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

O Yaw Addo and John H Himes

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 (≥85th percentile) or obese (≥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.

[1] From the Division of Epidemiology and Community Health, School of Public Health (OYA and JHH), and the Department of Food Science and Nutrition, University of Minnesota, Minneapolis, MN (OYA).

[2] Address correspondence to OY Addo, University of Minnesota, 1300 South 2nd Street, Suite 300, Minneapolis, MN 55454. E-mail: addo0008@umn.edu.

Received July 13, 2009. Accepted for publication December 14, 2009.

First published online January 6, 2010; doi: 10.3945/ajcn.2009.28385.

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 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).

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

Survey	Years	Sample size by skinfold thicknesses: Triceps	Subscapular	Subject age
		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.

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]

				Percentile									
Age	*L*	*M*	*S*	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.

The American Journal of Clinical Nutrition

TABLE 3
Smoothed percentiles for subscapular 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	−0.3827	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,

The American Journal of Clinical Nutrition

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

				Percentiles									
Age	*L*	*M*	*S*	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 categories. 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]

				Percentile									
Age	*L*	*M*	*S*	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 children and should not be used for this purpose. Determining the optimum skinfold percentile cutoffs to identify the overweight 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 subcutaneous fatness.

The authors' responsibilities were as follows—OYA and JHH: substantially contributed to the data analysis and writing of the manuscript. Neither of the authors had any conflicts of interest.

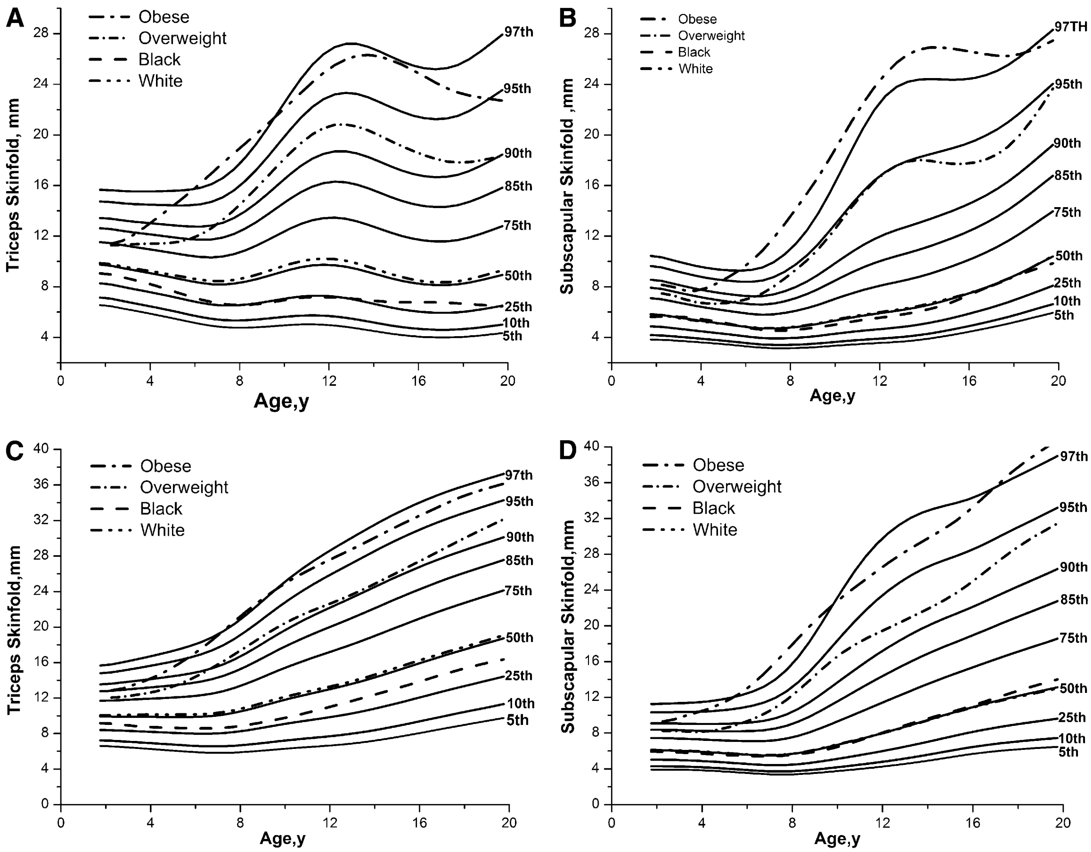

FIGURE 1. Smoothed percentile curves and group medians for triceps skinfold-for-age in boys (A), subscapular skinfold-for-age in boys (B), triceps skinfold-for-age in girls (C), and subscapular skinfold-for-age in girls (D). Smoothed group medians for overweight [BMI (in kg/m^2) between Centers for Disease 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.

REFERENCES

1. Garn S. Implications and applications of subcutaneous fat measurement to nutritional assessment and health risk evaluation. In: Himes JH, ed. Anthropometric assessment of nutritional status. New York, NY: Wiley-Liss, 1991:123–50.
2. Himes JH. Subcutaneous fat thickness as an indicator of nutritional status. In: Green LS, Johnston FE, eds. Social and biological predictors of nutritional status, physical growth, and neural development. New York, NY: Academic Press, Inc, 1980:9–32.
3. Bedogni G, Lughetti L, Ferrari M, et al. Sensitivity and specificity of body mass index and skinfold thicknesses in detecting excess adiposity in children aged 8-12 years. Ann Hum Biol 2003;30:132–9.
4. Freedman DS, Dietz WH, Srinivasan SR, Berenson GS. Risk factors and adult body mass index among overweight children: the Bogalusa Heart Study. Pediatrics 2009;123:750–7.
5. Jehn ML, Gittelsohn J, Treuth MS, Caballero B. Prevalence of overweight among Baltimore city schoolchildren and its associations with nutrition and physical activity. Obesity (Silver Spring) 2006;14: 989–93.
6. Steinberger J, Jacobs DR, Raatz S, Moran A, Hong CP, Sinaiko AR. Comparison of body fatness measurements by BMI and skinfolds vs dual energy X-ray absorptiometry and their relation to cardiovascular risk factors in adolescents. Int J Obes (Lond) 2005;29:1346–52.
7. Bellisari A, Roche AF. Anthropometry and ultrasound. In: Heymsfield S, Lohman T, ZiMian W, Going S, eds. Human body composition. 2nd ed. Champaign, IL: Human Kinetics, 2005:109–27.
8. Kuczmarski R, Ogden C, Grummer-Strawn L, et al. CDC growth charts: United States. Advance Data no. 314. Atlanta, GA: National Center for Health Statistics, 2000.
9. American Academy of Pediatrics Committee on Nutrition. Klienman RE, ed. Pediatric nutrition handbook. 6th ed. Elk Grove Village, IL: American Academy of Pediatrics, 2008.
10. Barlow SE. Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: summary report. Pediatrics 2007;120(suppl 4): S164–92.
11. Krebs NF, Himes JH, Jacobson D, Nicklas TA, Guilday P, Styne D. Assessment of child and adolescent overweight and obesity. Pediatrics 2007;120(suppl 4):S193–228.
12. Cronk CE, Roche AF. Race- and sex-specific reference data for triceps and subscapular skinfolds and weight/stature. Am J Clin Nutr 1982;35: 347–54.
13. Frisancho A. Anthropometric standards for the assessment of growth and nutritional status. Ann Arbor, MI: University of Michigan Press, 1990.
14. McDowell M, Fryar C, Hirsch R, Ogden C. Anthropometric reference data for children and adults: US population, 1999-2002, Advance Data no. 361. Atlanta, GA: National Center for Health Statistics, 2005.
15. Cole TJ. The LMS method for constructing normalized growth standards. Eur J Clin Nutr 1990;44:45–60.
16. McDowell A, Engel A, Massey JT, Maurer K. Plan and operation of the Second National Health and Nutrition Examination Survey, 1976-1980. Vital Health Stat 1 1981;15:1–8.
17. Miller HW. Plan and operation of the health and nutrition examination survey. United States–1971-1973. Vital Health Stat 1 1973;10a:1–46.
18. National Center for Health Statistics. Plan, operation, and response results of a program of children's examinations. Vital Health Stat 1 1967; 5:6–8.
19. National Center for Health Statistics. Plan and operation of a health examination survey of U.S. youths 12-17 years of age. Vital Health Stat 1 1969;8:8–12.
20. National Center for Health Statistics. Plan and operation of the Third National Health and Nutrition Examination Survey, 1988-94. Series 1: programs and collection procedures. Vital Health Stat 1 1994;32:1–3, 18, 20–22.

21. Kuczmarski RJ, Ogden CL, Guo SS, et al. 2000 CDC growth charts for the United States: Methods and development. Vital Health Stat 11 2002; 246:5–7.
22. Tukey J. Exploratory data analysis. Reading, MA: Addison-Wesley Publishing Company, 1977.
23. Harrison G, Buskirk E, Carter L, et al. Skinfold thickness and measurement technique. In: Lohman T, Roche AF, Martorell R, eds. Anthropometric standardization reference manual. Champaign, IL: Human Kinetics Books, 1988.
24. Johnston FE, Hamill PV, Lemeshow S. Skinfold thickness of children 6-11 years, United States. Vital Health Stat 11 1972;120:33–46.
25. Marks GC, Habicht JP, Mueller WH. Reliability, dependability, and precision of anthropometric measurements. The Second National Health and Nutrition Examination Survey 1976-1980. Am J Epidemiol 1989; 130:578–87.
26. Cole TJ, Green PJ. Smoothing reference centile curves: the LMS method and penalized likelihood. Stat Med 1992;11:1305–19.
27. van Buuren S, Fredriks M. Worm plot: a simple diagnostic device for modeling growth reference curves. Stat Med 2001;20:1259–77.
28. Pan H, Cole TJ. A comparison of goodness of fit tests for age-related reference ranges. Stat Med 2004;23:1749–65.
29. Must A, Dallal G, Dietz W. Reference data for obesity: 85th and 95th percentile body mass index (wt/ht^2) and triceps skinfold thickness. Am J Clin Nutr 1991;53:839–46.
30. Hughes JM, Li L, Chinn S, Rona RJ. Trends in growth in England and Scotland, 1972 to 1994. Arch Dis Child 1997;76:182–9.
31. Liem ET, De Lucia Rolfe E. L'abee C, Sauer PJ, Ong KK, Stolk RP. Measuring abdominal adiposity in 6 to 7-year-old children. Eur J Clin Nutr 2009;63:835–41.
32. Nooyens AC, Koppes LL, Visscher TL, et al. Adolescent skinfold thickness is a better predictor of high body fatness in adults than is body mass index: the Amsterdam Growth and Health Longitudinal Study. Am J Clin Nutr 2007;85:1533–9.
33. Sarria A, Moreno LA, Garcia-Llop LA, Fleta J, Morellon MP, Bueno M. Body mass index, triceps skinfold and waist circumference in screening for adiposity in male children and adolescents. Acta Paediatr 2001;90: 387–92.
34. Geiss HC, Parhofer KG, Schwandt P. Parameters of childhood obesity and their relationship to cardiovascular risk factors in healthy prepubescent children. Int J Obes Relat Metab Disord 2001;25:830–7.
35. Morrison JA, Barton BA, Biro FM, Daniels SR, Sprecher DL. Overweight, fat patterning, and cardiovascular disease risk factors in black and white boys. J Pediatr 1999;135:451–7.
36. Malina R. Variation in body composition associated with sex and ethnicity. In: Heymsfield S, Lohman T, ZiMian W, Going S, eds. Human body composition. 2nd ed. Champaign, IL: Human Kinetics, 2005: 271–311.
37. Freedman DS, Serdula MK, Srinivasan SR, Berenson GS. Relation of circumferences and skinfold thicknesses to lipid and insulin concentrations in children and adolescents: the Bogalusa Heart Study. Am J Clin Nutr 1999;69:308–17.
38. Freedman DS, Bowman BA, Otvos JD, Srinivasan SR, Berenson GS. Differences in the relation of obesity to serum triacylglycerol and VLDL subclass concentrations between black and white children: the Bogalusa Heart Study. Am J Clin Nutr 2002;75:827–33.
39. Malina R. Regional body composition: age, sex and ethnic variation. In: Roche A, Heymsfield S, Lohman T, eds. Human body composition. Champaign, IL: Human Kinetics, 1996:217–55.
40. Zillikens MC, Conway JM. Anthropometry in blacks: applicability of generalized skinfold equations and differences in fat patterning between blacks and whites. Am J Clin Nutr 1990;52:45–51.
41. Lohman TG, Pollock ML, Slaughter MH, Brandon LJ, Boileau RA. Methodological factors and the prediction of body fat in female athletes. Med Sci Sports Exerc 1984;16:92–6.
42. Himes JH, Bouchard C, Pheley AM. Lack of correspondence among measures identifying the obese. Am J Prev Med 1991;7:107–11.
43. Demerath EW, Schubert CM, Maynard LM, et al. Do changes in body mass index percentile reflect changes in body composition in children? Data from the Fels Longitudinal Study. Pediatrics 2006;117: e487–95.