Coronary heart disease risk factors in school children: The Muscatine study

The frequency of coronary risk factors was documented in 4,829 school children in Muscatine, Iowa, over a 14-month period of time. Serum cholesterol levels were similar for children at all ages; the mean serum cholesterol level was 182 mg/dl (SD ± 29). Twenty-four percent had levels ≥ 200 mg/dl, 9% were ≥ 220 mg/dl, 3% were ≥ 240 mg/dl, and 1% were ≥ 260 mg/dl. Casual levels of serum triglyceride increased with age: the mean level was 71 mg/dl (SD ± 36) at age 6 years and 108 mg/dl (SD ± 45) at age 18 years. Only 15% of the children had serum triglyceride levels of 140 mg/dl or more. Blood pressure increased strikingly with age. No child between 6 and 9 years of age had blood pressures ≥ 140 mm Hg systolic or ≥ 90 mm Hg diastolic. In the age group 14 to 18 years, 8.9% had systolic blood pressures ≥ 140 mm Hg, 12.2% had diastolic blood pressures ≥ 90 mm Hg, and in 4.4% both pressures were at or above these levels. Obesity also increased through the school years. At ages 6 to 9 years, 20% had weights relative to those of the group as a whole of ≥ 110%, and 5% were ≥ 130%; in the 14 to 18 years age group, 25% had relative weights of ≥ 110%, and 8% were ≥ 130%. These data indicate that a considerable number of school-age children have risk factors which in adults are predictive of coronary heart disease.

Ronald M. Lauer, M.D.,* William E. Connor, M.D.,** Paul E. Leaverton, Ph.D., Mary Ann Reiter, B.S., and William R. Clarke, M.S., Iowa City, Iowa

Coronary heart disease is the leading cause of death in adults in the United States. Although the clinically overt symptoms of sudden death, myocardial infarction, or angina pectoris are extremely rare in children, a cryptic stage of atheromatous vascular disease may well have its origins in childhood. Fatty streaks and frank atheromatous changes have been found in the aortas and coronary vessels of children and young adults dying of unrelated disease and war injuries. In the preclinical phase of coronary disease, a number of risk factors have been shown to be predictive in adults who subsequently develop clinical atheromatous disease. Studies carried out in Framingham, Massachusetts, Tecumseh, Michigan, and by life insurance companies have shown that there is a gradient of risk for coronary heart disease that is associated with the serum concentration of cholesterol, the level of blood pressure, and the amount of obesity. Isolated obesity, without hyperlipidemia or hypertension, is not related to subsequent myocardial infarction but is related to the occurrence of angina pectoris.

The purpose of this investigation was to determine the distribution of the serum cholesterol and triglyceride levels, the blood pressure, and excess body weight in a school-age population. Values established as predictive of the development of coronary heart disease

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DESCRIPTION OF POPULATION

The school children of Muscatine, Iowa, were selected as subjects for this study, not only because of their geographic proximity to the medical examining team in Iowa City but also because of the stability of the school population in that community. In the 1963-68 school terms, the Iowa Center for Research in School Education found a mean of 98% of each grade level of students progressing from one grade to the next and thus remaining in the Muscatine school system.

Local newspapers and radio stations described the significance of the study. The county medical society and school board officially approved the project. The school principals, teachers, and school nurses cooperated fully. A letter requesting parental consent to examine the children was sent home with each student. Approximately 70% of the school population, 4,829 students, returned with signed parental consent forms and were accepted into the study. As in any study in which less than 100% participation is accomplished, there may be some bias in the prevalence rates obtained. These children were in grades 1 through 12. Their ages were 6 through 18 years; 2,346 were boys and 2,483 were girls.

In the school population only 0.6% were black; 0.1% were American Indian, 0.1% were Oriental, and 2.8% were Spanish-American. The great majority (96.4%) were white.

METHOD OF EXAMINATION

All examinations were carried out during the school years of 1971-72 and 1972-73, over a 14-month period of time. On the morning of the examination, each student had venous blood drawn. Advice about fasting was purposely not given to the children. A dietary history was taken for the breakfast meal in 962 children (422 boys and 540 girls). Each item of food was recorded and its fat content estimated from standard food tables.

The blood was analyzed in duplicate for serum cholesterol and triglyceride content by a standard AutoAnalyzer (AA-1) technique. Duplicate analyses of 215 split samples for cholesterol in the AutoAnalyzer showed an average difference of 3.5 mg/dl with a standard deviation of the difference of 3.5 mg/dl; the average difference for triglycerides was 3.7 mg/dl with a standard deviation of the difference of 3.9 mg/dl.

On the afternoon of the same day, the blood pressure, height, body weight, and triceps skinfold thickness were measured. Blood pressure was taken with the student in a seated position, by means of blood pressure cuffs whose widths covered at least two thirds of the upper arm and whose rubber bags were sufficiently long to encompass most of the circumference of the arm without overlapping. The pressures were estimated on mercury-filled sphygmomanometers by specially instructed nurses and physicians. The first, fourth, and fifth Korotkoff sounds were recorded. The first readings of blood pressure were taken after the technique was explained to the student, and the cuff was inflated and deflated once. The pressures were obtained in both arms, and the average of the two readings was used for analyses. The fourth Korotkoff sounds were used for estimation of diastolic blood pressure. All observers were cautioned about digit preference and urged to read pressure to the closest 2 mm Hg. In both boys and girls the average difference in systolic blood pressure between right and left arm was 0.7 mm Hg with the standard deviation of the difference equal to 6.4 mm Hg; the mean difference of diastolic pressure between right and left arm was 0.4 mm Hg with the standard deviation of the difference equal to 5.4 mm Hg.

The standing height was measured with the subject in stocking feet using an anthropometric plane. Body weight was measured with the subject clothed and shoeless on a beam-type balance scale calibrated with standard weights.
Triceps skinfold thickness was taken at the measured midpoint between the acromion and the tip of the elbow over the triceps muscle of the left arm, utilizing a Lange skinfold caliper. The arm was hanging straight and in a relaxed condition. The skinfold thickness was measured three times and a mean of the three readings was used for analysis. Triplicate measures of triceps skinfold thickness showed close reproducibility, with an average variance of 0.43 mm and standard deviation of 0.66 mm.

All measurements with student identifying data including birth date, sex, date, and school were recorded on protocol sheets and then transferred to IBM cards.

**RESULTS**

**Serum cholesterol levels.** The mean serum cholesterol level in all subjects was 182 mg/dl (SD ±29). Of note was the similarity of the serum cholesterol levels at all ages, 6 to 18 years, for both boys and girls (Fig. 1A). Six-year-old children had a mean level of 171 mg/dl (SD ±27); 18-year-old subjects had a mean level of 177 mg/dl (SD ±26). There were little sex-related differences. The histogram of serum cholesterol levels for both boys and girls indicated a unimodal Gaussian distribution (Fig. 1B). The lowest 5% of the children had serum cholesterol levels of 140 mg/dl and below. Twenty-four per cent of the children had levels of 200 mg/dl and above, 9% were at least 220 mg/dl, 5% at least 230 mg/dl, 3% at least 240 mg/dl, and 1% were at least 260 mg/dl.

**Serum triglyceride levels.** Selected percentiles of serum triglyceride levels of boys and girls, ages 6 through 18 years, are provided in Fig. 2. There was little sex-related difference. There was a log-Gaussian distribution of the serum triglyceride levels in both sexes. At age 6 the mean serum triglyceride level was 72 mg/dl (SD ±36); at age 18 the mean serum triglyceride level was 108 mg/dl (SD ±46). Thus an increase in the mean serum triglyceride level occurred with age: 4.2 mg/dl per year in boys (t = 14.2; p < 0.01), whereas in girls it increased 1.9 mg/dl per year (t = 6.8; p < 0.001). About 15% of both sexes had triglyceride values exceeding 140 mg/dl, which is the ninety-seventh percentile of fasting levels for similar ages described by Fredrickson and associates. Only 1% were in excess of 260 mg/dl. The upper fifth percentile of these children was 183 mg/dl; the lower fifth percentile was 43 mg/dl.

Of subjects with serum triglyceride values of 140 mg/dl and above, 11% of the boys and 15% of the girls had cholesterol levels exceeding 230 mg/dl. Of subjects with triglyceride values less than 140 mg/dl, 3.3% of the boys and 5.2% of the girls had cholesterol levels in excess of 230 mg/dl.

**Dietary histories.** The mean fat intake for the breakfast meal in 962 children was 10.6 gm (SD ±10.1).
Twenty-five percent of the children ate no fat for breakfast and, in many instances, ate no breakfast. Another 22% had a very low breakfast fat intake (under 10 gm). In all, 79% of the children had no fat intake or had under 15 gm of fat for breakfast. Only 9% of the children ate a high-fat breakfast (above 25 g).

As expected, the serum cholesterol level was not related to the amount of fat in the breakfast (r = 0.02). The serum triglyceride level correlated only weakly with the breakfast fat intake (r = 0.18; p < 0.001) for the 962 children. There were no differences in this regard for boys and girls. However, a t-test comparing the fat intake for breakfasts of the children with the 15% highest and 15% lowest serum triglyceride levels showed a significant difference (t = 2.69; p < 0.01), indicating a trivial but significant influence of breakfast dietary fat upon the serum triglyceride distribution. This small effect of breakfast fat on serum triglyceride levels has also been observed by Schilling and colleagues in adult subjects.

Blood pressure. The systolic and diastolic blood pressures increased with age (Fig. 3). There was a 2.6 mm Hg per year increase in systolic pressure in boys (t = 22.0; p < 0.001) whereas in girls a 1.9 mm Hg per year rise occurred (t = 22.7; p < 0.001). Diastolic pressure increased 1.3 mm Hg per year in both boys and girls (t = 31.7; p < 0.001).

Table I shows blood pressure levels in the various age groups. Of great interest was the virtual absence of adult hypertensive levels in children ages 6 to 9 years (hypertension being defined as either a systolic blood pressure of 140 mm Hg or above, or a diastolic blood pressure of 90 mm Hg or above). Indeed, many children in this age range had exceptionally low blood pressure: 32.9% had a systolic blood pressure below 100 mm Hg and 45.3% had a diastolic blood pressure below 70 mm Hg.

Hypertension occurred commonly in children ages 14 to 18 years: 8.9% had systolic hypertension, 12.2% had diastolic hypertension, systolic and diastolic hypertension occurred together in 4.4%, and 16.7% had blood pressure elevations of either systolic pressure or diastolic pressure or both.

Measures of obesity. The heights and weights of the Muscatine children were greater than those of children described in the Iowa Growth Charts and the Stuart (Harvard) Growth Charts of 1946. The National Health Survey Data compiled in the 1960's for children ages 6 through 11 years, Midwest data, were similar to the measurements of the Muscatine children.

Relative weight has been used widely as a coronary risk index in adults; we present it herein as a view of the problem of childhood obesity, realizing that its importance when measured in children as a predictor of the development of coronary heart disease in adult life is not established.

Relative weights were computed for each subject as
percentage above or below the median weight for all subjects with the same height, age, and sex. Thus those with a relative weight of 100% were at the median weight for their height-age-sex category. At all ages approximately 23% of both boys and girls had relative weights of at least 110%. In the adolescent years, a greater number of children were observed to have relative weights in excess of 130%. In the age group 14 to 18 years, 24.1% of boys and 25% of girls had relative weights of 110% or more, 13.1% and 13.6%, respectively, were at least 120% and 7.0%, and 8.6%, respectively, were at least 130%. In the age group greater than 17 years, fewer students participated in the study than in the prepubescent years, and a fewer number with relative weights in excess of 130% were observed. Perhaps those who were markedly obese in the 17 to 18 year age group did not participate in the study.

A second measure of obesity is displayed in Figs. 4A and 4B, which show selected percentiles of triceps skinfold thickness by age and sex. Boys had a progressive mean increase in skinfold thickness, from ages 6 through 18 years, of 0.36 mm per year ($t = 10.3; p < 0.001$) with the greatest increase between 6 and 11 years. Girls had a contrastingly greater increase of 0.89 mm per year ($t = 25.8; p < 0.001$) with the increase being uniform throughout the years.

Seltzer and Mayer\textsuperscript{23} suggested the use of the triceps skinfold thickness greater than one standard deviation above the mean on a log normal scale as a criterion for assessing the presence of excess adiposity. By this definition, the upper 16% of subjects were obese. In Muscatine, the distribution of triceps skinfold thickness was less than that described by Seltzer and Mayer. The triceps skinfold thickness measured in Tecumseh children in 1958-60 was similar to that of the Muscatine children.\textsuperscript{24}

A third indication of obesity, the ponderal index, was calculated by dividing the height (inches) by the cube root of the weight (pounds). In both boys and girls the mean value of this ratio remained constant at all ages: 12.9 (SD $\pm 0.6$). In both sexes approximately 5% had values less than 12.0 at all ages, and 3.8% were less than 11.6, a value below which is associated with early death from coronary heart disease in adult males.\textsuperscript{25}

**Relationship among variables.** The correlation matrix of the measured variables is indicated in Table II. Serum cholesterol and triglyceride levels related only marginally to other variables. The three measures of obesity, triceps skinfold thickness, ponderal index, and relative weights, were closely related one to the other. However, if the subjects in the upper deciles of relative weight, cholesterol, triglyceride, and systolic and dia-
Table I. Muscatine study: Blood pressures

<table>
<thead>
<tr>
<th>Systolic blood pressures (mm Hg)</th>
<th>6-9 yr (% of total)</th>
<th>10-13 yr (% of total)</th>
<th>14-18 yr (% of total)</th>
<th>6-18 yr (% of total)</th>
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</thead>
<tbody>
<tr>
<td>At least 160</td>
<td>0.1</td>
<td>0.4</td>
<td>1.3</td>
<td>0.5</td>
</tr>
<tr>
<td>150-159</td>
<td>0.1</td>
<td>1.2</td>
<td>1.8</td>
<td>0.9</td>
</tr>
<tr>
<td>140-149</td>
<td>0.3</td>
<td>2.8</td>
<td>5.8</td>
<td>2.7</td>
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<tr>
<td>130-139</td>
<td>0.9</td>
<td>9.7</td>
<td>17.2</td>
<td>8.4</td>
</tr>
<tr>
<td>120-129</td>
<td>7.3</td>
<td>18.5</td>
<td>27.0</td>
<td>16.6</td>
</tr>
<tr>
<td>110-119</td>
<td>22.6</td>
<td>30.7</td>
<td>26.7</td>
<td>26.6</td>
</tr>
<tr>
<td>100-109</td>
<td>35.9</td>
<td>25.8</td>
<td>16.2</td>
<td>27.0</td>
</tr>
<tr>
<td>Under 100</td>
<td>32.9</td>
<td>10.9</td>
<td>3.9</td>
<td>17.4</td>
</tr>
<tr>
<td>N</td>
<td>1,845</td>
<td>1,669</td>
<td>1,315</td>
<td>4,829</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Diastolic blood pressures (mm Hg)</th>
<th>6-9 yr (% of total)</th>
<th>10-13 yr (% of total)</th>
<th>14-18 yr (% of total)</th>
<th>6-18 yr (% of total)</th>
</tr>
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<tr>
<td>At least 110</td>
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<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>100-109</td>
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<td>0.5</td>
<td>1.6</td>
<td>0.6</td>
</tr>
<tr>
<td>90-99</td>
<td>1.1</td>
<td>6.3</td>
<td>10.2</td>
<td>5.4</td>
</tr>
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<td>80-89</td>
<td>16.3</td>
<td>27.4</td>
<td>43.1</td>
<td>27.4</td>
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<td>70-79</td>
<td>37.3</td>
<td>41.4</td>
<td>35.8</td>
<td>38.3</td>
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<tr>
<td>60-69</td>
<td>31.9</td>
<td>19.5</td>
<td>7.5</td>
<td>21.0</td>
</tr>
<tr>
<td>50-59</td>
<td>12.3</td>
<td>4.2</td>
<td>1.2</td>
<td>6.5</td>
</tr>
<tr>
<td>40-49</td>
<td>1.1</td>
<td>0.4</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>N</td>
<td>1,845</td>
<td>1,669</td>
<td>1,315</td>
<td>4,829</td>
</tr>
</tbody>
</table>

Table II. Correlation coefficients (r) for measured variables*

<table>
<thead>
<tr>
<th></th>
<th>Triglyceride</th>
<th>Systolic blood pressure</th>
<th>Diastolic blood pressure</th>
<th>Triceps skinfold thickness</th>
<th>Ponderal index</th>
<th>Relative weight</th>
<th>Height</th>
<th>Weight</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cholesterol</td>
<td>0.24</td>
<td>0.04</td>
<td>0.06</td>
<td>0.17</td>
<td>-0.09</td>
<td>0.09</td>
<td>0.00</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Triglyceride</td>
<td>0.22</td>
<td>0.19</td>
<td>0.25</td>
<td>0.25</td>
<td>-0.16</td>
<td>0.20</td>
<td>0.23</td>
<td>0.28</td>
<td>0.21</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>0.62</td>
<td>0.39</td>
<td>0.39</td>
<td>-0.23</td>
<td>0.25</td>
<td>0.25</td>
<td>0.55</td>
<td>0.60</td>
<td>0.49</td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td>0.36</td>
<td>-0.21</td>
<td>0.19</td>
<td>0.44</td>
<td>0.49</td>
<td>0.49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skinlinef thickness</td>
<td>-0.65</td>
<td>0.68</td>
<td>0.34</td>
<td>0.61</td>
<td>0.42</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ponderal index</td>
<td>-0.89</td>
<td>0.07</td>
<td>-0.40</td>
<td>-0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative weight</td>
<td>0.04</td>
<td>0.46</td>
<td>0.03</td>
<td></td>
<td></td>
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</tbody>
</table>

*There was little difference in correlations between sexes in the measured variables with the exception of triceps skinfold thickness where relative weight is related in males (r = 0.45) and in females (r = 0.75).

Systolic blood pressure values are examined, a higher prevalence of associated high values of related variables are observed than the expected 10% if no association existed. For the upper decile of each variable (row) Table III gives the observed percentage in the upper deciles of the other variables (columns). For example, of subjects in the upper decile of relative weight, 84.8% have ponderal indices less than the tenth percentile; 74.0% have skinfold thicknesses greater than the ninetieth percentile; 17.7% have levels of serum cholesterol greater than the ninetieth percentile; 24.3% have levels of triglyceride greater than the ninetieth percentile; 28.6% have levels of systolic blood pressure greater than the ninetieth percentile; and 28.4% have diastolic pressures greater than the ninetieth percentile. The observation that the Pearson correlations are in many instances low and that there are appreciable numbers of subjects with high levels in more than one variable indicates that a relationship between the risk factors exists, but one cannot be predicted confidently from the other, except among the measures of obesity for which correlations are high.

Unlike serum cholesterol levels, the number of children with blood pressure elevation and relative weights at adult risk levels increased with age. It is thus important to focus attention particularly upon children in the age range 14 to 18 years for the occurrence of adult level risk factors. Defining risk factor categories as levels equal to or greater than 220 mg/dl for serum cholesterol, 140 mm Hg systolic or 90 mm Hg diastolic for blood pressure, and 130% for relative weight in the age group 14 to 18 years, it was found that 1% of the children have three criteria, 4.6% have two criteria, and 22.7% have only one risk factor at these adult predictive levels.

**DISCUSSION**

The striking finding of this study was the large number of children who seemed to be already at risk for the development of coronary heart disease. This conclusion
Table III. Relation of selected deciles of risk in measured variables*

<table>
<thead>
<tr>
<th></th>
<th>Ponderal index</th>
<th>Relative weight</th>
<th>Skinfold thickness</th>
<th>Serum cholesterol</th>
<th>Serum triglyceride</th>
<th>Blood pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤ 10%†</td>
<td>≥ 90%</td>
<td>≥ 90%</td>
<td>≥ 90%</td>
<td>≥ 90%</td>
<td></td>
</tr>
<tr>
<td>Ponderal index</td>
<td>(N = 466)</td>
<td>—</td>
<td>89.7</td>
<td>75.8</td>
<td>18.1</td>
<td>25.2</td>
</tr>
<tr>
<td>Relative weight</td>
<td>(N = 493)</td>
<td>84.8</td>
<td>—</td>
<td>74.0</td>
<td>17.7</td>
<td>24.3</td>
</tr>
<tr>
<td>Skinfold thickness</td>
<td>(N = 555)</td>
<td>63.1</td>
<td>65.2</td>
<td>—</td>
<td>17.8</td>
<td>23.5</td>
</tr>
<tr>
<td>Serum cholesterol</td>
<td>(N = 492)</td>
<td>16.7</td>
<td>17.3</td>
<td>19.3</td>
<td>—</td>
<td>21.5</td>
</tr>
<tr>
<td>Serum triglyceride</td>
<td>(N = 478)</td>
<td>23.8</td>
<td>24.3</td>
<td>26.2</td>
<td>22.1</td>
<td>—</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td>(N = 517)</td>
<td>26.5</td>
<td>27.3</td>
<td>31.7</td>
<td>12.5</td>
<td>16.2</td>
</tr>
<tr>
<td>Diastolic blood pressure</td>
<td>(N = 585)</td>
<td>24.3</td>
<td>23.9</td>
<td>29.0</td>
<td>15.0</td>
<td>15.1</td>
</tr>
</tbody>
</table>

*Each row gives the percentage of subjects in the upper† 10% of that variable who are also in the upper† 10% of the column variable. Therefore, the expected percentage in each cell is 10% under the hypothesis of no relationship. Note that all cells exceed 10% indicating various degrees of association.

†Ponderal index = height (inches)/√weight (pounds); a small index is associated with obesity. Therefore, the lower decile is comparable to the upper decile in all other risk variables.

Example: For those subjects in the lower 10% of ponderal index, 89.7% are also in the upper 10% of relative weight, 75.8% are in the upper 10% of skinfold thickness, 18.1% are in the upper 10% of serum cholesterol.

was based upon criteria which have been established for adults from data gathered from prospective studies in the United States and abroad and from world-wide epidemiologic studies. In adults there is a direct relationship of risk for coronary artery disease to the level of serum cholesterol, blood pressure, and relative weight. There are, however, no longitudinal data which relate childhood levels of serum lipids, blood pressure, and relative weight to later risk for atherosclerotic disease in adult life. Because there is a gradient of risk for these three variables, no one level clearly divides a population into normal and abnormal groups. Thus it would seem appropriate to identify and consider at risk children whose serum cholesterol concentration and blood pressure are at levels established in adults as predictive of the development of early occlusive atheromatous disease.

What level of serum cholesterol constitutes a risk factor for coronary heart disease in adults has long been, and is, a continuing topic for debate. Most certainly, the abnormal level cannot be taken at a cutoff of the ninety-fifth percentile of the population. In adults, for example, this would be above 290 to 310 mg/dl and clearly would not include the vast majority of those who do indeed have clinical coronary heart disease; their serum cholesterol levels range from 220 to 280 mg/dl. The Framingham study indicated a continuous gradation of risk for coronary heart disease with serum cholesterol levels above 180 mg/dl. In countries in which the incidence of coronary heart disease is very low, the mean serum cholesterol concentrations of adults are in the 140 to 160 mg/dl range. These are probably absolute target goals for the prevention of coronary heart disease in entire populations. In Japan, for example, the incidence of coronary heart disease in men age 55 to 60 years in one eighth that found in the United States. Men in this age range in the United States have serum cholesterol concentrations of 240 to 260 mg/dl, whereas in Japan the levels of the same age range are lower than 140 to 160 mg/dl. Furthermore, in experimental animals atherosclerosis does not develop when serum cholesterol levels are below 180 mg/dl.

Perhaps the 50% of children in the Muscatine study with serum cholesterol levels above 180 mg/dl can thus be considered at risk for the future development of coronary heart disease. The 24% of children with levels of 200 mg/dl or greater and the 9.1% with levels of 220 mg/dl or greater are clearly at higher risk. Only subsequent studies will indicate the relative permanence of serum cholesterol concentrations in children, but even if only one third have relatively fixed high values, this in itself would be a most significant number of children with a predictive factor identified early in life.

Another important reason for concern about serum cholesterol levels of 180 mg/dl is the knowledge that after the age of 24 years there is a progressive rise in the
level for the next 30 years.\textsuperscript{32} If the adult serum cholesterol level (220 mg/dl) at which treatment is recommended by the Food and Nutrition Board of the National Academy of Sciences\textsuperscript{33} is followed as a guideline, the extrapolated equivalent childhood level requiring therapeutic intervention would be 180 mg/dl.

Unlike children in Busselton in Western Australia described by Godfrey and associates,\textsuperscript{34} the Muscatine children had little difference in serum cholesterol values from ages 6 through 18 years. The sample of 1,292 Australian children had a median value of serum cholesterol at 6 years of age of 160 mg/dl; at 17 years of age this value had risen to 183 mg/dl. The reason for this geographic difference is not clear but could be explained by different dietary habits, especially among the younger children.

A sample of 5,000 preschool children from areas throughout the United States was studied by Owen and colleagues.\textsuperscript{35} These children, younger than those in this study, were classified according to socioeconomic characteristics. There was no significant difference in the levels of cholesterol at the various economic levels. The mean serum cholesterol value changed only slightly upward from one year of age to 6 years of age, and in the 60 to 71 month age group was 163 mg/dl (SD ±28).

Even in the postprandial blood specimens of the Muscatine children, the incidence of adult levels of hypertriglyceridemia was much less common than the occurrence of hypercholesterolemia. One factor that may be responsible for these differences in the relative incidence of the two common forms of hyperlipidemia is the increased amount of obesity in adults. The correlation of hypertriglyceridemia and obesity in adults is well established.\textsuperscript{36}

In the Muscatine children less than 9 years of age, few had blood pressures at adult risk levels. However, with increasing age the incidence of elevated blood pressure rose so that between 14 and 18 years, 16.7% had pressures greater than either 140 systolic or 90 diastolic or both. Of children in the upper decile of relative weight, 27.3% had systolic blood pressures in excess of the ninetieth percentile. The mechanism by which elevated blood pressure occurs with increased frequency in obese subjects is not clear. Dahl and colleagues\textsuperscript{37} have suggested that obese subjects may consume larger amounts of sodium along with excess calories, resulting in hypertension.

If, as estimates suggest,\textsuperscript{38, 39} approximately 20% of adults have levels of blood pressure placing them at risk, and if childhood peer relationships of blood pressure follow into adult life, children with blood pressures greater than the eightieth percentile for their age may eventually prove to be hypertensive adults. Only a long-term follow-up of children’s blood pressures will establish whether prediction of adult hypertension can be gained from childhood measurement of blood pressure.

The blood pressures of Muscatine children were measured on a single occasion. The level and distribution of blood pressures were similar to those of another school-age population described by Moss and Adams.\textsuperscript{40} No conclusion about the number of subjects who have persistently elevated blood pressures can be made, and none of these children with mild blood pressure elevations should necessarily be considered hypertensive. We believe, however, that it is important to follow those children whose pressures were measured at levels predictive of early coronary heart disease in adults. Observations in male college students and army officers with transient elevation of blood pressure have indicated that these subjects were more likely to have sustained high blood pressure in later years.\textsuperscript{41, 42}

The prevalence of obesity in the Muscatine children (23% with relative weights greater than 110%) would appear to be of considerable significance when related to reports indicating that obesity has its origins in childhood and persists into adult life,\textsuperscript{43} when the association of obesity with hyperlipidemia, hypertension, and diabetes is frequent. The increased prevalence of higher levels of blood pressure in the children with elevated relative weights shows that the relationship of obesity to blood pressure has its origins in childhood.

Children who have hyperlipidemia or who are obese require surveillance and instruction in dietary techniques to lower serum lipid values or induce weight loss if these factors persist. Of those found initially to be hypertensive, repeated measures of blood pressure are required to observe if these pressures are persistently elevated. In those with persisting hypertension, further investigation for neural, renal, endocrine, and vascular etiologies will be necessary before they can be considered to have essential hypertension. The efficacy of treatment for mild to moderate asymptomatic hypertension in childhood in order to prevent later complications has yet to be established. Although pharmacologic intervention is probably not justified, a reduction in caloric intake for the obese, dietary sodium chloride restriction, and continued surveillance would seem prudent. Those few older children who have moderate to severe hypertension should receive antihypertensive therapy in view of the proved benefits to adult subjects with similar levels of hypertension.\textsuperscript{44}

The observations in this large school-age population
revealed a considerable number of children, particularly adolescents, having levels of serum lipids, blood pressures, and relative weights which are known to relate to the early development of coronary artery disease in adults. The identification of such children, in addition to the benefits for themselves, may also allow the discovery of other family members with coronary risks because of the known clustering of hyperlipidemia, hypertension, and obesity within family members.45,46

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