Studies of Blood Pressure in Hyperlipidemic School Children

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To assess determinants of blood pressure and racial differences in blood pressure in hyperlipidemic children, and to compare blood pressure in hyperlipidemic and random recall groups of children, studies were carried out on 513 school children (ages 6 through 19 years), and 309 adults (ages 20 through 64), recalled by virtue of elevated cholesterol or triglyceride levels in the Cincinnati Lipid Research Clinic's Princeton School prevalence study. For systolic and diastolic blood pressure in children, there were positive simple correlations with plasma triglyceride and inverse correlations with plasma high density lipoprotein cholesterol. Race did not enter the multiple regression equations as a significant explanatory variable for children's systolic or diastolic blood pressures, but was a significant variable for adults' blood pressures; blacks had higher blood pressures. Major explanatory variables for systolic blood pressure in children included weight, pulse, and age; 46% of the variance was explained. Major variables for diastolic blood pressure in children included age, pulse, and Quetelet index; 25% of the variance was explained. After covariance adjusting for Quetelet index, blood pressures within race did not differ between the hyperlipidemic and the random recall groups. Quetelet index was the covariable that related positively to blood pressure and plasma triglycerides, and negatively to high density lipoprotein cholesterol. Although relative ponderosity does not appear to be an independent coronary heart disease risk factor variable, its inverse relationship to high density lipoprotein cholesterol and positive association with triglyceride and blood pressure in school children should provide a basis for prudent, early, therapeutic approaches to overweight children and those with persistently elevated blood pressure.

(Arteriosclerosis 1981; 1:280–286)
Study Population

The Princeton School study population group has been previously described. At the first evaluation of school children and adults (Visit 1), basic demographic data were obtained along with measurements of fasting plasma cholesterol and triglyceride. No BP determinations were made. Approximately 6 weeks later, two subsets of the initial cohort were retested (Visit 2): a 15% random recall group (independent of lipid levels) and a hyperlipidemic recall group (approximately 10%, dependent on lipid levels). The collaborative LRC arbitrary cutpoints for recall of children to the hyperlipidemic recall group at Visit 2 were 205 mg/dl for plasma cholesterol (the 95th percentile), and 150 mg/dl for triglyceride (the 98th percentile). This report describes BP recordings in the hyperlipidemic recall group. The Visit 2 adult population involved random and hyperlipidemic recall groups independent of the recall for children; this report includes the hyperlipidemic recall group of adults.

At Visit 2, multiple BP measurements, a detailed medication history, data on alcohol consumption and cigarette smoking, and a history of family heart disease, stroke, and associated coronary heart disease risk factors were obtained. Plasma cholesterol, triglyceride, and high and low density lipoprotein cholesterol (C-HDL, C-LDL) were measured along with secondary clinical chemistry tests. A 24-hour dietary recall was also obtained for each subject.

Blood pressure recording techniques, lipid and lipoprotein quantitation, and anthropometric measurements at Visit 2 in this cohort have already been described in considerable detail. The number of cigarettes smoked per day was recorded at Visit 2 by an LRC-trained interviewer. Education and occupation of the head of the household were recorded as measures of socioeconomic status using coding tables of the collaborative LRC program. Both variables were ordinal and ranged from 1 to 7. For education, completing a graduate or professional degree was coded as "1," and completion of less than the 7th grade was coded "7." For occupation, interviewers obtained a job description, and coding was completed using an LRC modification of Hollingshead's code at a later time. The code "1" represented a higher executive, major professional, or proprietor of a large concern, while code "7" represented unskilled labor.

We have excluded from the final data set American Indians and Orientals, following the study design exclusionary criteria of the LRC's collaborative prevalence protocol. All subjects were fasting 12 or more hours; those fasting less were excluded from the final data set.

Methods

Statistical Methods

Blood pressures measured by the standard sphygmomanometer and the zero muddler (a device that introduced a variable amount of mercury to vary BP readings to avoid terminal digit preference) were compared by one-way analysis of variance. There were no significant (p > 0.5) differences between devices. For succinctness of presentation, we have limited tabular arrays, regressions, and covariance analyses to the BP measurements obtained with the zero muddler.

For the hyperlipidemic recall group, the distributions of triglyceride, C-HDL, and C-LDL were examined for normality because of the possibility of truncated distributions. A square root transformation was found to normalize the C-HDL distribution, and a log10 transformation normalized the triglyceride distribution. Transformation of the C-LDL distribution was not necessary. Analyses were performed using both transformed and untransformed C-HDL and triglyceride data. Moreover, nonparametric correlations were calculated. There were no substantive differences between the results of analyses using transformed data and those using untransformed data or nonparametric rank correlations; therefore, all results are reported using the untransformed data.

Summary statistics for systolic and diastolic BPs for children by recall group, age, sex, and race were calculated, and are presented by arbitrarily selected age groups in table 1. Comparisons of systolic and diastolic BPs between various subgroups were made utilizing multiple one-way analyses of variance. Additional BP subgroup comparisons were made using covariance analysis. Because BP, plasma C-LDL, and triglycerides are all associated positively with Quetelet index, covariance analysis was utilized to assess recall group, black-white and male-female BP differences, after adjustment for Quetelet index.

The relationships between systolic and diastolic BP and the various demographic, lipoprotein, and anthropometric variables measured at Visits 1 and 2 were assessed by simple and partial correlations (adjusting for Quetelet index and age). The quantitative relationships between systolic and diastolic BP (as dependent variables) and various demographic and anthropometric variables (as independent or explanatory variables) were assessed using multiple regression analyses. The t values presented for the regression coefficients of the explanatory variables reflect the outcome of tests of the hypotheses that the coefficients of regressions equal zero. The independent explanatory variables selected for the multiple regression analyses were obtained from a screening program in
which the multiple $R^2$s of the response variables (BPs) were calculated using different subsets of explanatory variables. $R^2$ is the proportion of variance that is accounted for by explanatory variables in a model. The equation with the highest $R^2$ was selected, and the input of additional explanatory variables to the equation was stopped when additional variables increased the $R^2$ less than 1%. The following demographic and anthropometric variables measured at Visits 1 and 2 were tested as explanatory variables: age, sex, race, height, weight, Quetelet index, resting pulse rate, triceps skinfold thickness, cigarette smoking history, and education of the head of the household. The analyses were carried out for each recall group and the two recall groups combined; in this last case, the "recall group" was entered in the regression equation as a class variable (random recall group = 0; hyperlipidemic recall group = 1).

**Results**

**Study Population**

At Visit 2, 86% of the eligible children (87% of eligible white and 85% of eligible black children) were studied; 88% of the eligible adults were studied, including 90% of eligible whites and 77% of eligible blacks. The final data set for this report on the hyperlipidemic recall group comprised 513 children (ages 6 through 19 years), including 156 white males, 189 white females, 74 black males, and 94 black females. For adults, ages 20 through 64 years, the final data set comprised 305 subjects, with 115 white males, 136 white females, 22 black males, and 32 black females. The BP data from our previous report on the Princeton School study of 682 random recall children are also summarized in this paper for comparison with the hyperlipidemic recall group.

**Blood Pressure Levels In Hyperlipidemic and Random Recall Children**

Table 1 summarizes unadjusted mean and standard deviation (SD) levels for systolic and diastolic BPs by age, sex, and race groups for 513 children in the hyperlipidemic recall group. For comparison, the previously published data for 682 children in the random recall group are also displayed. No consistent pattern of differences in systolic and/or diastolic BPs between white and black children was observed in the hyperlipidemic recall group. The only significant difference between blacks and whites in the hyperlipidemic recall group was for systolic BP, which was higher in white than in black males, ages 10 through 14 years ($p < 0.05$). In both recall groups, a consistent increase in mean systolic and diastolic BP with increasing age was seen. Differences in BP between age groups were significant for all sex-, race-, and recall-specific groups.

Because the Quetelet index is positively associated with both BP and cholesterol, triglyceride, and C-LDL levels, covariance adjustment for Quetelet index (weight/height$^2$) was done to

### Table 1. Systolic and Diastolic Blood Pressures of Children by Recall Group, Age, Sex, and Race

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>White males</th>
<th>Black males</th>
<th>White females</th>
<th>Black females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>X</td>
<td>SD</td>
<td>n</td>
</tr>
<tr>
<td>Hyperlipidemic recall group, systolic blood pressure:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-9</td>
<td>44</td>
<td>96.1</td>
<td>11.73</td>
<td>26</td>
</tr>
<tr>
<td>10-14</td>
<td>74</td>
<td>104.9</td>
<td>12.20</td>
<td>29</td>
</tr>
<tr>
<td>15-19</td>
<td>38</td>
<td>116.8</td>
<td>13.26</td>
<td>19</td>
</tr>
<tr>
<td>Random recall group, systolic blood pressure:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-9</td>
<td>68</td>
<td>91.4</td>
<td>11.7</td>
<td>24</td>
</tr>
<tr>
<td>10-14</td>
<td>128</td>
<td>100.3</td>
<td>12.6</td>
<td>35</td>
</tr>
<tr>
<td>15-19</td>
<td>72</td>
<td>112.2</td>
<td>12.2</td>
<td>26</td>
</tr>
<tr>
<td>Hyperlipidemic recall group, diastolic blood pressure:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-9</td>
<td>44</td>
<td>58.1</td>
<td>13.02</td>
<td>26</td>
</tr>
<tr>
<td>10-14</td>
<td>74</td>
<td>62.6</td>
<td>10.96</td>
<td>29</td>
</tr>
<tr>
<td>15-19</td>
<td>38</td>
<td>69.4</td>
<td>12.97</td>
<td>19</td>
</tr>
<tr>
<td>Random recall, diastolic blood pressure:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-9</td>
<td>68</td>
<td>53.6</td>
<td>12.5</td>
<td>24</td>
</tr>
<tr>
<td>10-14</td>
<td>128</td>
<td>60.8</td>
<td>11.6</td>
<td>35</td>
</tr>
<tr>
<td>15-19</td>
<td>72</td>
<td>69.1</td>
<td>11.4</td>
<td>26</td>
</tr>
</tbody>
</table>
allow a more meaningful comparison of BPs between the random and hyperlipidemic recall group. Overall, the mean Quetelet index was 6% higher in the hyperlipidemic recall group as compared to the random recall group of children, $p < 0.0001$. After covariance adjustment for Quetelet index, there were no statistically significant differences in BP observed between recall groups within age-, sex-, and race-specific strata. However, in the hyperlipidemic recall group, after combining age groups, the covariance adjusted mean systolic BP in white male children was higher than in black male children, $p = 0.02$.

**Associations Between Blood Pressure and Demographic and Anthropometric Variables**

Simple correlation coefficients between systolic and diastolic BP and the various demographic and anthropometric variables and lipiddlipoprotein levels are summarized in table 2 for 508 hyperlipidemic recall group children and 681 random recall children who reported fasting 12 hours. In both recall groups, systolic BP was positively associated with age, age$^2$, height, weight, Quetelet index, skinfold thickness, triglycerides, and cigarette smoking. Systolic BP was inversely associated with C-HDL in both recall groups. In the hyperlipidemic recall group, systolic BP was positively correlated with sex, being higher in males. Comparing the correlation coefficients for the random and hyperlipidemic recall groups for systolic BP, we found the following correlations were significantly ($p \leq 0.05$) higher in the hyperlipidemic recall group: age, age$^2$, sex, weight, Quetelet index, and C-HDL.

Diastolic BP was positively correlated with age, age$^2$, height, weight, Quetelet index, skinfold thickness, plasma triglyceride, and smoking, and negatively correlated with C-HDL in both recall groups (table 2). Further, diastolic BP was positively correlated with pulse in the hyperlipidemic recall group, but not in the random recall group.

Because Quetelet index was strongly and positively correlated with systolic and diastolic BP and with nearly all the other variables assessed, partial correlation coefficients between BP and the other variables were calculated, after adjustment for Quetelet index and age (table 3). The partial correlation coefficients are summarized for the 494 hyperlipidemic recall group children and 661 random recall group children having no missing values for the anthropometric and demographic variables assessed.

In both recall groups, pulse was positively correlated with both systolic and diastolic BPs. In the hyperlipidemic recall group, systolic BP was positively correlated with sex, being higher in males. In the random recall group, both systolic and diastolic BPs were correlated with skinfold thickness, and systolic BP was positively associated with triglyceride.

The quantitative relationships between systolic and diastolic BPs as dependent variables, and demographic and anthropometric variables as independent or explanatory variables, were assessed using multiple regression analysis. For the children from the hyperlipidemic recall group, systolic BP was significantly associated with pulse, weight, age, and sex (table 4). A similar pattern of partial regression coefficients was observed for the random recall group. Of the vari-

### Table 2. Simple Correlations: Blood Pressure with Demographic and Anthropometric Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Systolic blood pressure</th>
<th>Diastolic blood pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Random recall</td>
<td>Hyperlipidemic</td>
</tr>
<tr>
<td>No. subjects</td>
<td>681</td>
<td>508</td>
</tr>
<tr>
<td>Age</td>
<td>0.467§</td>
<td>0.557‡</td>
</tr>
<tr>
<td>Age$^2$</td>
<td>0.463‡§</td>
<td>0.559‡</td>
</tr>
<tr>
<td>Sex</td>
<td>-0.025</td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td>-0.027</td>
<td>0.074</td>
</tr>
<tr>
<td>Education, head of household</td>
<td>0.068</td>
<td>-0.020</td>
</tr>
<tr>
<td>Pulse</td>
<td>0.039</td>
<td>0.067</td>
</tr>
<tr>
<td>Height</td>
<td>0.484‡</td>
<td>0.562‡</td>
</tr>
<tr>
<td>Weight</td>
<td>0.503‡§</td>
<td>0.646‡</td>
</tr>
<tr>
<td>Quetelet index</td>
<td>0.374†</td>
<td></td>
</tr>
<tr>
<td>Skinfold thickness</td>
<td>0.298‡</td>
<td>0.356‡</td>
</tr>
<tr>
<td>HDL cholesterol</td>
<td>-0.096§§</td>
<td>-0.220‡</td>
</tr>
<tr>
<td>LDL cholesterol</td>
<td>0.057</td>
<td>-0.017</td>
</tr>
<tr>
<td>Triglyceride</td>
<td>0.218‡</td>
<td>0.236‡</td>
</tr>
<tr>
<td>Smoking</td>
<td>0.128‡</td>
<td>0.163‡</td>
</tr>
</tbody>
</table>

* $p < 0.05$; $t p < 0.01$; §$p < 0.001$; correlation coefficients significantly different from zero.

|$p < 0.05$; ||$p < 0.01$; ¶$p < 0.001$; correlation coefficients significantly different from each other.
Table 3. Partial Correlation Coefficients: Blood Pressure with Demographic and Anthropometric Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Systolic blood pressure</th>
<th>Diastolic blood pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Random recall</td>
<td>Hyperlipidemic</td>
</tr>
<tr>
<td>No. subjects</td>
<td>661</td>
<td>494</td>
</tr>
<tr>
<td>Sex</td>
<td>-0.026</td>
<td>0.129†</td>
</tr>
<tr>
<td>Race</td>
<td>-0.044</td>
<td>0.055</td>
</tr>
<tr>
<td>Pulse</td>
<td>0.124‡</td>
<td>0.166‡</td>
</tr>
<tr>
<td>Education, head of household</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skinfold thickness</td>
<td>0.016</td>
<td>-0.044</td>
</tr>
<tr>
<td>HDL cholesterol</td>
<td>-0.003</td>
<td>-0.028</td>
</tr>
<tr>
<td>LDL cholesterol</td>
<td>0.044</td>
<td>0.02</td>
</tr>
<tr>
<td>Triglyceride</td>
<td>0.085†</td>
<td>0.077</td>
</tr>
<tr>
<td>Smoking</td>
<td>0.014</td>
<td>0.023</td>
</tr>
</tbody>
</table>

*p < 0.05; †p < 0.01; ‡p < 0.001.

ance in systolic BP in children, 46% for the hyperlipidemic recall group and 29% for the random recall group were accounted for by the explanatory variables included in the regression equation (table 4). Race was not a significant explanatory variable of children's systolic BP in either recall group.

For children from the hyperlipidemic recall group, diastolic BP was significantly associated with age, pulse, and Quetelet index. A similar pattern of partial regression coefficients was observed for the random recall group. Of the variance in diastolic BP in children, 25% for the hyperlipidemic recall group and 22% for the random recall group could be accounted for by the explanatory variables. Race was not a significant explanatory variable for diastolic BP in either recall group.

When the random and hyperlipidemic recall groups were combined, and the quantitative relationships between systolic and diastolic BP and various demographic and anthropometric variables were assessed by multiple regression analysis, with "reason for recall" entered as a class variable among the explanatory variables, the reason for recall was not among the significant explanatory variables for systolic (F = 0.0, p = 0.95) or diastolic BP (F = 1.26, p = 0.26).

Table 4. Multiple Regression Analysis, Blood Pressure, and Explanatory Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Random recall (n = 679)</th>
<th>Hyperlipidemic recall (n = 508)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regression Coefficient</td>
<td>t</td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>p</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td>-1.416</td>
<td>1.04</td>
</tr>
<tr>
<td>Sex</td>
<td>0.0208</td>
<td>0.006</td>
</tr>
<tr>
<td>Weight</td>
<td>0.0107</td>
<td>0.005</td>
</tr>
<tr>
<td>Pulse</td>
<td>0.5443</td>
<td>0.141</td>
</tr>
<tr>
<td>Age</td>
<td>0.5036</td>
<td>0.294</td>
</tr>
<tr>
<td>Height</td>
<td>0.0121</td>
<td>0.006</td>
</tr>
<tr>
<td>Intercept</td>
<td>56.52</td>
<td>6.98</td>
</tr>
<tr>
<td>Multiple R^2 = 0.289</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td>0.6505</td>
<td>1.08</td>
</tr>
<tr>
<td>Age</td>
<td>0.8708</td>
<td>0.307</td>
</tr>
<tr>
<td>Pulse</td>
<td>0.4737</td>
<td>0.148</td>
</tr>
<tr>
<td>Weight</td>
<td>0.0139</td>
<td>0.006</td>
</tr>
<tr>
<td>Skinfold</td>
<td>0.0096</td>
<td>0.005</td>
</tr>
<tr>
<td>Height</td>
<td>0.0058</td>
<td>0.006</td>
</tr>
<tr>
<td>Quetelet index</td>
<td>7.29</td>
<td>2.39</td>
</tr>
<tr>
<td>Intercept</td>
<td>20.00</td>
<td>4.43</td>
</tr>
<tr>
<td>Multiple R^2 = 0.215</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.05; †p < 0.01; ‡p < 0.001.
Discussion

This study allowed a comparison of BPs in the random and hyperlipidemic recall groups, a comparison of BPs of blacks vs whites in the hyperlipidemic recall group, and an assessment of BP determinants in both random and hyperlipidemic recall groups. After covariance adjusting for Quetelet index within race and age groups in both children and adults, BPs did not differ between hyperlipidemic and random recall groups.

Similar to the randomly recalled school children, there were no uniform black-white differences in either systolic or diastolic BPs, although covariance-adjusted systolic BP was slightly higher in white than in black male children from the hyperlipidemic recall group. Race did not enter the multiple regression equation as a significant explanatory variable for children's systolic or diastolic BP. However, race was a significant explanatory variable for both systolic (F = 15.4, p < 0.0001) and diastolic (F = 11.1, p < 0.0009) BP when random and hyperlipidemic adult recall groups were combined. Since environment, geography, and race have considerable direct and interactive effects on BP, the finding of pediatric black-white BP differences in Bogalusa, but not in Dayton, Ohio, the Princeton School study, or Bourbon County, Kentucky, may reflect in part the differing environments and their effects on BP.

In school children from a truncated (hyperlipidemic) portion of the cholesterol-triglyceride distribution, associations of various demographic and anthropometric determinants with BP were generally similar to those observed in children randomly recalled from the same school district. As was the case in randomly recalled children, the major explanatory variables for systolic BP included weight, pulse, and age. In the hyperlipidemic recall group of children, 46% of the variance of systolic BP was explained as compared to 29% in the randomly recalled children. This was presumably related to the marked contribution of weight to the regression matrix in the hyperlipidemic recall group. Major explanatory variables for diastolic BP in the hyperlipidemic recall group of children included age, pulse, and Quetelet index, similar to those in randomly recalled children (age, pulse, weight, and skinfold thickness).

The previously observed relationships between BP and lipoproteins in randomly selected children (i.e., positive simple correlations of BP with triglycerides, inverse correlations with C-HDL), were also found in the children from the hyperlipidemic recall group. The negative association of C-HDL with both systolic and diastolic BPs was twice as strong for the hyperlipidemic as for the random recall group of children. The covariables of age and relative obesity related positively to BP and to plasma triglycerides, and negatively to C-HDL levels in children. When the relationships between plasma C-HDL, plasma triglycerides, and BP were reexamined after adjusting for age and Quetelet index, only weak positive triglyceride-BP partial correlation coefficients remained (systolic BP, random recall group only), while the inverse C-HDL-BP relationships were not significant. Although obesity is not a strong independent coronary heart disease risk variable, its inverse relationship to C-HDL and positive association with triglyceride and BP in school children should provide a basis for a prudent early therapeutic approach to overweight children, and to those with persistently elevated BP.

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