Dietary Factors Relate to Cardiovascular Risk Factors in Early Life

Bogalusa Heart Study

Theresa A. Nicklas, Rosanne P. Farris, Carey G. Smoak, Gail C. Frank, Sathanur R. Srinivasan, Larry S. Webber, and Gerald S. Berenson

Relationships between diet and cardiovascular disease risk factors were studied in a cohort of infants in Bogalusa, Louisiana. The 24-hour dietary recalls and cardiovascular measurements were obtained on each child at age 6 months, yearly through age 4, and again at age 7 (cardiovascular measurements only). At ages 4 and 7, children with persistently high intakes of dietary cholesterol (three or more measurements in the upper tertile) had levels of serum total cholesterol approximately 14 mg/dl higher than children whose intakes of cholesterol were not persistently high. Children in the upper tertile for dietary cholesterol had levels of low density lipoprotein cholesterol (15 mg/dl at age 4 and 18 mg/dl at age 7) higher than children in the lower tertile for dietary cholesterol. Children with high intakes of animal fat were 2 to 6 kg heavier (p < 0.05) than those with lower intakes. Changes in dietary cholesterol correlated significantly with changes in serum total cholesterol (r = 0.42) and low density lipoprotein cholesterol (r = 0.50) from 6 months to 4 years of age. Changes in subcapular skinfold measurements correlated significantly with changes in intake of total protein (r = 0.31), total fat (r = 0.25), starch (r = 0.31), and energy (r = 0.39) from ages 6 months to 4 years. Results indicate that tracking of dietary components and their relationships with cardiovascular disease risk factors can be detected at an early age. These findings may well be the groundwork for later studies of obesity and the early onset of hyperlipoproteinemia. (Arteriosclerosis 8:193-199, March/April 1988)

**Diet** is a major determinant of cardiovascular (CV) risk. Because pathologic precursors of coronary heart disease (CHD) such as fatty streaks begin in childhood, there has been considerable interest in studying nutrient-serum lipid relationships in infants and children. In addition, eating habits formed during childhood have a potential lifelong effect on serum lipid levels and indirectly on CHD risk. Although studies have described dietary patterns and nutrient intake, relationships, and tracking of serum lipid and lipoprotein levels in children and adolescents, little association of diet to CV risk factors has been found. Here we describe the dietary intake and eating patterns of a cohort of infants and analyze the relationship of diet to CV risk factors.

**Methods**

**Population Sample**

The initial population sample represented a total 18-month birth cohort (n = 440, 97% participation) from a semirural, biracial population. The infants were followed longitudinally by CV risk-factor screening at selected intervals from birth to 7 years of age. The 24-hour dietary recalls were collected on a random sample of infants attending a screening at 6 months of age. A total of 125 recalls (35%) were obtained from the parents or guardians as respondents for their children. At the 1-year screening, 92 of the 125 mothers reported dietary recalls for their children. At the 2-year screening, a supplemental sample of 47 children was randomly selected to maintain an adequate sample size; thus, at the 2- and 3-year screenings, 135 and 106 mothers, respectively, completed the 24-hour dietary recalls for their children. Mothers of all children attending the 4-year screening were invited to complete a 24-hour dietary recall for their children and 219 responded. A modified CV examination was given at these five screenings, and again at age 7. Of the original sample of 125 children, 50 participated in all six screenings, and five dietary recalls were collected on each of these 50. This report summarizes the results of observations on this subsample of 50 children studied at all screenings. Of these 50 infants, 60% were white and 50% female. Data are presented elsewhere on the total cohort.

**Serum Lipid and Lipoprotein Analyses**

A sample of blood was obtained at each of the examination for determination of serum lipid and lipoprotein cholesterol levels. Serum total cholesterol and triglyceride levels were determined by a Technicon AutoAnalyzer II (Technicon Instrument Corporation, Tarrytown, New York)
Anthropometric Measurements

Various measurements (body length, subscapular skinfold thickness, weight, and indirect blood pressures) were determined. Duplicate determinations were made on 10% of the study population of infants. Detailed measurement procedures have been previously outlined. The coefficient of variations on replicate measurements was very low, varying from 0.3% to 0.9% for height and weight. Subscapular skinfold thickness was somewhat more difficult to measure. The coefficient of variation ranged for the various ages from 5.9% to 12.0%.

Dietary Data Accumulation

Trained interviewers collected 24-hour dietary recalls by methods described earlier. The respondent for each child was usually the mother or other care-giver such as the child's grandmother. When mothers were not present for the recall interview, follow-up phone calls or home visits verified the care-giver's responses. Duplicate recalls were obtained from care-givers of a 10% random sample of 6-month-old children attending the dietary sessions. The coefficients of variation for measurement error were 5.0% for cholesterol, 6.7% for protein, 10.0% for starch, 11.7% for energy, 12.9% for total fat, 15.8% for carbohydrate, and 12.0%.

Statistical Analysis

To examine if the subsample of 50 children participating in all five examinations was representative of the total cohort, we compared the characteristics of these 50 children with those missing one or more examinations. Dietary intake data of infants participating in all dietary interviews did not differ from those of children missing one or more interviews. In addition, serum lipid and lipoprotein cholesterol levels of the subsample of 50 children were not different from the total cohort.

Results

Composition of Dietary Intakes

Table 1 outlines the nutrient composition of the food consumed by these children during a 5-year period. Dietary components were expressed per 1000 kcal to adjust for differences in energy intake. Mean total energy intake at 6 months was 883 kcal, at 1 year 1293 kcal, at 2 years 1909 kcal, and at 3 and 4 years 2221 to 2123 kcal, respectively.

Protein intake/1000 kcal remained relatively stable (about 31 g) across the ages, with more than two-thirds coming from animal sources. Carbohydrate (CHO) intake/1000 kcal increased slightly from 6 months to 4 years of age. Most of this increase was accounted for by a large increase in sucrose intake/1000 kcal which more than compensated for the moderate decrease in lactose intake. Total sucrose intake/1000 kcal increased from 29 g at 6 months to 38 g by age 4 years. The increase in sucrose intake resulted in a sucrose-to-starch (Su/St) ratio greater than 1.1, reaching a maximum of 1.5 by age 4 years.

Total fat intake/1000 kcal was fairly constant across all ages. There was a slight shift in the type of fat, however, with age. In children from 6 months to 4 years of age, intake of saturated fat/1000 kcal decreased while intake of unsaturated fat increased. The polyunsaturated-to-saturated fatty acid ratio (P/S) remained between 0.4 and 0.5 at all ages.

The amount of cholesterol ingested/1000 kcal increased...
somewhat (but not significantly). By 6 months of age, children were consuming an average of 101 mg of cholesterol/1000 kcal. A maximum cholesterol intake of 194 mg was reached by age 2 years, with a slight decrease to 158 mg by 4 years of age. When these data are expressed on a per kilogram body weight basis, the highest level of cholesterol intake was found at age 4 years (24 mg/kg body weight). This level of cholesterol intake related to body size was considerably higher than values noted in older children and adults (6 mg/kg body weight).

A test for linear trends with age for the means of selected dietary components was conducted. Results indicate a significant decrease in saturated fat intake (p < 0.01) and an increase in intakes of sucrose (p < 0.01), starch (p < 0.10), Su/St ratio (p < 0.05), and P/S ratio (p < 0.05) from 6 months to 4 years of age. No significant age trends were noted in intakes of protein, CHO, total sugar, total fat, polyunsaturated fat (PUFA), and cholesterol for this cohort.

### Tracking of Dietary Components

Spearman rank correlations between various ages for selected dietary components are shown in Table 2. Little evidence of significant correlation between intakes at ages 6 months and 2 years was found for each dietary component.

At age 2 years, intakes of total protein, fat, and CHO correlated with intakes at ages 3 and 4 years. Energy intake at age 4 years was associated with previous levels of energy intake, as early as 1 year of age. Significant correlations over time were not seen for the P/S and Su/St ratios (data not shown). Consistent year-to-year correlations for dietary cholesterol intake were noted after age 2 years. A correlation coefficient of 0.49 (p < 0.001) was observed in cholesterol intake between ages 2 and 4 years.

### Relationship of Diet and Risk-Factor Variables

Few significant correlations were noted between absolute values for dietary components and CV risk-factor lev-
years (14.3 mg/dl higher) and 7 years (13.7 mg/dl higher) than children with consistently low intakes of dietary cholesterol. Similarly, those children with consistently high intakes of dietary cholesterol had higher levels of LDL cholesterol at ages 4 and 7 years. The magnitude of these differences is stronger if we adjust the dietary cholesterol for energy intake. Children with consistently high cholesterol intakes per 1000 kcal had significantly greater serum cholesterol levels at age 7 years (p < 0.05) and greater LDL cholesterol at both ages 4 years (p < 0.05) and 7 years (p < 0.05). When dietary cholesterol was adjusted for body weight, the same trend was noted.

A similar analysis was performed to examine the relationship between children with consistently high or low intakes of saturated fat and serum cholesterol and LDL cholesterol levels. Children with consistently high intakes of saturated fat per 1000 kcal had slightly higher levels of serum total cholesterol at ages 4 years (5.1 mg/dl higher) and 7 years (5.4 mg/dl higher), and higher levels of LDL cholesterol at ages 4 years (6.4 mg/dl higher) and 7 years (2.4 mg/dl higher) than children with consistently low intakes of saturated fat per 1000 kcal (Table 4). This positive relationship was not found when saturated fat was examined as total intake per day or intake per kilogram body weight.

Children with consistently high intakes of animal fat weighed 2.4 kg more at 4 years of age and 5.6 kg more at age 7 years (both p < 0.05) than those with consistently low intakes of animal fat (Table 5). This relationship disappeared when animal fat was expressed in terms of energy intake. For the Rohrer Index (wt/ht^3) the differences were 0.5 kg/m^3 at age 4 years and 0.7 kg/m^3 at age 7 years between infants having consistently high vs. those having consistently low intakes of animal fat. When animal fat intake was adjusted for either energy or body weight, the difference in the Rohrer Index became even smaller. Other dietary components including total fat and protein showed similar results as animal fat.

Table 3. Comparison of Serum Total Cholesterol and LDL Cholesterol Levels from 50 Young Children Stratified by Having Persistently High (Upper Tertile) Versus Persistently Low (Lower Tertile) Intakes of Exogenous Cholesterol. Bogalusa Heart Study

<table>
<thead>
<tr>
<th>Dietary cholesterol</th>
<th>mg/day</th>
<th>mg/1000 kcal</th>
<th>mg/kg body weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower tertile</td>
<td>Upper tertile</td>
<td>Lower tertile</td>
</tr>
<tr>
<td>Age 4 years</td>
<td>20</td>
<td>155.4 ±4.7</td>
<td>15</td>
</tr>
<tr>
<td>7 years</td>
<td>18</td>
<td>164.3 ±4.9</td>
<td>13</td>
</tr>
<tr>
<td>Age 4 years</td>
<td>20</td>
<td>96.0 ±4.9</td>
<td>15</td>
</tr>
<tr>
<td>7 years</td>
<td>15</td>
<td>93.1 ±6.2</td>
<td>13</td>
</tr>
</tbody>
</table>

Values are means ± SE. No. = number of children. Children remained in the lower or upper tertile for at least three of the five intake periods. *p<0.05.

Table 4. Comparison of Serum Total Cholesterol and LDL Cholesterol Levels from 50 Young Children Stratified by Having Persistently High (Upper Tertile) Versus Persistently Low (Lower Tertile) Intakes of Saturated Fat. Bogalusa Heart Study

<table>
<thead>
<tr>
<th>Saturated fat</th>
<th>g/day</th>
<th>g/1000 kcal</th>
<th>g/kg body weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower tertile</td>
<td>Upper tertile</td>
<td>Lower tertile</td>
</tr>
<tr>
<td>Age 4 years</td>
<td>18</td>
<td>164.8 ±5.7</td>
<td>14</td>
</tr>
<tr>
<td>7 years</td>
<td>14</td>
<td>171.6 ±7.1</td>
<td>15</td>
</tr>
<tr>
<td>Age 4 years</td>
<td>18</td>
<td>104.6 ±6.0</td>
<td>14</td>
</tr>
<tr>
<td>7 years</td>
<td>14</td>
<td>92.1 ±5.5</td>
<td>15</td>
</tr>
</tbody>
</table>

Values are means ± SE. No. = number of children. Children remained in the lower or upper tertile for at least three of the five intake periods. *p<0.05.
Table 6 shows how the change in dietary cholesterol intake with age is related to the change in serum lipid levels over the same ages. From ages 6 months to 1 year, the change in dietary cholesterol was not significantly associated with either the change in serum total cholesterol or LDL cholesterol. From ages 6 months to 4 years, however, the change in total dietary cholesterol intakes per day was significantly associated with both the changes in serum total cholesterol ($r = 0.50, p < 0.01$) and LDL cholesterol levels ($r = 0.42, p < 0.01$). Whether dietary cholesterol is expressed per 1000 kcal or per kg body weight, these same correlations remained statistically significant. No significant correlations were found between the changes in intakes of saturated fat with changes in serum total cholesterol and LDL cholesterol levels.

The relationship of changes in intakes of protein, fat, and starch were significantly associated with the changes in subscapular skinfold thickness (Table 7). From 6 months to 4 years of age, the changes in total protein ($r = 0.31, p < 0.05$), total fat ($r = 0.25, p < 0.08$), starch ($r = 0.31, p < 0.05$), and energy ($r = 0.39, p < 0.01$) intakes per day were significantly associated with changes in subscapular skinfold thickness. However, when total protein, total fat, and starch were expressed per 1000 kcal or per kg body weight, the correlations with subscapular skinfold thickness were not significant from 6 months to 4 years of age.

### Discussion

Dietary studies within populations have not shown striking relationships to CV risk factors, despite those seen in cross-cultural comparisons and by experimental observations on humans or on nonhuman primates. However, our studies of infants at 6 months and 1 year of age clearly showed a relationship to serum lipid and lipoprotein levels. By conjecture, the rapid metabolic rate, the greater intake of food compared to body size, and the homogeneous dietary patterns of the infants and young children may exaggerate diet-lipid relationships.

**Table 5. Weight and Rohrer Index Levels from 50 Young Children Stratified by Having Persistently High (Upper Tertile) Versus Persistently Low (Lower Tertile) Intakes of Animal Fat. Bogalusa Heart Study**

<table>
<thead>
<tr>
<th>Age</th>
<th>No.</th>
<th>Lower tertile</th>
<th>Upper tertile</th>
<th>No.</th>
<th>Lower tertile</th>
<th>Upper tertile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 years</td>
<td>16</td>
<td>16.2 ± 0.4</td>
<td>10</td>
<td>18</td>
<td>16.9 ± 0.6</td>
<td>12</td>
</tr>
<tr>
<td>7 years</td>
<td>15</td>
<td>23.7 ± 1.2</td>
<td>10</td>
<td>14</td>
<td>25.8 ± 1.6</td>
<td>9</td>
</tr>
<tr>
<td>Rohrer index (wt/ht³)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 years</td>
<td>16</td>
<td>15.4 ± 0.3</td>
<td>10</td>
<td>17</td>
<td>15.6 ± 0.3</td>
<td>12</td>
</tr>
<tr>
<td>7 years</td>
<td>15</td>
<td>13.1 ± 0.4</td>
<td>10</td>
<td>14</td>
<td>13.9 ± 0.6</td>
<td>9</td>
</tr>
</tbody>
</table>

Values are means ± SE. No. = number of children. Children remained in the lower or upper tertile for at least three of the five intake periods.

*p < 0.05.

**Table 7. Correlation of Change in Dietary Components with Change in Subscapular Skinfold in Early Childhood. Bogalusa Heart Study**

<table>
<thead>
<tr>
<th>Dietary component</th>
<th>6 months vs. 1 year</th>
<th>6 months vs. 4 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in subscapular skinfold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in total protein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total per day</td>
<td>-0.02</td>
<td>0.31*</td>
</tr>
<tr>
<td>Per 1000 kcal</td>
<td>0.03</td>
<td>0.08</td>
</tr>
<tr>
<td>Per kg body weight</td>
<td>-0.02</td>
<td>0.18</td>
</tr>
<tr>
<td>Change in total fat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total per day</td>
<td>0.01</td>
<td>0.25</td>
</tr>
<tr>
<td>Per 1000 kcal</td>
<td>-0.02</td>
<td>-0.20</td>
</tr>
<tr>
<td>Per kg body weight</td>
<td>-0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>Change in starch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total per day</td>
<td>0.12</td>
<td>0.31*</td>
</tr>
<tr>
<td>Per 1000 kcal</td>
<td>0.21</td>
<td>0.07</td>
</tr>
<tr>
<td>Per kg body weight</td>
<td>0.09</td>
<td>0.19</td>
</tr>
</tbody>
</table>

*p < 0.05.
The dietary intakes of Bogalusa children are comparable with national survey data. However, energy intakes of Bogalusa children are higher than earlier reports. Several circumstances may account for the high energy intakes that were reported in this study. Mothers or care-givers were the respondents for these 24-hour recalls and may not accurately report their child's intake inasmuch as their children are not under their care for a total 24-hour period. Many of the infants in the cohort spent most of their waking hours in nurseries or day-care facilities. Respondents for others often overestimated intake, in that they were asked to reflect a usual 24-hour food intake using the previous 24-hour eating period as a guide. Thereby, they may have reported additional amounts of food which they expected their children to consume but which were not actually consumed. Finally, we have observed that estimates of meat intake, especially during the evening meal, are difficult to assess. Often meat quantities are reported to be greater than those actually eaten. Because of this tendency, dietary components in our study were expressed and analyzed per 1000 kcal to adjust for energy intake and potential overestimation.

In general, these infants and young children are consuming a typical American diet high in total fat (especially saturated fat), cholesterol, and sucrose; moderate in protein; and low in complex CHO. In addition, there is excessive sucrose consumption, noted in the high Su/St ratio of 1.5 at 4 years of age, which is considerably greater than 1.1 noted in studies at later childhood ages. The high sucrose intakes at an early age may play a role in the development of, not only dental caries, but also childhood obesity.

Consistent tracking correlations for dietary cholesterol among the children began at age 2, with a correlation coefficient of 0.49 in dietary cholesterol intake between the ages of 2 and 4 years. Consistent tracking of total fat (r = 0.53) and energy intake (r = 0.59) also has implications for the development of childhood obesity. Dietary cholesterol and saturated fat have been reported to be positively related to serum cholesterol and lipoprotein levels. Data from this study confirm the relationship between dietary cholesterol and serum cholesterol and LDL cholesterol levels in young children. Children with high intakes of dietary cholesterol had higher serum cholesterol levels than children with lower intakes of cholesterol. This relationship continued to exist even after adjusting dietary cholesterol for energy intake and body weight. On the other hand, the present study shows that the relationship between saturated fat and serum cholesterol and LDL cholesterol was not consistent and, therefore, may not be a strong contributor to these serum variables.

Parent-child associations of height, weight, subscapular skinfold thickness, blood pressure, and serum lipid and lipoprotein levels were observed in this same cohort of infants and their parents. The most significant relationship between parents and their children was for height and weight. A relationship between parents and their children for serum total cholesterol was also noted at various ages. This relationship was not consistent from year to year, however. Significant correlations between nutrient intake of parents and children were documented for total CHO, saturated fat, polyunsaturated fat, and calories consumed. Parents' intake of cholesterol did not correlate with that of their children. After adjustment was allowed for race, age, and sex, however, the parent-child association of dietary cholesterol intake was significant.

Implications

Relationships between diet and risk-factor variables have now been documented in children 6 months to 4 years of age. The observation of tracking and noting the relationships of CV risk factors and specific dietary components at an early age underscore the necessity of a population approach to prevention. Identification by physicians of high-risk eating behaviors in young children may facilitate change in children's eating habits before patterns are maintained over time.

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