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**Background:** Recent guidelines classify persons with above-optimal blood pressure (BP) but not clinical hypertension as having prehypertension.

**Methods:** Data were analyzed for 3488 persons aged 20 years and older with BP measured in the 1999-2000 National Health and Nutrition Examination Survey. The prevalence of risk factors—above-normal (≥200 mg/dL [≥5.17 mmol/L]) and high (≥240 mg/dL [≥6.21 mmol/L]) total cholesterol levels, diabetes mellitus, current smoker, and overweight or obesity—and the number of risk factors present were compared among BP groups (normotension, prehypertension, and hypertension). Multivariable logistic regression included age, sex, and race/ethnicity as covariates.

**Results:** Overall, 39% of persons were normotensive, 31% were prehypertensive, and 29% were hypertensive. The age-adjusted prevalence of prehypertension was greater in men (39.0%) than in women (23.1%). African Americans aged 20 to 39 years had a higher prevalence of prehypertension (37.4%) than whites (32.2%) and Mexican Americans (30.9%), but their prevalence was lower at older ages because of a higher prevalence of hypertension. The probabilities of above-normal cholesterol levels, overweight/obesity, and diabetes mellitus were greater for persons with prehypertension vs normotension, whereas the probability of currently smoking was lower. Persons with prehypertension were 1.65 times more likely to have at least 1 other adverse risk factor than were those with normotension (P<.001). Among participants with prehypertension, there were no significant race/ethnic or sex differences in the likelihood of having at least 1 other risk factor.

**Conclusions:** The greater prevalence of risk factors in persons with prehypertension vs normotension suggests the continued need for early clinical detection and intervention of prehypertension and comprehensive preventive and public health efforts.

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**Hypertension Affects an estimated 50 million Americans in the United States, and it was a primary or contributing cause of approximately 251,000 deaths in 2000.**

In the 30 years since initiation of the National High Blood Pressure Education Program, the awareness, treatment, and control of high blood pressure (BP) have increased, but they remain suboptimal. Only approximately 34% of persons with high BP have it controlled. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (JNC 7) defines persons with above-optimal levels but not clinical hypertension as having “prehypertension.”

One justification for this new term is that persons with BPs in this range (systolic BP [SBP] of 120-139 mm Hg or diastolic BP [DBP] of 80-89 mm Hg) have a greater risk of developing clinical hypertension than do persons with lower BP levels. It is also possible that persons with above-optimal BP levels are more likely to have other heart disease and stroke risk factors that are high or above optimal. Whereas numerous studies have noted the clustering or coexistence of clinically high risk factors and their relation to heart disease and stroke, few studies have examined the co-occurrence of risk factors in persons with above-optimal BP levels. We examined data from a nationally repre-
sentative sample of the US population to compare differences in the prevalence of concomitant heart disease and stroke risk factors in persons with normal BP, prehypertension, and hypertension.

**METHODS**

The National Health and Nutrition Examination Survey (NHANES)\textsuperscript{13,14} is a stratified multistage probability sample of the civilian noninstitutionalized US population. The most recent NHANES was conducted in 1999 and 2000, and it is now a continuously operating survey. All participants provided informed consent, and the methods were approved by the Centers for Disease Control and Prevention institutional review board.

A certified technician performed BP measurements using a mercury sphygmomanometer and a standardized procedure. A cuff size appropriate for the participant’s arm circumference was used. Up to 4 BP readings were taken. The average of 3 readings was used for these analyses. Participants were classified as having normal BP if their average SBP was less than 120 mm Hg and their average DBP was less than 80 mm Hg. Prehypertension was defined by either an SBP of 120 to 139 mm Hg or a DBP of 80 to 89 mm Hg. Hypertension was defined by an average SBP of 140 mm Hg or higher or an average DBP of 90 mm Hg or higher or by reported use of antihypertensive medications. If a participant’s SBP and DBP levels fell into different categories, the participant was classified according to the BP category with the higher value.

Serum total cholesterol concentration was measured enzymatically at the Lipoprotein Analytical Laboratory at The Johns Hopkins Hospital, Baltimore, Md, which is certified by the Lipid Standardization Program of the Centers for Disease Control and Prevention. Individuals with a total cholesterol concentration of 240 mg/dL or greater (≥6.21 mmol/L) or who used cholesterol-lowering medications were considered to have high total cholesterol levels, and those with a concentration of 200 mg/dL or greater (≥5.17 mmol/L) were considered to have above-optimal/high cholesterol levels.

Body measurements were performed by a trained examiner. Weight and height data were captured electronically from the measuring instruments to minimize potential data-entry errors. Overweight status was defined as a body mass index (BMI) (calculated as weight in kilograms divided by the square of height in meters) of 25 or greater, and obesity status was defined as a BMI of 30 or greater.

Diabetes mellitus status was based on interview questions. Participants who reported having ever been told by a physician that they have diabetes mellitus or sugar diabetes or who reported taking insulin pills to lower blood glucose levels were classified as having diabetes mellitus.

Smoking status was based on interview questions. Participants were considered to be current smokers if they reported having smoked 100 cigarettes in their lifetime and still smoked every day or some days. Former smokers were those who reported having smoked 100 cigarettes in their lifetime but who did not currently smoke. Never smokers were those who had never smoked.

To compare the number of other adverse risk factors across BP categories, an index was created of the number of adverse risk factors present (cholesterol level ≥240 mg/dL [≥6.21 mmol/L], BMI ≥30, diabetes mellitus, or currently smoking), which ranged from 0 to 4. Persons with 3 or 4 risk factors were combined into a single category. A similar index using overweight (BMI ≥25) and above-optimal cholesterol levels (≥200 mg/dL [≥5.17 mmol/L]) was also created to examine differences in above-optimal levels of risk factors.

Of the 9282 participants examined in the NHANES, we limited our analyses to those 20 years and older (n=4880). In addition, we excluded participants with missing data for 1 or more of the following reasons: BP was not measured (n=436) or hypertension status could not be ascertained (n=727); race/ethnicity was other than white, African American, or Mexican American (n=441); or the participant was currently pregnant (n=259). These exclusions left data on 3488 persons for analyses. In addition, data for persons whose cholesterol status (n=693), BMI status (n=506), diabetes mellitus status (n=63), or smoking status (n=15) could not be ascertained were excluded from analyses in which these variables were of interest.

Data were weighted to adjust for oversampling, nonresponse bias, and poststratification population totals. To account for the complex sampling design, we used clustered-correlated data analysis software (SUDAAN; Research Triangle Institute, Research Triangle Park, NC) with a jackknife method for variance estimation. Risk factor prevalences were compared between BP groups, and odds ratios (ORs) and 95% confidence intervals (CIs) were calculated from multivariable logistic regression models that included age group, sex, and race/ethnicity as covariables. Age-adjusted estimates were calculated to the 2000 US standard population using 3 age groups.\textsuperscript{13} A P<.05 for 2-tailed tests was used to determine statistical significance.

**RESULTS**

Overall, approximately 39% of persons had normal BP levels, 31% had prehypertension, and 29% had hypertension (Table 1). The percentage of persons with normal BP was lower in men than in women, in the 2 older age groups than in the youngest age group, and in African Americans than in whites and Mexican Americans. Conversely, the percentage of persons with hypertension was about the same in men and women, was greater in the older age groups, and was higher in African Americans. The overall proportion of persons with prehypertension was lower in the older age groups, did not differ greatly among race/ethnic groups, and was higher in men than in women.

In each of the 3 age groups, the percentage of persons with prehypertension was greater in men than in women (Figure). Among persons aged 20 to 39 years, for example, 45% of men had prehypertension compared with 19% of women. In that same age group, African Americans had a greater prevalence of prehypertension (37.4%) than did Mexican Americans (30.9%) and whites (32.2%). Lower prevalences of prehypertension in African Americans aged 40 to 59 years and 60 years or older than in other race/ethnic groups in the same age groups were due to a greater prevalence of hypertension in African Americans at these ages.

The percentage of persons with above-normal and high cholesterol levels was greater in groups with prehypertension and hypertension than in those with normotension (Table 2). In logistic regression models adjusting for age, sex, and race/ethnicity, persons with prehypertension were significantly more likely to have above-optimal cholesterol levels (≥200 mg/dL [≥5.17 mmol/L]) than were persons with optimal BP levels (OR, 1.63; 95% CI, 1.24–2.14), as were persons with hypertension (OR, 1.64; 95% CI, 1.19–2.26). The percentage of persons who were overweight or obese was greater in those with prehypertension than in those with normotension. The likelihood of overweight (OR, 1.46; 95% CI, 1.20–1.79) or obesity (OR, 2.26; 95% CI, 1.67–3.08) re-
mained significant after adjusting for age, sex, and race/ethnicity. Similar results were observed for participants with hypertension compared with those with normal BP. The prevalence of diagnosed diabetes mellitus was also greater in those with more adverse BP levels, but significantly so only in those with hypertension after adjusting for demographic variables (OR, 2.47; 95% CI, 1.28-4.74). The percentage of persons who were current smokers was lower among those with prehypertension and hypertension compared with those with normal BP, significantly so among those with hypertension (OR, 0.70; 95% CI, 0.52-0.93).

The percentage of persons with at least 1 other risk factor that was above normal increased from 78.4% among those with normal BP to 88.8% among those with prehypertension and 95.2% among those with hypertension. After adjusting for age group, sex, and race/ethnicity, persons with prehypertension were 1.83 times more likely (95% CI, 1.30-2.58) and persons with hypertension were 3.85 times more likely (95% CI, 2.49-5.96) to have at least 1 other above-optimal risk factor.

Likewise, the percentage of persons with at least 1 other clinically high risk factor increased from 50.9% among those with normotension to 64.1% among those with prehypertension and 76.5% among those with hypertension. Compared with persons with normal BP, the odds of having at least 1 other risk factor was 1.65 (95% CI, 1.30-2.09) among persons with prehypertension and 2.82 (95% CI, 2.22-3.58) among persons with hypertension.

Among persons with prehypertension, the percentage with at least 1 other clinically high risk factor increased from 57% in those aged 20 to 39 years to 70% in those 60 years and older (Table 3). Almost 94% of persons 60 years and older with prehypertension had at least 1 other cardiovascular disease risk factor that was above optimal. The prevalence of having at least 1 other clinically high risk factor among those with prehypertension was 65% in whites, 63% in African Americans, and 57% in Mexican Americans. After adjusting for sex and age, there were no ethnic group differences in the likelihood of having at least 1 other clinically high risk factor, but Mexican Americans with prehypertension were more likely than whites to have at least 1 above-optimal risk factor (OR, 1.99; 95% CI, 1.04-3.79). This was due to a larger percentage of Mexican Americans being overweight (78.5%) compared with African Americans (69.2%) and whites (61.9%). There were no sex differences in the probability of having at least 1 other risk factor after adjusting for age group and race/ethnicity.

The JNC 7 guidelines consider a normal BP to be less than 120/80 mm Hg. This corresponds with the “optimal” BP category in the JNC VI guidelines. The prehypertension

### Table 1. Blood Pressure Status by Selected Characteristics (NHANES 1999-2000)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Participants, No.</th>
<th>Normotension, % (SE)</th>
<th>Prehypertension, % (SE)</th>
<th>Hypertension, % (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total, crude</td>
<td>3488</td>
<td>39.3 (1.48)</td>
<td>31.2 (0.98)</td>
<td>29.4 (1.21)</td>
</tr>
<tr>
<td>Total, age adjusted</td>
<td>3488</td>
<td>38.9 (1.46)</td>
<td>31.2 (0.99)</td>
<td>29.8 (1.23)</td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-39</td>
<td>1048</td>
<td>59.4 (2.57)</td>
<td>32.8 (1.66)</td>
<td>7.8 (1.17)</td>
</tr>
<tr>
<td>40-59</td>
<td>1054</td>
<td>34.6 (2.46)</td>
<td>34.7 (1.87)</td>
<td>30.7 (2.06)</td>
</tr>
<tr>
<td>≥60</td>
<td>1396</td>
<td>10.3 (1.12)</td>
<td>23.1 (1.11)</td>
<td>65.9 (1.72)</td>
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<tr>
<td>Race/ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>1728</td>
<td>39.3 (1.73)</td>
<td>31.3 (1.16)</td>
<td>29.3 (1.41)</td>
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<tr>
<td>African American</td>
<td>730</td>
<td>33.9 (2.08)</td>
<td>29.8 (1.82)</td>
<td>36.3 (2.27)</td>
</tr>
<tr>
<td>Mexican American</td>
<td>1030</td>
<td>48.3 (2.39)</td>
<td>32.2 (1.77)</td>
<td>19.4 (1.64)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>1754</td>
<td>32.1 (1.64)</td>
<td>39.4 (1.38)</td>
<td>28.4 (1.49)</td>
</tr>
<tr>
<td>F</td>
<td>1734</td>
<td>46.6 (1.91)</td>
<td>22.9 (1.30)</td>
<td>30.5 (1.59)</td>
</tr>
<tr>
<td>Race/ethnicity, age adjusted</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>1728</td>
<td>40.1 (1.76)</td>
<td>31.5 (1.18)</td>
<td>28.4 (1.41)</td>
</tr>
<tr>
<td>African American</td>
<td>730</td>
<td>30.2 (1.63)</td>
<td>28.9 (1.58)</td>
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<tr>
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<td>40.3 (1.66)</td>
<td>31.7 (1.41)</td>
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<td>Sex, age adjusted</td>
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<tr>
<td>M</td>
<td>1754</td>
<td>31.2 (1.67)</td>
<td>39.0 (1.39)</td>
<td>29.8 (1.61)</td>
</tr>
<tr>
<td>F</td>
<td>1734</td>
<td>47.5 (1.79)</td>
<td>23.1 (1.29)</td>
<td>29.4 (1.43)</td>
</tr>
</tbody>
</table>

Abbreviation: NHANES, National Health and Nutrition Examination Survey.

### Figure

Prevalence of prehypertension by sex and race/ethnicity according to age group, National Health and Nutrition Examination Survey, 1999-2000. Error bars represent 95% confidence intervals.

The JNC 7 guidelines consider a normal BP to be less than 120/80 mm Hg. This corresponds with the “optimal” BP category in the JNC VI guidelines. The prehypertension...
Furthermore, the percentage of persons with at least 1 other risk factor, but not hypertension, than did persons with normal BP levels. Among those with prehypertension, African Americans were more likely than whites and Mexican Americans to have hypertension at younger ages.

Race/ethnic, sex, and age differences in individual risk factors have been observed.1,17 Our observations highlight the prevalence of multiple risk factors in individuals at increased risk. Overweight/obesity was the most prevalent risk factor among persons with prehypertension, with 64% being overweight or obese. Obesity may have independent associations with BP, but it is also related through physical inactivity and nutrition,2 and it reinforces the need to reduce the risk of hypertension through lifestyle changes. In addition, however, 60% of persons with prehypertension also had above-optimal cholesterol levels. Furthermore, although persons with hypertension were less likely to smoke cigarettes than those without hypertension, almost 27% of persons with prehypertension smoked. The high prevalence of all risk factors among persons with prehypertension suggests opportunities for further prevention efforts.

These results, along with others,18-22 suggest the continued need for focused and comprehensive preventive and public health efforts that target hypertension, heart disease, and stroke. Recent studies using NHANES data...
have observed that the prevalence of high BP increased from 1988-1991 to 1999-2000,\(^7\) whereas the prevalence of high total cholesterol levels has changed little since the early 1990s.\(^6\) The prevalence of diagnosed and undiagnosed diabetes mellitus has remained about the same, with an increase in self-reported diabetes mellitus, suggesting increased awareness.\(^9\) In the Behavioral Risk Factor Surveillance System,\(^1\) a state-based telephone survey using self-reported data, the prevalence of no reported risk factors (hypertension, high blood cholesterol level, diabetes mellitus, smoking, or obesity) declined from approximately 42% in 1991 to 38% 1999. Greenland and colleagues\(^2\) recently reported that among persons in 3 prospective studies, 87% to 100% with a fatal coronary heart disease event had at least 1 elevated major risk factor. In the San Antonio Heart Study, persons with normal BP at baseline but who developed hypertension during 8 years of follow-up had higher baseline levels of BP, low-density lipoprotein cholesterol, triglycerides, glucose, insulin, and BMI and had lower high-density lipoprotein cholesterol levels than did those who did not develop hypertension.\(^11\)

The relation between BP and cardiovascular disease risk is graded and continuous.\(^23\) Therefore, our observations support the argument that appropriate prevention efforts can be initiated in persons with any level of BP to avert the development of adverse levels in the first place and to prevent cardiovascular complications. Lifestyle changes, such as physical activity and nutrition, aimed at preventing or controlling one risk factor may also affect other risk factor levels. In the Dietary Approaches to Stop Hypertension study,\(^24\) declines in high BP and blood cholesterol levels were observed. In the Lyon Diet Heart Study,\(^26\) lifestyle interventions seemed to have small effects on major biological risk factors, but they had substantial effects on lowering mortality from cardiovascular disease. Furthermore, previous studies have demonstrated that a beneficial cardiovascular risk factor profile is related to lower cardiovascular and noncardiovascular mortality rates and longer life expectancy,\(^9,27\) and to lower Medicare costs in later years.\(^28\)

Clinical\(^2,26-31\) and community\(^3,32\) guidelines for heart disease, stroke, and the major risk factors need to be fully implemented. The Centers for Disease Control and Prevention currently funds 32 states and the District of Columbia to develop comprehensive heart disease and stroke programs aimed at health promotion and primary and secondary prevention.\(^33\) In addition, the National High Blood Pressure Education Program and the National Cholesterol Education Program focus on clinical and community strategies to control high BP and cardiovascular disease risk factors. Recommendations by the National Cholesterol Education Program\(^32\) and others\(^35\) include assessment of 10-year cardiovascular disease risk in patients by means of multiple risk factor assessment. The JNC 7 guidelines\(^4\) also call for assessment of other cardiovascular disease risk factors.

Two potential limitations of the present study should be noted. First, some risk factors were directly measured and others were self-reported. It is unknown, for example, whether self-reported diabetes mellitus and hypertension status increase with one another because detection of one may prompt clinicians to check for the other. Likewise, it is unknown whether people may be less likely to report current smoking if they know that they have particular risk factors. On the other hand, data on the risk factors examined herein were collected independently, and so these potential biases should be minimal. Second, it is not known whether the prevalence of hypertension is higher or lower than the actual prevalence according to clinical guidelines that recommend that BP be measured on 2 separate occasions.

Nonetheless, our observation that people with prehypertension had more adverse risk factors than those with normotension suggests the need to further examine cardiovascular disease risk and to more aggressively pursue preventive strategies in people with prehypertension. The higher prevalence of hypertension in African Americans at younger ages than in whites and Mexican Americans suggests the need for more aggressive efforts at prevention and control in this group. Clinicians need to remain aware that persons with abnormal BP are more likely to have other cardiovascular disease risk factors that are high or above normal. Obtaining a comprehensive risk factor profile may provide more information for heart disease and stroke risk reduction and for targeted BP control.

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REFERENCES


