead to an elevation of blood pressure and development of hypertension. A paper from the Framingham Heart Study indicated that anxiety levels were a significant predictor of the subsequent incidence of hypertension among middle-aged men.[48] Randomized controlled trials, however, have not supported the value of stress management as an intervention for primary prevention of hypertension.[68]

Summary

Weight loss, dietary sodium reduction, alcohol moderation, potassium supplementation, and physical activity are the best proven interventions for primary prevention of hypertension. Other interventions may be more effective among certain subgroups. Dietary water-soluble fiber supplementation, vegetable protein supplementation, and coffee cessation may be useful and need additional study.

CONCLUSION

At least 43 million (24%) adults in the general population of the United States have hypertension. The prevalence of hypertension in-

creases with age and is higher in African-Americans compared to other ethnic groups. During the past several decades, the prevalence of hypertension in the general population of the United States has declined, and the proportion of hypertensives who are aware of their high blood pressure as well as the proportion who are being treated and controlled has improved. Hypertension is the most important modifiable risk factor for coronary heart disease, stroke, congestive heart failure, and end-stage renal disease. To achieve the final goal of eliminating all blood pressure–related disease in the community, detection and treatment of hypertension must be complemented by equally energetic approaches directed at primary prevention of hypertension. A small downward shift in the entire distribution of blood pressure in the general population would not only reduce the incidence of hypertension, but also substantially diminish the burden of blood pressure–related diseases in the general population.

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