Longitudinal Assessment of Blood Pressures in Black and White Children

Amita K. Manatunga, Jerrlyn J. Jones, J. Howard Pratt

The prevalence of hypertension is greater for blacks than 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 white children ($P=0.008$). 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 ($P=0.027$); 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, $P=0.002$, 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 ($P=0.013$). 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)

KEY WORDS • blacks • blood pressure • hypertension, essential • child

Hypertension is more common in blacks than in whites.1,2 It remains uncertain, however, whether blood pressure is higher in blacks than in whites before hypertension begins. Some cross-sectional studies found slightly higher blood pressure in black children,3-5 whereas others described inconclusive findings or found blood pressure to be lower in whites than in blacks.6-9 In one study of adolescents, blood pressure at night was higher in blacks than in whites.10 An increased level of arterial pressure in black children compared with white children would suggest that factors involved in the development of hypertension in blacks are functioning early in life. If the pathophysiology of the hypertension is indeed present in childhood, then studies that include young, normotensive individuals might provide useful information to an understanding of the etiology of hypertension.

We describe here a prospective, longitudinal study of blood pressure in black and white children. Blood pressure was measured every 6 months for a minimum of 2 years. Each subject's average blood pressure over time was calculated, and the rate of change in blood pressure with age for each subject was estimated. The mean blood pressure and the mean rate of change for whites and blacks were then compared. In contrast to previous cross-sectional comparisons of childhood blood pressure in blacks and whites, the present analyses were based on individual longitudinal measurements of blood pressure during a period when blood pressure normally increases with age.

Methods

Subjects

Children were recruited from schools in Indianapolis as has been described previously.5 Their participation was voluntary, and informed consent was obtained from each child as well as from his or her parents or guardian. The study was approved by the Institutional Review Board of Indiana University-Purdue University of Indianapolis. Children with a history of renal or cardiac disease, hypertension, or diabetes mellitus, and those taking medication that can affect blood pressure were excluded.

There were 715 subjects recruited for the study. However, only the subjects who had at least four measurements of blood pressure over the course of the study were used in the longitudinal analysis. When baseline characteristics such as age, race, weight, and blood pressure were compared, the subjects ($n=206$) who had less than four visits were not significantly different from those subjects ($n=509$) who were included in the longitudinal analysis.

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TABLE 1. Characteristics of Subjects at Entry Into Study

<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>Age (y)</td>
<td>8.84±2.15</td>
<td>8.39±1.65</td>
<td>8.74±2.02</td>
<td>8.82±1.78</td>
<td>.669</td>
<td>.343</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>30.75±9.76</td>
<td>32.66±9.99</td>
<td>30.07±9.47</td>
<td>33.26±10.56</td>
<td>.757</td>
<td>.0066</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>133.22±13.16</td>
<td>132.28±10.84</td>
<td>131.69±12.57</td>
<td>134.91±12.94</td>
<td>.872</td>
<td>.326</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>16.94±2.62</td>
<td>18.29±3.44</td>
<td>16.93±2.83</td>
<td>17.87±3.36</td>
<td>.588</td>
<td>.0001</td>
</tr>
<tr>
<td>SBP (mm Hg)</td>
<td>98.45±9.69</td>
<td>99.96±9.53</td>
<td>96.76±10.09</td>
<td>99.51±10.20</td>
<td>.144</td>
<td>.023</td>
</tr>
<tr>
<td>DBP (mm Hg)</td>
<td>70.71±10.11</td>
<td>61.43±9.89</td>
<td>60.68±10.31</td>
<td>61.05±12.12</td>
<td>.881</td>
<td>.591</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.

Measurments

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 measurements made at their schools; less than 5% of months for 2 to 5.5 years. The majority of subjects had their blood pressure measured in a research unit at Indiana University Hospital. 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 of 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 inter-subject 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 inter-subject and intra-subject 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

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subject the mean value of characteristics during the follow-up period was calculated. The mean characteristic 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 correlated with the mean systolic blood pressure (for age, 0.49; weight, 0.64; height, 0.59; and BMI, 0.50) and with the mean diastolic blood pressure (for age, 0.39; weight, 0.51; height, 0.48; and BMI, 0.41). When accounting for each correlated variable or combination of variables for both boys and girls, the difference in systolic blood pressure remained significant. However, the difference in diastolic blood pressure was no longer significantly different between blacks and whites. For example, after adjusting for age, height, and weight, for systolic blood pressure both the effect of gender (P = .0008) and the effect of race (P = .0033) were significant. Forty-four percent of the variation observed in systolic blood pressure was due to age, weight, sex, and race. Because 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

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**Table 2. Means of Characteristics of Subjects Over Period of Longitudinal Study**

<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>No. of visits</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>Age (y)</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>
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<tr>
<td>Weight (kg)</td>
<td>40.4±12.25</td>
<td>42.46±13.37</td>
<td>39.68±11.50</td>
<td>42.76±12.42</td>
<td>.584</td>
<td>.0141</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>145.60±13.64</td>
<td>142.86±11.42</td>
<td>143.42±11.77</td>
<td>145.16±11.48</td>
<td>.397</td>
<td>.784</td>
</tr>
<tr>
<td>BMI (kg/m²)</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>SBP (mm Hg)</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>DBP (mm Hg)</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.
Table 3. Rates of Change in Blood Pressure With Age in Whites and Blacks

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Boys</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of change in SBP with age (mm Hg/y)</td>
<td>Whites: 1.116</td>
<td>Blacks: 1.675</td>
<td>Whites: 0.555</td>
<td>Blacks: 1.566</td>
<td>.0676</td>
<td>.0002</td>
</tr>
<tr>
<td>Rate of change in DBP with age (mm Hg/y)</td>
<td>Blacks: 0.225</td>
<td>Blacks: 0.310</td>
<td>Whites: 0.356</td>
<td>Blacks: 1.534</td>
<td>.0131</td>
<td>.009</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.

Discussion

Although previous cross-sectional assessments of blood pressure in black and white children showed in some instances that blacks had higher pressures,3-5 this has not been true of most other comparisons.6-9 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
were asked if they were known to have high blood pressure. The perceived prevalence of hypertension among black adults. 


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