Blood Pressure, Fatness, and Fat Patterning
among USA Adolescents from Two Ethnic Groups

LORANN STALLONES, M.P.H., WILLIAM H. MUELLER, PH.D., AND BOBBE L. CHRISTENSEN, PH.D.

SUMMARY Many studies have explored the relationship between blood pressure and body size and composition in adults and preadults, but none has inquired into the relationship of blood pressure and the anatomical distribution of subcutaneous fat (fat patterning). Fat patterning has an association with chronic diseases (diabetes and cardiovascular disease) in adults. We sought the relationship between fatness, fat patterning, weight, and height among adolescents (12 to 17 years of age) of two ethnic groups (black and white) from the Health Examination Survey. Systolic blood pressure adjusted for age was related to body build variables in all sex/ethnic groups in decreasing order of importance as follows: body weight (independent of height), fatness (as assessed by a two skinfold index), and an excess of fat on trunk relative to fat on the leg (pattern index). Neither fatness nor fat patterning was significantly related to blood pressure after weight entered the regression equation. Relative fat patterning may be less important in predicting cardiovascular risk factors in adolescents than it is in adults. The fact that body weight was more important than fatness suggests that the weight/blood pressure association is due to components of body mass other than body fat.

(Hypertension 4:483-486, 1982)

KEY WORDS • adolescence • blood pressure • growth • fat patterning • weight

THE relationship of weight to blood pressure is well established in adults and preadults. Interest in blood pressure as an outcome is not only related to the importance of hypertension but also to the association between elevated blood pressure and cardiovascular diseases. Several studies have examined the relationship of chronic diseases and their risk factors, including atherosclerosis, coronary disease, and serum lipids to individual anatomical distribution of fat (fat patterning). Techniques for characterizing fat patterning have been developed that allow for examination of data available in youths that may relate to development of disease in later life. To our knowledge no one has examined the relationship between blood pressure and fat patterning in adolescents. This report utilizes techniques reported earlier to examine the relationship of fat patterning, fatness, and body size (height and weight) to levels of blood pressure in a sample from the United States Health Examination Survey (HES) Cycle III (12- to 17-year old adolescents).

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Materials and Methods

The HES examined 6768 persons who comprised a probability sample of the 12- to 17-year-old civilian noninstitutionalized population in 1966-1970. Details of the survey design have been presented. Because the focus of this project was on blood pressure and the potential confounding effects of the several variables, individuals who fell into any of the following categories were excluded prior to sample selection: those with significant cardiovascular findings, those with a history of rheumatic fever, those with significant heart murmurs, twins, and "other" races (neither white nor black). The original sample from the HES Cycle III tape was reduced to 6243 as a result of the exclusions (table 1). For the analysis that follows, a stratified random sample was taken of 20% of the total sample (after exclusions) so that there were approximately equal numbers in the four race-sex categories (white males, black males, white females, and black females). The results of the sampling technique are shown in table 1.

The variables used in the analysis include diastolic and systolic blood pressures, age, standing height in inches, weight in pounds, medial calf skinfold, and lateral chest skinfold. Three sets of blood pressure measurements were taken for each youth. The first two
were supine and the third, sitting. We chose to use the sitting blood pressure measurement as this seemed most comparable to methods of previous surveys. Blood pressures were measured with standard clinical mercury sphygmomanometers by two nurse examiners following guidelines of the American Heart Association.13 Readings were taken to the nearest 2 mm Hg. "Diastolic disappearance" was the criteria for diastolic blood pressure (DBP) measurement. Two cuff sizes were available (adult 13 cm and pediatric 9.5 cm). The choice of the appropriate cuff was based on its being at least 20% wider than the arm diameter of the youth or covering about two-thirds of the arm. Between the two nurse examiners observer variability in systolic blood pressure (SBP) was small, at 4 mm Hg difference in median values and 2 mm Hg for DBP.13 Skinfold thicknesses were measured with a Lange caliper. Several observers were used, and individuals were randomly assigned to an observer to avoid systematic errors between age and sex comparisons. Anthropometry quality control was carried out by periodic replicate measurements and field training sessions.16 Results of skinfold reliability have been published.16 Intra- and interobserver variance in skinfold measurement appears to account for from 5% to 12% of the intersubject variance in skinfold thickness depending on skinfold site, which is in agreement with data from other population-based surveys.17

Two indices were constructed, one representing subcutaneous fatness and a second representing the distribution or patterning of fat over the body. the second was concerned with individual differences in the relative distribution of fat on the trunk and the lower extremity, which is the aspect of anatomical patterning of fat most prevalent in human populations.13 The rationale and method used to develop the indices have been presented previously.14 The indices were constructed through use of principal components analysis and, therefore, are uncorrelated. The fatness index was derived by computing Z-scores (Z = (x-x/SD) ) for each individual for the two skinfolds (medial calf and lateral chest) and adding them together. The trunk-extremity fat patterning index was derived by using the same Z-scores but subtracting the medial calf from the lateral chest score. In the patterning index we were thus contrasting fat on one part of the body (trunk) with that on another (lower extremity). Race and sex-specific means were used to calculate the Z-scores for age groups combined. Age variability in these indices was then removed by forcing age on a first step in an analysis of regression of blood pressures on the body size variables.

Other variables initially examined in this analysis were income, size of town/city, and number of ciga-

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### Table 1. Distribution of the Original HES Sample, Sample Size After Occlusion, Sample of the Analysis

<table>
<thead>
<tr>
<th>Subjects</th>
<th>HES cycle III</th>
<th>Sample analyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>White males</td>
<td>3047</td>
<td>299</td>
</tr>
<tr>
<td>Black males</td>
<td>479</td>
<td>315</td>
</tr>
<tr>
<td>White females</td>
<td>2688</td>
<td>306</td>
</tr>
<tr>
<td>Black females</td>
<td>520</td>
<td>298</td>
</tr>
<tr>
<td>Total</td>
<td>6734</td>
<td>1218</td>
</tr>
<tr>
<td>Other males</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Other females</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6768</td>
<td></td>
</tr>
</tbody>
</table>

---

### Table 2. Correlation Matrices: Black Youths Above, White Youths Below

<table>
<thead>
<tr>
<th></th>
<th>SBP</th>
<th>Fatness index (T + E)</th>
<th>Patterning index (T - E)</th>
<th>Standing height</th>
<th>Weight (lbs)</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBP</td>
<td>0.36</td>
<td>0.18</td>
<td>0.44</td>
<td>0.60</td>
<td>0.38</td>
<td></td>
</tr>
<tr>
<td>Fatness index (T + E)</td>
<td>0.23</td>
<td>0.00</td>
<td>0.16</td>
<td>0.58</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Pattern index (T - E)</td>
<td>0.19</td>
<td>0.00</td>
<td>0.17</td>
<td>0.26</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>Standing height</td>
<td>0.48</td>
<td>0.07</td>
<td>0.16</td>
<td>0.80</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>0.56</td>
<td>0.53</td>
<td>0.24</td>
<td>0.80</td>
<td>0.62</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.40</td>
<td>0.02</td>
<td>0.15</td>
<td>0.69</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBP</td>
<td>0.40</td>
<td>0.07</td>
<td>0.23</td>
<td>0.47</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>Fatness index (T + E)</td>
<td>0.33</td>
<td>0.00</td>
<td>0.16</td>
<td>0.76</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>Pattern index (T - E)</td>
<td>0.09</td>
<td>0.00</td>
<td>0.05</td>
<td>0.08</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Standing height</td>
<td>0.12</td>
<td>0.18</td>
<td>-0.07</td>
<td>0.54</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>0.39</td>
<td>0.76</td>
<td>0.02</td>
<td>0.60</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.07</td>
<td>0.21</td>
<td>-0.05</td>
<td>0.36</td>
<td>0.41</td>
<td></td>
</tr>
</tbody>
</table>

**SBP** = systolic blood pressure; **T** = trunk skinfold (lateral chest wall); **E** = extremity skinfold (medial calf); both skinfolds transformed into standardized values (Z-scores) based on race and sex specific means and standard deviations.
Results

Correlations among the independent variables are shown in table 2. Of special concern are the correlations between age and weight (0.22–0.62), age and height (0.18–0.70), height and weight (0.54–0.80), and weight and the fatness index (0.53–0.76). The fat patterning index was uncorrelated with the fatness index, but among males the fat patterning index was correlated to weight (r = 0.24, 0.25) and age (r = 0.16, 0.37), and, therefore, a stepwise forward multiple regression of SBP on the independent variables was done. In this analysis, age was forced on the first step as an important moderating variable; fatness and the fat patterning indices were entered by the investigators on a second step, and both height and weight on the last step. Results of this analysis are given in table 3.

Age is significantly associated with SBP only in males, accounting for from 14% to 16% of SBP variation. The fatness index is positively associated with SBP in both race and sex groups (p < 0.01). An excess of fat on the trunk relative to fat on the leg (fat patterning index) is associated with increasing levels of SBP in all groups, but significantly so (p < 0.01) only among white males. Fatness together with fat patterning independent of age, account for from 7% to 17% of the variation in SBP in these adolescents. What is notable in table 3 is that weight, independent of age, fatness, fat patterning, or height, accounts for most of the variation in SBP. The R²’s after the third step, in which weight and height are entered, are: white males 0.33, black males 0.36, white females 0.19, and black females 0.23. When we forced weight and height on the second step, after age, neither fatness nor fat patterning entered as significant variables on the third step. In this second analysis, the R²’s after the second step were trivially different from those given above.

Discussion

There is great difficulty in partitioning the contribution of independent variables that are highly correlated with each other. For this reason the analysis was done separately for the variables that appeared to be contributing the most to the explanation of variance of blood pressure. The positive body weight/blood pressure association among these adolescents is expected from work done by others.22-24 There are some studies that differ in that chronological age is the most important variable related to blood pressure, but for the most part these studies include a wider age range than the study just reported.19 Among HES adolescents, the correlation between age and SBP is greater in males than in females (table 2), which is not surprising since males continue to grow up to 17 years of age while many females have ceased their growth by 15 years of age. Using the total sample of white males available in the HES Cycle III, Grose21 found that chronological age was the least useful predictor of blood pressure, while weight was the most useful. Further, that author21 included indices of physical maturation such as bone age
and appearance of secondary sex characteristics, which we did not include, and these contributed much less than weight alone. Our findings are in agreement with this work and extend results to the three other groups that we studied.

Weight is more significant in explaining variation in blood pressure than subcutaneous fatness. Skinfold thicknesses have been shown to correlate well with the percentage (total) of body fat. Thus, the weight/blood pressure relationship may be due to more than body fat, a conclusion also reached by Whyte studying the body size/blood pressure relationship in adults. Such things as skeletal mass, musculature, and body fluids may be important in blood pressure differences between individuals. Attempts should be made to partition body weight into the various components and determine which of them is the most significant contributor to blood pressure variability. Fat patterning was less significant than subcutaneous fatness or weight in predicting SBP variation in adolescents, but the direction of the fat pattern association — excessive fat on trunk relative to lower extremities — is in accord with the role of fat patterning in adult chronic disease. 7, 8, 22

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References

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