Persistence of High Diastolic Blood Pressure in Thin Children
The Bogalusa Heart Study

GREGORY L. BURKE, DAVID S. FREEDMAN, LARRY S. WEBBER, AND GERALD S. BERENSON

SUMMARY Relationships between initial anthropometric variables and subsequent diastolic blood pressure (fourth phase) were examined in children identified as being in the upper quintile for diastolic blood pressure at Year 1. Of 156 white children, aged 10 to 14 years, with diastolic blood pressure levels in the upper age-race-sex-specific quintile at Year 1, 38% remained in the upper quintile at Year 4. However, there was a definite trend for leaner children, defined by ponderosity (weight/height$^3$) to remain in the highest diastolic blood pressure quintile ($p < 0.001$). Of white children originally identified in the highest quintile for diastolic blood pressure and the lowest quintile for ponderosity (lean group), 67% (18 of 27) remained in the upper quintile at Year 4. In contrast, only 21% (11 of 52) of white children identified as being in the highest quintile for both diastolic blood pressure and ponderosity (obese group) at Year 1 were in the upper diastolic blood pressure quintile at Year 4. Similar results were seen in children examined 5 years later. Pearson correlation coefficients and linear regression analyses confirmed the negative relationship between initial ponderosity and subsequent diastolic blood pressure, especially in older children. A similar relationship was noted in black children. Potential differences in the etiological process of obesity-related and non-obesity-related high blood pressure were examined. These observations indicate that characteristics other than obesity can contribute to high blood pressure in late childhood. (Hypertension 8: 24-29, 1986)

KEY WORDS • hypertension • blood pressure • pediatrics • tracking

HYPERTENSION contributes substantially to increased cardiovascular morbidity and mortality. Since early treatment contributes to decreased cardiovascular sequelae in adults, a better understanding of the early natural history of hypertension is important. Blood pressure levels have been shown to “track” moderately well in pediatric subjects, and this ability to identify children at high risk for future hypertension provides an opportunity to explore approaches for prevention of hypertensive disease in later life.

Many studies have found a positive association between body size and blood pressure in both pediatric and adult populations. Obesity is known to exhibit a positive correlation with hypertension in adults. Children with high blood pressure levels also tend to have higher ponderal indices; however, many children tracking with high blood pressure levels are not obese. These observations are consistent with multifactorial influences in the early natural history of hypertension.

The Bogalusa Heart Study has collected cross-sectional and longitudinal observations on blood pressure levels on a total pediatric population for the past 10 years. The extensive time course of observation offers an excellent opportunity to study ponderosity related to persistence of blood pressure. This material explores differences in tracking of blood pressure between lean and obese groups of children in the high blood pressure quintile. Differences in blood pressure persistence across the various ponderosity groups may be related to differences in the cause of high blood pressure. Initial ponderosity (weight/height$^3$) may be useful for identifying groups of children who will have persistently high blood pressure many years later. Identification of these subgroups is also useful in investigating determinants of the early natural history of hypertension.

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Materials and Methods

The population consisted of all children residing in Ward 4 of Washington Parish, Louisiana, including the city of Bogalusa. This biracial community of approximately 22,000 people is two-thirds white and one-third black. The 700 children studied represent those in the highest quintile (≥80%) of diastolic (fourth phase) blood pressure (DBP) for their respective age-race-sex-specific groups in 1973–1974 (Year 1). Subsequent blood pressure measurements for these children were determined during the next two cross-sectional surveys 1976–1977 (Year 4) and 1978–1979 (Year 6).

Cardiovascular risk factors were ascertained on all eligible children according to detailed protocols. Protocols for obtaining blood pressure data and anthropometric information have remained constant for the duration of the study. Blood pressure, height, weight, triceps skinfold, and laboratory data were routinely collected. A physical examination, including secondary sexual maturation measures as described by Tanner, was performed on each child.

Right arm blood pressures were obtained from seated, relaxed subjects in the last stage of the screening flow. Arm measurements were made according to protocols to ensure proper cuff size for blood pressure determinations. Systolic and diastolic blood pressures were recorded as the first and fourth Korotkoff phases respectively. Each child’s blood pressure was measured by three different trained examiners; hence, nine observations were taken on each child, six with mercury sphygmomanometers (W.A. Baum, Copiague, NY, USA) and three with a Physiometrics automatic blood pressure recorder (Sphygmotronics, Woodland Hills, CA, USA). Only results from the six mercury sphygmomanometer readings were used in these data analyses.

The relationship between initial ponderosity (weight/height³) at Year 1 and subsequent blood pressure was examined. The analysis was stratified for race. Children were grouped into quintiles of DBP at each cross-sectional screening. Only those children initially in the uppermost quintile (≥80%) of DBP are described through Year 6. Initial ponderosity at Year 1 for those subjects in the high blood pressure group was calculated. The high blood pressure group was then subdivided into five groups based on quintile of ponderosity at Year 1. Differences in tracking were monitored in the five obesity groups. The attrition from this cohort was mainly due to older children at an earlier screen not being eligible for subsequent longitudinal school surveys (i.e., older than age 17 years). In fact, the most obese group and the most lean group remained in the cohort at almost identical levels at Year 4 and Year 6 (69% vs 74% at Year 4; 41% vs 40% at Year 6).

Analysis of variance techniques were used to detect any differences in DBP levels between the five obesity groups at Year 1. A test for trends, as described by Fleiss, was used to determine the significance level for differences in blood pressure tracking between the five obesity groups. Pearson correlation coefficients were generated, contrasting initial anthropometric parameters with subsequent blood pressure values. Linear regression analyses of blood pressure and anthropometric variables also were performed. Multivariable analyses were employed to examine the relationship between the initial anthropometric variables and subsequent blood pressure after controlling for initial blood pressure level.

Results

Distribution of ponderosity in the highest DBP group at the time of the initial examination is shown in Table 1. Similar trends between blood pressure persistence and obesity levels were seen for systolic blood pressure measures; however, DBP levels showed a stronger negative relationship with ponderosity, as will be outlined below. As expected, the more obese children (with the highest ponderal indices) were overrepresented in the upper quintile of DBP. This trend was seen in both white and black children (p < 0.005). Similar findings were seen at Year 4 and Year 6: more obese children were overrepresented in the upper quintile of diastolic blood pressure levels. The mean Year 1 DBP levels for the five ponderosity groups were compared to ascertain whether lean children had initially higher levels of DBP, which might explain increased tracking in this group. No significant difference in Year 1 DBP levels between the ponderosity groups was detected by analysis of variance in either black or white children.

Tracking

Frequency of persistence for white children in the upper quintile of DBP at Year 4 according to initial ponderosity is depicted in Table 2. In younger children (aged 5–9 years), the more obese groups persisted to a greater extent in the upper DBP quintile. A test for trend indicated that this relationship was statistically significant (p < 0.05).

Table 1 Distribution of Children in the Upper Quintile of Diastolic Blood Pressure at Year 1 by Ponderosity Grouping and Race the Bogalusa Heart Study

<table>
<thead>
<tr>
<th>Ponderosity group (weight/height³)*</th>
<th>White children</th>
<th>Black children</th>
<th>n</th>
<th>%</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean (&lt;20%)</td>
<td>62</td>
<td>30</td>
<td>14</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–40%</td>
<td>75</td>
<td>38</td>
<td>17</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40–60%</td>
<td>77</td>
<td>45</td>
<td>17</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60–80%</td>
<td>85</td>
<td>57</td>
<td>19</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obese (≥80%)</td>
<td>147</td>
<td>84</td>
<td>33</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>446</td>
<td>254</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Only children in the upper quintile for diastolic blood pressure were included
†Chi-square test for trends was significant (p < 0.001)
‡Chi-square test for trends was significant (p < 0.005).
In older white children (aged 10–14 years at Year 1), lean groups persisted to a greater extent in the upper DBP quintile. A test for trend showed that this relationship was highly significant \((p < 0.001)\). Black children exhibited a similar trend for tracking of DBP (data not shown). A positive trend between initial ponderosity and persistence of DBP levels was present in the younger black children (aged 5–9 years). In older black children (aged 10–14 years at initial examination), leaner subjects persisted to a greater extent in the upper quintile for DBP. A test for trends indicated that these relationships in black children were not statistically significant.

The propensity for lean children to persist to a greater extent in the upper quintile of DBP was examined at Year 6 of follow up (Table 3). Younger white children (aged 5–9 years) in the leaner groups persisted to a greater extent in the Year 6 upper quintile for DBP; however, this trend was not statistically significant. Older white children in the leaner groups persisted to a greater extent in the upper quintile of DBP, and this trend was highly significant \((p < 0.0025)\). A similar, but not statistically significant, trend was present in black children.

### Correlation Coefficients

Younger white children (aged 5–9 years at Year 1) exhibited a positive relationship between initial ponderosity, weight, height, triceps skinfold thickness, change in ponderosity, and change in weight with Year 4 blood pressure (Figure 1). Older white children (aged 10–14 years at Year 1) showed an interesting negative relationship between initial ponderosity and triceps skinfold with Year 4 DBP levels. Height and change in ponderosity were positively correlated with Year 4 DBP levels in these older children.

Young black children had positive correlation coefficients for initial weight and height, as well as for changes in weight and ponderosity over time, with Year 4 DBP. No significant correlation was noted between initial ponderosity and triceps skinfold thickness with Year 4 DBP level. A negative, although nonsig-
significant relationship between Year 1 ponderosity and triceps skinfold thickness with Year 4 blood pressure was seen in older black children (aged 10-14 years at Year 1).

Figure 2 shows correlation coefficients between Year 6 DBP level and initial anthropometric variables in children. Older white children (aged 10-14 years) again showed a negative trend between initial anthropometric variables and subsequent DBP levels. However, a negative but nonsignificant trend was seen between initial ponderosity and Year 6 blood pressure level even in younger children.

A negative relationship between initial ponderosity and Year 6 DBP level was seen in younger black children. A positive trend was seen with DBP level in younger black children for height, change in ponderosity, and change in weight. A negative trend was seen in the older black children between initial anthropometric variables and Year 6 DBP level. The negative trend between initial ponderosity and Year 6 DBP level was significant in both younger and older black children.

A linear regression model was constructed with follow-up DBP as the dependent variable and with initial ponderosity and initial DBP as independent variables for the subgroup of children in the highest quintile of DBP at Year 1 (data not shown). At Year 6 of follow-up, a negative relationship between initial ponderosity and DBP levels again was present in all four race-sex groups. The negative relation between initial ponderosity and subsequent blood pressure remained even after initial DBP was entered as a covariate.

Change in height from Year 1 to Years 4 and 6 was consistently higher for children who tracked for DBP and did not explain tracking differences observed in the ponderosity groups. Partial correlation coefficients were determined between initial ponderosity and subsequent blood pressure levels, adjusting for initial height. The partial correlation coefficient in older children identified in the upper DBP group at Year 1 between initial ponderosity and Year 6 DBP was $-0.29$ ($p < 0.001$); the relationship in younger children was $-0.19$ ($p < 0.01$). Therefore, even though height played an important role in the etiology of children's blood pressure levels, the relationship between blood pressure persistence and initial ponderosity appears unaffected by height relationships. Regression analy-
Discussion

Evaluation of a large population in an epidemiological study is apt to yield subsets of subjects tracking at various levels of blood pressure and of other cardiovascular risk factors. In this study an interesting relationship between leanness and tracking of high blood pressure became apparent in a select group of children. As expected, obese children were overrepresented in the high blood pressure group. Of those subjects identified in the "high risk" blood pressure group, however, lean children remained in the upper quintile of DBP to a greater extent. We were thus able to identify a special subset of lean children whose high DBP tended to persist.

Persistent tracking of high DBP in lean children was seen only in the older cohort of children at Year 4. However, negative correlation coefficients between Year 1 ponderosity and DBP level were seen in all four race-sex groups by Year 6. This difference may be present because older children have already attained more adultlike body morphology at Year 4, while a similar blood pressure–anthropometric relationship may be masked by puberty in younger children. The negative relation between initial ponderosity and subsequent blood pressure remained even after adjustment for Year 1 DBP levels.

The same trend in persistence of high DBP levels was present in black children, although this trend did not always achieve statistical significance. Identifying the high risk group and stratifying for ponderosity decreased the sample size and hence may have precluded a statistically significant result in black children.

The results of this investigation point toward initial ponderosity as an important determinant of future blood pressure status. The relationship between obesity and hypertension has been well established. Prevalence of high blood pressure is greater in overweight persons in both adult and pediatric age groups. Many investigators have demonstrated a blood pressure decrease with weight loss and an increase with weight gain, even without sodium restriction.

The finding that differences exist in the persistence of elevated blood pressure levels in the five ponderosity groups is consistent with differing mechanisms contributing to the high blood pressure. Other investigators have postulated numerous mechanisms to explain an increased prevalence of hypertension in obese persons. Dahl et al. suggested that the increased intake of sodium with a greater caloric load in obese persons is a mechanism for differences in blood pressure due to body size. Others have implicated obesity as an independent risk factor for hypertension, even when sodium intake is held constant. Frohlich and colleagues determined that obese hypertensive subjects have increased blood volume in the absence of elevated peripheral resistance, while lean hypertensive subjects have increased peripheral resistance with no change in blood volume. These differences may be related to changes in the renin-angiotensin system due to obesity. Obesity-induced increases in levels of endogenous steroids have been reported. These steroids may play a role in obesity-related hypertension, since higher doses of exogenous steroids have been shown to cause hypertension. Given the physiological diversity in obesity-related and non-obesity-related hypertension, the difference in persistence of high DBP levels seen in these children may indeed be related to differing mechanisms of increased blood pressure. White children with persistent high DBP levels thus become another subgroup to explore for mechanisms contributing to tracking.

Diagnosis of hypertension in children remains difficult and controversial. Blood pressure "tracks" to a moderate degree in childhood; however, predicting which children are likely to manifest hypertensive disease based on observations taken in pediatric populations is not entirely without error. The addition of leanness as a parameter accompanying clinical or laboratory data enhances the ability to identify children who are high DBP trackers. Information obtained from high risk groups could eventually contribute to prevention of hypertension.

Our findings warrant more intensive investigation. Further investigation could yield information pertaining to the etiological process of high blood pressure in children and, possibly, to different mechanisms of essential hypertension.

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