Body Fat Percentile Curves for U.S. Children and Adolescents

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Background: To date, several studies have been published outlining reference percentiles for BMI in children and adolescents. In contrast, there are limited reference data on percent body fat (%BF) in U.S. youth.

Purpose: The purpose of this study was to derive smoothed percentile curves for %BF in a nationally representative sample of U.S. children and adolescents.

Methods: Percent fat was derived from the skinfold thicknesses of those aged 5–18 years from three cross-sectional waves of the National Health and Nutrition Examination Survey (NHANES) IV (1999–2000, 2001–2002, and 2003–2004; N=8269). The LMS (L=skewness, M=median, and S=coefficient of variation) regression method was used to create age- and gender-specific smoothed percentile curves of %BF.

Results: Growth curves are similar between boys and girls until age 9 years. However, whereas %BF peaks for boys at about age 11 years, it continues to increase for girls throughout adolescence. Median %BF at age 18 years is 17.0% and 27.8% for boys and girls, respectively.

Conclusions: Growth charts and LMS values based on a nationally representative sample of U.S. children and adolescents are provided so that future research can identify appropriate cut-off values based on health-related outcomes. These percentiles are based on skinfolds, which are widely available and commonly used. Using %BF instead of BMI may offer additional information in epidemiologic research, fitness assessment, and clinical settings.
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Introduction

The increasing prevalence[1–6] and adverse medical,[7] economic,[8] and psychosocial[9,10] consequences of childhood obesity have been well documented. The majority of studies that identify the magnitude and consequences of this health problem rely on the classification of overweight or obesity using age- and gender-specific thresholds or reference values of BMI. Several sets of reference values for BMI in children and adolescents have been published, with the most widely recognized being the international thresholds by Cole et al.[11] and the CDC thresholds.[12] Although these reference values are widely used, a major limitation of BMI is its inherent inability to differentiate between fat mass and fat-free mass.[13] Similar sets of reference values are needed for body fatness to improve public health surveillance, facilitate clinical screening, and advance obesity prevention research.

Despite the importance of body fatness to health, there are limited reference data available on percent body fat (%BF). Percentiles for body fat have been developed using bioelectrical impedance analysis (BIA)-derived %BF values in British children[14] and skinfold-derived %BF values in Spanish adolescents.[15] Both BIA and measuring skinfold thickness are simple and feasible methods to assess adiposity. In children and adolescents, skinfold thickness values are often converted to %BF using the Slaughter equation,[16] as in the aforementioned study by Moreno et al.[15] Rodriguez et al.[17] specifically recommended the use of the Slaughter equation for male and female adolescents after reviewing several skinfold-to-%BF prediction equations. Reference data are not currently available using skinfold-derived %BF in U.S. youth. Therefore, this paper presents smoothed percentile curves for %BF using LMS (L=skewness, M=median, and S=coefficient of variation) regression in a

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nationally representative sample of white, black, and Mexican-American U.S. children and adolescents.

Methods

Subjects

The National Health and Nutrition Examination Survey (NHANES), conducted by the National Center for Health Statistics, CDC, is a program of studies designed to assess the health and nutritional status of adults and children in the U.S. through interviews and direct physical examinations. In this paper, anthropometric and body composition data of those aged 5–18 years from three cross-sectional waves of NHANES IV (1999–2000, 2001–2002, and 2003–2004) were included. Approximately 1.85% of the eligible sample (aged 5–18 years) had one or both skinfolds that exceeded the range of the calipers and were excluded. In addition, pregnant women were excluded from the analyses. Complete data were available for 1219 non-Hispanic white male, 1169 non-Hispanic white female, 1485 non-Hispanic black male, 1338 non-Hispanic black female, 1569 Mexican-American male, and 1489 Mexican-American female school-aged and adolescent youths aged 5–18 years.

Anthropometry

Stature was measured to the nearest 0.1 cm using a wall-mounted, digital stadiometer, and body mass was measured to the nearest 0.1 kg using a digital scale. BMI was calculated by standard formula. Skinfold thickness was measured as a double fold of skin underlying the soft tissue on the right side of the body using Holtain calipers. All measurements were taken by trained health technicians in the NHANES Mobile Examination Center following standard procedures. Quality control checks were included throughout the data collection procedure. The training procedures, examination protocol and procedures, and quality control protocol are outlined in the NHANES anthropometry and body composition procedures manuals available at www.cdc.gov/nchs/nhanes.htm.

Percent body fat was calculated using the equations of Slaughter et al.[16] from the triceps and subscapular sites since this equation is widely used in pediatric research and with FITNESSGRAM®. The SE of the estimate for this equation is 3.6% for men/boys and 3.9% for women/girls. The equation for whites was used to estimate %BF in Mexican-Americans. Previous research[17] compared several skinfold equations to dual-energy x-ray absorptiometry (DXA) and found the Slaughter equation for whites to be the best available for Spanish adolescents. Because the regression intercepts in boys are based on biological maturity status (prepubescent, pubescent, or postpubescent), and biological maturity status was not assessed in the NHANES IV (1999–2004) waves, the following assumptions were made based on national estimates of age of entry into different stages of secondary sex characteristics:[18] Boys aged $<$12.0 years were classified as prepubescent; boys aged 12.0–13.99 years as pubescent; and boys aged $>$14.0 years as postpubescent.

Data Analysis

Descriptive statistics by gender were calculated using SAS v 9.1 (SAS Institute, Cary, NC). Construction of the age- and gender-specific percentile curves was performed using the LMS ChartMaker Pro Version 2.3 software program (The Institute of Child Health, London, U.K.), which fits smooth percentile curves to reference data using the LMS method.[19] In brief, the LMS method summarizes a changing distribution with three curves, with skewness expressed as a Box–Cox power transformation. By using penalized likelihood, the three curves were fit as cubic splines by nonlinear regression, and the extent of smoothing required is expressed in terms of smoothing parameters or equivalent df. Initially, ethnicity-specific curves were created (data not shown). However, the shapes of the curves were similar for non-Hispanic whites, non-Hispanic blacks, and Mexican-American boys and girls. Thus, to simplify the resulting curves and future use, these three ethnic groups were combined to create one set of percentiles rather than maintaining separate percentiles based on ethnicity.

Results

Tables 1 and 2 include the %BF values across the percentiles by age and gender. The corresponding percentiles are graphically displayed in Figures 1 and 2. In general, %BF for boys increased throughout middle to late childhood and peaked at approximately age 11 years. During adolescence, %BF decreased slightly or leveled off in the mid and lower percentiles, but increased again (starting at about age 16–17 years) within the upper percentiles. Median %BF for boys at age 18 years was 17.0%. Girls displayed a similar pattern of age-related changes in %BF compared to boys through about age 9 years. However, through adolescence, %BF for girls increased across all percentiles. Median %BF at age 18 years for girls was 27.8%. By age 18 years, girls had approximately 1.5 times greater %BF than boys.

Discussion

This paper provides age- and gender-specific %BF reference percentiles for U.S. children and adolescents. The skinfold-derived percentile values were derived using nationally representative data and address a well-defined need in pediatric obesity research.[20] Currently, most of the pediatric literature relies on BMI to identify children as overweight and obese. Although an important epidemiologic and clinical tool,[21] BMI does not distinguish between fat mass and fat-free mass, with individuals of the same BMI showing varying levels of fatness.[22]

Although there is no perfect tool for estimating %BF in epidemiologic surveys, skinfold thicknesses provide some advantages and have previously been recommended for identifying obesity and health risk in youth.[23] Skinfold thicknesses can easily be taken in the field, are inexpensive and noninvasive, and currently are used in school-based health-related fitness testing programs, such as FITNESSGRAM. A disadvantage of skinfolds is the difficulty in obtaining accurate measurements in obese individuals. Nonetheless, the percentiles reported herein provide valuable reference data since they can be

Table 1. Smoothed LMS curves for selected percentiles of percent body fat for boys in three waves of NHANES IV

Age (years)	2nd	5th	10th	25th	50th	75th	85th	90th	95th	98th
5	8.5	9.2	10.0	11.6	14.0	17.2	19.6	21.5	24.9	30.1
6	8.1	8.9	9.8	11.5	14.2	17.9	20.6	22.8	26.8	33.0
7	7.9	8.8	9.7	11.6	14.6	18.8	21.9	24.4	29.1	36.2
8	7.9	8.9	10.0	12.2	15.5	20.4	24.0	27.0	32.4	40.8
9	8.1	9.2	10.4	12.9	16.8	22.5	26.6	30.1	36.4	46.0
10	8.3	9.5	10.8	13.7	18.0	24.5	29.2	33.2	40.4	51.2
11	8.2	9.5	10.9	14.0	18.8	25.8	31.0	35.4	43.3	55.1
12	7.8	9.1	10.6	13.7	18.6	26.0	31.4	35.9	44.2	56.6
13	7.2	8.5	9.9	12.9	17.8	25.1	30.5	35.0	43.3	55.7
14	6.5	7.7	9.1	11.9	16.6	23.6	28.8	33.2	41.2	53.2
15	6.0	7.2	8.4	11.2	15.6	22.3	27.3	31.5	39.3	51.0
16	5.9	7.1	8.3	11.1	15.5	22.2	27.3	31.6	39.5	51.3
17	6.1	7.3	8.6	11.4	16.1	23.2	28.5	33.0	41.3	53.9
18	6.4	7.7	9.0	12.1	17.0	24.6	30.3	35.1	44.1	57.6

Note: Data are from 1999–2000, 2001–2002, and 2003–2004. Age indicates whole age group (e.g., 8.0–8.99 years).
LMS, L=skewness, M=median, and S=coefficient of variation; NHANES, National Health and Nutrition Examination Survey

used to identify differences during growth between the genders across the school-age years.

Comparisons with other data are challenging due to differences in samples, measurements, procedures, and time. A set of BIA-derived %BF reference curves (based on children in the U.K.) has been widely used, but these were based on data from a 1985 survey.[14] The shapes of the curves are generally similar, but the use of more

Table 2. Smoothed LMS curves for selected percentiles of percent body fat for girls in three waves of NHANES IV

Age (years)	2nd	5th	10th	25th	50th	75th	85th	90th	95th	98th
5	9.4	10.2	11.1	12.8	15.4	18.9	21.3	23.3	26.9	32.3
6	9.4	10.4	11.3	13.2	16.0	19.8	22.5	24.6	28.5	34.3
7	9.6	10.6	11.6	13.7	16.8	21.0	23.9	26.3	30.5	36.5
8	9.9	11.0	12.2	14.5	17.9	22.6	25.8	28.4	32.9	39.3
9	10.4	11.7	13.0	15.6	19.4	24.5	28.0	30.8	35.6	42.3
10	11.0	12.4	13.8	16.7	20.8	26.4	30.1	33.0	37.9	44.7
11	11.5	13.0	14.5	17.6	22.0	27.8	31.6	34.5	39.4	46.0
12	12.0	13.6	15.2	18.5	23.1	28.9	32.6	35.5	40.3	46.5
13	12.6	14.3	16.0	19.4	24.0	29.8	33.5	36.3	40.8	46.7
14	13.2	14.9	16.7	20.2	24.8	30.6	34.1	36.8	41.1	46.6
15	13.8	15.6	17.4	20.9	25.5	31.1	34.6	37.1	41.2	46.2
16	14.4	16.3	18.1	21.6	26.2	31.7	35.0	37.4	41.2	46.0
17	15.0	16.9	18.8	22.4	27.0	32.3	35.5	37.9	41.5	46.0
18	15.6	17.6	19.5	23.2	27.8	33.1	36.3	38.6	42.2	46.5

Note: Data are from 1999–2000, 2001–2002, and 2003–2004. Age indicates whole age group (e.g., 8.0–8.99 years).
LMS, L=skewness, M=median, and S=coefficient of variation; NHANES, National Health and Nutrition Examination Survey

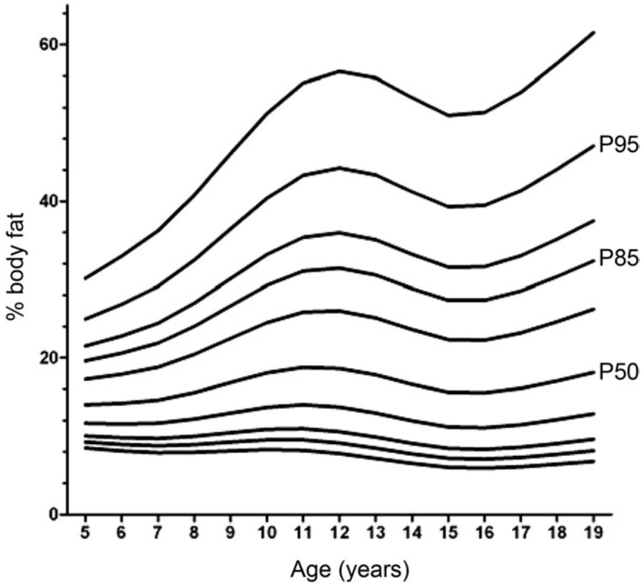

Figure 1. Smoothed LMS curves
Note: Curves are for the 2nd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, and 98th percentiles of percent body fat for boys in NHANES IV (1999–2004).
LMS, L=skewness, M=median, and S=coefficient of variation; NHANES, National Health and Nutrition Examination Survey; P, percentile

recent, nationally representative data in the present study provide updated information to characterize the status of obesity in the U.S. Mueller et al.[24] created BIA-derived %BF percentiles based on Texas children ranging in age from 8.5 to 17.5 years.

There was little difference among studies in the shape of the curve for the median values, but some differences were evident in the upper percentiles for boys. In the present study, the 95th percentile declined during early to mid adolescence and then increased into adulthood, whereas the 95th percentile from the Mueller et al.[24] study showed a sharp decrease. Although noteworthy, these differences are likely due to variations within the samples, methodology of %BF estimation, and the smaller sample size (n=678) in the Mueller study to estimate percentiles at the extremes. Reference curves using triceps and subscapular skinfolds have recently been created for U.S. youth.[25] However, these values were not converted to %BF, making it difficult to make direct comparisons to the present results.

Recently, a set of body fat reference values for U.S. children was created using DXA.[26] These percentiles were also created using a sample of youth from NHANES IV (1999–2004), although results are provided using age groups (8–11 years, 12–15 years, and 16–19 years) rather than separate ages. Overall, shapes of the median curves are similar to those shown here, with %BF in boys decreasing during adolescence whereas %BF in girls increases throughout. However, the DXA-derived %BF is consistently higher than the skinfold-derived %BF values in the current study. The magnitude of the difference varies depending on the percentile: approximately 5%–7% lower for boys and 7%–10% lower for girls. Differences appear to be greater at younger ages.

It is difficult to reconcile these differences since both studies used the same NHANES IV (1999–2004) sample. Recently, there have been some questions about the DXA model (Hologic QDR 4500A) used for determining body composition in NHANES IV (1999–2004). Previous research has found this model to overestimate fat-free mass and underestimate fat mass in adults.[27,28] Using pooled data from seven studies of adults (n=1195, mean age=55 years), it was found that the Hologic QDR 4500A overestimated lean mass in each of the samples (range=3%–9%, M=5%).[27]

A correction factor was applied to the NHANES IV (1999–2004) DXA data, where lean mass was decreased by 5% and an equivalent weight was added to fat mass to maintain the original total mass. The correction was applied to all DXA data, even though the pooled data from which the correction factor was derived did not include youth. This certainly merits examination, since it is unknown how the correction factor would perform in children, where growth and maturation influence chemical maturity and assessment of body composition.[29]

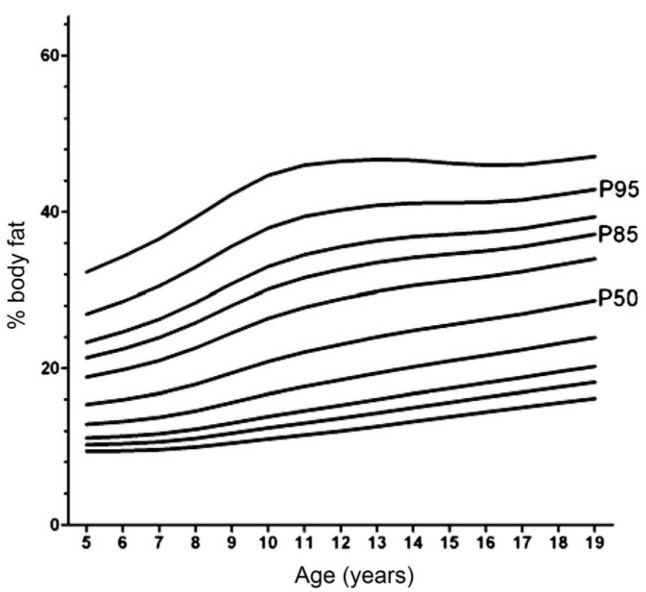

Figure 2. Smoothed LMS curves
Note: Curves are for the 2nd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, and 98th percentiles of percent body fat for girls in NHANES IV (1999–2004).
LMS, L=skewness, M=median, and S=coefficient of variation; NHANES, National Health and Nutrition Examination Survey; P, percentile

Further, the Hologic software version 12.1 (as used in NHANES IV [1999–2004]) has a substantial impact on soft-tissue assessment in children, and this influence is modified by gender and body mass.[30] Additional investigation is required to determine the validity of the Hologic QDR 4500A model and software, and the accompanying correction factor for fat and fat-free mass estimates in children. These factors could affect the accuracy of the DXA-derived %BF reference values, but the discrepancies in percentile values could also be due to limitations in the current design.

The Slaughter equation[16] utilized in the current study was developed on a group of youth that was leaner and older than the current sample. Also, error was probably introduced by assuming pubertal status by chronologic age for the calculation of %BF in boys, although in an epidemiologic design, the impact may have been minimal. In any case, the percentiles described here based on skinfold-derived %BF may be potentially underestimating adiposity in this sample.

An additional issue hindering research on youth obesity is the lack of definitive cut offs based on adverse health risks. Previous studies on pre-obesity epidemic epidemiologic data suggest using the 85th and 95th percentiles.[14] Although these may be defensible (based on the use of similar values for BMI), thresholds should be established based on increased health risk rather than a population distribution.

Dwyer and Blizzard[31] previously proposed thresholds of 20% fat for boys and 30% for girls based on at-risk groups for dyslipidemia and hypertension. Using a modified Slaughter equation, Williams et al.[32] identified %BF thresholds of 25% in boys and 30% in girls that were indicative of an increased risk of being in the highest quintile for blood pressure and serum lipoproteins in adolescents. The Williams et al. thresholds have been used within FITNESSGRAM,[33] but a limitation of these thresholds is that they present static values and hence do not take into consideration the normal growth and maturation of adiposity. As shown here and in previous growth studies, there are distinct age- and gender-associated variations in %BF. The lack of definitive standards may be due, in part, to the lack of appropriate reference data to characterize growth and maturation.

Although there are limitations with the Williams thresholds (25% for boys and 30% for girls), it provides a useful way to compare the relative utility of the present percentiles relative to the DXA-derived ones. Based on the values from the current study, approximately 15%–25% of American youth would be categorized as overweight, whereas 25%–75% would be categorized as overweight with the DXA values. It is not possible to determine which set is more accurate. The results with the present percentiles seem to be more consistent with current prevalence of overweight based on BMI, but this is only one way to evaluate the results. Clearly more work is needed to evaluate this issue.

The LMS parameters presented here (Table 3) may help to address the need to easily quantify and compare levels of adiposity and advance research on youth obesity. The SD score or z-score can be calculated from the LMS values by using the following equation, where Y is the measurement value (%BF), and the age- and gender-specific LMS values are obtained from Table 3:

$$\text{z-score} = [(Y/M)^L - 1]/(L \times S).$$

Table 3. LMS parameters for the calculation of *z*-scores in boys and girls

Age (years)	Boys L	Boys M	Boys S	Girls L	Girls M	Girls S
5	−0.688	13.977	0.290	−0.680	15.357	0.284
6	−0.603	14.160	0.322	−0.592	15.950	0.299
7	−0.521	14.568	0.353	−0.503	16.764	0.314
8	−0.446	15.525	0.382	−0.415	17.931	0.326
9	−0.380	16.800	0.408	−0.328	19.392	0.335
10	−0.323	18.037	0.431	−0.244	20.847	0.338
11	−0.277	18.756	0.454	−0.169	22.047	0.336
12	−0.244	18.611	0.474	−0.101	23.050	0.330
13	−0.223	17.787	0.491	−0.041	24.001	0.320
14	−0.211	16.580	0.503	0.013	24.839	0.308
15	−0.206	15.588	0.512	0.065	25.543	0.295
16	−0.205	15.488	0.517	0.117	26.233	0.282
17	−0.204	16.071	0.522	0.169	26.960	0.273
18	−0.202	17.022	0.526	0.222	27.810	0.265

Note: Age indicates whole age group (e.g., 8.0–8.99 years).
LMS, L=skewness, M=median, and S=coefficient of variation

A major strength of the current study is the use of nationally representative data to create age- and gender-specific %BF percentiles. The reference percentiles and LMS parameters also allow the opportunity to use %BF along with BMI in epidemiologic research, fitness assessment, and clinical practice. By using recent data, these percentiles provide further information about the magnitude of the current obesity epidemic based on body fat rather than BMI. For this reason, it should be noted that commonly used reference percentiles (e.g., 85th or 95th percentile) may not be appropriate for use as an overfat threshold, since these data were collected during the obesity epidemic. More appropriate thresholds, perhaps based on current or future health risk, are needed. Future studies should focus on identifying health-related %BF thresholds during growth and maturation, and investigating the discrepancies between these percentiles and those derived from the NHANES IV (1999–2004) DXA data.

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