Racial Contrasts in Cardiovascular Response Tests for Children from a Total Community

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SUMMARY Cardiovascular risk factors in childhood were assessed by re-examining a random sample of 278 children stratified by diastolic blood pressure (BP), obtained from 3524 children aged 7-15 years in an entire geographic biracial community (Bogalusa). Re-examination included plasma renin and serum electrolytes, 24-hour urine electrolytes, heart rates, and BP at rest and in response to standardized physical stresses (orthostatic, isometric handgrip, and cold pressor tests). The BP responses in these tests were not increased in the high BP strata, which argues against a prevailing labile phase in early essential hypertension. Black children tended toward larger BP responses than whites. In black boys of the high BP stratum (n = 25), systolic supine or stressed BP were higher than for other race-sex groups; these pressures were associated negatively with plasma renin activity, which was low. White children in the high BP strata had increased heart rates, possibly indicating hyperkinetic circulation. These findings indicate that multiple mechanisms operate to control BP at different intensities for black and white children. (Hypertension 2: 686-694, 1980)

KEY WORDS • blood pressure • hypertension • heart rate • epidemiology • renin

IT IS now apparent that blood pressure (BP), serum lipids, and other cardiovascular risk factors already "track" in childhood,1 and their level in adolescence and early adulthood becomes predictive of later disease.2 Therefore, it seems important to examine the control mechanism of these risk factors in childhood. To this end we have completed a community-wide survey of children aged 5-14 years and have reported elsewhere3 that height, weight, and to a lesser extent external maturation, hemoglobin level, black race, and male sex are correlates of higher BP levels.

To explore further determinants of BP levels in children, a random sample was selected stratified according to diastolic pressure and specific for age, race, and sex. The sample was weighted in favor of the extreme BP ranks. In this group we have previously reported that blacks had lower plasma renin activity (PRA), especially in the high BP strata, and lower serum dopamine β-hydroxylase levels, and lower urinary K+ excretion than white children.8 In the high BP stratum, urinary sodium excretion in the black children was positively associated with their BP levels as measured on the same day,4 while in white children in the high BP stratum, resting heart rates were faster5 and the 1-hour glucose of a tolerance curve was greater.6

Selected physiologic responses of these children and some parameters of three cardiovascular stresses were examined.

Methods

Study Population

During the 1973-1974 school year, 3524 children in Bogalusa, Louisiana, aged 5-14 years were examined. Resting, sitting BP was measured by three observers: two each used a mercury sphygmomanometer instrument and one a Physiometrics USM-105 automatic BP recorder (Woodland Hills, California).7 Each observer measured systolic and diastolic (4th phase) pressures three times. Selection on BP level of the children for more in-depth study was accomplished as follows: Three age groups of children were considered, namely those 6-7, 9-10, and 12-13 years of age. In each of these groups, the four race-sex combinations were considered separately, resulting in 12 subgroups. For each subgroup, the rank of median diastolic
pressure value of each child in each observer station was assessed, and the child's three ranks were added. The resulting summed rank score for each child formed the basis for stratified random sampling, sex- and race-specific, with weighting of the extreme pressures: a 100% sampling fraction was drawn of children belonging to the upper and lower two centiles of the BP distribution for Strata 1 and 5; a 70% random sampling fraction was drawn from the next 4-9 centiles of both upper and lower pressures for Strata 2 and 4; and a 4%-8% random sampling fraction was drawn from the children in the remaining centiles for Stratum 3, to obtain equal numbers of children for each of the four race-sex groups (table 1).

In this manner, 368 children were sampled for amplified re-examination and grouped in five strata labeled from 1 (low BP) to 5 (high BP). The re-examination took place 1-2 years after the original survey, with 314 children still residing in the community; 53 children had moved away, and one had died. Of those remaining, 32 refused participation and four were unavailable. Thus, 278 (76% of those selected but 90% of those available) were re-examined. Among the attending children there was balance in age, race, and sex within each of the BP strata.

Re-examination Procedures

About 10 children per day were re-examined according to a protocol discussed in more detail elsewhere. They were allocated a sequence by a preprinted randomized list. The observers were blind to the BP stratum of each child, and were assigned to instrument teams according to a randomized preprinted list; observer teams were all biracial. Briefly, the re-examination included the following.

Blood Sampling

Fasting blood was collected from the cubital vein after the child had been standing upright for some 1½ hours at school. It was collected into tubes containing EDTA (edetate), immediately placed in ice water, later centrifuged at 4° C, and stored in dry ice packs for transportation.

Physical Examination

Physical examination, including clean-catch urinalysis was performed on each child by a physician as part of an attempt to exclude children with potential secondary hypertension. Urinalysis included standard dipstick techniques, microscopy of a centrifuged sediment, and culture for microorganisms.

Cardiovascular Response Tests

Repeated BP measurements are described elsewhere. Previously, the child had been taught how to use the handgrip, a 19117M Smedley hand dynamometer (Stoelting Company, Chicago, Illinois), according to the manufacturer's manual, and a maximum voluntary contraction (MVC) had been assessed in three trials. For the stress tests, the child was randomly allocated to one of two teams of four nurses, who performed the cardiovascular response tests in sequence on that child before proceeding with the next child allocated to that team. At the beginning of the test series, a Whittaker B250L Sphygmostat cuff (Waltham, Massachusetts) was strapped to the child's left arm, and electrocardiographic limb leads to his extremities for heart rate recording. The Sphygmostat, which measures systolic and diastolic pressures fairly accurately, was chosen because of its light weight, ease of handling on moving patients, and simplicity of reading. Each Whittaker instrument was periodically tested against a mercury column. (Whittaker Sphygmostat and mercury sphygmomanometer were compared on a subgroup of 46 children in the same age range from a neighboring community (table 2)). Heart rates were obtained by measuring 6-second intervals on the recorded ECG strips. During the orthostatic test, the child lay supine on an examining table.

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**Table 1. Number of Children Available in Sampling Frame and in Selected Sample, by Race, Sex, and Blood Pressure Centile**

<table>
<thead>
<tr>
<th>Blood pressure strata (centiles)</th>
<th>White boys Avail</th>
<th>White girls Avail</th>
<th>Black boys Avail</th>
<th>Black girls Avail</th>
<th>Total Avail</th>
<th>Total Select</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper 2</td>
<td>15</td>
<td>15</td>
<td>8</td>
<td>7</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>Next 4-9</td>
<td>28</td>
<td>20</td>
<td>35</td>
<td>36</td>
<td>132</td>
<td>93</td>
</tr>
<tr>
<td>Middle</td>
<td>633</td>
<td>563</td>
<td>343</td>
<td>309</td>
<td>1848</td>
<td>96</td>
</tr>
<tr>
<td>Next 4-9</td>
<td>28</td>
<td>20</td>
<td>35</td>
<td>36</td>
<td>132</td>
<td>93</td>
</tr>
<tr>
<td>Lower 2</td>
<td>15</td>
<td>15</td>
<td>8</td>
<td>7</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>Total available</td>
<td>719</td>
<td>655</td>
<td>429</td>
<td>395</td>
<td>2198</td>
<td></td>
</tr>
<tr>
<td>Total selected</td>
<td>92</td>
<td>94</td>
<td>91</td>
<td>91</td>
<td>368</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 2. Comparison of Blood Pressures* as Measured by Whittaker Sphygmomanometer and Mercury Sphygmomanometer in 48 Children

<table>
<thead>
<tr>
<th>Korotkoff phases</th>
<th>Whittaker sphygmomanometer (mm Hg)</th>
<th>Mercury sphygmomanometer (mm Hg)</th>
<th>Product-moment correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>118 ± 4</td>
<td>116 ± 3</td>
<td>0.67</td>
</tr>
<tr>
<td>4</td>
<td>74 ± 2</td>
<td>64 ± 3</td>
<td>0.68</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>0.60</td>
</tr>
</tbody>
</table>

*The mean of three measures was entered for each phase in each of the 46 children.
†In a two-way analysis of variance test (controlling for the effect of the individual child) the difference between instruments ("instrument effect") was not significant (p > 0.1) for Phase 1, but was significant for Phases 4 (p < 0.0001) and 5 (p < 0.005).

Statistical Analysis

Maximal values for BP and heart rate under stress were obtained, and in each individual the various measurements taken during and immediately after the stress were compared.

In most presentations, BP Strata 1 and 2 were combined to form the "low" stratum, and Strata 4 and 5 to form the "high" stratum. A three-factor analysis of variance model for unequal size samples was used to test for race, sex, or BP stratum effect. If statistically significant three-factor or two-factor interactions existed, then only simple effects were examined (no corrections made for multiple comparisons); otherwise, main effects were tested.15

Results

Physical Examination

No signs of hyperthyroidism, cardiac valvular disease, coarctation of the aorta, or palpable renal abnormalities were found. Urinary findings were abnormal in six cases based on proteinuria or red and white blood cells in the urine sediment. These cases have been excluded in the analysis of the data, resulting in a study population of 272 children. Height, weight, and skinfold measurements showed that children in the higher BP strata were both taller and heavier than in the lower (table 3). Percent body fat as estimated from skinfolds measured at six body sites was clearly greater in the higher BP strata for the white boys, and marginally so for the other race-sex groups (unpublished data).

Relaxed-Sitting and Resting Blood Pressures and Resting Heart Rates

Before cardiovascular response tests were performed, the children underwent repeated sitting BP examinations in an anxiety-free, relaxed atmosphere according to a protocol described earlier. In our hands, the methodology yields BP levels comparable to basal levels.7 The results of these measurements are presented in table 4. After 1 or 2 years, the mean BP for each stratum kept its systolic pressure rank relative to the other strata, both for whites and blacks. As reported earlier,7 blacks had slightly higher BP than whites.

![Figure 1](http://hyper.ahajournals.org/)

**Figure 1.** Schematic flow of measurements during the three cardiovascular response tests. *t = time in minutes; BP = blood pressure measurement; HR = heart rate recording. During the orthostatic test, the command "Stand!" was given immediately after the third BP measurement. As soon as the child was standing (always within 1 minute) the command "Time!" was given whereupon both the BP observer and heart rate recorder began measurements.**
Resting supine systolic BPs as measured by the Whittaker instrument are presented in the upper left quadrant of figure 2 by race, sex, and BP stratum. There was a significant (p < 0.05) three-factor interaction between the effects of race, sex, and BP stratum on resting-supine systolic blood pressure. Only the black boys showed a significant increase from low to high BP stratum (p < 0.0001, linear regression test for slope), and in the high BP stratum they had significantly higher BPs than white boys (p < 0.0001). The resting supine pulse pressures were higher for blacks than for whites (p < 0.0001) and higher for boys than for girls (p < 0.0001). In the high BP stratum, black boys had higher pulse pressures than white boys (p < 0.001).

Resting supine heart rates are given in the upper left quadrant of figure 3 by race, sex, and BP stratum. There is a marked positive increase in resting heart rate over the BP strata for whites, but this was not noted for blacks (race versus BP stratum interaction, p < 0.005).

In the black boys of the high BP strata, the relaxed or sitting systolic BP was negatively related to the plasma renin activity (PRA) taken from the child after 1-1.5 hours' standing,* where those children with the lowest PRA had the highest BPs, respectively for supine (Whittaker) and sitting (Physiometrics and mercury sphygmomanometric) pressures. The 24-hour urine Na+/K+ ratio was positively related to resting BP and negatively to PRA (table 5).

An index of cardiac oxygen consumption is given by the workload of the heart as indicated by the product of heart rate and mean BP (systolic + diastolic)/3.18 We found that, for white boys and girls, this product increased from the low to the high BP stratum (slope of linear regression is positive, p < 0.0001 in both cases), but not for black children (race vs BP stratum interaction, p < 0.005).

Cardiovascular Response Tests

Resting and maximal values for BP and heart rate are presented by test and by BP stratum for all children, race and sex combined, in figure 4. A BP stratum trend is noted for resting and stressed BP levels, but not for resting and stressed heart rates.

Like the resting-supine systolic levels, the maximal stressed systolic levels showed significant positive BP trends over the BP strata only for the black boys (significant two or three factor interaction, p < 0.05). For black boys in the high BP stratum, the systolic level was in all stress tests significantly higher than for the white boys (orthostatic test, p < 0.001; handgrip test, p < 0.01; cold pressor test p < 0.001; fig. 2). On

### Table 3. Body Height and Weight, Mean ± 2 SE, by Sex and Blood Pressure Stratum, in Children, Aged 7-15 Years

<table>
<thead>
<tr>
<th>Measure</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys (50)</td>
<td>Girls (51)</td>
<td>Boys (38)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>144 ± 4</td>
<td>145 ± 4</td>
<td>152 ± 5</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>36 ± 3</td>
<td>36 ± 3</td>
<td>44 ± 5</td>
</tr>
</tbody>
</table>

*Sample size in brackets.

Aged 7-16 Years

<table>
<thead>
<tr>
<th>Measure</th>
<th>Sample size in brackets.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP, mm Hg</td>
<td></td>
</tr>
<tr>
<td>DBP, mm Hg</td>
<td></td>
</tr>
<tr>
<td>Physiometrics</td>
<td></td>
</tr>
</tbody>
</table>

*One child had missing data because his leg was in a cast.

### Table 4. Relaxed-sitting Blood Pressures (mean ± 2 SE) on Two Instruments, by Race and by Blood Pressure Stratum, in Children, Aged 7-15 Years

<table>
<thead>
<tr>
<th>Recorder</th>
<th>BP phase</th>
<th>Low (mm Hg)</th>
<th>Medium (mm Hg)</th>
<th>High (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Whites (50)</td>
<td>Blacks (51)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(33)</td>
<td>(42)</td>
<td>(51)</td>
</tr>
<tr>
<td></td>
<td>Hg. sphyg.</td>
<td>97.2 ± 2.8</td>
<td>98.4 ± 3.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>52.0 ± 2.6</td>
<td>55.6 ± 2.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physiometrics</td>
<td>98.4 ± 3.6</td>
<td>102.4 ± 3.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>56.0 ± 2.0</td>
<td>58.4 ± 2.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SBP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>102.4 ± 3.6</td>
<td>104.4 ± 3.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>59.6 ± 2.8</td>
<td>60.5 ± 2.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>103.9 ± 4.1</td>
<td>106.8 ± 3.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>61.6 ± 2.8</td>
<td>63.7 ± 2.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>60.6 ± 2.0</td>
<td>63.8 ± 2.4</td>
<td></td>
</tr>
</tbody>
</table>

*Sample size in brackets.

SBP = systolic blood pressure; DBP = diastolic blood pressure phase 4.
FIGURE 2. Resting-supine and maximal-stressed systolic blood pressure (BP) (mean ± 2 SE) as measured by the Whittaker Sphygmostat, by race, sex, and BP stratum. Only black boys showed significant (p < 0.005) positive trends over the BP strata.

FIGURE 3. Resting-supine and maximal-stressed heart rate (mean ± 2 SE), by race, sex, and BP stratum. In whites, the heart rate was increased in the high blood pressure (BP) strata. This was not the case for blacks.
FIGURE 4. Resting and maximal values for blood pressure (BP) and heart rate (mean ± SE) in three cardiovascular response tests, by BP stratum. A trend is noted for resting and stressed BP levels, but not for heart rates. Race and sex differences as presented in figures 2 and 3 are not reflected in these combined data.

Responses in BP level and heart rate to the stress tests are presented by BP stratum in tables 6 and 7. In general, there was no response trend over the BP strata. In an analysis of variance in which the systolic and diastolic BP and heart rate responses were the respective dependent variables and race, sex, and BP strata the independent variables, the regression on BP stratum was not statistically significant. (Exceptions were the regressions of diastolic pressure responses on BP stratum for: 1) the handgrip test in black boys, where the regression slope was positive \( p < 0.05 \), and 2) the cold pressor test in the combined race-sex groups, where the regression slope was negative \( p < 0.005 \).) Blood pressure responses of the black children were higher than those of the white children in orthostatic test diastolic pressure \( p < 0.05 \), and in cold pressor test systolic \( p < 0.005 \) and diastolic \( p < 0.05 \) pressure. Boys reacted more than girls in handgrip test systolic \( p < 0.005 \) and diastolic \( p < 0.0001 \), and in cold pressor test diastolic \( p < 0.0001 \) pressure.

These data were also analyzed separately for children whose age and re-examination was less than 12 years versus 12 years and older. No deviations from the patterns above were noted.

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**TABLE 5. Product-Moment Coefficients of Correlation Between Resting Systolic Blood Pressure (Measured on the Day of Urine Collection), Plasma Renin, and 24-hour Urine Na+/K+ Ratio in Black Boys of the High Blood Pressure Stratum**

<table>
<thead>
<tr>
<th>Resting SBP</th>
<th>PRA*</th>
<th>Log (Na+/K+)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hg sphygmomanometer</td>
<td>-0.69†</td>
<td>0.64‡</td>
</tr>
<tr>
<td>(sitting)</td>
<td>(22)</td>
<td></td>
</tr>
<tr>
<td>Physiometrics</td>
<td>-0.33</td>
<td>0.53**</td>
</tr>
<tr>
<td>(sitting)</td>
<td>(22)</td>
<td></td>
</tr>
<tr>
<td>Whittaker</td>
<td>-0.51*</td>
<td>0.46**</td>
</tr>
<tr>
<td>(supine)</td>
<td>(22)</td>
<td></td>
</tr>
</tbody>
</table>

*Correlation of renin vs log (Na+/K+) is -0.42.
†Sample size in brackets; two renin values were missing.
‡p < 0.001.
§p < 0.01.
**p < 0.05.
Table 6. Increase in Blood Pressure (mean ± SE) for Three Cardiovascular Response Tests, by Blood Pressure Stratum, in Children Aged 7-16 Years

<table>
<thead>
<tr>
<th>Test</th>
<th>Low (101)* (mm Hg)</th>
<th>Medium (75) (mm Hg)</th>
<th>High (98) (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthostatic heart rate acceleration</td>
<td>SBP 6.02 ± 1.34</td>
<td>6.76 ± 1.80</td>
<td>7.14 ± 1.47</td>
</tr>
<tr>
<td></td>
<td>DBP 12.92 ± 1.35</td>
<td>13.43 ± 1.48</td>
<td>13.03 ± 1.24</td>
</tr>
<tr>
<td>Isometric hand grip</td>
<td>SBP 16.37 ± 2.23</td>
<td>19.85 ± 3.00</td>
<td>18.18 ± 2.20</td>
</tr>
<tr>
<td></td>
<td>DBP 17.43 ± 2.07f</td>
<td>20.85 ± 2.65f</td>
<td>19.05 ± 2.10</td>
</tr>
<tr>
<td>Cold pressor</td>
<td>SBP 19.33 ± 2.30</td>
<td>16.72 ± 2.10</td>
<td>16.25 ± 2.21</td>
</tr>
<tr>
<td></td>
<td>DBP 22.20 ± 2.27f</td>
<td>19.55 ± 2.61</td>
<td>17.45 ± 2.25f</td>
</tr>
</tbody>
</table>

*Sample size in brackets.
†Within test, the difference between these two means is statistically significant (p < 0.05).
SBP = systolic blood pressure; DBP = diastolic blood pressure phase 4.

Table 7. Increase in Heart Rate (Mean ± SE) for Two Cardiovascular Response Tests, by Blood Pressure Stratum, in Children Aged 7-16 Years

<table>
<thead>
<tr>
<th>Test</th>
<th>Low (101)* (beats/min)</th>
<th>Medium (75) (beats/min)</th>
<th>High (98) (beats/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthostatic heart rate acceleration</td>
<td>23.16 ± 2.13</td>
<td>20.87 ± 2.60</td>
<td>22.03 ± 2.14</td>
</tr>
<tr>
<td>Isometric hand grip</td>
<td>20.33 ± 2.65</td>
<td>19.64 ± 3.00</td>
<td>18.79 ± 2.07</td>
</tr>
</tbody>
</table>

*Sample size in brackets.

Discussion

Orthostatic Test

Frohlich et al. hypothesized that labile hypertension (defined as a patient's arterial pressure found to be elevated on several occasions with many intervening periods in which normal arterial pressure is observed) is "an early development stage of hypertension, manifested by hyperkinetic circulation, elevated plasma renin activity, and normal plasma volume." They measured orthostatic acceleration of the heart rate, and found this to be elevated in cases of labile hypertension.

Kuchel et al. stated that "the most typical characteristic of labile hypertension is the extreme variability of blood pressure, with increases occurring often within seconds or minutes under the influence of common stimuli (such as emotion, cold, pain, exercise, posture, etc.)" and that "the central and autonomous nervous systems are responsible for such extreme variations in the blood pressure."

In the present study of children, no positive trends among the BP strata of increases in heart rate or BP in response to orthostatic or other tests could be demonstrated in the children sampled. The present data do not seem to indicate the prevalence of labile hypertension in this age group based on different BP strata within the age span. However, we did observe that white children in the high strata of diastolic pressures had high heart rates, and this finding may reflect the observation by Frohlich et al. that borderline hypertensives had a hyperkinetic circulation. In interpreting these findings, we need to consider other observations, since selecting for BP levels in younger age groups results in taller and heavier children in the higher BP groups.

Isometric Handgrip

Alam and Smirk reported a rise in BP upon weight lifting by patients with essential and renal hypertension, and by normotensive persons. Clarke et al., Lind et al., Lind et al., Lind et al. and Donald et al. confirmed the existence of a neural reflex pathway originating in the exercised limb, which is necessary for the BP rise to occur. This rise is thought to be independent of muscle mass and hence can be elicited by contraction of small muscles. Two isometric exercises performed simultaneously in two muscle groups have no additive effect. When humoral agents derived from the exercised muscle were bypassed by vascular occlusion, the pressor response mechanism remained intact. Ewing et al. and Hoel et al. found that for hypertensive adults the isometric handgrip response was of similar magnitude compared to normotensives.

In the present study there was generally no positive trend, among the BP strata, of handgrip-induced BP increase. This is consistent with the current theory that this is not a sensitive test for hypertension.

Cold Pressor

The cold pressor test was initiated by Hines and Brown. Its ability to predict hypertension was supported in studies by Miller and Bruger and Ayman and Goldshine, but not by Pickering and Kissin. All of these studies employed cross-sectional population study data.

Longitudinal, prospective studies were performed by Harlan et al. and by Armstrong and Rafferty with 30 and 7 years of follow-up respectively. Both studies found that the cold pressor test had no predic-
tive value. However, Alan and Langdon (as quoted by Harlan et al.27) did find the test predictive of hypertension in subjects over 35 years of age at the time of the baseline test. The predictiveness of this test was more recently confirmed by Keys et al.28 and Voudoukis29 for middle-aged subjects.

In the present study of children, there was no positive trend in BP response over the BP strata. This is compatible with the existing concept that the test's predictiveness, if any, is limited to subjects of older age. Blacks generally showed higher BP responses than whites.

Present Findings of Cardiovascular Parameters at Rest and under Stress

In general, results from stress testing did not show a trend in the responses to stress among the BP strata; this finding argues against the general prevalence of a moment-to-moment labile phase in early essential hypertension.30 Marked trends in stressed systolic and diastolic pressure levels observed among the BP strata were already observed during the relaxed-sitting examination (table 4). The differences among BP strata in table 4 reflect the "tracking" of BP levels in these children, since the strata were defined from data collected 1–2 years previously.

The black boys of the high BP strata showed higher systolic resting and stressed BPs than any other group. These pressure levels were negatively associated with the PRA, which was very low in this group.4 Julius and Esler31 have suggested that such combined findings may point to an increased central blood volume in mild low-renin hypertensives. We reported elsewhere that in the black children of the high BP strata the relaxed-sitting BP levels were positively associated with 24-hour urine sodium, and that black children seem to excrete less urinary potassium than whites for the same intake. These combined observations are suggestive of beginning sodium retention in the black boys with higher BP levels.32 Their differences with black girls in the high BP strata may be explained by a possible sodium-retaining action of androgenic hormones.34

For white subjects, both heart rate and cardiac output increase have been observed in early transient stages of hypertension.35–37 Our finding of increased resting heart rate in white children of the high BP strata tends to support the notion of an increased adrenergic stimulation in white children in the high BP strata, and perhaps are evidence of a hyperkinetic circulation.

The early natural history and pathogenesis of essential hypertension are being explored. The parameters for the resting and standard-stressed state may serve as predictors of future hypertension, as, for example, in black boys the systolic pressure,38 and in white children the heart rate.39 The findings described here for children are indicative of the multiple and complex mechanisms active in or before the very early onset of essential hypertension, operating at different intensities for black and white children.

Conclusions

High blood pressure is a known risk factor of cardiovascular disease, and essential hypertension probably begins in childhood. The manner in which it is predetermined apparently differs between white and black children. Our present observations from cardiovascular response testing are compatible with the notion that black children in the high BP strata show the beginning of sodium sensitivity, and that certain cardiovascular observations like faster heart rate in white children of the high BP strata reflect greater adrenergic activity. Overall responses to cardiovascular stress tests in individual patients will not likely reflect tendencies to hypertension, but responses of some groups can be differentiated.

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