The prevalence of hypertension is greater for blacks than for whites. Whether black children have higher blood pressure than white children is less clear. We investigated this issue through a prospective longitudinal assessment of blood pressure in 345 white children and 164 black children. Each child had his or her blood pressure measured every 6 months for 2 to 5.5 years. The means for systolic and diastolic blood pressures for each individual were calculated, and the rate of change in blood pressure over time for each subject was estimated. The mean blood pressure and the mean rate were compared between gender-specific black and white groups. For both boys and girls, the mean systolic blood pressure was 2 mm Hg higher in black children than in white children \( (P=0.0008) \). Boys had a higher systolic blood pressure than girls \( (P=0.0048) \). The mean diastolic blood pressure was 1.5 mm Hg higher in black children than in white children \( (P=0.0270) \); no significant gender difference in diastolic blood pressure was observed. Age, weight, height, and body mass index were highly correlated with blood pressure. When accounting for these variables, for girls the racial difference in systolic blood pressure remained significant, whereas the difference in diastolic blood pressure in boys and girls was no longer significant. The rate of increase in blood pressure over time was significantly greater in blacks than whites: for systolic blood pressure, \( P=0.0002 \), and for diastolic blood pressure, \( P=0.009 \). There was no sex difference in rate of change in systolic blood pressure, whereas girls showed a greater increase in diastolic blood pressure over time than boys \( (P=0.0131) \). In summary, the average blood pressure for black children was higher than in white children, and the blood pressure increased at a faster rate in blacks compared with whites. The findings suggest that mechanisms that predispose blacks to hypertension may be functioning in childhood. (Hypertension 1993;22:84-89)
**TABLE 1. Characteristics of Subjects at Entry Into Study**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whites (n=191)</td>
<td>Blacks (n=75)</td>
</tr>
<tr>
<td>Age (y)</td>
<td>8.84±2.15</td>
<td>8.39±1.65</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>30.75±9.76</td>
<td>32.66±9.99</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>133.22±13.16</td>
<td>132.28±10.84</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>16.94±2.62</td>
<td>18.29±3.44</td>
</tr>
<tr>
<td>SBP (mm Hg)</td>
<td>98.45±9.69</td>
<td>99.96±9.53</td>
</tr>
<tr>
<td>DBP (mm Hg)</td>
<td>60.71±10.11</td>
<td>61.43±9.89</td>
</tr>
</tbody>
</table>

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure. Values are mean±SD.

*P values correspond to level of statistical significance of the sex effect after adjusting for race via analysis of variance.

†P values correspond to level of statistical significance of the race effect after adjusting for gender via analysis of variance.

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**Measurements**

The children's blood pressure was measured every 6 months for 2 to 5.5 years. The majority of subjects had measurements made at their schools; less than 5% of subjects had their blood pressure measured in a research unit at Indiana University Hospital. Blood pressure in the right arm was determined with a random zero sphygmomanometer (Hawksley and Sons, Lancing, Sussex, England) while the subject was seated and after the subject had rested for approximately 5 minutes. The first and fifth Korotkoff sounds were used to designate systolic and diastolic blood pressures, respectively. If the blood pressure that corresponded to the fifth Korotkoff sound was zero, then the fourth sound was used to designate diastolic blood pressure. Three readings taken 2 minutes apart were obtained, and the average of the last two readings was used as the final blood pressure measurement. Weights and heights were also measured.

**Statistical Analysis**

Statistical analyses of differences in means of characteristics at entry into the study between black and white groups were performed using analysis of variance. For each follow-up period of each subject, we calculated the mean age, weight, body mass index (BMI), and systolic and diastolic blood pressures. The BMI was calculated using the formula weight (kg)/(height [m])². Since white children had a greater number of measurements on average than black children, the mean values of the above characteristics were compared using a weighted analysis of variance.

Assuming that the increase in blood pressure with age was approximately linear, the rate of increase in blood pressure (slope of blood pressure versus age) was calculated for each subject using a method of least squares. The assumption of linearity appeared to be reasonable since the follow-up period was relatively short, and thus the blood pressure curve in the observed interval was approximated by a straight line. For each subject, the slope of the blood pressure versus age can be interpreted as the rate of increase in blood pressure for a subject's average age. Because the number of visits per individual varied from 4 to 11, the estimated slopes had different variances. We used the Empirical Bayes method to stabilize the least-squared estimated slopes by removing variation due to the smaller number of visits for some individuals. This permitted an estimate of the individual slopes with greater accuracy by reducing individual slope estimates to a common mean value. In addition, the Empirical Bayes model assisted in selecting ranks for individual slopes, permitted an estimate of the variation among slopes, and estimated the histogram of individual specific slopes. The analysis was done for blacks and whites separately. The residual sums of squares about the regression line was used to calculate the unexplained variation that consisted of true biological variability and measurement error. A simple z test was carried out to test for the significant difference in variability between blacks and whites. Individual rates of change with their associated intra-subject and intersubject variance was estimated using adjusted likelihood methods. When comparing the mean values of rates of change between blacks and whites, we used analysis of variance methods by weighting the inverse of the sum of the intersubject and intrasubject variance.

**Results**

**Characteristics of Subjects at Entry Into the Study**

Of the 509 subjects who participated in the study, there were 345 white and 164 black children. The characteristics of black and white children at time of entry into the study are shown in Table 1. There were more boys in the white group, but the difference in the proportion of boys (55% and 46%) was marginally significant (P = .042). For both black and white groups, the average age, weight, height, and blood pressure did not differ significantly between boys and girls. Because we did not find a significant difference in any variable between boys and girls, the overall racial difference is reported herein. Black children were on average 2.55 kg (P = .0066) heavier than the white children. Also, BMI for black children was on average 1.14 kg/m² greater than in the white children. The average height was not significantly different in the two racial groups. The mean systolic blood pressure was 2.13 mm Hg higher in blacks than in whites (P = .023), whereas the mean diastolic blood pressure was not significantly different between blacks and whites.

**Characteristics of Subjects During the Follow-up Period**

To describe the distributions of blood pressure measurements between black and white children, we summarized multiple observations of each subject by his or her average blood pressure and the change in blood pressure during his or her study period. Also, for each
subject the mean value of characteristics during the follow-up period was calculated. The mean characteristics of a subject for a certain outcome variable can be interpreted as the average value of that variable for the subject during his or her follow-up period.

For the follow-up period, the means of characteristics of subjects are shown in Table 2. The number of blood pressure measurements ranged from 4 to 11 for both black and white children. The white group of children had a higher mean number of blood pressure measurements than the black group (8.5 versus 7.6 mean number of measurements, P = .0001). The means depicted in Table 2 were obtained by first calculating the average of within-individual measurements for the follow-up period of each individual and then averaging across individuals. For black and white children, the mean age, weight, height, and BMI did not differ significantly between boys and girls. During the study period, white children were on average 5.5 months older than black children (P = .0210), whereas black children were on average 2.47 kg heavier than white children (P = .0141). The BMI was on average, 1.15 kg/m² higher in black children (P = .0001) than in white children. The mean height was not significantly different in the two groups.

### Longitudinal Measurements of Blood Pressure

For both boys and girls, the mean systolic blood pressure was on average 2 mm Hg higher in black children than in white children (P = .0008) (Table 2). Also, boys had a higher mean systolic blood pressure (P = .0048) than girls in black and white children. A further analysis indicated that for girls the mean systolic blood pressure was about 3 mm Hg higher in blacks than whites (P = .001); for boys, although the mean systolic blood pressure was higher in blacks, this difference was not significantly different. The mean diastolic blood pressure was about 1.5 mm Hg higher in black children than in white children (P = .0270). No gender difference was found in diastolic blood pressure.

To determine whether the factors that are correlated with blood pressure might have influenced the difference in blood pressure levels between whites and blacks, we compared blood pressures between groups after adjusting for those factors. The mean age, weight, height, and BMI were highly correlated to each other, no attempt was made to adjust for all of them simultaneously. Also, a detailed analysis showed that after adjusting for BMI and age, the race effect on systolic blood pressure remained significant for girls (about 2 mm Hg higher in blacks), but the racial difference in systolic blood pressure was not significant for boys. We found similar results after adjusting for weight and age. In each of the analyses, we accounted for the difference in number of measurements among subjects.

For each individual, the change in blood pressure over time is summarized by the slope of the curve representing the relation between blood pressure and age. For each individual, the slope estimates the change in blood pressure for every year increase in age. For example, for black boys systolic blood pressure increased on average 1.7 mm Hg per year (see Table 3). Fig 1 shows the histograms of individual slopes for systolic and diastolic blood pressures in black and white children. All rates were adjusted for differences in the number of measurements between subjects. The histograms for the black children (for both systolic and diastolic blood pressures) are shifted to the right, indicating that the slopes for white children are lower than for black children. Specifically, 55% of blacks had rates of increase in systolic blood pressure that exceeded 1.5 mm Hg per year, compared with only 22% of whites. Similarly, for diastolic blood pressure, 31% of blacks and only 9% of whites had rates greater than 1.5 mm Hg per year. Also, 31% of blacks compared with 8% of whites had rates of increase in systolic blood pressure greater than 2.0 mm Hg per year. Seventeen percent of blacks compared with 2% of whites had diastolic rates greater than 2.0 mm Hg per year.

As shown in Table 3, the mean rate of increase in blood pressure was significantly greater for blacks than whites (for systolic pressure P = .0002 and for diastolic

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Whites (n=191)</th>
<th>Blacks (n=75)</th>
<th>Whites (n=154)</th>
<th>Blacks (n=89)</th>
<th>P (sex)*</th>
<th>P (race)†</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of visits</strong></td>
<td>8.58±1.85</td>
<td>7.69±2.14</td>
<td>8.56±1.98</td>
<td>7.65±1.85</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td><strong>Age (y)</strong></td>
<td>10.90±2.13</td>
<td>10.17±1.66</td>
<td>10.80±2.00</td>
<td>10.61±1.72</td>
<td>.748</td>
<td>.0210</td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td>40.60±12.25</td>
<td>42.6±13.37</td>
<td>39.68±11.50</td>
<td>42.76±12.42</td>
<td>.584</td>
<td>.0141</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td>145.60±13.64</td>
<td>142.86±11.42</td>
<td>143.4±11.77</td>
<td>145.16±11.48</td>
<td>.397</td>
<td>.784</td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td>18.55±2.89</td>
<td>20.19±4.21</td>
<td>18.77±3.46</td>
<td>19.77±3.96</td>
<td>.906</td>
<td>.0001</td>
</tr>
<tr>
<td><strong>SBP (mm Hg)</strong></td>
<td>100.99±7.86</td>
<td>102.15±7.50</td>
<td>98.42±6.84</td>
<td>101.94±7.60</td>
<td>.0048</td>
<td>.0008</td>
</tr>
<tr>
<td><strong>DBP (mm Hg)</strong></td>
<td>59.98±6.34</td>
<td>61.51±7.32</td>
<td>59.90±6.36</td>
<td>61.40±7.45</td>
<td>.828</td>
<td>.0270</td>
</tr>
</tbody>
</table>

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure. Values are mean±SD.

*P values correspond to level of statistical significance of the sex effect after adjusting for race via weighted analysis of variance.

†P values correspond to level of statistical significance of the race effect after adjusting for gender via weighted analysis of variance.
pressure $P = 0.009$). There was no significant sex difference in rate of change in systolic blood pressure, whereas the rate of change in diastolic pressure was significantly greater in girls ($P = 0.0131$). Rates of change of both systolic and diastolic blood pressures showed no significant correlation with age, weight, height, or BMI. As has been described previously, the rate of increase in blood pressure was greater for systolic than diastolic pressure in both blacks and whites (Table 3). The within-subject standard deviations for blood pressure were not significantly different in blacks and whites: for systolic blood pressure, 6.7 and 6.3 mm Hg in whites and blacks, respectively ($P = 0.24$), and for diastolic blood pressures, 8.0 and 8.2 mm Hg in whites and blacks, respectively ($P = 0.51$). On the other hand, the intersubject variation associated with individual rates of change was greater for blacks compared with whites: variation in systolic blood pressure for whites was 1.68 and for blacks, 2.59 (mm Hg/y)²; for diastolic blood pressure the variation for whites was 1.94 and for blacks, 3.42 (mm Hg/y)². The variation in rate of change in systolic blood pressure was approximately 1.5 times greater ($P = 0.0005$) and in diastolic blood pressure 1.8 times greater ($P = 0.0001$) for blacks than whites.

**Discussion**

Although previous cross-sectional assessments of blood pressure in black and white children showed in some instances that blacks had higher pressures, it has not been true of most other comparisons. A difficulty in discerning a blood pressure difference between groups of children is related in part to the high within-individual variation in children's blood pressure; for example, in children of the present study there was a variation of about 6% in systolic and 13% in diastolic blood pressure. However, we found that mean values of systolic blood pressure measured repeatedly every 6 months were significantly higher in blacks than whites. An even more striking finding was the higher rate at which blood pressure increased in black children. On average, over the period of observation, both systolic and diastolic blood pressures increased in boys about 1.5 times faster in blacks than whites, whereas in girls systolic and diastolic blood pressures increased about three times faster in blacks than whites. Blood pressure measurements at baseline were higher in blacks, and thus the black children were more likely to achieve levels of blood pressure that would clearly exceed those of whites.

**TABLE 3. Rates of Change in Blood Pressure With Age in Whites and Blacks**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of change in SBP with age (mm Hg/y)</td>
<td>1.116</td>
<td>0.555</td>
</tr>
<tr>
<td>Rate of change in DBP with age (mm Hg/y)</td>
<td>0.225</td>
<td>0.356</td>
</tr>
</tbody>
</table>

SBP, systolic blood pressure; DBP, diastolic blood pressure.

* $P$ values correspond to level of statistical significance of the sex effect after adjusting for race via weighted analysis of variance.

† $P$ values correspond to level of statistical significance of the race effect after adjusting for gender via weighted analysis of variance.

**FIG 1.** The rates of increase with age in systolic (upper panel) and diastolic (lower panel) blood pressures in white and black children. Results depict the percentage of each racial group for a given rate of increase in blood pressure.
reached by whites, consistent with the known high prevalence of hypertension among black adults. Blood pressure levels showed more variability among blacks as a group than whites as a group. The wider range of blood pressure levels placed more blacks than whites at levels of blood pressure approaching values consistent with hypertension.

The blacks in the present study were heavier than the whites and had a higher mean BMI. This is consistent with previous reports of black children weighing more than white children. Several factors are known to be related to blood pressure. In the present study, we found that age, weight, height, and BMI were related to blood pressure with a high correlation that ranged from 0.4 to 0.6. After adjusting for these factors, for both boys and girls, black children consistently had higher levels of blood pressure than white children, but only in girls was a significant race effect observed for systolic blood pressure. Thus, it appeared that the observed racial difference was partially explained by the difference in body mass in blacks and whites. The racial difference in the rate of change in blood pressure over time was not significantly related to body size.

Why the black children had higher levels of blood pressure is not clear. The increase in the production of androgens in the adrenals, referred to as adrenarche, is greater in black children than white children, and some studies, although not all, have suggested that adrenal androgen production during adrenarche may be associated with higher levels of blood pressure. Puberty is accompanied by an accelerated rate of increase in blood pressure, and although blacks may reach puberty earlier than whites (by approximately 3.4 months in one study), the black children in the present study were as a group younger than white children (by 5.3 months). It was thus unlikely that a racial difference in the onset of puberty contributed to a racial difference in levels of blood pressure.

Several other factors might have contributed to the observed racial differences in blood pressure. Diets that are low in potassium are more commonly consumed by blacks than whites and may be associated with higher blood pressures. Conceivably a lower intake of potassium increases the blood pressure in black children. Unknown environmental factors may have contributed to the influence of race on blood pressure, including factors that stem from differences in socioeconomic factors. Other yet uncharacterized mechanisms, possibly genetically based, may have contributed to the higher levels of blood pressure in black children. Urinary kallikrein excretion, plasma renin activity, and urinary and plasma aldosterone levels have all been reported as being different in blacks and whites during childhood.

It might be argued that a recruitment bias may have affected the difference in blood pressure between racial groups. Participation in the study was voluntary. It is possible that black children with a family history of hypertension had a desire to monitor blood pressure through participation in a research study of hypertension. At the time of entry into the study, the parents were asked if they were known to have high blood pressure. Twenty-nine percent of the black children and 15% of the white children had at least one parent with a history of high blood pressure. The perceived prevalence of self-reported hypertension in the parents of the children was comparable to the estimated prevalence of hypertension in early, middle-aged black and white adult populations.

Whether a slightly higher blood pressure affects the cardiovascular system of black children is unknown. Conceivably, a higher arterial pressure during a period when vasculature may be at a more formative stage could have permanent injurious effects. The higher prevalence and the earlier onset of arterial disease resulting in kidney failure and stroke in blacks might stem in part from exposure to higher levels of blood pressure early in life.

In summary, over time, black children had higher mean blood pressure values and a greater rate of rise in blood pressure. Mechanisms that lead to hypertension in blacks may exist in children long before hypertension becomes established.

Acknowledgments

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