Cardiovascular Disease Risk Factor Variables at the Preschool Age

The Bogalusa Heart Study

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SUMMARY As part of a study to describe the early natural history of atherosclerosis, 714 children, 2½ to 5½ years of age, were examined. Height, weight, triceps skinfold, blood pressure, serum lipids and lipoproteins, and a complete physical examination were obtained on each child. Black children were both taller and heavier than white children, but triceps skinfolds were greater for whites. Mean blood pressure readings obtained on each of three instruments showed different levels of blood pressure. The Infrasonde gave the lowest readings while the Baumanometer gave the highest, and an age gradient was observed only for the Infrasonde. Multiple regression analysis indicated that 12% to 22% of the variability of blood pressure could be explained by selected independent variables. Serum levels of total cholesterol, β-lipoproteins and α-lipoproteins were slightly higher in black boys than white boys. The reverse was true for triglycerides and pre-β-lipoproteins. For triglycerides, significant racial and sex effects and a relationship with weight relative to height (W/H²) were noted. Age and W/H² were positively associated with pre-β-lipoproteins. When the preschool-aged children are compared to our previously studied school-aged population, the magnitude of the interaction of the risk factor variables tends to increase with age, suggesting that environmental factors tend to exert an increasing effect.

CURRENT OBSERVATIONS INDICATE that coronary artery disease and hypertension originate during early childhood. Although clinical symptoms may not appear until late adulthood, evidence of cardiovascular disease may already be present during the first and second decades of life. Of primary concern is the need to understand the early natural history of arteriosclerosis (this term is used for subject matter related to both atherosclerosis and hypertension) so that preventive measures can be instituted early in life. It is clear, however, that before efforts for primary prevention can be formulated for pediatric populations, adult risk factors for arteriosclerosis disease such as blood pressure, blood lipids, and obesity must be characterized in children.

The Bogalusa Heart Study was initiated in Bogalusa, Louisiana, in order to describe the distributions, interrelationships, and time course of arteriosclerosis risk factor variables from birth through 14 years of age. Previous reports have described findings on school-aged children, 5–14 years. This paper will focus on the preschool-aged population, 2½–5½ years.

Materials and Methods

Population

All children born in 1969–1971 in Bogalusa, Louisiana (Ward 4 of Washington Parish), were eligible to participate in the study. Of 898 eligible children, 714 (80%) participated. Of the total examined, 32% were black and 68% white. The parents were instructed not to give their child breakfast or fluids (except water) on the morning of the examination.

Collection of Blood Specimens

Blood was drawn for both serum lipids and hemoglobin. Antecubital venous blood was collected in vacutainer tubes. Serum was obtained by allowing blood to clot; the samples were transferred to tubes containing thimerosal (Aldrich Chemical Co.) and sent in a cold-packed box by bus to the New Orleans Core Lipid Laboratory of the SCOR-A. An additional aliquot of blood was randomly collected each day from four children and processed from collection to data analysis in a blind manner. Blood samples could not be obtained from 2.8% of the children, and 5.6% of the children were reported nonfasting.

Examination of Children

The details of the various aspects of the examination have been described earlier. Briefly, each child was given a complete physical examination. Anthropometric measurements were included, consisting of height, weight, upper-arm length (acromion-olecranon), upper-arm circumference (mid-point), and triceps skinfold. Weight was measured to the nearest 0.1 kg while the other measurements were made to the nearest millimeter.

At the end of the examination, the children's blood pressures were measured according to a written protocol in random order at three separate stations. A different instrument was used at each station — the mercury sphygmomanometer (Baumanometer), the Infrasonde 3000 and the Arteriosonde 1010. For each instrument, the size of the cuff bladder was selected as large as feasible in order to avoid a small-cuff artifact. Since the transducers of the automatic instruments were not flush with the inner surface of the cuff bladder, a firm sponge rubber, the thickness of the transducer, was tapered and adapted to encircle the transducers to aid in reducing a potential artifact. The 1st, 4th, and 5th Korotkoff phases were recorded and three readings were made with each instrument, totaling nine measurements per child.

To save time, two teams were used, each team observing...
at three stations. Both examiners and the children were randomly allocated to a team and to the three stations within each team. The Infrasonde and Arteriosonde units were assigned randomly to the two teams each week. At the end of the examination each morning, a sample of four children of one sex was selected randomly for a second complete examination (except for venipuncture) to enable us to assess the measurement error of each variable.

**Dietary Studies**

A 24-hour dietary recall was obtained on 25 children with the mother serving as the respondent. The recall was intended to reflect a usual 24-hour eating period. The method for the recall employs graduated food models and was previously used for children 10-11 years of age. The eating times during the day and salting habits were also assessed.

**Serum Lipid and Lipoprotein Analyses**

Serum cholesterol and triglycerides were determined simultaneously in a Technicon AutoAnalyzer II in the Core Laboratory of SCOR-A according to the protocol developed by Lipid Research Clinics in collaboration with the Center for Disease Control (CDC), Atlanta, Georgia. The Core Laboratory has been designated “Standardized” by the CDC and currently is in the surveillance phase of its quality control program.

The serum lipoprotein levels (β- , pre-β-, and α-) were measured by a combination of heparin-Ca²⁺ precipitation and agar-agarose gel electrophoresis methods. A detailed description of the lipoprotein method was reported elsewhere, including its application on 3,182 school-aged children. As in the previous study, direct determination of cholesterol in the β- and pre-β-lipoprotein fractions (obtained by heparin-Ca²⁺ precipitation) was related to the β + pre-β-lipoprotein index (turbidity measured at 600 nm) in 10% of the randomly assigned serum samples. The two variables correlated highly (r = 0.98) and a factor of 469 was obtained by constructing a regression line through the origin [β + pre-β-lipoprotein cholesterol = 469 × (β + pre-β-lipoprotein index)]. Measurement errors of the lipids and lipoproteins obtained on approximately 20% of the children are given in table 1. These values represent the errors associated with the collection, processing, and analysis of the blood samples as well as the processing and reporting of the data. Hemoglobin studies are reported elsewhere.

**Statistical Analyses**

Various statistical approaches were used in analysis of the data. An analysis of variance (least squares analysis) for a two-factor experiment was used in analyzing the anthropometric data and multiple regression analyses were employed in examining blood pressure and lipid data. Age (last birthday, years) was computed from date of birth and date of examination.

**Results**

**Anthropometric Studies**

Figure 1 and table 2 show the cross-sectional growth pattern of the preschool-aged children. The distribution of height is symmetrical within both races and sexes. An

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**TABLE 1. Blind Duplicate Analysis for Serum Lipids and Lipoproteins of Children**

<table>
<thead>
<tr>
<th>Serum variable</th>
<th>Number of pairs</th>
<th>Original (mg/dl)</th>
<th>Blind duplicate (mg/dl)</th>
<th>Mean difference (mg/dl)</th>
<th>Mean of absolute differences (mg/dl)</th>
<th>Standard deviation (mg/dl)</th>
<th>Coefficient of variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cholesterol</td>
<td>141</td>
<td>155.6</td>
<td>157.1</td>
<td>-1.5</td>
<td>6.3</td>
<td>7.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Triglycerides*</td>
<td>130</td>
<td>64.0</td>
<td>64.7</td>
<td>-0.7</td>
<td>5.2</td>
<td>5.5</td>
<td>8.6</td>
</tr>
<tr>
<td>β-lipoprotein*</td>
<td>130</td>
<td>190.0</td>
<td>192.2</td>
<td>-2.2</td>
<td>10.3</td>
<td>13.5</td>
<td>7.1</td>
</tr>
<tr>
<td>Pre-β-lipoprotein*</td>
<td>130</td>
<td>28.7</td>
<td>28.9</td>
<td>-1.2</td>
<td>3.9</td>
<td>3.7</td>
<td>12.7</td>
</tr>
<tr>
<td>α-lipoprotein*</td>
<td>130</td>
<td>355.5</td>
<td>353.6</td>
<td>-0.1</td>
<td>40.3</td>
<td>40.1</td>
<td>12.2</td>
</tr>
</tbody>
</table>

*Fasting children only.

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**Figure 1.** Height, weight, and triceps skinfold measurements of preschool-aged children. Median, 10th, and 90th percentile values are shown according to age, race, and sex of the children.
asymmetrical weight distribution is noted, however, for black children with variability increasing with age. In boys, the median heights and weights between blacks and whites differed slightly while black girls were generally taller and heavier than white girls (fig. 1). Among all children, blacks averaged 2.0 cm taller ($P < 0.005$) and 0.6 kg heavier ($P < 0.01$) than their white age peers.

Skewness and variability in the weight distribution may simply reflect developmental differences in growth for children of the same chronological age. Therefore, we investigated the distribution of weight for children of the same height (fig. 2). The children showed an increase in the variability of weight with increases of height as well as of age. Additionally, skewness is noticeable in this distribution for black girls indicating a disproportionate amount of weight for a given height among some black children. Since the relationship between weight and height is not independent, we employed the ponderosity index of weight divided by the cubed height ($W/H^3$), which is independent of height on theoretic and morphologic grounds. This index was found to be negatively correlated with height ($P < 0.001$) for this age group with correlations ranging from $-0.47$ for black girls to $-0.63$ for white boys. Based on this index, ponderosity decreased with increasing height consistent with a decrease in chubbiness from infancy.

Plots of selected percentiles for $W/H^3$ against height showed no separate group of children whose weight was clearly disproportionate to their height. Boys were more ponderous than girls of the same height. The use of another W/H index ($W/H^3$), calculated specifically for this population and used in a different context, is discussed below.

In the distribution of the triceps skinfold thickness (fig. 1) only black preschool children displayed the skewness usually present for older children and adults. Skinfolds of preschool children tended to decrease with increasing age, except for white girls. The sex and race differences in triceps skinfold data, exhibited by older children and adults, are seen to begin in early childhood. White children of each sex had a greater mean triceps skinfold thickness than did the black children (d = 1.2 mm, $P < 0.0005$), and girls had greater skinfolds than boys (d = 1.4 mm, $P < 0.0005$).

A racial difference was also evident in the distribution of the right upper-arm length and circumference of preschool children (unpublished observations). Black children had arm lengths which averaged 0.8 cm greater ($P < 0.0005$) than those of white children but their arm circumferences were smaller by 0.2 cm. Skewness in arm circumference data and the relative symmetry of arm length data reflect the skewness in the triceps skinfold.

**Comment.** Anthropometric data most clearly describe the status of physical development within pediatric populations and serve as a background for studying other risk factor variables. Observations in this age group may relate to certain racial differences in risk factor variables noted in older children. Owen and Lubin reviewed current anthropometric data and concluded that while black infants were smaller with respect to lengths and weights at birth, by 24 months they surpassed white children in these mea-

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**Table 2. Number of Children, Mean, and Standard Deviation for Height and Weight of Children**

<table>
<thead>
<tr>
<th>Mean age at last birthday</th>
<th>White boys</th>
<th>White girls</th>
<th>Black boys</th>
<th>Black girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>$\bar{x}$ ± $\sigma$</td>
<td>$\bar{x}$ ± $\sigma$</td>
<td>$\bar{x}$ ± $\sigma$</td>
</tr>
<tr>
<td></td>
<td>(cm)</td>
<td>(cm)</td>
<td>(cm)</td>
<td>(cm)</td>
</tr>
<tr>
<td>2.75</td>
<td>37</td>
<td>93.9 ± 3.1</td>
<td>33</td>
<td>90.9 ± 4.7</td>
</tr>
<tr>
<td>3.50</td>
<td>80</td>
<td>98.7 ± 4.7</td>
<td>78</td>
<td>97.3 ± 4.4</td>
</tr>
<tr>
<td>4.50</td>
<td>89</td>
<td>105.2 ± 4.8</td>
<td>86</td>
<td>105.1 ± 4.3</td>
</tr>
<tr>
<td>5.25</td>
<td>41</td>
<td>111.3 ± 4.8</td>
<td>42</td>
<td>110.2 ± 4.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mean age at last birthday</th>
<th>White boys</th>
<th>White girls</th>
<th>Black boys</th>
<th>Black girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>$\bar{x}$ ± $\sigma$</td>
<td>$\bar{x}$ ± $\sigma$</td>
<td>$\bar{x}$ ± $\sigma$</td>
</tr>
<tr>
<td></td>
<td>(kg)</td>
<td>(kg)</td>
<td>(kg)</td>
<td>(kg)</td>
</tr>
<tr>
<td>2.75</td>
<td>37</td>
<td>14.1 ± 1.5</td>
<td>32</td>
<td>13.1 ± 1.9</td>
</tr>
<tr>
<td>3.50</td>
<td>80</td>
<td>15.5 ± 2.6</td>
<td>77</td>
<td>15.0 ± 1.8</td>
</tr>
<tr>
<td>4.50</td>
<td>88</td>
<td>16.9 ± 2.1</td>
<td>86</td>
<td>16.8 ± 2.0</td>
</tr>
<tr>
<td>5.25</td>
<td>41</td>
<td>19.1 ± 2.8</td>
<td>42</td>
<td>19.2 ± 4.6</td>
</tr>
</tbody>
</table>

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**Figure 2.** Weight per height interval for the preschool-aged children at selected percentiles according to sex and race of the children.
measurements. Previous studies\textsuperscript{15} have shown that through adolescence, black school-aged children are generally taller, heavier, and have less subcutaneous fat than white children of the same age, even when matched on socioeconomic status. However, only a few studies have supplied information about the preschool growth period. No subset of the preschool children could be clearly characterized as having a weight in excess of their height as judged by the ponderosity index (W/H\textsuperscript{2}). In contrast, among Bogalusa children 5-14 years of age, measures of ponderosity indicated the existence of a group of children gaining weight disproportionately to their height.\textsuperscript{3} This emergence of a more ponderous subset among school children likely reflects the influence of environmental factors and eating patterns.

Another measure of obesity, the triceps skinfold thickness, increased with age in the preschool group only for the white girls, while boys lost arm subcutaneous fat. A similar loss of fat by young boys was reported in the Ten-State Nutrition Survey (TSNS)\textsuperscript{16} and was also observed in the Health and Nutrition Examination Survey (HANES).\textsuperscript{17}

In general, the mean heights of Bogalusa children were greater than those of the TSNS but were similar to those observed in the Preschool Nutrition Survey (PNS)\textsuperscript{18} and the HANES. Similar mean weights of girls were found in the three studies, but Bogalusa boys were lightest after age 3. The obvious racial difference in triceps skinfold thickness at this early age without corresponding racial difference in obesity clearly suggests the hereditary origin of differences in triceps skinfold thickness.

Blood Pressure Studies

We used three different instruments to observe their individual attributes for measuring blood pressure. Thirty-eight of the 714 children were excluded from the blood pressure analyses since their values were measured using different instruments as part of the previously reported study of school children.\textsuperscript{4} Table 3 shows mean (± sd) blood pressures by age for the three instruments for the children. An age gradient was observed only for the systolic pressures on the Infrasonde with considerable difference in levels noted for each instrument. The mean readings in blood pressure levels differed significantly between each pair of instruments (\(P < 0.001\), F-test), both for systolic and for diastolic pressures. A comparison of blood pressure percentiles between children aged 2½-5½ and those aged 5-14 is given in figure 3 for two types of instruments: a) mercury sphygmomanometer (Baumanometer), and b) two other instruments which use a low frequency transducer (the Physiometrics automatic recorder, which was used for the school-aged children and was not considered feasible for this age group, and the Infrasonde, a nonrecording instrument). The observations with the mercury sphygmomanometer showed a systolic leveling off beginning at age 9 and a diastolic

![Figure 3](http://circ.ahajournals.org/)

**Figure 3.** Indirect blood pressure measurements on preschool-aged and school-aged children recorded by mercury sphygmomanometer and by instruments using a low frequency transducer (Physiometric and Infrasonde) at various intervals. Selected percentiles are shown.
U-shaped curve, with levels relatively high at ages below 7 years. On all instruments, the diastolic blood pressure variability increased with younger children. On the other hand, observations with the infrasonic units suggested linear increases occur with age for both systolic and diastolic pressures. For this reason data from the Infrasone were used in the subsequent analyses.

In order to find determinants of blood pressure levels in this study population, all parameters measured on the children were entered as independent variables into a multiple regression analysis in which blood pressure level was the dependent variable. This was done separately for systolic and diastolic pressures on the Infrasone data. The results of the blood pressure regression analysis are presented in table 4. The mood score had a universal effect with a magnitude of 1.0–2.0 mm Hg per scoring unit. Some measure of body size was the second most consistent determinant of blood pressure. There was no association with age or serum lipids. The diastolic Infrasone pressure readings were somewhat affected by the individual examiners. The results are comparable to those from the same geographic population for school-aged children, especially with respect to internal consistency of the findings. An exception is the apparent greater relationship to mood.

**Table 4. Stepwise Multiple Linear Regression for Blood Pressure as Measured by the Infrasone Instrument and Selected Variables in Children**

<table>
<thead>
<tr>
<th>Independent variables entered</th>
<th>Systolic (mm Hg)</th>
<th>Diastolic (fourth phase - mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic</td>
<td>Source</td>
<td>Regression coefficient</td>
</tr>
<tr>
<td>Age</td>
<td>Years</td>
<td>Mean 40.14</td>
</tr>
<tr>
<td>White = 1, Black = 2</td>
<td></td>
<td>4.14</td>
</tr>
<tr>
<td>Male = 1, Female = 2</td>
<td></td>
<td>1.84§</td>
</tr>
<tr>
<td>Anthropometric</td>
<td></td>
<td>Observer 4 -4.59§</td>
</tr>
<tr>
<td>Height cm</td>
<td></td>
<td>Observer 6 3.88§</td>
</tr>
<tr>
<td>Ponderosity† = Weight/Height³ kg/cm³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper-arm circumference† cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triceps skinfold thickness† mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mood</td>
<td>Score ranging from lethargic to crying 1-8</td>
<td></td>
</tr>
<tr>
<td>Laboratory</td>
<td>Total cholesterol† mg/dl</td>
<td>Mean -4.72</td>
</tr>
<tr>
<td>Triglycerides† mg/dl</td>
<td>Observer 2 -6.77§</td>
<td>-0.24</td>
</tr>
<tr>
<td>Pre-ß-lipoprotein† mg/dl</td>
<td>Observer 8 -4.76§</td>
<td>-0.18</td>
</tr>
<tr>
<td>ß-lipoprotein† mg/dl</td>
<td>Arm circumf. 42.92§</td>
<td>0.17</td>
</tr>
<tr>
<td>Pre-ß-lipoprotein/ß-lipoprotein† mg/dl</td>
<td>Mood 0.57§</td>
<td>0.15</td>
</tr>
<tr>
<td>Hemoglobin g/dl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood pressure observers No. 1-9 Yes = 1, No = 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*43 out of 676 children not analyzed due to missing data.
†Log,
‡P < 0.001,
§P < 0.0001.

Comment. Besides mood score, body size also correlates with blood pressure level in this preschool-aged population as it did for the school-aged children.

A gradual increase in basal or fundamental blood pressure level from birth to adulthood is more likely than a sudden increase after birth to levels that are equal to those of adolescents. Our observations with the mercury sphygmomanometer and the Arteriosonde are therefore inconsistent in this regard. Changes in the arterial sounds under the deflating cuff bladder seem to be optimally transmitted and detected in the low frequency region of the sound spectrum, a region that may not be audible to the human ear but is detectable by the Infrasone. These two considerations lead us to speculate that the Infrasone systolic readings, at least, may be closer to realistic values than the observations from the other instruments.

**Serum Lipid and Lipoprotein Studies**

**Table 5. Number of Children, Mean, and Standard Deviation for Serum Lipids of Children**

<table>
<thead>
<tr>
<th>Serum variable (mg/dl)</th>
<th>White boys N</th>
<th>White girls N</th>
<th>Black boys N</th>
<th>Black girls N</th>
<th>All children N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x ± sd</td>
<td>x ± sd</td>
<td>x ± sd</td>
<td>x ± sd</td>
<td>x ± sd</td>
</tr>
<tr>
<td>Total cholesterol</td>
<td>243 155 ± 24</td>
<td>231 158 ± 25</td>
<td>106 161 ± 26</td>
<td>114 158 ± 29</td>
<td>694 157 ± 25</td>
</tr>
<tr>
<td>Triglycerides*</td>
<td>229 169 ± 26</td>
<td>216 69 ± 26</td>
<td>101 57 ± 19</td>
<td>109 58 ± 22</td>
<td>655 63 ± 27</td>
</tr>
<tr>
<td>ß-lipoprotein*</td>
<td>229 189 ± 44</td>
<td>216 197 ± 41</td>
<td>101 199 ± 52</td>
<td>109 199 ± 53</td>
<td>655 195 ± 46</td>
</tr>
<tr>
<td>Pre-ß-lipoprotein*</td>
<td>229 28 ± 27</td>
<td>216 30 ± 27</td>
<td>101 25 ± 20</td>
<td>109 30 ± 25</td>
<td>655 29 ± 26</td>
</tr>
<tr>
<td>ß-lipoprotein*</td>
<td>229 356 ± 107</td>
<td>216 353 ± 114</td>
<td>101 369 ± 118</td>
<td>109 346 ± 121</td>
<td>655 355 ± 113</td>
</tr>
</tbody>
</table>

*Fasting children only.
†Sex differences significant at P <0.05 (F-test).
‡§Race differences significant at P <0.05, P <0.001 (F-test).
fasting in school-aged children. However, the values for triglycerides and lipoproteins are given only for children who were reported as fasting. Serum levels of total cholesterol, \( \beta \)-lipoproteins and \( \alpha \)-lipoproteins were slightly higher at all ages in black boys than in white boys. On the other hand, white boys showed slightly higher levels of triglycerides and pre-\( \beta \)-lipoproteins than black boys. Among girls, only triglycerides and \( \beta \)-lipoproteins showed such race-related trends; however, the observed differences due to race were statistically significant \( (P < 0.001) \) only with triglycerides. White girls had slightly higher levels of total cholesterol, triglyceride, \( \beta \)-lipoproteins and pre-\( \beta \)-lipoproteins and lower levels of \( \alpha \)-lipoproteins than white boys. Similar sex-related differences in lipid and lipoprotein levels were seen among black children only for triglycerides, pre-\( \beta \)-lipoproteins, and \( \alpha \)-lipoproteins. None of the above variables showed a statistically significant sex-related difference except triglycerides \( (P < 0.05) \).

Changes in Lipids and Lipoproteins with Age. Changes in serum lipid and lipoprotein levels (mg/dl, mean ± 2 SE) with age are shown in figures 4 and 5. In this age group, serum cholesterol for all children combined tended to increase slightly with age, especially after age 3 \( (155 ± 3.4 \text{ at age } 3 \text{ vs } 159 ± 4.5 \text{ at age } 5) \). Triglyceride levels were slightly higher at age 2 \( (67 ± 5.7) \) than at ages 3 through 5 \( \text{(range of } 61 ± 3.2 \text{ to } 64 ± 5.5 \text{) } \). Beta-lipoprotein decreased from a level of 203 ± 9.3 at age 2 to 194 ± 6.2 at age 3 and changed very little at age 5 \( (192 ± 8.4) \). The levels of pre-\( \beta \)-lipoproteins changed little between ages 2 and 4 \( (29 ± 5.0 \text{ vs } 27 ± 3.2) \); however, there was a definite increase at age 5 \( (34 ± 5.6) \). Alpha-lipoprotein levels also increased, especially between ages 3 and 5 \( (348 ± 14.5 \text{ vs } 363 ± 19.6) \). Regression analyses with age of serum lipids and lipoproteins indicated no significant increase in this 3-year age span except in \( \alpha \)-lipoproteins. However, regression analyses may not accurately depict age-related trends if any of these variables tend to decrease or increase abruptly at certain age intervals, which appears to happen around ages 2 and 3.

**Figure 4.** Serum cholesterol and triglyceride levels by age, race and sex of the preschool-aged children. As noted in older children, serum cholesterol levels tended to be higher in black children and triglycerides higher in white children.

**Figure 5.** Serum lipoprotein levels in preschool-aged children by age, race and sex.

**Normal Range (percentiles).** The statistical normal limits for serum lipids and lipoproteins in these preschool-aged children were estimated from their 5th, 50th (median) and 95th percentile values (table 6). At the 95th percentile level, white children had 6% lower total cholesterol, 19% higher triglycerides, 13% lower \( \beta \)-lipoproteins, 8% higher pre-\( \beta \)-lipoproteins, and 6% lower \( \alpha \)-lipoproteins than black children. Similar differences were seen at the 50th percentile.

**Table 6. Selected Percentile Levels for Serum Lipids and Lipoproteins of Children.**

<table>
<thead>
<tr>
<th>Serum variables</th>
<th>5th</th>
<th>50th</th>
<th>95th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cholesterol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All children</td>
<td>116</td>
<td>157</td>
<td>198</td>
</tr>
<tr>
<td>Whites</td>
<td>116</td>
<td>156</td>
<td>195</td>
</tr>
<tr>
<td>Blacks</td>
<td>114</td>
<td>159</td>
<td>207</td>
</tr>
<tr>
<td>Triglycerides*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All children</td>
<td>34</td>
<td>57</td>
<td>113</td>
</tr>
<tr>
<td>Whites</td>
<td>35</td>
<td>59</td>
<td>117</td>
</tr>
<tr>
<td>Blacks</td>
<td>29</td>
<td>54</td>
<td>98</td>
</tr>
<tr>
<td>( \beta )-lipoprotein*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All children</td>
<td>124 (58)†</td>
<td>192 (90)</td>
<td>276 (129)</td>
</tr>
<tr>
<td>Whites</td>
<td>126 (59)</td>
<td>190 (89)</td>
<td>265 (124)</td>
</tr>
<tr>
<td>Blacks</td>
<td>119 (56)</td>
<td>195 (91)</td>
<td>306 (144)</td>
</tr>
<tr>
<td>Pre-( \beta )-lipoprotein*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All children</td>
<td>4 (1)</td>
<td>20 (4)</td>
<td>79 (18)</td>
</tr>
<tr>
<td>Whites</td>
<td>4 (1)</td>
<td>20 (4)</td>
<td>82 (18)</td>
</tr>
<tr>
<td>Blacks</td>
<td>5 (1)</td>
<td>20 (4)</td>
<td>76 (17)</td>
</tr>
<tr>
<td>( \alpha )-lipoprotein*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All children</td>
<td>171 (29)</td>
<td>356 (60)</td>
<td>533 (90)</td>
</tr>
<tr>
<td>Whites</td>
<td>172 (29)</td>
<td>359 (61)</td>
<td>527 (89)</td>
</tr>
<tr>
<td>Blacks</td>
<td>163 (28)</td>
<td>347 (59)</td>
<td>562 (95)</td>
</tr>
</tbody>
</table>

*Fasting children only.
†Corresponding lipoprotein cholesterol values are given in parentheses.
levels with some exceptions (pre-β-lipoproteins and α-lipoproteins). The 5th percentile level of lipids and lipoproteins did not reflect the differences of the 95th percentile level except in triglycerides. In general, the statistical upper normal limits (95th percentile) observed in this group of children are definitely lower than the currently recommended normal limits for serum lipids and lipoproteins (except α-lipoproteins). However, since normal limits are not well established, these data can serve as guidelines. The lipid values for school-aged children in the Bogalusa Heart Study are comparable to those found by SCOR-A in Rochester, Minn. (personal communication, Dr. Ralph Ellefson) and by the Lipid Research Clinic, Cincinnati, Ohio.

**Table 7.** Pearson Product Moment Correlation Coefficients between Serum Lipids and Lipoproteins by Race in Fasting Children, 445 Whites and 210 Blacks

<table>
<thead>
<tr>
<th></th>
<th>Triglycerides</th>
<th>β-lipoprotein</th>
<th>Pre-β-lipoprotein</th>
<th>α-lipoprotein</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total cholesterol</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whites</td>
<td>0.100*</td>
<td>0.735†</td>
<td>0.082</td>
<td>0.491†</td>
</tr>
<tr>
<td>Blacks</td>
<td>0.188†</td>
<td>0.726†</td>
<td>0.162*</td>
<td>0.420†</td>
</tr>
<tr>
<td><strong>Triglycerides</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whites</td>
<td>0.268‡</td>
<td>0.799‡*</td>
<td>-0.408‡</td>
<td></td>
</tr>
<tr>
<td>Blacks</td>
<td>0.322‡</td>
<td>0.593‡</td>
<td>-0.288‡</td>
<td></td>
</tr>
<tr>
<td><strong>β-lipoprotein</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whites</td>
<td>0.269†</td>
<td>-0.193‡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blacks</td>
<td>0.214†</td>
<td>-0.290†</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pre-β-lipoprotein</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whites</td>
<td>-0.497‡,§</td>
<td>-0.292‡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blacks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Levels of significance: correlation coefficient different from zero, *P <0.05; †P <0.01; ‡P <0.001.

Significant racial differences in correlation coefficients, §P <0.01; ***P <0.001.

The interrelationship between the blood lipids and such factors as age, race, sex, and obesity was determined using multiple linear regression techniques (table 8). In these studies an index of obesity, W/H², was calculated using the method of Benn, which calculates a value independent of height (r = 0.04). This index, derived from our population sample, is specific to our population and is associated with an independent assessment of adiposity, namely the triceps skinfold (r = 0.69). Table 8 illustrates that of five independent variables (age, race, sex, W/H², or triceps skinfold) only a few are statistically significant when related to specific serum lipid classes. None are significantly related to cholesterol.

For triglyceride, there is a significant racial effect (blacks lower than whites) and sex effect (males lower than females), as well as a relationship with weight relative to height (W/H²). There is no independent relationship of triceps skinfold with triglycerides beyond the relationship with W/H². Both age and W/H² are weakly but positively associated with pre-β-lipoproteins. As stated earlier, there was no detectable relationship of lipids to blood pressure in this age group.

**Comment.** The serum lipid and lipoprotein levels in these preschool-aged children showed a definite racial difference only in triglycerides. Although white children tended to have slightly higher pre-β-lipoprotein and lower α-lipoprotein levels than black children, the differences were not as striking as in the school-aged children (5-14 years) from the same community. Whether the children tend to show a definitive race-related pattern only after a certain age due to genetic or environmental factors is not clear. For instance, any differences in dietary pattern and nutritional status among children of various age groups (preschool-age vs school-age) might affect the lipid and lipoprotein profiles.

**Table 8.** Stepwise Multiple Linear Regression for Serum Lipids and Selected Variables

<table>
<thead>
<tr>
<th>Coefficient for multiple linear regression equation</th>
<th>Serum variable (mg/dl)</th>
<th>Number of children</th>
<th>Constant</th>
<th>Age (yrs)</th>
<th>Race</th>
<th>Sex</th>
<th>Wt/H²</th>
<th>TSF</th>
<th>Multiple R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cholesterol</td>
<td>689</td>
<td>139.9</td>
<td>1.3</td>
<td>3.1</td>
<td>1.5</td>
<td>0.2</td>
<td>0.3</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Triglycerides*</td>
<td>650</td>
<td>25.5</td>
<td>-0.1</td>
<td>-8.9**</td>
<td>4.9†</td>
<td>3.0$</td>
<td>-0.3</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>β-lipoprotein*</td>
<td>650</td>
<td>184.4</td>
<td>-2.3</td>
<td>6.4</td>
<td>5.7</td>
<td>-0.0</td>
<td>0.3</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Pre-β-lipoprotein*</td>
<td>650</td>
<td>-10.9</td>
<td>2.4†</td>
<td>-2.4</td>
<td>3.9</td>
<td>2.1†</td>
<td>-0.6</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>α-lipoprotein*</td>
<td>650</td>
<td>331.0</td>
<td>9.3</td>
<td>3.7</td>
<td>-12.8</td>
<td>-1.5</td>
<td>2.2</td>
<td>0.01</td>
<td></td>
</tr>
</tbody>
</table>

*Fasting children only.
Abbreviations: w = white; b = black; m = male; f = female; wt = weight; ht = height; TSF = triceps skinfold thickness.
Levels of significance (t-test): *P <0.05; fP <0.01; **P <0.001.
Interestingly, the changes with age (2½–14 years) in median levels of pre-β and α-lipoproteins in children of this community indicated a progressive increase in differences (especially in pre-β-lipoproteins) related to race after age 7 or 8. The sex-related changes in preschool-aged children indicated a common tendency for girls (especially white girls) to have higher serum total cholesterol, triglycerides, and β and pre-β-lipoproteins and lower α-lipoprotein concentrations than boys, which was similar to our earlier observations in the school-aged children.

A pattern seems to emerge from the lipid and lipoprotein profiles at birth and in infant, preschool-aged, and school-aged children from this community. Serum lipid and lipoprotein levels seem to dramatically increase between birth and 2 years of age. (A peculiar overshoot appears to occur around six months to one year of age in triglyceride levels.) Later, there seems to be a slight but definite increase in total cholesterol and α-lipoproteins between the ages of 2 and 6. Afterwards certain changes occur around puberty.

Five major independent variables (age, race, sex, W/H², and triceps skinfold) help explain only 1 to 5% of the variance (as seen by the multiple R²) in the serum lipid and lipoprotein levels, leaving 95% or more to be explained by other unnamed factors. To some extent these associations explain less variability than in children 5–14 years of age, and probably even less than in adults, suggesting that a transition occurs from childhood to adulthood with greater influence of environment over time. An inherent metabolic response to environmental factors controlled by genetic influences, mono- and/or polygenic, seems to be paramount in accounting for this variability.

### Dietary Studies

Parents of 25 children (21 white, 4 black) were included in a sample of convenience and asked to provide a 24-hour dietary recall relating to their child. The median relative weight for the subsample was 1.9% higher than that of the total community of preschool children.

Table 9 compares the composition of the preschool diets with that of a larger, randomized sample of Bogalusa 10 to 11-year-old children reported elsewhere. The percentage contributions of carbohydrate, fat, and protein were similar for the two groups. The preschool children did have higher mean intakes of all diet components expressed per kg of body weight than the school children (this includes cholesterol as well), but the mean intakes were similar when expressed per 1000 calories. Sodium intake and the ratio of polyunsaturated fatty acids (linoleic, linolenic, and arachidonic) to saturated fatty acids (P/S) as well as the sucrose-to-starch-ratio (S/S) were both slightly higher in the preschool intake.

Diet intakes of these preschool children generally resembled those of preschoolers studied in the North Central Region of the U.S.; however, the Bogalusa sample had a slightly higher P/S ratio and mean fat intake, but a slightly lower mean protein intake. It is recognized that with only one 24-hour eating period assessed per child, only a rough group description of food intake and nutritional adequacy is possible. Intakes were, however, compared with Recommended Dietary Allowances (RDA). Thirteen of the 18 children 4 to 5 years of age (72%) did not meet the RDA of 1800 kcal, whereas all seven younger children (2 and 3 years) consumed more than their recommended 1300 kcal. Sixty-four percent of the children achieved less than two-thirds the suggested iron intake. Most children ingested at least 65% of the calcium RDA (800 mg), but their mean intake, X = 600 mg, was less than the values which Fox et al. reported for children of the North Central Region.

Protein intake was more than adequate (greater than 100% of RDA) for 84% of the children. Eighteen of the mothers (72%) reported salting their child’s food only during cooking; five during cooking and after tasting the food at the table; and two, during cooking and before tasting the food at

### Table 9. Mean and Standard Error for Caloric and Nutrient Intakes of 25 Preschool-aged Children and 185 School Children

<table>
<thead>
<tr>
<th>Dietary component</th>
<th>School children age 10 years</th>
<th>Preschool children aged 2½–5 ½ years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intake</td>
<td>Percent of total calories</td>
<td>Intake</td>
</tr>
<tr>
<td>Calories (kcal)</td>
<td>2141 ± 62</td>
<td>1722 ± 153</td>
</tr>
<tr>
<td>kcal per kg body weight</td>
<td>66 ± 2.1</td>
<td>103 ± 10.1</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>69.1 ± 2.2</td>
<td>55.2 ± 8.1</td>
</tr>
<tr>
<td>g per kg body weight</td>
<td>2.1 ± 0.07</td>
<td>3.3 ± 0.53</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>261.5 ± 8.0</td>
<td>200.5 ± 16.3</td>
</tr>
<tr>
<td>g per kg body weight</td>
<td>8.1 ± 0.28</td>
<td>11.8 ± 1.0</td>
</tr>
<tr>
<td>S/S ratio*</td>
<td>1.11</td>
<td>1.29</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>93.1 ± 3.4</td>
<td>79.4 ± 8.5</td>
</tr>
<tr>
<td>g per kg body weight</td>
<td>2.8 ± 0.11</td>
<td>4.8 ± 0.55</td>
</tr>
<tr>
<td>P/S ratio†</td>
<td>.311</td>
<td>.383</td>
</tr>
<tr>
<td>Cholesterol (mg)</td>
<td>324 ± 16</td>
<td>236 ± 42</td>
</tr>
<tr>
<td>mg per kg body weight</td>
<td>10 ± 0.53</td>
<td>14 ± 2.7</td>
</tr>
<tr>
<td>Sodium (mg)</td>
<td>3330 ± 117</td>
<td>2489 ± 248</td>
</tr>
<tr>
<td>mg per kg body weight</td>
<td>102.4 ± 3.9</td>
<td>145.2 ± 14.6</td>
</tr>
</tbody>
</table>

*Ni sucrose 1 Ni 1 N_i ≠ 1.2
1 Ni 1 N_i = 1.2
1 Ni 1 N_i

### Notes

1. N_i

2. N_i

3. N_i

4. N_i

5. N_i

6. N_i

7. N_i

8. N_i

9. N_i
Discussion

In an effort to study the early evidence of factors related to risk for coronary artery disease or hypertension, many programs are focusing on school-aged children. But it is as important to extend observations into the preschool years to broaden our information on the early natural history of arteriosclerosis. Numerous studies have characterized growth patterns from infancy onward, but there are few studies of child populations where anthropometric, blood pressure, lipid and nutritional data are collected simultaneously.

An early report on the lipids and lipoproteins of children indicated the mean levels of total serum cholesterol of children ages 3 to 4 years were already as high as those observed in medical students and that there was a marked range and variability of lipid levels. Information on the early transition of lipid levels as well as other parameters then become of interest. The mean serum cholesterol value of 157 mg/dl in this study is unusually close to 161 mg/dl reported by Owen et al. in children aged 2-5 years in the Preschool Nutrition Survey. Since the PNS did not collect blood from fasting children it is difficult to compare results for triglycerides. Those investigators did, however, report that both in the PNS and later with fasting children, triglyceride values were consistently higher in whites than in blacks.

Blood pressure was measured in all ages in Tecumseh, Michigan, as part of the Tecumseh Community Study. Their measurements taken with a mercury sphygmomanometer tend, in children aged 3-4 years, to be 7-8 mm higher in both systolic and diastolic (4th phase) blood pressures than those of our children of the same age taken with the same type of instrument. As we previously mentioned with regard to our school-aged children, these relatively low blood pressure readings can be largely attributed to the efforts of our staff to create a calm, relaxed environment during the examination. This same logic holds for the preschool children although many tended to be more anxious than did the school children.

In the present study, we observe that some racial differences are already apparent during the preschool years. Black children tend to be slightly taller, have longer arm lengths, weigh more, and have thinner triceps skinfolds. These early childhood findings are in accord with the anthropologic theories of adaptive selection, which state that individuals whose ancestors have resided in cooler climates (primarily whites) tend to have less surface area (shorter limbs) and more insulatory fat than individuals who have historically adapted to warmer climates. We can likewise speculate that the racial differences in triceps skinfold is related to the increased level of triglycerides found in white children.

Perhaps one of the most interesting observations is the apparent low correlation between the risk factor variables. That is, less interrelationship is observed in groups of preschool-aged children than in older individuals. For example, a ponderosity index did not relate to blood pressure levels, and the multiple independent variables could explain only about 20% of blood pressure variability and 5% of the lipid variability. These values are about one-half of those observed for school-aged children. Garn et al. have observed that a positive skewness of weight distribution relative to height becomes more manifest after 9 years of age. Therefore, observations of these young children become more important since they show less of the compounding environmental effects on the risk factor variables that occur at older ages. Further, if young children remain fixed at age-specific percentile levels ("tracking"), which is likely, then it is important to observe the risk factors at young ages.

Current studies are in progress to test the tracking hypothesis by determining trends over time for the risk factor variables from birth to young adulthood. Certainly, single observations at one point in time, as described in this study, are not recommended but they do form the basis of future studies to observe the direction in which the maturing child will change over time.

Acknowledgment

The authors wish to express appreciation to the entire Bogalusa Heart Study staff for collecting the data, and the Bogalusa children, without whom this study would never have been possible.

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