# Reference curves for triceps and subscapular skinfold thicknesses in US children and adolescents[1,2]

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## ABSTRACT

**Background:** Skinfold thicknesses have long been considered important and valid measurements of subcutaneous fat. Nevertheless, there are no current skinfold reference data for US children and adolescents.

**Objective:** We developed new percentile reference curves for triceps and subscapular skinfold thicknesses by using the same national samples as those included in the reference curves for body mass index (BMI) in the Centers for Disease Control and Prevention 2000 Growth Charts.

**Design:** We included triceps and subscapular skinfold-thickness measurements for 32,783 individuals who also had complete data for BMI. The LMS method was used to derive 10 smoothed skinfold-thickness percentile reference curves and to generate the $L$, $M$, and $S$ parameters that allow the calculation of standardized $z$ scores.

**Results:** The new reference curves exhibit established age- and sex-related patterns of development, including dramatic prepubescent increases in subcutaneous fatness in boys at the highest percentiles. Comparisons of smoothed medians for race-ethnicity groups confirm greater subcutaneous fatness in white children than in black age mates at the triceps site but similar median subscapular skinfold thicknesses. Median skinfold thicknesses for children considered overweight ($\geq$85th percentile) or obese ($\geq$95th percentile) on the basis of BMI cutoffs do not follow closely the skinfold percentile reference channels across age, especially in boys, which suggests a certain degree of independence between BMI and skinfold thickness at the upper extremes of the BMI distribution.

**Conclusions:** The age- and sex-standardized skinfold percentiles and $z$ scores will be appropriate for a wide range of research applications that consider measures of subcutaneous fat. Because they were developed by using the same children as those used for the 2000 BMI curves of the Centers for Disease Control and Prevention, they provide an important new complementary assessment tool that should be appropriate for almost all US children and adolescents.      *Am J Clin Nutr* 2010;91:635–42.

## INTRODUCTION

Double thicknesses of skin and subcutaneous fat measured as skinfold thicknesses have a long history in nutrition-related research (1, 2). Accordingly, skinfold thicknesses have been used in myriad studies of nutritional status, body composition, and relative subcutaneous fat distribution (3–6). Because the thicknesses of subcutaneous fat are very specific to adipose tissue and can be measured noninvasively, skinfold thickness remains an important and valid anthropometric indicator of regional and total body fatness, especially in research settings (3, 7).

The Centers for Disease Control and Prevention (CDC) 2000 Growth Charts were developed from combined prior national surveys of US children, and they include percentiles and corresponding $z$ scores for important growth variables, including recumbent length, stature, weight, weight-for-length, weight-for-stature, head circumference, and body mass index (BMI) (8). These growth curves are used routinely in clinical and research settings and have been recommended widely as the preferred reference data for evaluating the physical growth of American children (9). Recent recommendations have reconfirmed the appropriateness of using BMI-for-age to assess overweight and obesity in children and they have specified the CDC 2000 Growth Charts as the most appropriate percentile criteria for doing so (10, 11).

Reference curves for skinfold thicknesses corresponding to the CDC 2000 Growth Charts were not published with the other growth variables. Researchers who wish to evaluate skinfold thicknesses for US children must rely on percentiles for skinfold thicknesses from select earlier national surveys (12, 13), although they are now out of date, comprise only subsets of the children included in the CDC 2000 Growth Charts, often used outdated statistical procedures, and do not allow for derivation of $z$ scores. McDowell et al (14) provided unsmoothed percentiles for children and adolescents examined between 1999 and 2002 in the continuing National Health and Nutrition Examination Surveys (NHANES), but these children and adolescents were not included in the CDC 2000 Growth Charts.

The purpose of this research was to provide reference percentiles for triceps and subscapular skinfold thickness for US children that directly correspond to the CDC 2000 Growth Charts by using the same children and sample weights used for the development of the growth curves for BMI-for-age. The summary values of LMS parameters (15) allow for the calculation of corresponding $z$ scores standardized for age and sex groups. Finally, we summarize trends related to race-ethnicity groups and groups identified as overweight and obese defined by recommended BMI criteria.

## METHODS

A goal was to reproduce the sample used to construct the BMI percentiles in the CDC 2000 Growth Charts (8) as much as possible, even though the statistical methods were not identical. Accordingly, the study sample comprised data from 5 US national surveys conducted between 1963 through 1994: 2 National Health Examination Surveys (NHES, cycles II and III) and 3 National Health and Nutrition Examination Surveys (NHANES I–III). Each of these surveys used a stratified, multistage probability design. The surveys represented the total civilian, noninstitutionalized population of the United States. Complete methods and sampling frames used in these national surveys are described elsewhere (16–20).

Individuals with missing height or weight measurements were excluded to match the BMI reference sample. Individuals with missing measurements for both triceps and subscapular skinfold thicknesses were not included, but individuals were included in the respective samples if they had only one of the skinfold-thickness measurements. Following the sample of the CDC 2000 Growth Charts, data for subjects ≥6.0 y of age from NHANES III were not included (21).

To develop the skinfold percentile curves, we excluded a small number of outliers (4 for triceps and 69 for subscapular) following Tukey's criteria for identifying "far outside" values within each age- and sex-specific group (22). This is a very conservative nonparametric procedure identifying values beyond approximately ±5 SD in normally distributed populations. The intent was to exclude only values that were probable errors.

The sources of data and the overall unweighted sample sizes used are shown in **Table 1**. Approximately 99.4% of the sample used for the CDC 2000 BMI Growth Charts was included in the new skinfold reference curves within corresponding age ranges. The age- and sex-specific sample sizes ranged from 132 to 628, with the smallest sample sizes in the youngest and oldest 6-mo age groups. Individuals who had their skinfold thicknesses coded as "too large to measure with calipers" were used to estimate the percentiles to maintain their ordinal contributions to the skinfold thickness distribution.

Triceps and subscapular skinfold thicknesses were measured by highly trained and standardized technicians following recommended protocols (23). Skinfold thicknesses were measured to the nearest 0.5 mm by using Lange calipers (Cambridge Scientific, Cambridge, MA) during all of the national surveys

**TABLE 1**
Data sources for the skinfold reference curves[1]

| Survey | Years | Sample size by skinfold thicknesses | | Subject age |
|--------|-------|---------|-------------|-------------|
| | | Triceps | Subscapular | |
| | | *n* | | *y* |
| NHES II | 1963–1965 | 7118 | 7112 | 6.00–12.08 |
| NHES III | 1966–1970 | 6757 | 6757 | 12.00–18.08 |
| NHANES I | 1971–1974 | 7310 | 7301 | 1.50–19.99 |
| NHANES II | 1976–1980 | 7371 | 7349 | 1.99–19.99 |
| NHANES III | 1988–1994 | 4227 | 4199 | 2.00–6.00 |
| Total | | 32,783 | 32,718 | 1.50–19.99 |

[1] NHES, National Health Examination Survey; NHANES, National Health and Nutrition Examination Survey.

except for NHANES III, in which Holtain calipers (Holtain Ltd, Crymych, United Kingdom) were used to measure skinfold thicknesses to the nearest 0.2 mm. The reliability of the skinfold-thickness measurements in the national surveys has been documented (24, 25).

Investigation of the potential influence of the design effects of the surveys on the pooled variance estimates showed that the large number of sampling units involved across the 5 surveys and the large natural variability associated with skinfold thicknesses yielded interclass correlations that were extremely small, such that the overall design effects were inconsequential. The percentiles were calculated by using the sample weights for cases to account for nonresponse and sampling probabilities. The resultant percentiles and parameters for calculating $z$ scores are representative of US children and adolescents during the years the surveys were collected.

For defining race-ethnicity groups, the only descriptors used consistently across all surveys was the identification of children as black or white. Children were considered overweight (BMI ≥ 85th percentile) or obese (BMI ≥ 95th percentile) relative to the CDC 2000 Growth Charts (8) and following recent recommendations (11).

The LMS method (15) was used to generate smoothed percentile values and curves fitted across age separately for each sex and for each skinfold. LMS Chartmaker Pro (version 2.3 software; Cole and Pan 2006) was used to derive the smoothed percentiles. The LMS method uses cubic splines to fit smoothed $L$, $M$, and $S$ curves across each age category by maximized penalized likelihood (26). The smoothed percentile estimates and the $L$, $M$, and $S$ parameters were derived from the underlying distribution of raw weighted data in each age category and separately for each skinfold and sex in single-stage modeling. This approach is completely valid but it differs somewhat from that used for the CDC Growth Charts. Again, the intent was to mimic the CDC sample, not the exact statistical method to derive the skinfold curves.

The following equivalent df was used to obtain the smoothed $L$, $M$, and $S$ curves for each sex and skinfold, respectively: 3, 7, and 4 for triceps skinfold thickness in boys; 3, 6, and 4 for triceps skinfold thickness in girls; 4, 9, and 5 for subscapular skinfold thickness in boys; and 4, 7, and 6 for subscapular skinfold thickness in girls. We evaluated the fit of the curves by overlaying the empirical percentiles and smoothed curves. Also, worm plots were used to evaluate goodness of fit (27). Finally, we used $Q$ tests for fit to assess the global goodness-of-fit of our final models (28).

Ten percentile values were computed (3rd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, and 97th) within 6-m age groups from 1.50 to 19.99 y. The 85th percentile was added to the others symmetric about the median because this level has been used previously as a criterion cutoff for obesity using skinfold thicknesses and BMI (13, 29). With the use of the same LMS smoothing algorithms consistent with the population curves, age-specific median skinfold thicknesses for groups based on race-ethnicity, overweight, and obesity were smoothed across ages.

## RESULTS

The smoothed age-specific percentiles and the corresponding LMS parameters are presented in **Tables 2–5** for boys and girls

separately. The percentiles describe the expected patterns of subcutaneous fatness development with age and the expected sex differences. In boys, a dramatic increase in fatness preceding the adolescent spurt was evident at the percentile levels greater than the median. Some of these patterns can be better appreciated graphically in **Figure 1**, which includes the smoothed median skinfold thicknesses for groups defined as black, white, overweight, or obese.

Median subscapular skinfold thicknesses for black and white children of both sexes approximate the overall medians throughout the age range. Median triceps skinfold thicknesses for white children, however, were consistently larger than those for black children, especially from 8 to 14 y of age in boys. The median triceps skinfold thickness for black boys approximates the 25th percentile at several ages.

The median skinfold thicknesses for individuals considered overweight or obese by BMI criteria did not track neatly in skinfold percentile channels across age, especially in boys

(Figure 1). The age-related divergence of median subscapular skinfold thickness for boys considered overweight and obese by BMI at ≈14 y of age and then returning toward each other later was unexplained, but it did follow the patterns of the empiric medians and did not appear to be an artifact of smoothing.

## DISCUSSION

The smoothed curves for skinfold thickness present nationally representative percentiles for US children and adolescents similar to what has existed for the same population used for the CDC 2000 Growth Charts. Although BMI is the recommended measure for determining overweight and obesity status, the percentiles and $z$ scores of triceps and subscapular skinfold thicknesses will allow better assessment of adiposity per se. In children, skinfold thicknesses are more highly correlated with measures of total body fat than is BMI (30–33). Other investigators have found BMI to be more closely related to select risk

**TABLE 2**
Smoothed percentiles for triceps skinfold-for-age (mm): boys aged 1.50–19.99 y[1]

| Age | L | M | S | Percentile | | | | | | | | | |
| | | | | 3rd | 5th | 10th | 25th | 50th | 75th | 85th | 90th | 95th | 97th |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.50–1.99 y | −0.0982 | 9.7466 | 0.2464 | 6.20 | 6.55 | 7.14 | 8.27 | 9.75 | 11.52 | 12.62 | 13.43 | 14.74 | 15.66 |
| 2.00–2.49 y | −0.1065 | 9.6551 | 0.2495 | 6.11 | 6.46 | 7.05 | 8.17 | 9.66 | 11.44 | 12.55 | 13.37 | 14.69 | 15.63 |
| 2.50–2.99 y | −0.1229 | 9.4769 | 0.2559 | 5.94 | 6.29 | 6.87 | 7.99 | 9.48 | 11.28 | 12.41 | 13.25 | 14.60 | 15.57 |
| 3.00–3.49 y | −0.1392 | 9.3113 | 0.2626 | 5.77 | 6.12 | 6.70 | 7.82 | 9.31 | 11.14 | 12.29 | 13.14 | 14.54 | 15.53 |
| 3.50–3.99 y | −0.1555 | 9.1537 | 0.2698 | 5.62 | 5.96 | 6.54 | 7.65 | 9.15 | 11.01 | 12.18 | 13.06 | 14.50 | 15.53 |
| 4.00–4.49 y | −0.1715 | 8.9913 | 0.2778 | 5.45 | 5.79 | 6.36 | 7.48 | 8.99 | 10.88 | 12.08 | 12.98 | 14.47 | 15.54 |
| 4.50–4.99 y | −0.1871 | 8.8176 | 0.2866 | 5.28 | 5.61 | 6.18 | 7.29 | 8.82 | 10.74 | 11.97 | 12.90 | 14.44 | 15.56 |
| 5.00–5.49 y | −0.2021 | 8.6349 | 0.2963 | 5.09 | 5.42 | 5.99 | 7.10 | 8.63 | 10.59 | 11.86 | 12.82 | 14.42 | 15.60 |
| 5.50–5.99 y | −0.2164 | 8.4553 | 0.3071 | 4.91 | 5.23 | 5.80 | 6.90 | 8.46 | 10.45 | 11.76 | 12.76 | 14.44 | 15.67 |
| 6.00–6.49 y | −0.2298 | 8.2999 | 0.3189 | 4.73 | 5.06 | 5.62 | 6.73 | 8.30 | 10.35 | 11.70 | 12.75 | 14.51 | 15.82 |
| 6.50–6.99 y | −0.2423 | 8.1976 | 0.3314 | 4.59 | 4.91 | 5.47 | 6.59 | 8.20 | 10.32 | 11.73 | 12.83 | 14.71 | 16.11 |
| 7.00–7.49 y | −0.2540 | 8.1739 | 0.3445 | 4.49 | 4.81 | 5.38 | 6.52 | 8.17 | 10.39 | 11.88 | 13.06 | 15.07 | 16.59 |
| 7.50–7.99 y | −0.2648 | 8.2395 | 0.3578 | 4.44 | 4.77 | 5.35 | 6.52 | 8.24 | 10.57 | 12.17 | 13.43 | 15.62 | 17.29 |
| 8.00–8.49 y | −0.2748 | 8.3857 | 0.3712 | 4.43 | 4.77 | 5.36 | 6.58 | 8.39 | 10.87 | 12.59 | 13.96 | 16.36 | 18.20 |
| 8.50–8.99 y | −0.2841 | 8.5913 | 0.3844 | 4.45 | 4.80 | 5.42 | 6.69 | 8.59 | 11.25 | 13.11 | 14.61 | 17.25 | 19.30 |
| 9.00–9.49 y | −0.2926 | 8.8356 | 0.3974 | 4.49 | 4.86 | 5.50 | 6.83 | 8.84 | 11.68 | 13.70 | 15.34 | 18.25 | 20.54 |
| 9.50–9.99 y | −0.3006 | 9.0972 | 0.4099 | 4.55 | 4.92 | 5.59 | 6.98 | 9.10 | 12.14 | 14.33 | 16.12 | 19.33 | 21.87 |
| 10.00–10.49 y | −0.3082 | 9.3464 | 0.4217 | 4.60 | 4.98 | 5.67 | 7.12 | 9.35 | 12.59 | 14.95 | 16.88 | 20.40 | 23.21 |
| 10.50–10.99 y | −0.3153 | 9.5503 | 0.4328 | 4.63 | 5.02 | 5.73 | 7.22 | 9.55 | 12.97 | 15.49 | 17.57 | 21.39 | 24.46 |
| 11.00–11.49 y | −0.3222 | 9.6840 | 0.4429 | 4.63 | 5.03 | 5.75 | 7.28 | 9.68 | 13.26 | 15.91 | 18.12 | 22.21 | 25.54 |
| 11.50–11.99 y | −0.3286 | 9.7329 | 0.4520 | 4.60 | 5.00 | 5.73 | 7.28 | 9.73 | 13.42 | 16.19 | 18.51 | 22.83 | 26.38 |
| 12.00–12.49 y | −0.3347 | 9.6954 | 0.4600 | 4.53 | 4.94 | 5.66 | 7.22 | 9.70 | 13.45 | 16.30 | 18.70 | 23.20 | 26.93 |
| 12.50–12.99 y | −0.3405 | 9.5778 | 0.4669 | 4.44 | 4.84 | 5.56 | 7.10 | 9.58 | 13.36 | 16.25 | 18.70 | 23.33 | 27.19 |
| 13.00–13.49 y | −0.3460 | 9.3915 | 0.4728 | 4.33 | 4.72 | 5.42 | 6.94 | 9.39 | 13.17 | 16.07 | 18.54 | 23.24 | 27.18 |
| 13.50–13.99 y | −0.3512 | 9.1601 | 0.4777 | 4.20 | 4.58 | 5.26 | 6.75 | 9.16 | 12.89 | 15.78 | 18.25 | 22.97 | 26.96 |
| 14.00–14.49 y | −0.3559 | 8.9122 | 0.4816 | 4.06 | 4.43 | 5.10 | 6.55 | 8.91 | 12.59 | 15.44 | 17.89 | 22.60 | 26.60 |
| 14.50–14.99 y | −0.3601 | 8.6733 | 0.4848 | 3.94 | 4.30 | 4.95 | 6.37 | 8.67 | 12.28 | 15.10 | 17.52 | 22.20 | 26.19 |
| 15.00–15.49 y | −0.3635 | 8.4643 | 0.4872 | 3.84 | 4.19 | 4.82 | 6.21 | 8.46 | 12.01 | 14.79 | 17.19 | 21.83 | 25.80 |
| 15.50–15.99 y | −0.3660 | 8.2983 | 0.4892 | 3.75 | 4.10 | 4.72 | 6.08 | 8.30 | 11.80 | 14.54 | 16.92 | 21.53 | 25.48 |
| 16.00–16.49 y | −0.3673 | 8.1842 | 0.4909 | 3.70 | 4.04 | 4.65 | 5.99 | 8.18 | 11.65 | 14.37 | 16.73 | 21.33 | 25.27 |
| 16.50–16.99 y | −0.3673 | 8.1258 | 0.4923 | 3.66 | 4.00 | 4.61 | 5.94 | 8.13 | 11.58 | 14.30 | 16.66 | 21.25 | 25.20 |
| 17.00–17.49 y | −0.3663 | 8.1247 | 0.4936 | 3.65 | 3.99 | 4.60 | 5.93 | 8.12 | 11.59 | 14.32 | 16.69 | 21.30 | 25.27 |
| 17.50–17.99 y | −0.3642 | 8.1877 | 0.4949 | 3.67 | 4.01 | 4.63 | 5.98 | 8.19 | 11.69 | 14.45 | 16.84 | 21.50 | 25.52 |
| 18.00–18.49 y | −0.3615 | 8.3189 | 0.4961 | 3.72 | 4.07 | 4.69 | 6.07 | 8.32 | 11.88 | 14.69 | 17.13 | 21.88 | 25.96 |
| 18.50–18.99 y | −0.3582 | 8.5027 | 0.4973 | 3.80 | 4.15 | 4.79 | 6.19 | 8.50 | 12.15 | 15.03 | 17.53 | 22.38 | 26.56 |
| 19.00–19.49 y | −0.3546 | 8.7141 | 0.4984 | 3.88 | 4.24 | 4.90 | 6.34 | 8.71 | 12.46 | 15.42 | 17.98 | 22.95 | 27.23 |
| 19.50–19.99 y | −0.3509 | 8.9348 | 0.4994 | 3.97 | 4.34 | 5.02 | 6.50 | 8.93 | 12.79 | 15.82 | 18.45 | 23.55 | 27.93 |

[1] L, Box-Cox transformation power; M, median; S, generalized CV.

**TABLE 3**
Smoothed percentiles for subscapular skinfold-for-age (mm): boys aged 1.50–19.99 y[1]

| Age | L | M | S | 3rd | 5th | 10th | 25th | 50th | 75th | 85th | 90th | 95th | 97th |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Percentile | | | | | | |
| 1.50–1.99 y | −0.3827 | 5.8414 | 0.2767 | 3.63 | 3.84 | 4.19 | 4.88 | 5.84 | 7.09 | 7.92 | 8.55 | 9.63 | 10.44 |
| 2.00–2.49 y | −0.4078 | 5.7779 | 0.2748 | 3.61 | 3.82 | 4.16 | 4.83 | 5.78 | 7.01 | 7.82 | 8.45 | 9.52 | 10.32 |
| 2.50–2.99 y | −0.4582 | 5.6469 | 0.2711 | 3.57 | 3.76 | 4.09 | 4.74 | 5.65 | 6.83 | 7.63 | 8.24 | 9.30 | 10.09 |
| 3.00–3.49 y | −0.5086 | 5.5132 | 0.2677 | 3.52 | 3.71 | 4.02 | 4.64 | 5.51 | 6.66 | 7.44 | 8.04 | 9.08 | 9.86 |
| 3.50–3.99 y | −0.5591 | 5.3813 | 0.2651 | 3.47 | 3.64 | 3.94 | 4.54 | 5.38 | 6.50 | 7.25 | 7.84 | 8.87 | 9.66 |
| 4.00–4.49 y | −0.6095 | 5.2551 | 0.2638 | 3.41 | 3.58 | 3.86 | 4.44 | 5.26 | 6.34 | 7.09 | 7.67 | 8.70 | 9.49 |
| 4.50–4.99 y | −0.6597 | 5.1370 | 0.2638 | 3.34 | 3.51 | 3.79 | 4.34 | 5.14 | 6.21 | 6.94 | 7.53 | 8.56 | 9.37 |
| 5.00–5.49 y | −0.7094 | 5.0215 | 0.2654 | 3.28 | 3.43 | 3.70 | 4.24 | 5.02 | 6.08 | 6.82 | 7.41 | 8.47 | 9.30 |
| 5.50–5.99 y | −0.7579 | 4.9017 | 0.2689 | 3.19 | 3.35 | 3.61 | 4.14 | 4.90 | 5.96 | 6.70 | 7.31 | 8.40 | 9.27 |
| 6.00–6.49 y | −0.8040 | 4.7885 | 0.2743 | 3.11 | 3.26 | 3.51 | 4.03 | 4.79 | 5.85 | 6.61 | 7.24 | 8.39 | 9.32 |
| 6.50–6.99 y | −0.8466 | 4.7139 | 0.2817 | 3.04 | 3.19 | 3.44 | 3.95 | 4.71 | 5.80 | 6.59 | 7.25 | 8.49 | 9.52 |
| 7.00–7.49 y | −0.8844 | 4.7007 | 0.2910 | 3.01 | 3.15 | 3.41 | 3.92 | 4.70 | 5.83 | 6.68 | 7.39 | 8.76 | 9.93 |
| 7.50–7.99 y | −0.9163 | 4.7407 | 0.3018 | 3.00 | 3.15 | 3.40 | 3.93 | 4.74 | 5.94 | 6.85 | 7.64 | 9.19 | 10.56 |
| 8.00–8.49 y | −0.9416 | 4.8172 | 0.3139 | 3.01 | 3.16 | 3.42 | 3.97 | 4.82 | 6.10 | 7.10 | 7.99 | 9.77 | 11.41 |
| 8.50–8.99 y | −0.9603 | 4.9274 | 0.3268 | 3.04 | 3.19 | 3.47 | 4.03 | 4.93 | 6.31 | 7.42 | 8.42 | 10.50 | 12.48 |
| 9.00–9.49 y | −0.9729 | 5.0737 | 0.3402 | 3.09 | 3.25 | 3.53 | 4.12 | 5.07 | 6.58 | 7.81 | 8.95 | 11.38 | 13.81 |
| 9.50–9.99 y | −0.9802 | 5.2439 | 0.3535 | 3.14 | 3.31 | 3.60 | 4.23 | 5.24 | 6.88 | 8.26 | 9.55 | 12.41 | 15.38 |
| 10.00–10.49 y | −0.9832 | 5.4157 | 0.3662 | 3.20 | 3.37 | 3.68 | 4.34 | 5.42 | 7.19 | 8.71 | 10.16 | 13.48 | 17.10 |
| 10.50–10.99 y | −0.9828 | 5.5760 | 0.3776 | 3.25 | 3.43 | 3.75 | 4.44 | 5.58 | 7.48 | 9.14 | 10.75 | 14.55 | 18.85 |
| 11.00–11.49 y | −0.9797 | 5.7219 | 0.3874 | 3.30 | 3.49 | 3.82 | 4.53 | 5.72 | 7.74 | 9.53 | 11.29 | 15.54 | 20.51 |
| 11.50–11.99 y | −0.9745 | 5.8541 | 0.3952 | 3.35 | 3.54 | 3.88 | 4.62 | 5.85 | 7.97 | 9.87 | 11.77 | 16.40 | 21.96 |
| 12.00–12.49 y | −0.9670 | 5.9749 | 0.4010 | 3.39 | 3.59 | 3.94 | 4.70 | 5.97 | 8.17 | 10.17 | 12.16 | 17.08 | 23.07 |
| 12.50–12.99 y | −0.9572 | 6.0965 | 0.4047 | 3.44 | 3.64 | 4.00 | 4.78 | 6.10 | 8.37 | 10.42 | 12.48 | 17.58 | 23.81 |
| 13.00–13.49 y | −0.9453 | 6.2330 | 0.4065 | 3.51 | 3.71 | 4.08 | 4.88 | 6.23 | 8.56 | 10.67 | 12.77 | 17.95 | 24.21 |
| 13.50–13.99 y | −0.9318 | 6.3961 | 0.4066 | 3.59 | 3.80 | 4.18 | 5.01 | 6.40 | 8.78 | 10.92 | 13.05 | 18.23 | 24.38 |
| 14.00–14.49 y | −0.9167 | 6.5929 | 0.4054 | 3.70 | 3.92 | 4.31 | 5.17 | 6.59 | 9.03 | 11.21 | 13.35 | 18.48 | 24.42 |
| 14.50–14.99 y | −0.9001 | 6.8202 | 0.4032 | 3.83 | 4.05 | 4.46 | 5.35 | 6.82 | 9.32 | 11.52 | 13.67 | 18.71 | 24.40 |
| 15.00–15.49 y | −0.8817 | 7.0694 | 0.4006 | 3.97 | 4.21 | 4.63 | 5.55 | 7.07 | 9.63 | 11.85 | 14.00 | 18.96 | 24.38 |
| 15.50–15.99 y | −0.8609 | 7.3362 | 0.3981 | 4.12 | 4.36 | 4.81 | 5.76 | 7.34 | 9.96 | 12.21 | 14.36 | 19.23 | 24.39 |
| 16.00–16.49 y | −0.8376 | 7.6251 | 0.3961 | 4.27 | 4.53 | 5.00 | 5.99 | 7.63 | 10.32 | 12.61 | 14.77 | 19.56 | 24.51 |
| 16.50–16.99 y | −0.8110 | 7.9385 | 0.3948 | 4.44 | 4.71 | 5.20 | 6.24 | 7.94 | 10.72 | 13.05 | 15.23 | 19.96 | 24.74 |
| 17.00–17.49 y | −0.7809 | 8.2763 | 0.3944 | 4.61 | 4.90 | 5.41 | 6.50 | 8.28 | 11.15 | 13.54 | 15.74 | 20.45 | 25.08 |
| 17.50–17.99 y | −0.7475 | 8.6462 | 0.3948 | 4.79 | 5.09 | 5.63 | 6.78 | 8.65 | 11.64 | 14.09 | 16.33 | 21.03 | 25.54 |
| 18.00–18.49 y | −0.7111 | 9.0550 | 0.3960 | 4.98 | 5.30 | 5.87 | 7.09 | 9.06 | 12.18 | 14.71 | 16.99 | 21.72 | 26.15 |
| 18.50–18.99 y | −0.6723 | 9.4930 | 0.3978 | 5.18 | 5.52 | 6.12 | 7.42 | 9.49 | 12.76 | 15.38 | 17.72 | 22.48 | 26.85 |
| 19.00–19.49 y | −0.6314 | 9.9431 | 0.4000 | 5.37 | 5.74 | 6.38 | 7.75 | 9.94 | 13.36 | 16.08 | 18.47 | 23.27 | 27.58 |
| 19.50–19.99 y | −0.5892 | 10.3940 | 0.4025 | 5.56 | 5.94 | 6.63 | 8.08 | 10.39 | 13.97 | 16.78 | 19.22 | 24.05 | 28.32 |

[1] L, Box-Cox transformation power; M, median; S, generalized CV.

factors than skinfold thicknesses for children between ages 4 and 9 y (34) and percentage body fat estimated from skinfold thicknesses (Slaughter equations) in children (6). In another study in boys 10–15 y old, BMI was found to be more closely correlated to cardiovascular disease risk than skinfold-determined central adiposity, although the observation differed across races (35). Consequently, the choice of whether to include skinfold thicknesses and/or BMI in a particular study should depend on the specific outcomes.

Because the triceps skinfold thickness is measured at an extremity site and the subscapular skinfold is measured on the trunk, the current percentiles and z scores will facilitate analyses of subcutaneous fat distribution. The black-white median differences in triceps skinfold thicknesses but not in subscapular skinfold thickness are examples of established group differences in subcutaneous fat distribution (12, 36), as are the differential risks of cardiovascular disease and insulin resistance (37, 38).

A specific decision was made not to present different sets of skinfold thickness percentiles and z scores calculated separately for white children and for black children. This would double the number of growth charts, be potentially useful for only triceps skinfold thicknesses, and complicate the application of the charts in many situations in which race-ethnicity is considered as other than black or white or in which a child is reported to have a substantial mixture between black and white heritage. Appropriate interpretation of results from a single reference for all children will, however, require clinical awareness that black children usually have less extremity fat than white children at the same age and at the same level of total body fatness (36, 39, 40).

The new reference curves are based on carefully measured skinfold thicknesses with documented amounts of measurement errors (24). Nevertheless, this high level of measurement reliability requires standardized training and considerable experience measuring skinfold thicknesses. Investigators should be reminded of these requirements to obtain high-quality skinfold thickness data.

Before NHANES III, skinfold thicknesses were measured by using Lange skinfold calipers, whereas, for NHANES III,

**TABLE 4**
Smoothed percentiles for triceps skinfold-for-age (mm): girls aged 1.50–19.99 y[1]

| Age | L | M | S | Percentiles | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 3rd | 5th | 10th | 25th | 50th | 75th | 85th | 90th | 95th | 97th |
| 1.50–1.99 y | 0.0360 | 9.9142 | 0.2451 | 6.23 | 6.61 | 7.23 | 8.40 | 9.91 | 11.69 | 12.77 | 13.55 | 14.79 | 15.67 |
| 2.00–2.49 y | 0.0302 | 9.9121 | 0.2491 | 6.18 | 6.56 | 7.19 | 8.38 | 9.91 | 11.72 | 12.82 | 13.62 | 14.89 | 15.78 |
| 2.50–2.99 y | 0.0187 | 9.9069 | 0.2572 | 6.09 | 6.48 | 7.12 | 8.33 | 9.91 | 11.78 | 12.92 | 13.76 | 15.10 | 16.03 |
| 3.00–3.49 y | 0.0073 | 9.8997 | 0.2654 | 6.00 | 6.39 | 7.04 | 8.28 | 9.90 | 11.84 | 13.03 | 13.90 | 15.31 | 16.29 |
| 3.50–3.99 y | −0.0038 | 9.8896 | 0.2739 | 5.91 | 6.30 | 6.96 | 8.22 | 9.89 | 11.90 | 13.14 | 14.05 | 15.53 | 16.56 |
| 4.00–4.49 y | −0.0145 | 9.8783 | 0.2828 | 5.82 | 6.21 | 6.88 | 8.17 | 9.88 | 11.96 | 13.25 | 14.21 | 15.75 | 16.85 |
| 4.50–4.99 y | −0.0245 | 9.8683 | 0.2921 | 5.72 | 6.12 | 6.80 | 8.11 | 9.87 | 12.02 | 13.37 | 14.37 | 16.00 | 17.16 |
| 5.00–5.49 y | −0.0338 | 9.8612 | 0.3017 | 5.62 | 6.03 | 6.72 | 8.05 | 9.86 | 12.10 | 13.50 | 14.55 | 16.27 | 17.49 |
| 5.50–5.99 y | −0.0420 | 9.8656 | 0.3118 | 5.53 | 5.94 | 6.64 | 8.00 | 9.87 | 12.19 | 13.66 | 14.76 | 16.57 | 17.86 |
| 6.00–6.49 y | −0.0492 | 9.8987 | 0.3220 | 5.45 | 5.87 | 6.58 | 7.98 | 9.90 | 12.31 | 13.86 | 15.02 | 16.93 | 18.30 |
| 6.50–6.99 y | −0.0553 | 9.9820 | 0.3322 | 5.40 | 5.83 | 6.55 | 7.99 | 9.98 | 12.51 | 14.13 | 15.36 | 17.39 | 18.85 |
| 7.00–7.49 y | −0.0603 | 10.1312 | 0.3424 | 5.39 | 5.82 | 6.57 | 8.05 | 10.13 | 12.78 | 14.50 | 15.81 | 17.97 | 19.54 |
| 7.50–7.99 y | −0.0643 | 10.3502 | 0.3524 | 5.41 | 5.86 | 6.63 | 8.18 | 10.35 | 13.15 | 14.98 | 16.37 | 18.69 | 20.38 |
| 8.00–8.49 y | −0.0671 | 10.6312 | 0.3620 | 5.46 | 5.93 | 6.73 | 8.34 | 10.63 | 13.60 | 15.55 | 17.03 | 19.52 | 21.34 |
| 8.50–8.99 y | −0.0687 | 10.9571 | 0.3712 | 5.54 | 6.03 | 6.86 | 8.55 | 10.96 | 14.10 | 16.18 | 17.77 | 20.44 | 22.41 |
| 9.00–9.49 y | −0.0689 | 11.3030 | 0.3797 | 5.63 | 6.13 | 7.00 | 8.77 | 11.30 | 14.64 | 16.84 | 18.54 | 21.40 | 23.51 |
| 9.50–9.99 y | −0.0674 | 11.6449 | 0.3876 | 5.72 | 6.24 | 7.14 | 8.99 | 11.64 | 15.16 | 17.50 | 19.30 | 22.34 | 24.59 |
| 10.00–10.49 y | −0.0643 | 11.9683 | 0.3947 | 5.80 | 6.34 | 7.28 | 9.19 | 11.97 | 15.65 | 18.12 | 20.02 | 23.23 | 25.61 |
| 10.50–10.99 y | −0.0596 | 12.2721 | 0.4010 | 5.87 | 6.43 | 7.40 | 9.38 | 12.27 | 16.12 | 18.69 | 20.68 | 24.05 | 26.55 |
| 11.00–11.49 y | −0.0533 | 12.5632 | 0.4065 | 5.94 | 6.51 | 7.52 | 9.57 | 12.56 | 16.56 | 19.24 | 21.31 | 24.82 | 27.42 |
| 11.50–11.99 y | −0.0458 | 12.8489 | 0.4110 | 6.01 | 6.60 | 7.64 | 9.76 | 12.85 | 16.98 | 19.76 | 21.90 | 25.53 | 28.23 |
| 12.00–12.49 y | −0.0373 | 13.1392 | 0.4146 | 6.09 | 6.70 | 7.76 | 9.95 | 13.14 | 17.40 | 20.26 | 22.47 | 26.22 | 28.99 |
| 12.50–12.99 y | −0.0281 | 13.4475 | 0.4171 | 6.19 | 6.82 | 7.91 | 10.16 | 13.45 | 17.84 | 20.78 | 23.04 | 26.89 | 29.73 |
| 13.00–13.49 y | −0.0186 | 13.7811 | 0.4186 | 6.31 | 6.95 | 8.08 | 10.40 | 13.78 | 18.29 | 21.30 | 23.63 | 27.56 | 30.46 |
| 13.50–13.99 y | −0.0088 | 14.1399 | 0.4190 | 6.45 | 7.11 | 8.28 | 10.66 | 14.14 | 18.76 | 21.85 | 24.22 | 28.23 | 31.18 |
| 14.00–14.49 y | 0.0010 | 14.5203 | 0.4183 | 6.61 | 7.30 | 8.49 | 10.95 | 14.52 | 19.25 | 22.40 | 24.81 | 28.88 | 31.88 |
| 14.50–14.99 y | 0.0109 | 14.9146 | 0.4166 | 6.79 | 7.50 | 8.73 | 11.26 | 14.91 | 19.75 | 22.95 | 25.40 | 29.52 | 32.54 |
| 15.00–15.49 y | 0.0209 | 15.3149 | 0.4141 | 6.98 | 7.71 | 8.98 | 11.57 | 15.31 | 20.23 | 23.48 | 25.96 | 30.12 | 33.16 |
| 15.50–15.99 y | 0.0311 | 15.7180 | 0.4110 | 7.19 | 7.94 | 9.24 | 11.90 | 15.72 | 20.71 | 24.00 | 26.50 | 30.69 | 33.74 |
| 16.00–16.49 y | 0.0413 | 16.1220 | 0.4075 | 7.40 | 8.17 | 9.51 | 12.23 | 16.12 | 21.19 | 24.51 | 27.03 | 31.23 | 34.29 |
| 16.50–16.99 y | 0.0518 | 16.5208 | 0.4038 | 7.61 | 8.40 | 9.78 | 12.56 | 16.52 | 21.65 | 24.99 | 27.53 | 31.74 | 34.80 |
| 17.00–17.49 y | 0.0625 | 16.9078 | 0.4000 | 7.82 | 8.64 | 10.04 | 12.88 | 16.91 | 22.09 | 25.46 | 28.00 | 32.22 | 35.26 |
| 17.50–17.99 y | 0.0737 | 17.2818 | 0.3961 | 8.03 | 8.86 | 10.30 | 13.19 | 17.28 | 22.52 | 25.90 | 28.45 | 32.66 | 35.69 |
| 18.00–18.49 y | 0.0853 | 17.6471 | 0.3923 | 8.24 | 9.09 | 10.56 | 13.50 | 17.65 | 22.93 | 26.32 | 28.87 | 33.07 | 36.09 |
| 18.50–18.99 y | 0.0975 | 18.0086 | 0.3885 | 8.44 | 9.31 | 10.81 | 13.81 | 18.01 | 23.33 | 26.73 | 29.28 | 33.48 | 36.48 |
| 19.00–19.49 y | 0.1101 | 18.3699 | 0.3848 | 8.64 | 9.53 | 11.06 | 14.12 | 18.37 | 23.73 | 27.14 | 29.69 | 33.87 | 36.86 |
| 19.50–19.99 y | 0.1228 | 18.7333 | 0.3812 | 8.84 | 9.76 | 11.32 | 14.43 | 18.73 | 24.13 | 27.55 | 30.11 | 34.27 | 37.24 |

[1] L, Box-Cox transformation power; M, median; S, generalized CV.

skinfold thicknesses were measured by using Holtain skinfold calipers. Studies that compared results from the 2 calipers generally have found that the Lange calipers measured slightly higher (1–5 mm) (33, 35), with greater differences as skinfold thicknesses increased in size beyond ≈20 mm. SEMs among observers for these skinfold thicknesses are also ≈1.0 mm (23). We are not aware of any robust equations to convert Holtain-measured skinfold thicknesses to Lange-measured skinfold thicknesses.

Because NHANES III is the most recent survey included and because of the concomitant secular increase in obesity in the United States, the national survey data do not allow conclusive comparisons across surveys that can disentangle possible caliper-related methodologic differences from secular changes or other possible methodologic differences. Approximately 44% of the total sample children aged <6 y are from NHANES III. Analysis to assess the effect of the caliper change showed that earlier measurements made with Lange calipers were ≈1 mm higher than those made with Holtain calipers within these age catego-

ries. This average difference is small and includes a mixture of temporal changes, sample differences, and any other methodologic differences associated with the NHANES III survey, eg, observers, calipers, rounding. The major benefits gained from including the children from NHANES III during the first 5 y are the enhanced sample size and the direct comparability of the sample to those of the BMI and other CDC 2000 Growth Charts. Given the small survey differences observed (especially given the expected errors of measurement) and an inability to adjust for them in a completely satisfactory way, we believe the benefits of including the NHANES III skinfold thicknesses for children aged <6 y outweigh the drawbacks of excluding them.

Heretofore, smoothed z scores have not been available for skinfold thicknesses for a nationally representative sample of US children and adolescents. The new z scores will greatly facilitate comparisons across ages, between sexes, and among other anthropometric indicators. The z scores corresponding to the percentile rankings for the skinfold-thickness measurements are

**TABLE 5**
Smoothed percentiles for subscapular skinfold-for-age (mm): girls aged 1.50–19.99 y[1]

| Age | L | M | S | Percentile | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 3rd | 5th | 10th | 25th | 50th | 75th | 85th | 90th | 95th | 97th |
| 1.50–1.99 y | −0.3964 | 6.0797 | 0.2903 | 3.71 | 3.93 | 4.30 | 5.03 | 6.08 | 7.45 | 8.38 | 9.09 | 10.32 | 11.25 |
| 2.00–2.49 y | −0.4191 | 6.0672 | 0.2901 | 3.71 | 3.93 | 4.29 | 5.03 | 6.07 | 7.44 | 8.37 | 9.09 | 10.33 | 11.27 |
| 2.50–2.99 y | −0.4644 | 6.0349 | 0.2900 | 3.71 | 3.92 | 4.28 | 5.00 | 6.03 | 7.41 | 8.34 | 9.08 | 10.35 | 11.32 |
| 3.00–3.49 y | −0.5086 | 5.9881 | 0.2907 | 3.70 | 3.90 | 4.26 | 4.97 | 5.99 | 7.36 | 8.31 | 9.05 | 10.36 | 11.36 |
| 3.50–3.99 y | −0.5508 | 5.9274 | 0.2928 | 3.66 | 3.87 | 4.21 | 4.91 | 5.93 | 7.31 | 8.26 | 9.02 | 10.37 | 11.43 |
| 4.00–4.49 y | −0.5904 | 5.8579 | 0.2968 | 3.62 | 3.81 | 4.16 | 4.85 | 5.86 | 7.25 | 8.23 | 9.01 | 10.42 | 11.53 |
| 4.50–4.99 y | −0.6267 | 5.7831 | 0.3029 | 3.55 | 3.75 | 4.09 | 4.77 | 5.78 | 7.20 | 8.20 | 9.02 | 10.51 | 11.70 |
| 5.00–5.49 y | −0.6588 | 5.7054 | 0.3109 | 3.48 | 3.67 | 4.01 | 4.69 | 5.71 | 7.15 | 8.20 | 9.06 | 10.64 | 11.94 |
| 5.50–5.99 y | −0.6862 | 5.6263 | 0.3205 | 3.40 | 3.59 | 3.92 | 4.60 | 5.63 | 7.11 | 8.20 | 9.12 | 10.83 | 12.25 |
| 6.00–6.49 y | −0.7085 | 5.5517 | 0.3317 | 3.31 | 3.50 | 3.83 | 4.51 | 5.55 | 7.08 | 8.23 | 9.21 | 11.07 | 12.65 |
| 6.50–6.99 y | −0.7258 | 5.5058 | 0.3443 | 3.24 | 3.43 | 3.75 | 4.44 | 5.51 | 7.10 | 8.32 | 9.37 | 11.42 | 13.20 |
| 7.00–7.49 y | −0.7385 | 5.5156 | 0.3579 | 3.19 | 3.38 | 3.72 | 4.42 | 5.52 | 7.20 | 8.51 | 9.66 | 11.94 | 13.99 |
| 7.50–7.99 y | −0.7468 | 5.5937 | 0.3723 | 3.18 | 3.38 | 3.72 | 4.44 | 5.59 | 7.39 | 8.82 | 10.09 | 12.68 | 15.07 |
| 8.00–8.49 y | −0.7507 | 5.7454 | 0.3870 | 3.21 | 3.41 | 3.77 | 4.53 | 5.75 | 7.68 | 9.26 | 10.69 | 13.66 | 16.47 |
| 8.50–8.99 y | −0.7501 | 5.9649 | 0.4015 | 3.28 | 3.49 | 3.86 | 4.66 | 5.96 | 8.07 | 9.82 | 11.43 | 14.84 | 18.17 |
| 9.00–9.49 y | −0.7447 | 6.2339 | 0.4154 | 3.37 | 3.59 | 3.98 | 4.83 | 6.23 | 8.54 | 10.48 | 12.28 | 16.20 | 20.10 |
| 9.50–9.99 y | −0.7346 | 6.5311 | 0.4287 | 3.47 | 3.70 | 4.12 | 5.02 | 6.53 | 9.04 | 11.18 | 13.20 | 17.64 | 22.15 |
| 10.00–10.49 y | −0.7199 | 6.8411 | 0.4410 | 3.57 | 3.82 | 4.26 | 5.22 | 6.84 | 9.56 | 11.91 | 14.13 | 19.08 | 24.18 |
| 10.50–10.99 y | −0.7012 | 7.1598 | 0.4519 | 3.68 | 3.94 | 4.40 | 5.43 | 7.16 | 10.09 | 12.63 | 15.05 | 20.46 | 26.07 |
| 11.00–11.49 y | −0.6794 | 7.4882 | 0.4612 | 3.79 | 4.06 | 4.56 | 5.65 | 7.49 | 10.62 | 13.35 | 15.94 | 21.75 | 27.75 |
| 11.50–11.99 y | −0.6559 | 7.8240 | 0.4687 | 3.90 | 4.19 | 4.72 | 5.87 | 7.82 | 11.15 | 14.04 | 16.79 | 22.91 | 29.18 |
| 12.00–12.49 y | −0.6318 | 8.1690 | 0.4743 | 4.03 | 4.33 | 4.88 | 6.10 | 8.17 | 11.68 | 14.72 | 17.59 | 23.93 | 30.35 |
| 12.50–12.99 y | −0.6082 | 8.5264 | 0.4779 | 4.16 | 4.48 | 5.07 | 6.35 | 8.53 | 12.21 | 15.37 | 18.34 | 24.84 | 31.31 |
| 13.00–13.49 y | −0.5856 | 8.8932 | 0.4796 | 4.31 | 4.65 | 5.26 | 6.61 | 8.89 | 12.73 | 16.00 | 19.05 | 25.63 | 32.07 |
| 13.50–13.99 y | −0.5644 | 9.2649 | 0.4794 | 4.47 | 4.83 | 5.47 | 6.88 | 9.26 | 13.24 | 16.60 | 19.70 | 26.30 | 32.66 |
| 14.00–14.49 y | −0.5450 | 9.6395 | 0.4775 | 4.64 | 5.01 | 5.68 | 7.16 | 9.64 | 13.74 | 17.16 | 20.29 | 26.87 | 33.09 |
| 14.50–14.99 y | −0.5272 | 10.0125 | 0.4743 | 4.82 | 5.21 | 5.91 | 7.45 | 10.01 | 14.21 | 17.69 | 20.83 | 27.35 | 33.41 |
| 15.00–15.49 y | −0.5105 | 10.3772 | 0.4708 | 5.00 | 5.40 | 6.13 | 7.73 | 10.38 | 14.67 | 18.19 | 21.35 | 27.80 | 33.72 |
| 15.50–15.99 y | −0.4939 | 10.7312 | 0.4682 | 5.17 | 5.59 | 6.34 | 8.00 | 10.73 | 15.13 | 18.69 | 21.86 | 28.28 | 34.09 |
| 16.00–16.49 y | −0.4767 | 11.0737 | 0.4671 | 5.32 | 5.75 | 6.54 | 8.26 | 11.07 | 15.58 | 19.20 | 22.41 | 28.83 | 34.57 |
| 16.50–16.99 y | −0.4585 | 11.4021 | 0.4677 | 5.45 | 5.90 | 6.71 | 8.49 | 11.40 | 16.03 | 19.73 | 22.98 | 29.44 | 35.16 |
| 17.00–17.49 y | −0.4391 | 11.7132 | 0.4696 | 5.55 | 6.02 | 6.87 | 8.71 | 11.71 | 16.47 | 20.25 | 23.56 | 30.09 | 35.81 |
| 17.50–17.99 y | −0.4189 | 12.0085 | 0.4721 | 5.64 | 6.13 | 7.00 | 8.91 | 12.01 | 16.90 | 20.76 | 24.13 | 30.72 | 36.46 |
| 18.00–18.49 y | −0.3980 | 12.2922 | 0.4750 | 5.72 | 6.23 | 7.13 | 9.09 | 12.29 | 17.32 | 21.26 | 24.68 | 31.34 | 37.08 |
| 18.50–18.99 y | −0.3765 | 12.5686 | 0.4783 | 5.79 | 6.31 | 7.24 | 9.27 | 12.57 | 17.73 | 21.76 | 25.23 | 31.95 | 37.69 |
| 19.00–19.49 y | −0.3545 | 12.8429 | 0.4820 | 5.85 | 6.39 | 7.35 | 9.44 | 12.84 | 18.14 | 22.25 | 25.79 | 32.57 | 38.33 |
| 19.50–19.99 y | −0.3323 | 13.1192 | 0.4859 | 5.91 | 6.46 | 7.45 | 9.61 | 13.12 | 18.56 | 22.76 | 26.36 | 33.21 | 38.99 |

[1] L, Box-Cox transformation power; M, median; S, generalized CV.

calculated from the individual skinfold-thickness measurement (y) and the values for the parameters L, M, and S from the appropriate skinfold, sex, and age group in Tables 1–4: $z = [(y/M)^L - 1]/SL$. These z scores express the skinfold-thickness measurement in terms of SD units greater than or less than the mean skinfold thickness for that specific sex and age group.

In the past, fixed percentile cutoffs for skinfold thickness, eg, 85th percentile, have been used to identify obesity across age groups (13, 24). Nevertheless, as is apparent from the patterns in Figure 1, the median skinfold thickness of children identified as overweight and obese by BMI criteria do not follow fixed channels of skinfold percentiles across the ages, especially in boys. These patterns suggest that no single skinfold percentile cutoff is appropriate at all ages for identifying those considered overweight and obese by using BMI. The patterns of median skinfold thicknesses presented are not sufficient, however, to determine the optimum skinfold percentiles to correctly identify overweight and obese chil-dren and should not be used for this purpose. Determining the optimum skinfold percentile cutoffs to identify the over-weight and obese would require additional correspondence analysis using receiver operating characteristics or similar methods.

The changing relations between skinfold thicknesses and BMI across age is a reminder that BMI, although good indicator of total body fatness, especially at the extremes (42), only captures body mass, and that changes in BMI with age include substantial changes in lean mass as well as fat (43). Applications using these new reference curves for triceps and subscapular skinfold thickness should greatly facilitate studies attempting to separate body mass from adiposity per se and will aid in standardizing findings across studies requiring independent measures of sub-cutaneous fatness.
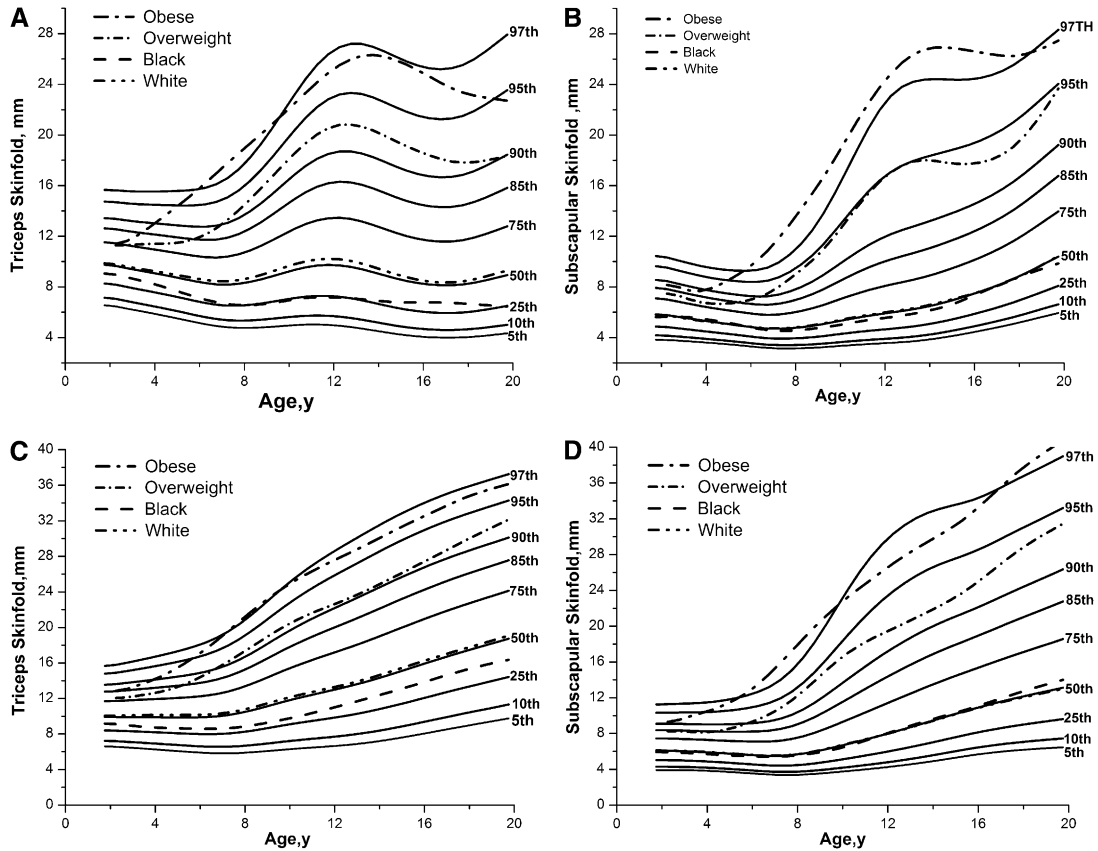
**FIGURE 1.** Smoothed percentile curves and group medians for triceps skinfold-for-age in boys (A), subscapular skinfold-for-age in boys (B), triceps skinfold-for-age in girls (C), and subscapular skinfold-for-age in girls (D). Smoothed group medians for overweight [BMI (in kg/m²) between Centers for Disease Control and Prevention 85th and 94th percentiles], obese (BMI greater than or equal to Centers for Disease Control and Prevention BMI 95th percentile), whites, and blacks.

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