Percent Body Fat and Chronic Disease Risk Factors in U.S. Children and Youth

Scott B. Going, PhD, Timothy G. Lohman, PhD, Ellen C. Cussler, MS, Daniel P. Williams, PhD, John A. Morrison, PhD, Paul S. Horn, PhD

Background: The dramatic increase in pediatric obesity has renewed interest in accurate methods and screening indexes for identifying at-risk children and youth. Whether age-specific standards are needed is a factor that remains uncertain.

Purpose: This study was designed to describe the age-specific fatness–risk factor relationship in boys and girls across a wide age range.

Methods: Data were from 12,279 white, black, and Mexican-American children and adolescents from the National Health and Nutritional Examination Surveys (NHANES) III (1998–1994) and IV (1999–2004). Children were grouped based on percent fat, estimated from subscapular and triceps skinfolds, and the age-specific relationships between percent fat and chronic disease risk factors (e.g., blood pressure, lipids and lipoprotein levels, glucose, insulin, and circulating C-reactive protein levels) were described in boys and girls, aged 6–18 years.

Results: Percent fat was significantly related to risk factor levels. At higher levels of percent fat, the prevalence of adverse cardiovascular disease risk factors was higher, particularly above 20% fat in boys and above 30% fat in girls. In boys and girls, the interaction term age by percent fat was a significant predictor of risk factors, whereas the percent fat by race interaction term was nonsignificant.

Conclusions: The results demonstrate a strong relationship between chronic disease risk factors and percent fat in children and youth that varies by age in boys and girls.

Introduction

Childhood and adolescent overweight and obesity are important public health concerns. The most recent U.S. national surveys indicate that 31.7% of youth are overweight,\(^1\) and more than half of this group, 16.9%, are obese. The high prevalence of overweight and obesity in children and youth, with its attendant health risks,\(^2\)–\(^7\) has renewed interest in the development of accurate methods for body composition assessment and screening indexes for identifying children and youth at risk for obesity-related comorbidities.

Common definitions of pediatric overweight and obesity are based on the BMI. Early recommendations set the 85th percentile of age- and gender-specific BMI as the level at which children and youth were considered at risk of overweight (now called overweight instead of at risk of overweight), and the corresponding 95th percentile of BMI was defined as overweight (now called obesity).\(^8\) These definitions continue to be used today, although present-day surveys compare children and youth to BMI distributions that existed in the 1960s and 1970s.\(^9\)

Although BMI is a practical, easy-to-obtain index, its application assumes that differences in BMI among individuals reflect differences in adiposity and that individuals with identical BMI have identical body composition. Clearly these assumptions are not valid,\(^10\)\(^11\) although it is the degree of variation that matters when setting a screening standard. A more important limitation may be the arbitrariness of a definition based on the population distribution of the BMI rather than an a priori criterion, such as disease risk.
Although studies have shown that increasing levels of BMI are associated with higher levels of disease risk especially in youth, some studies have shown that worrisome levels of risk occur at percentiles higher than the 95th percentiles of BMI,\(^9\) whereas only modest risk is associated with the current recommendations.\(^6,12\) Age-, gender-, and race/ethnicity-related variation in the BMI–body fat relationship potentially limit the widespread use of BMI for assessing disease risk.\(^13-15\) An alternative approach to setting obesity standards is to study the association of a more direct measure of adiposity with risk factors to determine the level of fatness associated with high levels of risk factors, although the challenges of measuring fatness directly outside of the laboratory are acknowledged. Using this approach, body fat levels ranging from 20%–25% in boys and 30%–35% in girls have been shown to be associated with health risk.\(^16-19\) These ranges are remarkably similar, given the differences in samples, sample sizes, and methodology in these studies.

In one of the largest studies of percent fat and risk factors, Williams et al.\(^19\) reported that body fat levels ≥25% in boys and ≥30% in girls were associated with over-representation (excess risk) in the highest fifth of age-, gender-, and race-specific distributions of cardiovascular disease (CVD) risk factors. These fatness levels have been used to differentiate between unhealthy and healthier levels of body fat in children and youth ranging from age 5–18 years (www.cooperinstitute.org/). The appropriateness of applying the same standard across such a wide age range is a factor that has remained uncertain. Developing standards against a surrogate for adiposity such as BMI in absolute units of kg/m\(^2\) is confounded by differential changes in fat and fat-free mass at different stages of maturation that likely influence the relationships between BMI and risk factors, which is why age- and gender-specific BMI percentiles are used.\(^9,20\)

When risk is defined against more direct measures of body fat, the level of body fatness that confers risk may be very similar at different ages. However, due to the changes in hormonal profile and fat-free mass that accompany maturation, the relationships between body fat and risk factors may also vary with age, thereby suggesting that health-related adiposity standards for boys and girls should be defined differently at different ages. Given the uncertainty concerning the influence of age on the fatness–risk factor relationship, the present analysis was undertaken to describe the age-specific percent fat–risk factor relationship in boys and girls across a wide age range in a large sample representative of U.S. boys and girls.

## Methods

### Participants

Data for a cohort of children (aged 6–18 years) were selected from the National Health and Nutritional Examination Surveys (NHANES) III (1988–1994; Series 11 data; \(n=8559\)) and IV (1999–2004; \(n=10,324\)). Standardized interviews, clinical examinations, and laboratory tests were conducted for both surveys. Results were reviewed for the examination and laboratory portions of the surveys, and based on the aim, children were excluded for the following reasons: aged <6 years (\(n=1625\)), for limited numbers of outcome measurements and numerous implausible body weight measures among younger children; race other than white, black, or Mexican-American (\(n=944\)) because sample sizes from other racial groups were too small for meaningful analysis; missing percent fat by skinfolds (triceps and subscapular) (\(n=865\)); evidence of acute inflammation due to infection from self-report or diagnostic coding (\(n=199\)); pregnancy (\(n=30\)); having a pacemaker (\(n=1\)); and taking medication for high blood pressure and/or diabetes (\(n=21\)).

Since missing data were not imputed, the number included in each analysis varied somewhat. Analysis with glucose was limited to boys and girls aged 9–18 years since results for younger children were not available. Analysis with insulin was limited to adolescents since results for children aged <12 years were not collected. The final sample for analysis (\(n=12,279\) children and adolescents) included 6222 boys and 6057 girls.

### Anthropometry

For NHANES III (1998–1994), subscapular and triceps skinfold measurements were taken twice, by two different technicians, in centimeters to the nearest 0.1 cm using Holtain skinfold calipers. Standing height was measured in centimeters to the nearest 0.1 cm using an electronic stadiometer. Weight was measured in kilograms to the nearest 0.1 kg using a Toledo self-zeroing weight scale. The mean of repeated measures was used in the analyses. BMI was calculated as weight (kg) divided by the square of standing height in meters. In NHANES IV (1999–2004), the same standardized protocols were used to measure height and weight. For greater accuracy, the measured heights and weights were fed directly into the Integrated Survey and Information System (ISIS) computer system. Skinfold measurements in NHANES IV (1999–2004) were obtained by a single technician. Detailed training procedures, examination protocols, and procedures for all anthropometric measures can be found on the NHANES website.\(^21\) Quality control checks are included throughout the data collection procedure.\(^22,23\)

### Percent Body Fat

Percent fat was calculated from triceps and subscapular skinfolds using the equations of Williams et al.,\(^19\) which adjust for age-related differences in the composition of the fat-free mass that confound other skinfold equations in children and youth. In this approach, gender- and race-specific regression equations are used to estimate body density from age and the sum of skinfolds using quadratic equations that adjust for the curvilinear nature of the skinfold–body density relationship. Subsequently, body density is converted to percent fat using age-adjusted, gender-specific regression equations that modify the youth-specific body density con-
Blood Pressure

Blood pressure levels were measured by a physician using the appropriate size cuff (based on measured arm circumference) so that the lower edge was 1 inch above the antecubital space. Both systolic and diastolic pressures were measured in millimeters of mercury (mm Hg) three to four times after the participant rested quietly for 5 minutes, and the means of the final two measures were used in the analysis.24,25

Blood Specimens

Blood samples were drawn from survey participants, and serum and/or plasma was analyzed according to standardized NHANES protocols.26-27 Circulating lipid and lipoprotein cholesterol levels, including total cholesterol, high-density lipoprotein cholesterol (HDL-C), and triglycerides, were assessed in milligrams per deciliter. Low-density cholesterol (LDL-C) was calculated (in milligrams per deciliter) from total cholesterol, HDL-C, and triglycerides in those individuals without extremely high triglyceride levels. Circulating C-reactive protein (CRP) levels were assessed in milligrams per liter. Fasting glucose (milligrams per deciliter) from total cholesterol, HDL-C, and triglycerides in those individuals without extremely high triglyceride levels.

Statistical Analysis

For analysis, children were grouped based on percent body fat as follows: for boys, <10.0%, 10.0%–14.9%, 15.0%–19.9%, 20.0%–24.9%, 25.0%–29.9%, and ≥30.0%, and for girls, <20.0%, 20.0%–24.9%, 25.0%–29.9%, 30.0%–34.9%, and ≥35.0%. Similar groupings have been used in past analyses.19 Although the aim in the current study was to stratify by percent fat into as many gender-specific groups (5% fat intervals) as possible, sample sizes became smaller as percent fat increased, and they became limiting above 30% fat in boys and 35% fat in girls.

Children and adolescents were grouped into age, gender, and race-specific quintiles for each risk factor. Binary variables were then constructed from quintiles so that the median (or one) represented membership in the top quintile (top 20%) for the risk factor, and zero (0) represented membership in the bottom four quintiles (lower 80%). HDL-C groups were reverse coded, since it is the lower levels of HDL-C that are worrisome. The numeral one (1) represented membership in the lowest quintile for the risk factor, and zero (0) represented membership in the top four quintiles (upper 80%).

Means and SDs for age, anthropometry, body composition, CVD risk factors, and percentages for race were calculated for boys and girls separately. Cross-tabulation was used to test for differences in the percentages of boys and girls at different ages in the most adverse fifth (or 20%) of each age-, gender-, and race-specific risk factor distribution across percentage body fat levels. Chi-square tests were conducted using the null hypothesis that the percentage of youth in the adverse fifth of the risk factor distribution would be similar across all levels of body fat within each age and gender-specific group. The alpha level for significance was set at α=0.05, two-sided. Chi-square tests were used to identify body fatness levels within each age- and gender-specific group wherein significant under- (<20%) and over-representation (>20%) of the most adverse fifth of the risk factor distribution was present.

To further compare children in the most adverse fifth to children in the more favorable four fifths of a specific risk factor distribution, multiple logistic regression models were developed with levels of percent body fat as the independent variable of interest. Models were adjusted for NHANES (III [1998–1994] or IV [1999–2004]), the ratio of subscapular to triceps skinfolds, race, the interaction of race by percent fat, and the interaction of age by percent fat. In these analyses, the subscapular to triceps skinfold ratio adjusted for the influence of truncal versus limb fat patterning, which may vary with age and race.

Because of a wide range in reported fasting times prior to venipuncture, models predicting glucose and insulin outcomes were compared with and without a covariate for fasting hours. ORs and 95% CIs for percent fat groups were computed showing the odds of being in the most adverse fifth for a risk factor at increasing levels of percent body fat relative to the lowest percent body fat group (referent). All analyses were stratified by gender and age group because of the gender differences in the assignment to percent fat groups and to describe any potential age-related differences in the threshold levels of body fat associated with the most adverse fifth of the risk factor distributions. Analysis was conducted in PASW Statistics Version 17.0.

Results

Approximately 36% of the sample was black, ~36% was Mexican American, and ~28% was white (Table 1). The race distribution was very similar in boys and girls. Using the CDC age- and gender-specific 85th and 95th percentiles of BMI,9 approximately 30% of the boys and girls were overweight or obese, and approximately 15% were obese. Body fat averaged 17.6% of body weight in boys and 23.9% of body weight in girls. The number of boys and girls in each of the gender-specific body fat categories (<10% to ≥30% in boys and <20% to ≥35% in girls) are reported in Table 2. Thirty percent of boys had body fat ≥20% of body weight, and 19% had body fat ≥25% of body weight, levels of percent fat that have been related to elevated CVD risk factors.16,19 Twenty percent of girls had body fat ≥30% of body weight—levels of percent fat that have been related to elevated CVD risk factors.16,19

Odds ratios describing the chances of being in the most adverse risk factor group (highest fifth, except for HDL-C, which was defined as the lowest fifth) are reported by increasing body fat levels in Table 2. All of the ORs were adjusted for survey (NHANES III [1998–1994] or IV [1999–2004]); race; the ratio of subscapular to triceps skinfold thickness (a measure of truncal versus limb fat patterning); and the interactions of percent fat with race and age. In children (aged 6–11 years) and adolescents (aged 12–18 years), the odds of membership in the most adverse risk factor group increased with increasing levels of percent fat in boys and girls. However, there was considerable variation in the magnitude of the ORs and in...
the level of percent fat at which the lower bounds of the 95% CI around the ORs were greater than 1.00.

In part, the variability in the ORs and in the width of the 95% CIs about them reflects the variability in the independent relationships between increasing percent fat levels and the likelihood of membership in each of the most-adverse risk factor groups. The variability in the ORs and in the width of the 95% CIs about them also reflects the variability in the post hoc sampling and sample sizes within the age, gender, and body fat–specific groups, which likewise affect the magnitude and the precision of the OR estimates. The interaction term, percent fat by race, included in the logistic regression analysis with each risk factor, was always nonsignificant in both boys and girls. In boys, there was a greater and more reliable likelihood of being in the most adverse risk factor group above 20% fat. In girls, there was a greater and more reliable likelihood of being in the most-adverse risk factor groups to some extent above 25% fat and, in particular, above 30% fat.

The prevalence of each of the adverse CVD risk factors by age and body fat groups is illustrated in Figure 1 for boys and in Figure 2 for girls. The influence of age and percent fat on the prevalence of high blood pressures, low HDL-C, and high triglyceride levels is shown because these variables (in some combination) are usually included in youth-specific definitions of the metabolic syndrome. The influence of age and percent fat on the prevalence of elevated CRP, glucose, and insulin levels is also shown, as systemic inflammation and insulin resistance may provide common mechanistic links among the CVD risk factors that constitute the metabolic syndrome in youth.

The figures clearly depict the rising prevalence of adverse CVD risk factors at higher levels of percent fat. The sharply rising prevalence of elevated CRP and insulin levels are particularly evident above 20% fat in boys (Figure 1) and above 30% fat in girls (Figure 2). The influence of age and body fat on adverse CVD risk factor prevalence are complex and undoubtedly affected by a variety of biological and behavioral factors, including an effect of age on the prevalence of boys and girls in the most adverse group of any given risk factor at the various levels of percent fat. In multiple logistic regression analyses, the multiplicative interaction term for age × percent fat was a significant predictor (data not shown) of elevated systolic and diastolic blood pressures, elevated total cholesterol levels, elevated triglycerides, elevated LDL-C/HDL-C ratios, elevated CRP levels, and of low HDL-C levels in boys. The interaction term for age × percent fat was likewise a significant predictor (data not shown) of elevated

---

**Table 1. Characteristics of selected children (n=12,279) aged 6–18 years who participated in the NHANES III (1998–1994) or NHANES IV (1999–2004) survey**

<table>
<thead>
<tr>
<th>Boys (n=6,222)</th>
<th>Girls (n=6,057)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td><strong>Race</strong></td>
</tr>
<tr>
<td>12.2 (3.7)</td>
<td>White</td>
</tr>
<tr>
<td>12.1 (3.7)</td>
<td>Black</td>
</tr>
<tr>
<td></td>
<td>Mexican-American</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Unweighted Ms; race limited to white, black, Mexican-American with measurements for triceps and subscapular skinfolds, not pregnant, no pacemaker, no indication of infection, not using blood pressure or diabetes (insulin) medications; body weight ≥10 kg

% fat calculated per Williams et al. 18

Number of blood tests performed was substantially lower than number with race and anthropometry

HDL, high-density lipoprotein; LDL, low-density lipoprotein.
Table 2. ORs\(^a\) for being in the most-adverse fifth of the risk-factor distribution by percent fat within gender- and age-specific groups

<table>
<thead>
<tr>
<th>Risk factor by age in years</th>
<th>Boys (n=6222)</th>
<th>Girls (n=6057)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10.0–14.9</td>
<td>15.0–19.9</td>
</tr>
<tr>
<td></td>
<td>(n=2377)</td>
<td>(n=1189)</td>
</tr>
<tr>
<td>Systolic BP (mm Hg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6–11</td>
<td>1.64 (0.99, 2.71)</td>
<td>2.66 (1.53, 4.63)</td>
</tr>
<tr>
<td>12–18</td>
<td>1.69 (1.19, 2.40)</td>
<td>2.72 (1.85, 4.01)</td>
</tr>
<tr>
<td>Diastolic BP (mm Hg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6–11</td>
<td>1.39 (0.85, 2.28)</td>
<td>1.84 (1.07, 3.17)</td>
</tr>
<tr>
<td>12–18</td>
<td>0.99 (0.75, 1.31)</td>
<td>1.05 (0.76, 1.45)</td>
</tr>
<tr>
<td>Triglycerides (mg/dL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6–11</td>
<td>1.62 (0.97, 2.71)</td>
<td>1.86 (1.05, 3.29)</td>
</tr>
<tr>
<td>12–18</td>
<td>1.43 (0.94, 2.18)</td>
<td>1.80 (1.12, 2.91)</td>
</tr>
<tr>
<td>HDL cholesterol (mg/dL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6–11</td>
<td>1.05 (0.69, 1.61)</td>
<td>1.07 (0.66, 1.73)</td>
</tr>
<tr>
<td>12–18</td>
<td>1.09 (0.78, 1.52)</td>
<td>1.18 (0.80, 1.74)</td>
</tr>
<tr>
<td>C-reactive protein (mg/L)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6–11</td>
<td>1.15 (0.56, 2.36)</td>
<td>1.18 (0.54, 2.56)</td>
</tr>
<tr>
<td>12–18</td>
<td>1.28 (0.83, 1.98)</td>
<td>1.57 (0.96, 2.56)</td>
</tr>
<tr>
<td>Glucose, fasting (mg/dL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6–11</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>12–18</td>
<td>1.23 (0.84, 1.80)</td>
<td>1.12 (0.72, 1.74)</td>
</tr>
<tr>
<td>Insulin (mU/mL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6–11</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>12–18</td>
<td>1.33 (0.61, 2.91)</td>
<td>2.70 (1.17, 6.20)</td>
</tr>
</tbody>
</table>

Note: Comparison groups; boys, percent fat ≤10% (n=767); girls, percent fat ≥20% (n=2106). ORs with parenthetical 95% CIs that do not include 1.00 are shown in bold.

*Adjusted for NHANES III (1998–1994) versus IV (1999–2004); race (white, black, Mexican-American); ratio of triceps to subscapular skinfold thickness; and interaction terms for percent fat with race and age in multiple logistic regression.

BP, blood pressure; HDL, high-density lipoprotein.
systolic blood pressure, elevated triglycerides, and elevated LDL-C/HDL-C ratios in girls.

Discussion

The results of the present analyses show significant relationships between percent body fat estimated from skinfold thicknesses and various chronic disease risk factors in children and adolescents across a wide age span. Although this is not the first study to examine these relationships, the majority of past studies have used BMI as a surrogate for a more direct measure of body composition, which has previously identified limitations.

Given that it is excess adiposity that creates risk rather than excess weight for height per se, studies with more direct measures of fatness are necessary to define risk, especially in children and adolescents who are experiencing changes in both adipose and non-adipose tissues at different rates depending on the stage of maturation. It is acknowledged that the current approach—estimation of body density from skinfolds, followed by conversion to percent fat—is also indirect. Nevertheless, skinfolds provide a more accurate estimate of percent fat than does BMI, and the conversion equations used are designed to adjust for variation in the composition of fat-free mass that confounds other equations used to estimate percent fat from body density in children and youth.

The current findings, in a large sample representative of U.S. children and adolescents, confirm findings in smaller samples, and in samples from other countries. The relationships are particularly striking for insulin and CRP, followed by HDL-C, triglycerides, and blood pressures. Clearly, there is considerable heterogeneity across risk factors; nevertheless, across the age span of the children and adolescents in the present study, there is a clear relationship between higher estimated body fat percentages and an increased risk for more adverse levels of CVD risk factors in boys and girls.

Past attempts to define body composition standards have been largely based on population distributions of BMI. Although age- and gender-specific BMI percentiles are correlated with CVD risk factors, thresholds should be derived using direct measures of adiposity related to increased health risk rather than rely on a population-based distribution of an indirect index of adiposity. In one of the few studies using a criterion-referenced approach, Dwyer and Blizzard proposed thresholds of 20% fat for boys and 30% fat for girls based on at-risk groups for dyslipidemia and hypertension. In a large U.S. sample, Williams et al. identified remarkably similar thresholds of 25% fat in boys and 30% fat in girls that were indicative of an increased risk of being in the highest quintile for blood pressure and serum lipoprotein ratios in children and adolescents. In a relatively large sample of Asian boys and girls aged 9–10 years, Washino et al. reported that fatness above 23% of body weight was related to a greater risk of an adverse atherogenic index. Although there is relatively good agreement across the age groups represented in these studies, the effect of age on the percent fat–risk factor relationships was not investigated directly. This limitation notwithstanding, the results of Williams et al. were used to develop thresholds that have been applied across a wide age range in the FITNESSGRAM® program (www.cooperinstitute.org).

A criticism of this approach has been that “static” thresholds do not take into consideration the normal changes in adiposity that occur with growth and maturation. As shown by Laurson et al., there are predictable age- and gender-specific changes in percent body fat that may influence the percent fat–risk factor relationships. Indeed, the results of the present analyses showed that age modified the relationship for several of the risk factors in both boys and girls, suggesting that age-specific adiposity standards may be useful.

In contrast to age, race/ethnicity was not independently associated either by itself or in its interaction with body fat with adverse CVD risk factor levels. Similarly, in their work, Williams et al. found no effect of race on the percent fat–risk factor relationship in black or white boys and girls from the Bogalusa Heart Study. Their results suggest percent fat standards are robust, and equivalent thresholds can be used in different race/ethnic groups, although more research on this question is warranted.

Whether this is true of the contemporary age- and gender-but not race-specific BMI standards for overweight and obesity is uncertain. Many studies have shown the BMI–percent fat relationship varies among race/ethnic groups, which could potentially confound application of a single BMI cutoff across these groups.

Although there is a clear relationship with percent fat, there is considerable variability across risk factors (Figures 1 and 2). The challenge of creating efficacious and feasible thresholds is obvious. Although it is of interest to define thresholds relative to individual risk factors to better understand the relationships, having multiple thresholds is clearly not feasible for screening programs. In adults, the concept of metabolic syndrome as an integrated index that captures overall risk has widespread support. More recently, definitions have been proposed for youth. The use of the metabolic syndrome as a more integrated way to potentially capture CVD and type 2 diabetes risk may provide a feasible method for developing health-related obesity thresholds. Studies in adults have clearly demonstrated a strong relationship between obesity and the metabolic syndrome. Far fewer studies
Figure 1. Relationships between cardiovascular disease risk factors and percent fat in boys at various ages
HDL, high-density lipoprotein
Figure 2. Relationships between cardiovascular disease risk factors and percent fat in girls at various ages
HDL, high-density lipoprotein
have been done in youth, although available reports support a similar relationship in adolescents.\textsuperscript{35,37}

The present study has several strengths, including the use of a large, representative sample of U.S. children and adolescents across a broad age range. The inclusion of multiple race and ethnic groups is also a strength, as is the use of measures of skinfold thicknesses to obtain percent fat estimates using equations that were developed to adjust for the age-related variation in the chemical composition of lean tissue that confounds many other skinfold equations.\textsuperscript{38} Although sampling weights were not used to adjust for the NHANES complex sampling procedure, and this may be viewed as a limitation, the purpose for the current paper was not to generalize to the U.S. population. Rather, the goal was to demonstrate whether age modified the relationship between percent fat and risk factors. Sampling variation and smaller sample sizes for some risk factors undoubtedly contributed to some of the variation in the relationships. Nevertheless, it is clear that age is an important variable to consider in the development of percent fat thresholds. Future studies with large, representative samples are needed to precisely define the percent fat–risk factor relationships at different ages.

**Conclusion**

The current results demonstrate a strong relationship between chronic disease risk factors and percent fat in children and youth. The relationship varies with age for most risk factors, and the results suggest that criterion-referenced body composition standards should vary by age and gender in children and youth aged 6–18 years.

Publication of this article was supported by The Cooper Institute through a philanthropic gift from Lyda Hill.

No financial disclosures were reported by the authors of this paper.

**References**


