Cardiovascular diseases (CVD) are the leading cause of death in the United States and worldwide.¹ Although the clinical manifestations of CVD most commonly begin to appear in middle age, the underlying pathophysiological processes are evident in childhood and adolescence.²,³ Several routinely measured traditional CVD risk factors, including obesity, hypertension, dyslipidemia, glucose intolerance, and tobacco smoke exposure are known to cause CVD. No children had ideal levels for either zero or all 4 metrics. Ideal healthy diet score was least prevalent, ranging from 0 to 0.1%, whereas ideal blood pressure was most prevalent ranging from 88% to 93% across sex, race/ethnicity groups. Ideal BMI was less frequent at ages 6 to 11 years than at ages 2 to 5 years (67% versus 77%). Approximately 40% of children had intermediate or poor total cholesterol levels. The dietary intake of diet score components was associated with BMI, which was associated with blood pressure and total cholesterol.

**Background**—The American Heart Association recently defined cardiovascular health (CVH) to monitor it over time for all Americans. Nationally representative prevalence estimates for children under 12 years according to sex and race/ethnicity have not been reported.

**Methods and Results**—The study sample comprised 8961 children aged 2 to 11 years from 2003 to 2010 National Health and Nutrition Examination Surveys. National prevalence of ideal, intermediate, and poor CVH as defined by American Heart Association was estimated for each of 4 available metrics (body mass index [BMI], healthy diet score, total cholesterol, and blood pressure). No children had ideal levels for either zero or all 4 metrics. Ideal healthy diet score was least prevalent, ranging from 0 to 0.1%, whereas ideal blood pressure was most prevalent ranging from 88% to 93% across sex, race/ethnicity groups. Ideal BMI was less frequent at ages 6 to 11 years than at ages 2 to 5 years (67% versus 77%). Approximately 40% of children had intermediate or poor total cholesterol levels. The dietary intake of diet score components was associated with BMI, which was associated with blood pressure and total cholesterol.

**Conclusions**—Ideal CVH status for BMI, total cholesterol, and blood pressure was prevalent in young children, whereas ideal diet was rare. Diet and BMI were important components to achieve ideal CVH metrics in children. Limited availability of data for all CVH metrics is a major obstacle for CVH assessment in the youngest age groups and represents an important missed opportunity for surveillance and secular trends analyses with aging. (Circ Cardiovasc Qual Outcomes. 2015;8:164-171. DOI: 10.1161/CIRCOUTCOMES.114.001274.)

**Key Words:** children ■ epidemiology

Cardiovascular diseases (CVD) are the leading cause of death in the United States and worldwide.¹ Although the clinical manifestations of CVD most commonly begin to appear in middle age, the underlying pathophysiological processes are evident in childhood and adolescence.²,³ Several routinely measured traditional CVD risk factors, including obesity, hypertension, dyslipidemia, glucose intolerance, and tobacco smoke exposure are known to cause CVD. Maintenance of optimal levels of CVD risk factors from young ages, even from childhood, has been shown to be associated with a substantially lower burden of subclinical CVD⁴ and subsequent CVD incidence and mortality in adulthood.⁵,⁶ These observations underscore the importance of understanding the current status of cardiovascular health (CVH) among children.

American Heart Association (AHA)’s 2020 Strategic Impact Goal defined CVH and set the goal of a 20% improvement in CVH of all Americans by 2020.⁵ Cross-sectional data have appeared to indicate a successive decline in prevalence of ideal CVH from childhood and adolescence through young adulthood to middle and older ages.¹⁰-¹² However, detailed data on the current CVH status among US children are sparse. There are reasons for concern. The prevalence of obesity among US children tripled from 1971 to 1974 to 2007 to 2008,¹³,¹⁴ and childhood obesity increases the likelihood of developing cardiovascular risk factors and consistently predicts adult CVD.¹⁵,¹⁶ Nutrition in early life may have long-term influences on CVH in adulthood.¹⁷ Energy-dense and nutrient-poor dietary intake in childhood can lead to obesity and unfavorable levels of CVH components, further putting children and adolescents at risk for CVD.¹⁸ Obtaining a more clear understanding of the status of CVH in children at young ages is a critical starting point for promoting maintenance of CVH and primordial prevention of CVD.

Using nationally representative The National Health and Nutrition Examination Surveys (NHANES) data conducted
WHAT IS KNOWN

- Maintenance of optimal levels of cardiovascular disease risk factors from childhood and young ages has been shown to be associated with a substantially lower burden of subclinical cardiovascular disease and subsequent cardiovascular disease incidence and mortality in adulthood.
- Detailed data on current cardiovascular health status among US children are sparse.

WHAT THE STUDY ADDS

- This nationally representative analysis demonstrates that ideal cardiovascular health status for body mass index, total cholesterol, and blood pressures is prevalent in young children.
- The majority of children exhibit 2 or 3 ideal cardiovascular health components, and no children have either 0 or all 4 ideal cardiovascular health metrics; ideal diet is extremely rare in children.
- Body mass index and diet are significantly associated with blood pressure, total cholesterol level in children.

From 2003 to 2010, we estimated age-, sex-, and race/ethnicity-specific prevalence of available CVH metrics in US children aged 2 to 11 years. In addition, we report sex- and race-specific prevalence estimates for children having 0 to 4 available CVH metrics at ideal levels. Further, we examine associations between body mass index (BMI) and healthy diet score, total cholesterol, and blood pressure, which add to understanding of these critical aspects of CVH in children. These estimates provide current national reference data for monitoring progress toward achievement for the AHA 2020 Strategic Impact Goal at ages below 12 years.

Methods

Study Sample

Detailed methods and protocols for NHANES are reported elsewhere. Children aged from 2 to 11 years who attended both mobile and home examinations in the 2003 to 2004, 2005 to 2006, 2007 to 2008, and 2009 to 2010 NHANES cycles were eligible for this study. The analysis sample for this report consisted of 8961 children aged from 2 to 11 years at the time of examination. Any child with an eligible measurement was included for the specific analyses for individual CVH metrics. Only children aged 8 to 11 years with available measures for all 4 CV health metrics could be included in the analyses examining the number of ideal CVH metrics. Written informed consent was given by all participants, and the study design, data collection, and analyses were performed in accordance with the ethical standards of the supervising institutional review boards of all centers involved. Age, sex, and race/ethnicity compositions for each metric were shown in Table 1 in the Data Supplement. Race/ethnicity was categorized as non-Hispanic White, non-Hispanic Black, American Hispanic, or Other.

Cardiovascular Health Metrics

AHA defined CVH based on 7 metrics, including BMI, total cholesterol, blood pressure, diet score, current smoking, physical activity, and fasting blood glucose. All components of CVH are categorized as poor, intermediate, and ideal according to the criteria outlined in the AHA 2020 Strategic Impact Goals. Components of BMI, total cholesterol, blood pressure, and diet score were assessed in this study. Data on the other 3 components (current smoking, physical activity, and fasting blood glucose) were not collected in the study. Criteria for CV health for children <12 years old are outlined in Table 1.

BMI was calculated as the percentile of weight (kg)/height (m²) according to the 2002 Centers for Disease Control and Prevention Growth Charts for the United States. BMI was categorized as ideal (<85th percentile), intermediate (85th–95th percentile), and poor (>95th percentile). Total cholesterol level was defined as ideal (<170 mg/dL), intermediate (170–199 mg/dL), and poor (≥200 mg/dL). Blood samples were obtained and sent to central laboratories for determination of blood lipids as described in NHANES Laboratory/Medical Technologists Procedures Manual [http://www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm].

Dietary intake was assessed via 2 interviewer-administered 24-hour recalls. The procedure was conducted with a proxy (usually a parent or guardian). The AHA healthy diet score included 5 dietary criteria goals shown in Table: fruits and vegetables ≥4.5 cups/day; fish ≥2 two 3.5 ounce servings/week; whole grains ≥3 1 ounce servings/day; sodium <150 mg/day; added sugar in sugar-sweetened beverages ≤450 kcal/week. All dietary factors were calculated using the MyPyramid Equivalents Database according to the methodology established by the USDA Center for Nutrition Policy and Promotion. Children were categorized by the number of intake goals they achieved as having an ideal (4–5 components), intermediate (2–3 components), or poor (0–1 component) healthy diet score.

Statistical Analysis

All analyses were performed using SAS 9.2 (SAS institute, Cary, NC). To incorporate the complex multistage sampling design of NHANES in the statistical analysis, SAS procedures SURVEYFREQ and SURVEYMEANS were used. Sample weights for laboratory and physical examination data were used to estimate the number of noninstitutionalized US children in each age, sex, and race/ethnicity group as appropriate. Final sampling weights were divided by the number of combined surveys to estimate population averages. Sample weights and design are incorporated in calculating prevalence estimate and standard errors. For prevalence estimates, nonoverlapping 95% confidence intervals (CIs) indicate statistical significance. The 95% CIs were calculated using the Wald method, which is based on a t-statistic with degrees of freedom equal to the difference between the number of primary sampling units and the number of strata. Age stratification was further applied to prevalence estimates for BMI and total cholesterol to examine patterns with age. Age-, sex-, and race/ethnicity-adjusted, survey-weighted correlation coefficients were used to examine the associations of BMI and each of the other metrics, including the healthy diet score and each of its components.

Results

Our final analysis sample included 8961 individuals, representing ~43.6 million noninstitutionalized US children aged 2 to 11 years. The study sample comprised 4518 boys and 4443 girls, with the mean age of 6.8 years. The race/ethnic composition of the sample was predominantly non-Hispanic white (58%), followed by non-Hispanic black (15%), Mexican American (15%), and other (12%).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence, % (95% CI)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Body mass index (ages 2–11 y)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor (&gt;95th Percentile)</td>
<td>(n=4511)</td>
<td>(n=4435)</td>
</tr>
<tr>
<td>Intermediate (85th–95th Percentile)</td>
<td>17.0 (15.6–18.4)</td>
<td>14.7 (13.3–16.1)</td>
</tr>
<tr>
<td>Ideal (&lt;85th Percentile)</td>
<td>14.3 (13.1–15.6)</td>
<td>15.3 (13.9–16.6)</td>
</tr>
<tr>
<td><strong>Age 6–11</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor (&gt;95th Percentile)</td>
<td>(n=2673)</td>
<td>(n=2696)</td>
</tr>
<tr>
<td>Intermediate (85th–95th Percentile)</td>
<td>12.3 (10.6–14.1)</td>
<td>11.2 (9.3–13.2)</td>
</tr>
<tr>
<td>Ideal (&lt;85th Percentile)</td>
<td>13.0 (10.6–15.5)</td>
<td>12.0 (10.3–13.7)</td>
</tr>
<tr>
<td><strong>Body mass index (ages 2–11 y)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor (&gt;95th Percentile)</td>
<td>(n=1838)</td>
<td>(n=1739)</td>
</tr>
<tr>
<td>Intermediate (85th–95th Percentile)</td>
<td>74.6 (71.7–77.5)</td>
<td>76.8 (74.3–79.2)</td>
</tr>
<tr>
<td><em><em>Healthy diet score</em> (ages 5–11 y)</em>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor (0–1 components)</td>
<td>85.6 (83.7–86.7)</td>
<td>83.1 (81.2–84.9)</td>
</tr>
<tr>
<td>Intermediate (2–3 components)</td>
<td>14.3 (12.4–16.3)</td>
<td>16.9 (15.0–18.7)</td>
</tr>
<tr>
<td>Ideal (4–5 components)</td>
<td>0.03 (0–0.08)</td>
<td>0.05 (0–0.11)</td>
</tr>
</tbody>
</table>

Detailed prevalence estimates for 4 specific health behaviors and factors by age and sex are shown in Table, and population estimates are shown in Table II in the Data Supplement. Prevalence estimates stratified by sex and race/ethnic groups are displayed in Figures 1 and 2 and Tables III and IV in the Data Supplement.

**Body Mass Index (Ages 2–11 Years, N=8946)**

Approximately 70% of children aged 2 to 11 years exhibited ideal BMI (BMI <85th Percentile). Preschool children aged 2 to 5 years had significantly higher prevalence of ideal BMI than elementary school children aged 6 to 11 years. The prevalence of ideal BMI differed between these 2 age groups in boys (74.6% versus 65.4%) and in girls (76.8% versus 66.3%), respectively. 17% of boys (or 3.8 million) and 15% of girls (or 3.1 million) were obese (BMI >95th Percentile), with 15% of boys and girls (or 6.4 millions) overweight (BMI 85th–95th percentile). Among girls, African Americans had the largest proportion classified as having poor BMI, and non-Hispanic white girls had the least difference in prevalence of poor BMI and ideal BMI between these 2 age groups. Among boys, Mexican Americans had the greatest difference in prevalence of poor and ideal BMI between these 2 age groups.

**Healthy Diet Score (Ages 5–11 Years, N=6169)**

Healthy diet score was the least favorable of the 4 available CVH metrics. Less than 1% of children aged 5 to 11 years were classified as having an ideal healthy diet score (4 or 5 out of 5 components), and <20% of children exhibited an intermediate healthy diet score (2 or 3 out of 5 components). There was no significant difference in diet score status across all sex and race/ethnic groups. Further, we examined the proportions of children who met the goals for each of the 5 individual components of the healthy diet score as shown in Figure 3. The whole grain metric was the least frequently achieved component, with only 3.0% of boys and 2.4% of girls meeting this goal. Approximately 10% of boys and girls met the goal of sodium intake <1500 mg daily. More than 50% of children consumed more than the recommend amount of sugar-sweetened
beverages. Fewer than 10% of boys and girls attained the recommended levels of fruit and vegetable or fish intake.

**Total Cholesterol (Ages 6–11 Years, N=4450)**

Although 60% of children aged 6 to 11 years had ideal total cholesterol levels (<170 mg/dL), 30% (or 6.4 millions) of children exhibited elevated total cholesterol in the intermediate levels (170–199 mg/dL) and <10% (or 2.2 millions) of children had poor total cholesterol levels (≥200 mg/dL) across all sex and race/ethnic groups, except for non-Hispanic black boys, at 12.2%. Overall, the proportion with poor total cholesterol levels was higher at older ages in boys compared with girls. Prevalence in boys was 8% at age 6 to 8 years and 12% at ages 9 to 11 years; in girls, these figures were 8% and 10%, respectively. The largest differences across age groups were observed among non-Hispanic White children. We further examined the lipid profiles to determine whether sex differences in total cholesterol could be as a result of sex-specific differences in the cholesterol subfractions by age. We did not observe substantial differences in high-density lipoprotein cholesterol and low-density lipoprotein cholesterol between boys and girls at the examined ages. However, older boys exhibited lower triglyceride levels than younger boys (80.3 versus 92.5 mg/dL) and older girls had higher triglyceride levels than younger girls (97.4 versus 76.3 mg/dL).

**Blood Pressure (Ages 8–11 Years, N=3611)**

The majority of children aged 8 to 11 years (or 17.2 millions) were classified as having ideal blood pressure (systolic and diastolic BP <90th percentile), which was the most favorable of the 4 available CVH metrics. Boys and girls had similarly low prevalence of poor blood pressure levels (3% and 4%,
respectively), and there were no notable differences across race/ethnic groups at these ages.

**Numbers of CVH Metrics (Ages 8–11 Years, N=3032)**

Prevalence estimates for the number of ideal CVH metrics (0–4) exhibited by boys and girls are shown in Figure 4. None of the children aged 8 to 11 years had either 0 or all 4 CVH metrics at ideal levels. Overall, children most frequently exhibited 2 or 3 ideal CVH components. The prevalence of having 3 CV health factors at ideal levels were 39% (or 3.1 millions) among boys and 38% (or 2.8 millions) among girls. Non-Hispanic black children displayed the lowest prevalence of having 3 CVH components at ideal levels.

**Associations Between BMI and Other CVH Metrics (Ages 8–11 Years)**

The age-, sex-, and race/ethnicity-adjusted partial correlation coefficients of BMI with other CVH metrics were calculated. BMI was significantly positively associated with total cholesterol levels ($r=0.08; 95\% CI, 0.04–0.11$), systolic blood pressure ($r=0.29; 95\% CI, 0.26–0.32$), and diastolic blood pressure ($r=0.09; 95\% CI, 0.06–0.13$). Among the 5 individual components of the healthy diet score, dietary intakes of whole grain, sodium, and sugar-sweetened beverages were significantly associated with BMI ($r=-0.03, 95\% CI, -0.05$ to $-0.01; r=0.04, 95\% CI, 0.02–0.06; r=0.07, 95\% CI, 0.05–0.09$, respectively). On the other hand, dietary intakes of fish, fruit, and vegetable were not significantly related with BMI.

**Discussion**

We presented data on nationally representative prevalence estimates for 4 CVH metrics among US children aged 2 to 11 years by sex, age, and race/ethnicity. Overall, the majority of children exhibited 2 or 3 ideal CVH components with no children having either 0 or all 4 CVH metrics at ideal levels. Approximately 30% of children were obese or overweight. Older children (6–11 years) had higher prevalence of obesity compared with younger age groups (2–5 years), particularly in minority populations. Fewer than 1% of children aged 5 to
11 years had an ideal healthy diet score and the proportions of children who met the goal levels of intake for individual components—in particular, whole grains and sodium were strikingly low in general. Appropriately 40% of children aged 6 to 11 years were classified as having intermediate or poor levels of total blood cholesterol. More than 90% of children aged 8 to 11 years exhibited ideal levels of blood pressure. BMI was significantly associated with blood pressure, cholesterol, and healthy diet score components in these young children.

Atherogenesis and atherosclerosis progression can begin in childhood. Data from the Bogalusa Heart Study and the Pathobiological Determinants of Atherosclerosis in Youth (PDAY) study demonstrated associations of CV risk factors with the development and progression of atherosclerotic processes in children.22,23 Pooled analyses from 4 longitudinal studies recently showed that CV risk factors measured at age ≥29 years were associated with subclinical atherosclerosis (carotid intima-media thickness) in adulthood 2 decades later, suggesting that children with unfavorable levels of major CVD risk factors may be on the fast-track for development of premature clinical CVD events.24 Similarly, the Cardiovascular Risk in Young Finns Study recently reported that the AHA’s CV health metrics measured in children were associated with subsequent cardiometabolic outcomes and carotid artery intima-media thickness in adulthood.25 Therefore, policies and practices aimed at primordial prevention and preservation of the ideal CVH profile from childhood into adulthood should become the cornerstone of CVH promotion and disease prevention in healthcare and public health.

The prevalence of overweight and obesity among children in the United States increased from 6% to 18% and 16% to 33%, respectively, between 1976 and 2010.26 Several unfavorable eating habits frequently observed among children, including extensive intake of energy-dense, nutrient-sparse foods and beverages, seem to play a significant role in the rising trend of pediatric obesity.27,28 Higher consumption of sugar-sweetened beverages is associated with excess weight gain and obesity, and greater intake of fruits and vegetables are associated with a lesser increase in BMI in children.29–32 This NHANES data showed that the majority of young children consume a diet that is of poor quality. The significant associations between healthy diet score and BMI further differentiate major contributions of certain dietary habits to the high prevalence of obesity in children.

Obesity is associated with major CVD risk factors, including hypertension, dyslipidemia, and diabetes mellitus, and to increased long-term risks for cardiovascular disease.33–35 One recent study reported that 67% of severely obese children aged ≤12 years already exhibited ≥1 clinically elevated CVD risk factors. They showed that ≈50% of young children who were obese already had hypertension.36 In the present investigation, we likewise observed significant correlations between BMI and blood pressure and cholesterol levels, consistent with these previous findings.

Higher childhood blood pressure is a risk factor for hypertension in early adulthood.37 The marked increase in the prevalence of childhood obesity and the strong causal association between obesity and hypertension is evidence that hypertension is becoming a significant health issue among children and adolescents. Because weight loss through dietary and physical activity interventions has been shown to reduce blood pressure in overweight and obese children,38 reduction of childhood obesity may be a significant preventive intervention for hypertension.

Even though a decrease in the prevalence of elevated total cholesterol among youths has been reported between 1988 to 1994 and 2007 to 2010, almost 10% of youths had elevated total cholesterol in 2007–2010.39 A positive association between BMI and unfavorable serum lipid concentrations has been reported; thus further research may be needed for screening approaches among obese children.40,41 Total cholesterol concentration differs related to the maturity index in boys and girls, being lower in pubertal children than prepubertal children.42 In this study population, 11-year-old children comprised the 20% of this study population who are generally entering puberty, so the total cholesterol levels may be underestimated.

The status of all 7 AHA CVH metrics for US adolescents from age 12 to 19 has been reported recently.43 Compared with our results of children below age 12, adolescents were found to have lower prevalence of ideal levels of BMI (66% in males and 67% in females), healthy diet score (0% in males and females), and blood pressure (78% in males and 90% in females). There is higher prevalence of ideal total cholesterol level among adolescents, which may be a result of decreasing total cholesterol in adolescence.44 Therefore, our results, together with those at ages 12 to 19 years, show a general loss of ideal CVH from childhood to adolescence. Limited availability of data for all CVH metrics in early childhood is a major obstacle for the assessment of CVH in the youngest age groups and represents an important missed opportunity for surveillance of CVH in the population and analysis of secular trends and changes with aging. NHANES should be expanded to close the serious data gaps to monitor each of the 7 CVH metrics from the earliest feasible ages and permit adequate monitoring of CVH for all Americans.

There are limitations to our evaluations. NHANES data are cross-sectional thereby in themselves precluding causal conclusions. Twenty-four hour dietary recalls provided by parents/guardians who may or may not have witnessed the child’s actual dietary intake have inherent limitations. Furthermore, because it is difficult to estimate caloric intake accurately and to know the appropriate caloric intake for each child based on age, height, growth, and physical activity, we were unable to scale the dietary metrics accurately. Because of this limitation, the metrics for fruit, vegetable, and sugar-sweetened beverages may not be sensitive to the actual intakes of the youngest children. Multiple cycles of NHANES examinations were combined to have sufficient numbers of participants, so variations of prevalence estimates over time may be obscured. The lack of physical activity data meant we were unable to assess its contribution to BMI and other CV health metrics. Diabetes mellitus status was not included in the NHANES metrics for children, so these data were unavailable. However, given the strong relations of obesity and diabetes mellitus in adults, the increasing prevalence of childhood obesity may likely drive the concomitant increase of type 2 diabetes mellitus rates in children. Previous data reported that <2% of 7th grade students were smokers; thus, it can be expected that the rate would be lower in younger children.
In conclusion, with the exception of diet rated as intermediate or poor for nearly all children, the majority of children observed from age 2 to 11 years had ideal CVH for BMI, total cholesterol, and blood pressure, thereby starting life with generally favorable CVH metrics. The prevalence of ideal metrics declines with age, both during childhood and adolescence. It seems that children in the United States are losing their ideal CVH status, thereby undermining achievement of the AHA 2020 Impact Goal to improve CVH by 20%. Efforts to preserve and promote CVH in childhood and adolescence are urgently needed to reduce the loss of this precious health asset, a consequence in large part to the rising prevalence of obesity. Promoting the recommended dietary habits, physical activity as part of daily life, and arresting the growing trend of obesity are keys to achieving more favorable CVH metrics and long-term freedom from cardiovascular disease.

Disclosures
None.

References


Status of Cardiovascular Health in US Children Up to 11 Years of Age: The National Health and Nutrition Examination Surveys 2003–2010
Hongyan Ning, Darwin R. Labarthe, Christina M. Shay, Stephen R. Daniels, Lifang Hou, Linda Van Horn and Donald M. Lloyd-Jones

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