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Development of subcutaneous fat in Spanish and Latin American children and adolescents: reference values for biceps, triceps, subscapular and suprailiac skinfolds

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Abstract

Subcutaneous fat skinfolds represent a reliable assessment instrument of adiposity status. This study provides current percentile references for four subcutaneous skinfolds (biceps, triceps, subscapular, suprailiac) applicable to children and adolescents in Spain and in Latin American countries where data are scarce.

The design consisted of a cross-sectional multicenter study performed with identical methods in 5 countries (Argentina, Cuba, Mexico, Spain and Venezuela). Total sample comprised 9163 children and youths (boys 4615 - girls 4548) aged 6-18 years, healthy and without apparent pathologies. Percentiles 3, 5, 10, 25, 50, 75, 90, 95 and 97 were calculated by the LMS method. Sexual dimorphism was assessed using the t-test and age differences with ANOVA. Normalized growth percentile references were obtained according to sex and age for each skinfold. The mean values of four skinfolds were significantly greater in girls than boys ($p<0.001$) and, in both sexes, all skinfolds show statistical differences through age ($p<0.001$) with different magnitudes.

Except triceps in girls, peaks between 11 and 12 years of age are more noticeable in boys than in girls. Although the general model of growth is known, the skinfold measurements show variability among populations and differences of magnitude are presented according to the analyzed population. Therefore, these age and sex-specific reference percentile values for biceps, triceps, subscapular and suprailiac skinfolds, derived from a large sample of Spanish and Latin American children and adolescents, are a useful tool for adiposity diagnosis in this population for which no reference values were available.

Introduction

The growth pattern of human populations is characterized by great plasticity, resulting from the interaction of multiple temporally and spatially varying environmental factors that modulate the expression of genetic potential (Alfaro et al., 2004; Bogin, 1999; Cameron and Bogin, 2012; Eveleth and Tanner, 1976; Lasker, 1969). It is theoretically assumed that human populations follow a similar growth pattern in similar environmental conditions; however, it cannot be ignored that some of the interpopulation differences in an ontogenetic model might reflect not only the influence of the environment, but also actual differences in the genetic potential of human groups (Butte et al., 2007).

On every continent and both in industrialized and developing countries, the obesity has shown a positive secular trend that affects individuals of all ages (Uauy et al., 2001). Its progress is particularly worrying among children and young people, since according to the International Obesity Task Force (IOTF) at the beginning of this century there were some 155 million overweight and 30-45 million obese children. In the Americas, 40% overweight and 15% obesity in childhood were estimated at the beginning of past decade (Lobstein, 2010), although large variations in terms of socio-economic environment and ethnicity factors were detected (Marrodán et al., 2007; Toselli et al., 2014). It should be noted that, paradoxically, in most Latin American countries, excess weight coexists with malnutrition. Persistence or increase of inequalities in access to nutritional resources, lack of health promotion and education and chronic deficiency of medical services constitute this new paradigm of "obesity in poverty" which means a double burden of malnutrition as was defined by Peña and Bacallao (2000). Some nationwide studies, as developed in Argentina by Oyhenart et al. (2008), perfectly epitomize this situation, which is replicated in most Latin American countries.

With regard to Spain, the prevalence of childhood obesity is difficult to determine because of the lack of national epidemiological records and methodological differences in the criteria used to establish obesity among studies (body mass index [BMI] / percentiles P85 and P95, P90 and P97 / triceps skinfold). In spite of it, studies on childhood obesity have increasingly shown a positive secular trend in relation to the incidence of overweight and obesity, both of them remain wide spread among Spanish children.

Thus, in the cross-sectional population study of Spanish children, PAIDOS'84 survey (1985), 4.9% of childhood obesity was reported for children between 6 and 13 years (boys: 5,1% and girls: 4,6%). The figure rose to 13,9% (boys: 15,6% and girls: 12.0%) in the EnKid study in the early 2000 (Serra-Majém et al., 2003). For the same age span, a sample taken between 1999 and 2002 by Marrodán et al. (2006) gave the following results: overweight: 12,5% (boys) and 9,6% (girls); obesity: 14,9% (boys) and 11.9% girls. National Standards for BMI (Hernández et al., 1988) were used as a reference.

The ALADINO study consisted of a national survey of prevalence of overweight and obesity among Spanish children between 6 and 9 years of age (Pérez-Farinós et al., 2013), using the BMI. According to this survey the prevalence of overweight in boys ranged from 14.1% to 26.7%, and in girls from 13.8% to 25.7%. The prevalence of obesity in boys ranged from 11.0% to 20.9%, and in girls from 11.2% to 15.5%, depending on the cut-off criteria (Spanish reference tables, International Obesity Task Force [IOTF] reference values and World Health Organization [WHO] growth standards).

BMI is an imperfect index of fatness, whereas skinfold thickness provides a more direct measurement of adiposity. In this situation, it is important to have appropriate references to improve the diagnosis of obesity in early ages. Due to its low cost and non-invasive procedure, the evaluation of skinfold thickness is one of the most objective anthropometric measurements to assess body fat because of its high compatibility with other methods of direct measurement of body fat mass (Marrodán et al., 2012). Excess adiposity assessed by skinfolds was associated in children and adolescents with increased blood lipids (triglycerides and cholesterol) and insulin resistance, markers for increased risk of metabolic syndrome (Weiss et al., 2004, Freedman et al., 2015). References regarding percentiles of Spanish population subcutaneous skinfolds are scarce (Aguilera et al., 1990; Hernández et al., 1988; Marrodán Serrano et al., 1999; Moreno et al., 2005) and virtually nonexistent for Latin American populations, the latter resulting from intense mixing processes (Wang et al., 2008) and exposed to varied and extreme environmental and ecological conditions (Bolzan et al., 1999). Thus, the objective of this collaborative multicenter study was to establish the percentile references for subscapular, triceps, biceps and suprailiac skinfold measurements in a Hispanic American child and young population by means of the LMS method (Cole, 1988; Cole and Green, 1992).

Materials and methods

Sample composition

The sample consisted of 9163 individuals (4615 boys and 4548 girls) aged 6 to 18 years, healthy and without apparent pathologies. The research was based on a cross-sectional analysis and participants were recruited at public schools, corresponding to middle socioeconomic level and in different locations in Argentina (Catamarca and Jujuy; boys:1635, girls:1648), Cuba (Havana; boys:360, girls:467), Mexico (Hermosillo, Sonora; boys: 407, girls:401), Spain (Madrid; boys: 1532, girls:1370) and Venezuela (Caracas and Merida; boys: 688, girls: 653). The date of birth of the participants was obtained from the national identity card or school registration forms and the decimal age was estimated from this date (Tanner et al., 1966). This study was previously approved by Ethical Committee of the coordination center (Complutense University of Madrid, Spain). After obtaining the informed consent of parents or guardians and abiding by the Helsinki protocol (World Medical Association, 2004).

Measurements

Anthropometric measurements were obtained by trained staff with standardized instruments and following techniques recommended by the International Biological Programme (Weiner and Lourie, 1981). The measurements of skinfolds were taken on the left side of the body by means of Holtain skinfold calipers (GPH, Switzerland) taking into account a constant pressure on the body and a precision in tenths of a millimeter. The same calipers model was used in the five countries.

Holding the individual's extended and relaxed arm, triceps and biceps folds were taken in the mesobrachial region. In the first case, a fold of skin and adipose tissue on the triceps was taken between the left hand thumb and fore finger, avoiding the inclusion of muscle tissue in the acromial-radial midline. The same procedure was used in the second case, but measuring the adipose tissue deposited on the biceps in the arm at the midpoint of the acromial-radial line. The subscapular skinfold was taken by separating the adipose tissue at the inferior angle of the scapula at its vertebral border, obliquely downward and outward at an angle of 45 degrees with the horizontal line passing through the lower edge of the scapula. The suprailiac skinfold was taken at the intersection of the iliac-axillary line (the left anterior superior iliac spine to the anterior axillary border) and a horizontal line along the upper edge of the ileum (Cabañas and Esparza, 2009). Technical errors of measurement, intra- and inter-observer, were calculated being less than 5%, a limit established by International Society for the Advancement of Kinanthropometry for measurement reliability in skinfold thickness (ISAK, 2011).

Statistical analysis

The dispersion of the raw data was analyzed and 20 outliers were removed using a ± 4 standard deviations (SD) cutoff according to the criterion used by Alfaro et al. (2008). Normal distribution and homogeneity of the variances were checked for all age groups. Sexual dimorphism of skinfolds was assessed using Student's t test and mean differences among age groups of 6 months from 6 to 18 years were established by means of an analysis of variance (ANOVA). For statistical analysis SPSS v.21.0 software was used considering in all tests a significant p value less than 0.05.

The LMS method to calculate percentiles was applied. This method synthesizes the changing distribution of a measurement according to some covariate, often age. The method establishes the changing distribution using the L, M and S curves representing respectively the skewness (lambda), median (mu) and measure of variation (sigma). The LMS method uses the Box-Cox transformation to adapt the distribution of anthropometric data to a normal distribution, essentially minimizing the effects of skewness (Cole and Green, 1992). The parameters L, M and S were calculated according to the method of maximum penalized likelihood. Centiles were calculated from the values of L, M and S, according to the following formula (Cole, 1988):

$$C = M\,[1+LSZ]^{1/L}$$

where L, M and S are the values calculated for each age and Z is the corresponding percentile searched. Age- and sex- specific percentile values (3, 5, 10, 25, 50, 75, 90, 95 and 97) were calculated and their corresponding curves were smoothed. Data processing was performed using the LMS Chart Maker Pro (The Institute of Child Health, London) software. Q test was used to establish the goodness of fit according to the recommended procedure (Pan and Cole, 2011).

Results

Tables 1 to 8 and Figures 1 to 4 show values for 3, 5, 10, 25, 50, 75, 90, 95 and 97 percentiles as normalized growth centile references corresponding to the biceps, triceps, subscapular and suprailiac skinfolds for boys and girls from 6 to 18 years old, classified by periods of 6 months. Tables also include L, M, S parameters previously calculated to obtain the percentiles according to the statistical method used.

The trends observed during the studied period of age, with respect to the analyzed variables, correspond to the general pattern of variation found in human populations, although the percentile values vary. ANOVA have shown that the mean values of each skinfold vary significantly through age periods in both sexes: biceps (boys: $F= 7.51$ $p<0.001$; girls: $F= 6.26$ $p<0.001$), triceps (boys: $F= 5.90$ $p<0.001$; girls: $F= 19.03$ $p<0.001$), subscapular (boys: $F= 13.49$ $p<0.001$; girls: $F= 19.34$; $p<0.001$), and suprailiac (boys: $F= 14.42$ $p<0.001$; girls: $F= 18.06$ $p<0.001$). The mean values of the four skinfolds are significantly higher in the female series with respect to males at all ages ($p<0.001$).

As can be seen in Figures 1 to 4, the studied skinfolds thicknesses increase continuously until the age of 11-12 years in both sexes. Except, as shown in Figure 2, in where girls' triceps remains rising until the end of the studied period (18 years), all other skinfolds decline after 12 years, producing a peak which is more pronounced in boys than girls (Figs. 1, 3 and 4). Subsequently, at the age of 15 years, a new pattern arises with values stabilization excluding the ascent of biceps skinfold in boys and the aforementioned triceps in girls.

INSERT Tables 1-8 AND Figs 1-4 ABOUT HERE

Discussion and conclusions

The present study is the first to consider a child and adolescent group of Spanish and Latin American origin to establish percentiles of four skinfolds. It provides reference data for anthropological and epidemiological studies. The evidence of a secular trend in the skinfold thickness and the scarcity of standards of reference applicable to populations such as Spanish and Latin American justify this research in which percentile values are provided not only with respect to triceps and subscapular skinfold but also for biceps and suprailiac, for an extended period of age.

Body mass index (BMI) is the most widely used anthropometric indicator for the diagnosis of malnutrition, possibly due to the simplicity of its calculation and dimensions. However, it is not a good estimator of the body composition; the study of the skinfold thickness is more useful than BMI in the analysis of development of fatness since that allows to analyze the distribution of body fat and provides better information about body composition changes. Different body regions where skinfold thickness is measured may indicate different patterns of fat distribution. Triceps and biceps skinfolds reflect peripheral fat, whereas subscapular and suprailiac skinfolds refer to central/visceral fat (Cicek et al., 2014; Klimek-Piotrowska et al., 2015). The analysis of skinfolds is considered an important tool for clinical application. For example, the ratios of skinfolds have often been used as an indicator of the distribution of subcutaneous fat between peripheral and central depots, which has been proposed as a marker of cardiovascular risk (Moreno et al., 2001; Santos et al., 2016; Sarriá Chueca et al., 1997).

In order to analyze the secular trend in the fatness, Olds (2009) carried out a meta-analysis of historical studies which included a total of 154 surveys involving nearly half a million young people from 30 developed countries, studied between 1951 and 2004. Triceps and subscapular skinfold thicknesses, percentage body fat (% BF) and triceps/subscapular ratio were analyzed. In spite of the problems found in relation to the sampling frames, sample sizes and methods used by the different studies, an increase in the two analyzed skinfolds, triceps and subscapular was found. The rate was of 0.4-0.5 mm per decade in both skinfolds and 0.9% per decade with respect to % BF. In addition, the triceps/subscapular ratio was becoming more central. The author concluded that there were adverse changes in body composition of children and youth during the time period analyzed, with a potential future increase in the incidence of cardiometabolic diseases. Despite the long period of time considered (1951-2004), Olds's paper only included two Spanish series (Aguilera et al., 1990; Marrodán Serrano et al., 1999) and one from Latin America (Argentina, Bolzan et al., 1999). Most of the data came from the U.S.A., U.K., Australia and Canada (60%).

The values of tricipital and subscapular skinfolds corresponding to the present study were also comparatively higher in both sexes, than those calculated for white population from the United States of America by Frisancho in 1990, which included the samples from National

Health and Nutrition Examination Surveys NHANES I and II, obtained between 1971 and 1980 (Frisancho, 1990). The percentiles were not softened by the LMS method and skinfold measurements were collected with Lange calipers to the millimeter accuracy which is less than the Holtain skinfold caliper used in this study.

A more extended analysis was developed by Addo and Himes (2010) establishing percentile reference curves for triceps and subscapular skinfold thicknesses corresponding to U.S.A. children and adolescents. National samples between 1963 and 1994 (more than 30,000 individuals) were obtained from the Centers for Disease Control and Prevention (CDC) and these samples were previously used as data sources for various skinfold reference curves such as those of Frisancho (1990). As in the study of Olds (2009), previously mentioned, the methods and sampling frames presented variations following the different sources of data. For example, in the study of NHANES III (included in the CDC samples) the skinfold thicknesses were measured by using Holtain calipers (0.2 mm of precision) while Lange calipers (0.5 mm) were used during all the rest of the national surveys incorporated in the study. This situation could have resulted in some errors when curves were elaborated. Smoothed percentiles for triceps and subscapular skinfolds were calculated considering age and sex, developing a single reference for all black and white children.

The curves established by Addo and Himes (2010) are commonly used in clinical and research fields and widely recommended as representative references for assessing the physical growth of U.S.A. children and young. However, it is noted that 50th percentile values of triceps and subscapular skinfolds in Spanish and Latin American current samples are greater compared to their general series for all ages, reaching a difference up to 2 mm. In Europe, the percentile values regarding triceps and subscapular skinfolds were calculated for German adolescents aged between 12 and 18 years by Haas et al. (2011). Compared to those values, the adolescents of the current study have greater thickness for both skinfolds being particularly different in male series.

The AVENA study analyzed six skinfolds and the distribution of trunk fat in 2160 Spanish adolescents between 13 and 18 years of age from different places of the Iberian Peninsula (Moreno et al., 2007). This study have provided figures for the relationship (subscapular + suprailiac / biceps + triceps + subscapular + suprailiac skinfolds) x 100 = trunk-to-total skinfolds percent (TTS%). This index showed a sexual dimorphism with significantly greater values in males. The authors confirmed a tendency to a central pattern of fat distribution, assessed by means of TTS. The values of the triceps and subscapular skinfolds found in the present research were lower in both sexes and in most comparable percentiles (5, 10, 25, 50, 77, 90 and 95) than those calculated with the LMS method by AVENA study.

For future research it would be interesting to assess the influences of other factors related to genetics and environment on adiposity, especially in samples with individuals belonging to different ethnic groups because they could have a different growth potential. For example, the link between height and subcutaneous fat levels has been demonstrated at certain ages from infancy to adulthood (Freedman et al., 2004; Himes and Roche, 1986; Wells and Cole, 2014).

In conclusion, there are valuable references for skinfolds derived from large samples of the U.S.A. population (Addo and Himes, 2010; Frisancho, 1990; Olds, 2009). These samples include Hispanic residents whose specific origin is often unknown. The strength of this study is that it provides updated information based on a large number of data from Spain and four specific Latin American countries for comparison. The distribution of percentiles of biceps, triceps, subscapular and suprailiac skinfolds of contemporary children and adolescents from different locations in Spain, Argentina, Cuba, Mexico and Venezuela presented in this work, could be used as reference data to identify children and adolescents with a risk of developing obesity or malnutrition disorders and provide a baseline for future studies of temporal trends.

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Legends for Figures

Fig. 1. Smoothed curves of percentile values for biceps subcutaneous skinfold by sex.

Fig. 2. Smoothed curves of percentile values for triceps subcutaneous skinfold by sex.

Fig. 3. Smoothed curves of percentile values for subscapular subcutaneous skinfold by sex.

Fig. 4. Smoothed curves of percentile values for suprailiac subcutaneous skinfold by sex.

Table 1. Smoothed percentiles and L, M and S values for biceps subcutaneous skinfold. Boys.

Age (Years)	L	M	S	3	5	10	25	50	75	90	95	97
6.0	-0.2887	5.6052	0.4327	2.70	2.93	3.35	4.24	5.61	7.60	10.26	12.44	14.18
6.5	-0.2769	5.7362	0.4466	2.70	2.94	3.37	4.29	5.74	7.86	10.70	13.04	14.92
7.0	-0.2652	5.9180	0.4593	2.72	2.97	3.42	4.39	5.92	8.18	11.22	13.75	15.79
7.5	-0.2539	6.1440	0.4706	2.77	3.03	3.51	4.53	6.14	8.55	11.82	14.55	16.74
8.0	-0.2431	6.3923	0.4802	2.83	3.10	3.60	4.68	6.39	8.96	12.45	15.37	17.72
8.5	-0.2333	6.6364	0.4881	2.89	3.18	3.70	4.83	6.64	9.35	13.05	16.15	18.65
9.0	-0.2249	6.8457	0.4944	2.94	3.24	3.79	4.96	6.85	9.68	13.56	16.81	19.43
9.5	-0.2182	6.9991	0.4995	2.98	3.29	3.84	5.06	7.00	9.93	13.95	17.31	20.03
10.0	-0.2135	7.1181	0.5035	3.00	3.32	3.89	5.13	7.12	10.13	14.25	17.71	20.51
10.5	-0.2108	7.2220	0.5065	3.03	3.35	3.93	5.19	7.22	10.30	14.52	18.05	20.92
11.0	-0.2100	7.2805	0.5085	3.05	3.37	3.95	5.23	7.28	10.39	14.67	18.27	21.18
11.5	-0.2110	7.2573	0.5097	3.03	3.35	3.94	5.21	7.26	10.37	14.66	18.26	21.18
12.0	-0.2138	7.1415	0.5100	2.98	3.30	3.87	5.12	7.14	10.21	14.44	18.00	20.90
12.5	-0.2182	6.9356	0.5098	2.90	3.21	3.77	4.98	6.94	9.92	14.04	17.51	20.34
13.0	-0.2237	6.6724	0.5091	2.80	3.10	3.63	4.79	6.67	9.54	13.51	16.87	19.60
13.5	-0.2297	6.3919	0.5079	2.69	2.98	3.48	4.60	6.39	9.13	12.94	16.16	18.80
14.0	-0.2360	6.1346	0.5062	2.60	2.87	3.35	4.42	6.13	8.76	12.41	15.50	18.04
14.5	-0.2421	5.9390	0.5040	2.53	2.79	3.26	4.28	5.94	8.47	11.99	14.99	17.44
15.0	-0.2474	5.8362	0.5015	2.50	2.75	3.21	4.22	5.84	8.31	11.75	14.69	17.09
15.5	-0.2512	5.8438	0.4988	2.52	2.77	3.23	4.23	5.84	8.31	11.73	14.65	17.04
16.0	-0.2532	5.9338	0.4958	2.57	2.83	3.29	4.30	5.93	8.42	11.87	14.80	17.20
16.5	-0.2535	6.0721	0.4925	2.64	2.91	3.38	4.41	6.07	8.59	12.08	15.04	17.46
17.0	-0.2523	6.2469	0.4888	2.73	3.00	3.49	4.55	6.25	8.81	12.35	15.34	17.78
17.5	-0.2500	6.4497	0.4846	2.84	3.12	3.62	4.71	6.45	9.07	12.67	15.69	18.15
18.0	-0.2472	6.6639	0.4802	2.95	3.24	3.76	4.88	6.66	9.34	12.99	16.05	18.52

Table 2. Smoothed percentiles and L, M and S values for biceps subcutaneous skinfold. Girls.

Age (Years)	L	M	S	3	5	10	25	50	75	90	95	97
6.0	-0.0564	6.6265	0.4371	2.97	3.27	3.82	4.95	6.63	8.92	11.71	13.81	15.38
6.5	-0.0529	6.5506	0.4456	2.88	3.19	3.73	4.86	6.55	8.87	11.70	13.84	15.44
7.0	-0.0494	6.5874	0.4532	2.86	3.17	3.72	4.86	6.59	8.96	11.88	14.08	15.74
7.5	-0.0457	6.7560	0.4595	2.89	3.21	3.78	4.97	6.76	9.23	12.27	14.58	16.32
8.0	-0.0413	6.9942	0.4644	2.97	3.30	3.88	5.12	6.99	9.59	12.78	15.20	17.02
8.5	-0.0356	7.2329	0.4676	3.04	3.39	4.00	5.29	7.23	9.93	13.26	15.78	17.68
9.0	-0.0286	7.4566	0.4692	3.12	3.48	4.11	5.44	7.46	10.25	13.68	16.27	18.23
9.5	-0.0201	7.6627	0.4695	3.19	3.56	4.21	5.59	7.66	10.53	14.04	16.69	18.68
10.0	-0.0107	7.8466	0.4684	3.26	3.64	4.31	5.72	7.85	10.77	14.33	17.01	19.02
10.5	-0.0007	8.0052	0.4661	3.33	3.72	4.41	5.85	8.01	10.96	14.55	17.24	19.24
11.0	0.0094	8.1458	0.4627	3.40	3.79	4.49	5.96	8.15	11.12	14.72	17.39	19.38
11.5	0.0196	8.2728	0.4587	3.47	3.87	4.58	6.07	8.27	11.26	14.84	17.50	19.46
12.0	0.0297	8.3704	0.4544	3.52	3.93	4.65	6.15	8.37	11.36	14.91	17.53	19.47
12.5	0.0400	8.4212	0.4504	3.56	3.97	4.70	6.20	8.42	11.39	14.90	17.48	19.37
13.0	0.0504	8.4216	0.4470	3.57	3.98	4.71	6.22	8.42	11.36	14.81	17.34	19.19
13.5	0.0610	8.3733	0.4447	3.55	3.96	4.69	6.19	8.37	11.27	14.66	17.13	18.93
14.0	0.0713	8.2862	0.4435	3.51	3.92	4.64	6.12	8.29	11.14	14.47	16.88	18.63
14.5	0.0809	8.1769	0.4434	3.45	3.86	4.57	6.04	8.18	10.99	14.25	16.61	18.33
15.0	0.0896	8.0815	0.4439	3.39	3.80	4.51	5.97	8.08	10.86	14.08	16.39	18.08
15.5	0.0976	8.0295	0.4449	3.35	3.76	4.47	5.92	8.03	10.79	13.99	16.28	17.95
16.0	0.1047	8.0075	0.4461	3.33	3.73	4.44	5.90	8.01	10.77	13.95	16.24	17.90
16.5	0.1113	7.9908	0.4472	3.30	3.71	4.42	5.88	7.99	10.75	13.93	16.21	17.86
17.0	0.1173	7.9555	0.4482	3.27	3.68	4.39	5.85	7.96	10.71	13.87	16.13	17.77
17.5	0.1229	7.8844	0.4489	3.23	3.64	4.34	5.79	7.88	10.61	13.75	15.99	17.61
18.0	0.1282	7.7872	0.4494	3.18	3.58	4.28	5.72	7.79	10.48	13.57	15.78	17.38

Table 3. Smoothed percentiles and L, M and S values for triceps subcutaneous skinfold. Boys.

Age (Years)	L	M	S	3	5	10	25	50	75	90	95	97
6.0	0.0544	9.0370	0.3979	4.21	4.64	5.39	6.90	9.04	11.80	14.95	17.20	18.83
6.5	0.0656	9.3628	0.4060	4.28	4.73	5.51	7.10	9.36	12.28	15.62	18.01	19.73
7.0	0.0766	9.7389	0.4131	4.37	4.85	5.67	7.35	9.74	12.83	16.37	18.89	20.72
7.5	0.0867	10.1320	0.4191	4.48	4.98	5.85	7.61	10.13	13.40	17.13	19.79	21.71
8.0	0.0951	10.5090	0.4238	4.58	5.11	6.02	7.87	10.51	13.94	17.84	20.63	22.65
8.5	0.1012	10.8380	0.4273	4.68	5.23	6.17	8.09	10.84	14.40	18.46	21.36	23.45
9.0	0.1049	11.0890	0.4300	4.76	5.32	6.29	8.26	11.09	14.76	18.94	21.92	24.07
9.5	0.1061	11.2481	0.4324	4.80	5.37	6.35	8.37	11.25	14.99	19.26	22.30	24.50
10.0	0.1052	11.3596	0.4350	4.82	5.40	6.40	8.44	11.37	15.17	19.51	22.61	24.84
10.5	0.1022	11.4648	0.4380	4.84	5.42	6.43	8.50	11.47	15.34	19.76	22.92	25.21
11.0	0.0976	11.5332	0.4414	4.85	5.43	6.45	8.53	11.54	15.46	19.97	23.19	25.53
11.5	0.0917	11.5270	0.4450	4.82	5.40	6.42	8.51	11.53	15.49	20.05	23.33	25.70
12.0	0.0848	11.4513	0.4489	4.76	5.34	6.35	8.43	11.45	15.42	20.02	23.33	25.74
12.5	0.0775	11.3194	0.4529	4.68	5.25	6.25	8.31	11.32	15.29	19.90	23.24	25.67
13.0	0.0703	11.1365	0.4568	4.58	5.14	6.12	8.16	11.13	15.08	19.69	23.03	25.48
13.5	0.0637	10.9114	0.4601	4.47	5.02	5.98	7.98	10.91	14.82	19.40	22.74	25.18
14.0	0.0580	10.6762	0.4625	4.37	4.90	5.84	7.80	10.68	14.53	19.07	22.38	24.82
14.5	0.0534	10.4708	0.4637	4.28	4.80	5.73	7.64	10.48	14.27	18.76	22.04	24.46
15.0	0.0498	10.3429	0.4636	4.24	4.75	5.66	7.55	10.35	14.11	18.55	21.81	24.21
15.5	0.0472	10.3251	0.4621	4.25	4.76	5.66	7.55	10.33	14.07	18.50	21.75	24.14
16.0	0.0453	10.3825	0.4590	4.30	4.81	5.72	7.61	10.39	14.12	18.55	21.79	24.18
16.5	0.0441	10.4703	0.4544	4.38	4.89	5.80	7.69	10.48	14.20	18.61	21.83	24.21
17.0	0.0431	10.5728	0.4484	4.47	4.99	5.91	7.80	10.58	14.29	18.66	21.86	24.21
17.5	0.0424	10.6826	0.4414	4.59	5.11	6.02	7.92	10.69	14.37	18.69	21.85	24.17
18.0	0.0416	10.7978	0.4336	4.71	5.23	6.15	8.04	10.80	14.45	18.72	21.83	24.11

Table 4. Smoothed percentiles and L, M and S values for triceps subcutaneous skinfold. Girls.

Age (Years)	L	M	S	3	5	10	25	50	75	90	95	97
6.0	0,2426	10,2182	0,3796	4,66	5,19	6,09	7,84	10,22	13,10	16,19	18,28	19,74
6.5	0,2418	10,2411	0,3871	4,60	5,13	6,04	7,82	10,24	13,19	16,36	18,52	20,03
7.0	0,2410	10,3751	0,3932	4,59	5,14	6,06	7,89	10,38	13,42	16,69	18,93	20,49
7.5	0,2407	10,6371	0,3977	4,66	5,22	6,18	8,06	10,64	13,79	17,20	19,53	21,16
8.0	0,2414	10,9626	0,4004	4,77	5,35	6,34	8,29	10,96	14,24	17,78	20,20	21,90
8.5	0,2439	11,2813	0,4015	4,90	5,49	6,51	8,52	11,28	14,66	18,32	20,81	22,56
9.0	0,2489	11,5819	0,4011	5,02	5,63	6,68	8,75	11,58	15,05	18,79	21,34	23,12
9.5	0,2567	11,8683	0,3995	5,15	5,78	6,85	8,98	11,87	15,40	19,20	21,78	23,59
10.0	0,2670	12,1456	0,3967	5,28	5,93	7,03	9,20	12,15	15,73	19,57	22,17	23,99
10.5	0,2789	12,4202	0,3930	5,43	6,09	7,22	9,43	12,42	16,04	19,90	22,50	24,32
11.0	0,2920	12,7014	0,3888	5,58	6,26	7,41	9,67	12,70	16,35	20,22	22,83	24,64
11.5	0,3057	12,9947	0,3846	5,74	6,43	7,62	9,92	12,99	16,68	20,57	23,17	24,98
12.0	0,3200	13,2871	0,3807	5,89	6,61	7,82	10,16	13,29	17,01	20,91	23,51	25,32
12.5	0,3347	13,5612	0,3773	6,03	6,76	8,00	10,39	13,56	17,31	21,23	23,84	25,64
13.0	0,3498	13,8000	0,3747	6,14	6,89	8,16	10,59	13,80	17,58	21,51	24,12	25,91
13.5	0,3654	13,9893	0,3729	6,22	6,98	8,27	10,74	13,99	17,80	21,73	24,33	26,12
14.0	0,3810	14,1268	0,3718	6,26	7,04	8,35	10,85	14,13	17,95	21,89	24,48	26,26
14.5	0,3962	14,2198	0,3711	6,28	7,07	8,39	10,92	14,22	18,05	21,99	24,57	26,34
15.0	0,4107	14,3015	0,3708	6,29	7,09	8,43	10,98	14,30	18,15	22,08	24,65	26,41
15.5	0,4243	14,4005	0,3707	6,30	7,11	8,47	11,06	14,40	18,26	22,20	24,77	26,53
16.0	0,4368	14,5000	0,3709	6,31	7,13	8,51	11,12	14,50	18,39	22,33	24,91	26,66
16.5	0,4483	14,5797	0,3715	6,31	7,14	8,53	11,18	14,58	18,49	22,45	25,02	26,78
17.0	0,4588	14,6489	0,3723	6,29	7,14	8,55	11,22	14,65	18,58	22,55	25,13	26,89
17.5	0,4684	14,7237	0,3733	6,28	7,14	8,57	11,26	14,72	18,68	22,67	25,26	27,02
18.0	0,4775	14,8182	0,3745	6,28	7,14	8,59	11,32	14,82	18,81	22,83	25,43	27,20

Table 5. Smoothed percentiles and L, M and S values for the subscapular subcutaneous skinfold. Boys.

Age (Years)	L	M	S	3	5	10	25	50	75	90	95	97
6.0	-0.8287	6.1475	0.3670	3.56	3.76	4.13	4.90	6.14	8.111	11.15	14.20	17.12
6.5	-0.7979	6.3752	0.3860	3.59	3.81	4.20	5.03	6.37	8.536	11.96	15.45	18.87
7.0	-0.7671	6.6361	0.4040	3.64	3.87	4.29	5.18	6.63	9.009	12.83	16.81	20.75
7.5	-0.7368	6.9243	0.4207	3.71	3.95	4.39	5.35	6.92	9.520	13.76	18.23	22.70
8.0	-0.7069	7.2200	0.4358	3.78	4.04	4.50	5.52	7.22	10.03	14.69	19.62	24.58
8.5	-0.6777	7.5012	0.4487	3.84	4.12	4.61	5.69	7.50	10.52	15.54	20.87	26.24
9.0	-0.6493	7.7515	0.4595	3.90	4.19	4.70	5.84	7.75	10.95	16.28	21.91	27.56
9.5	-0.6220	7.9630	0.4680	3.94	4.24	4.78	5.96	7.96	11.31	16.86	22.70	28.49
10.0	-0.5960	8.1558	0.4742	3.98	4.29	4.85	6.08	8.15	11.62	17.34	23.28	29.10
10.5	-0.5711	8.3505	0.4780	4.04	4.36	4.93	6.21	8.35	11.92	17.74	23.71	29.48
11.0	-0.5475	8.5412	0.4793	4.10	4.43	5.02	6.34	8.54	12.19	18.06	23.97	29.59
11.5	-0.5252	8.7155	0.4779	4.17	4.51	5.12	6.47	8.71	12.40	18.24	24.02	29.41
12.0	-0.5038	8.8597	0.4739	4.24	4.59	5.21	6.58	8.85	12.55	18.29	23.84	28.92
12.5	-0.4829	8.9652	0.4674	4.30	4.66	5.29	6.68	8.96	12.62	18.18	23.44	28.15
13.0	-0.4619	9.0456	0.4590	4.37	4.73	5.37	6.77	9.04	12.63	17.97	22.89	27.21
13.5	-0.4399	9.1205	0.4491	4.44	4.81	5.45	6.86	9.12	12.62	17.71	22.28	26.22
14.0	-0.4162	9.2125	0.4383	4.53	4.90	5.56	6.97	9.21	12.62	17.47	21.71	25.29
14.5	-0.3903	9.3448	0.4272	4.64	5.02	5.68	7.11	9.34	12.68	17.30	21.24	24.50
15.0	-0.3617	9.5399	0.4164	4.78	5.17	5.85	7.30	9.53	12.82	17.26	20.96	23.96
15.5	-0.3299	9.8097	0.4067	4.95	5.35	6.06	7.54	9.80	13.07	17.38	20.89	23.69
16.0	-0.2948	10.1238	0.3983	5.14	5.56	6.29	7.81	10.12	13.39	17.60	20.96	23.60
16.5	-0.2561	10.4439	0.3912	5.32	5.75	6.51	8.09	10.44	13.72	17.86	21.10	23.60
17.0	-0.2140	10.7415	0.3854	5.47	5.92	6.71	8.34	10.74	14.03	18.10	21.23	23.61
17.5	-0.1689	10.9960	0.3806	5.59	6.06	6.88	8.55	10.99	14.29	18.29	21.31	23.58
18.0	-0.1215	11.2086	0.3767	5.68	6.16	7.01	8.72	11.20	14.50	18.43	21.34	23.51

Table 6. Smoothed percentiles and L, M and S values for the subscapular subcutaneous skinfold. Girls.

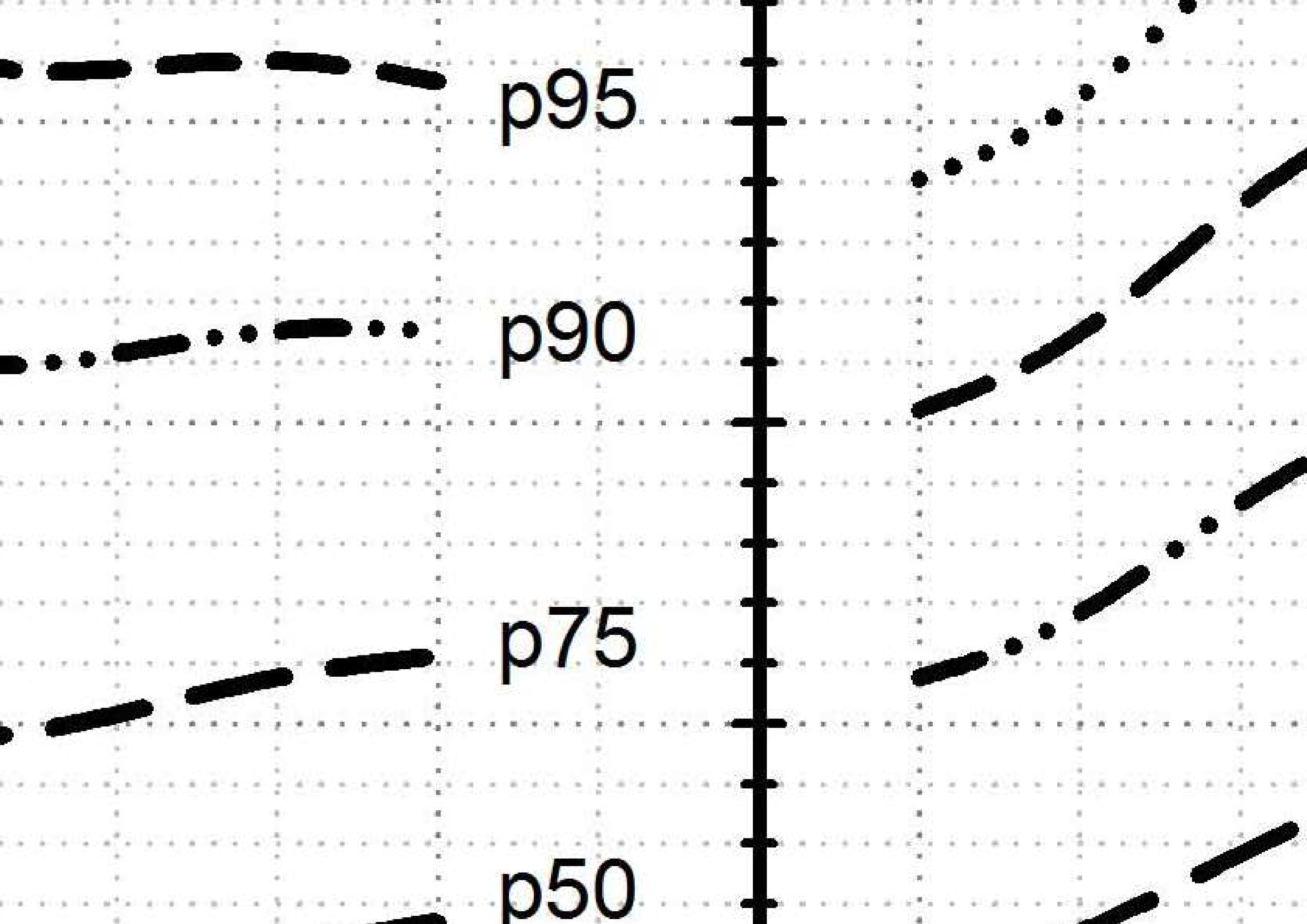
Age (Years)	L	M	S	3	5	10	25	50	75	90	95	97
6.0	-0.6267	6.9170	0.4123	3.68	3.93	4.38	5.35	6.93	9.39	13.14	16.73	20.01
6.5	-0.6055	7.0303	0.4221	3.68	3.94	4.40	5.41	7.03	9.61	13.54	17.31	20.75
7.0	-0.5841	7.2237	0.4310	3.72	3.99	4.48	5.52	7.22	9.93	14.07	18.04	21.67
7.5	-0.5622	7.5036	0.4389	3.81	4.09	4.60	5.71	7.50	10.37	14.75	18.95	22.76
8.0	-0.5399	7.8128	0.4454	3.91	4.21	4.75	5.91	7.81	10.84	15.46	19.85	23.83
8.5	-0.5169	8.0968	0.4505	4.01	4.32	4.89	6.11	8.10	11.27	16.07	20.61	24.69
9.0	-0.4928	8.3771	0.4538	4.11	4.44	5.02	6.30	8.38	11.67	16.62	21.25	25.36
9.5	-0.4673	8.6870	0.4552	4.23	4.57	5.19	6.52	8.69	12.10	17.17	21.83	25.93
10.0	-0.4401	9.0306	0.4548	4.37	4.73	5.38	6.77	9.03	12.56	17.71	22.38	26.42
10.5	-0.4114	9.4032	0.4525	4.53	4.91	5.59	7.05	9.40	13.03	18.24	22.87	26.81
11.0	-0.3815	9.7940	0.4485	4.71	5.11	5.82	7.36	9.79	13.51	18.74	23.30	27.11
11.5	-0.3505	10.1880	0.4429	4.91	5.32	6.07	7.67	10.19	13.97	19.19	23.63	27.29
12.0	-0.3185	10.5600	0.4360	5.10	5.54	6.31	7.97	10.56	14.38	19.54	23.84	27.32
12.5	-0.2853	10.8870	0.4284	5.27	5.73	6.54	8.25	10.89	14.72	19.78	23.91	27.20
13.0	-0.2508	11.1503	0.4205	5.42	5.89	6.73	8.48	11.15	14.97	19.90	23.84	26.93
13.5	-0.2151	11.3427	0.4132	5.53	6.01	6.87	8.65	11.34	15.12	19.90	23.65	26.55
14.0	-0.1781	11.4773	0.4067	5.60	6.10	6.97	8.78	11.48	15.21	19.84	23.40	26.12
14.5	-0.1399	11.5755	0.4013	5.65	6.16	7.04	8.87	11.58	15.25	19.74	23.14	25.70
15.0	-0.1008	11.6660	0.3969	5.68	6.20	7.10	8.96	11.67	15.30	19.67	22.92	25.35
15.5	-0.0610	11.7722	0.3935	5.71	6.24	7.16	9.05	11.77	15.38	19.65	22.79	25.11
16.0	-0.0204	11.8911	0.3908	5.73	6.28	7.22	9.14	11.89	15.49	19.67	22.71	24.94
16.5	0.0211	12.0114	0.3888	5.75	6.31	7.28	9.23	12.01	15.60	19.72	22.67	24.82
17.0	0.0635	12.1178	0.3871	5.75	6.33	7.32	9.31	12.12	15.70	19.75	22.62	24.69
17.5	0.1069	12.2008	0.3856	5.73	6.33	7.34	9.37	12.20	15.77	19.75	22.54	24.53
18.0	0.1508	12.2776	0.3840	5.72	6.32	7.36	9.43	12.28	15.83	19.74	22.45	24.37

Table 7. Smoothed percentiles and L, M and S values for suprailiac subcutaneous skinfold. Boys.

Age (Years)	L	M	S	3	5	10	25	50	75	90	95	97
6.0	-0.5159	5.9582	0.4917	2.80	3.03	3.45	4.39	5.96	8.57	12.77	16.97	20.94
6.5	-0.4689	6.2735	0.5126	2.83	3.08	3.54	4.55	6.27	9.15	13.76	18.35	22.64
7.0	-0.4225	6.6473	0.5328	2.88	3.15	3.65	4.76	6.65	9.82	14.88	19.87	24.48
7.5	-0.3770	7.0925	0.5520	2.95	3.25	3.79	5.01	7.09	10.59	16.15	21.55	26.48
8.0	-0.3331	7.5889	0.5695	3.04	3.36	3.95	5.29	7.59	11.45	17.51	23.33	28.55
8.5	-0.2913	8.1025	0.5851	3.12	3.47	4.11	5.58	8.10	12.32	18.88	25.07	30.54
9.0	-0.2523	8.5802	0.5984	3.19	3.56	4.26	5.84	8.58	13.13	20.12	26.60	32.25
9.5	-0.2169	8.9839	0.6091	3.23	3.63	4.37	6.06	8.98	13.82	21.13	27.80	33.53
10.0	-0.1853	9.3573	0.6171	3.27	3.69	4.47	6.27	9.36	14.43	22.01	28.81	34.58
10.5	-0.1582	9.7428	0.6223	3.33	3.77	4.60	6.49	9.74	15.04	22.85	29.77	35.55
11.0	-0.1354	10.0950	0.6245	3.39	3.86	4.72	6.70	10.10	15.58	23.55	30.52	36.29
11.5	-0.1169	10.3554	0.6237	3.45	3.93	4.82	6.87	10.36	15.94	23.97	30.89	36.57
12.0	-0.1023	10.4812	0.6202	3.48	3.97	4.88	6.96	10.48	16.07	24.01	30.79	36.30
12.5	-0.0913	10.4577	0.6143	3.49	3.98	4.89	6.96	10.46	15.95	23.67	30.19	35.46
13.0	-0.0831	10.3469	0.6063	3.48	3.97	4.87	6.92	10.35	15.69	23.10	29.31	34.29
13.5	-0.0769	10.2198	0.5965	3.48	3.97	4.86	6.88	10.22	15.38	22.47	28.35	33.04
14.0	-0.0723	10.1066	0.5853	3.50	3.98	4.87	6.85	10.11	15.09	21.86	27.42	31.83
14.5	-0.0682	10.0354	0.5730	3.55	4.03	4.90	6.85	10.04	14.85	21.32	26.58	30.74
15.0	-0.0643	10.0684	0.5599	3.63	4.12	4.99	6.93	10.07	14.76	20.99	26.02	29.96
15.5	-0.0601	10.2532	0.5463	3.78	4.27	5.16	7.12	10.25	14.88	20.97	25.83	29.61
16.0	-0.0553	10.5446	0.5323	3.98	4.48	5.40	7.39	10.54	15.15	21.14	25.87	29.53
16.5	-0.0499	10.8777	0.5177	4.20	4.72	5.66	7.69	10.88	15.47	21.36	25.97	29.52
17.0	-0.0440	11.2011	0.5027	4.44	4.97	5.93	8.00	11.20	15.76	21.53	26.01	29.42
17.5	-0.0376	11.4772	0.4871	4.66	5.21	6.19	8.28	11.48	15.97	21.59	25.89	29.16
18.0	-0.0309	11.7093	0.4712	4.88	5.44	6.44	8.53	11.71	16.12	21.54	25.66	28.76

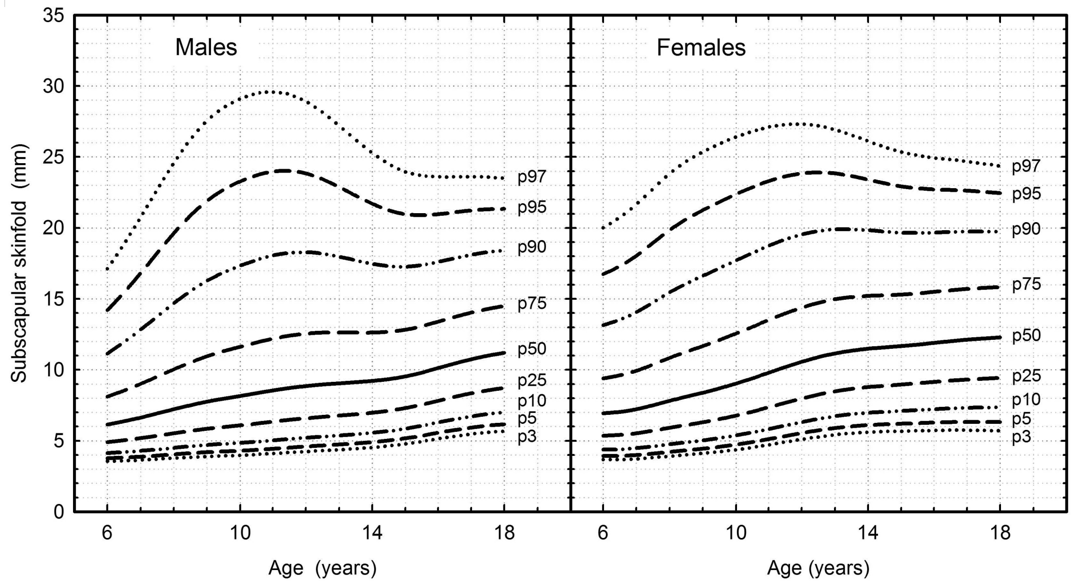
Table 8. Smoothed percentiles and L, M and S values for suprailiac subcutaneous skinfold. Girls.

Age (Years)	L	M	S	3	5	10	25	50	75	90	95	97
6.0	-0.3148	7.4395	0.5215	3.16	3.48	4.06	5.33	7.44	10.80	15.76	20.22	24.05
6.5	-0.2809	7.6024	0.5315	3.15	3.48	4.08	5.40	7.60	11.09	16.19	20.73	24.58
7.0	-0.2467	7.8707	0.5408	3.18	3.52	4.15	5.55	7.87	11.54	16.83	21.49	25.39
7.5	-0.2125	8.2616	0.5491	3.25	3.62	4.29	5.78	8.26	12.15	17.71	22.52	26.52
8.0	-0.1782	8.7033	0.5559	3.34	3.73	4.45	6.05	8.70	12.83	18.65	23.62	27.69
8.5	-0.1443	9.1286	0.5607	3.42	3.84	4.61	6.32	9.13	13.47	19.49	24.56	28.66
9.0	-0.1112	9.5784	0.5630	3.52	3.97	4.78	6.60	9.58	14.12	20.32	25.45	29.55
9.5	-0.0794	10.1022	0.5623	3.66	4.14	5.01	6.95	10.10	14.85	21.22	26.40	30.49
10.0	-0.0489	10.6751	0.5588	3.83	4.34	5.28	7.35	10.68	15.62	22.13	27.34	31.40
10.5	-0.0196	11.2540	0.5525	4.02	4.57	5.57	7.76	11.25	16.36	22.96	28.16	32.16
11.0	0.0082	11.7986	0.5439	4.22	4.81	5.86	8.17	11.80	17.02	23.64	28.77	32.68
11.5	0.0348	12.2698	0.5337	4.42	5.03	6.14	8.54	12.27	17.55	24.12	29.13	32.91
12.0	0.0598	12.6286	0.5226	4.59	5.23	6.38	8.84	12.63	17.90	24.35	29.20	32.82
12.5	0.0832	12.8495	0.5115	4.71	5.37	6.55	9.05	12.85	18.06	24.33	28.98	32.42
13.0	0.1050	12.9587	0.5012	4.80	5.47	6.66	9.18	12.96	18.07	24.13	28.57	31.84
13.5	0.1254	12.9936	0.4922	4.86	5.53	6.73	9.26	12.99	17.99	23.84	28.10	31.20
14.0	0.1440	12.9843	0.4845	4.89	5.57	6.78	9.29	12.98	17.87	23.53	27.61	30.57
14.5	0.1608	12.9628	0.4780	4.91	5.59	6.80	9.31	12.96	17.75	23.25	27.18	30.02
15.0	0.1761	12.9754	0.4726	4.93	5.62	6.84	9.35	12.98	17.69	23.07	26.89	29.63
15.5	0.1901	13.0562	0.4681	4.98	5.68	6.90	9.43	13.06	17.74	23.04	26.79	29.47
16.0	0.2034	13.1768	0.4643	5.04	5.75	6.99	9.53	13.18	17.85	23.11	26.80	29.44
16.5	0.2162	13.3006	0.4609	5.09	5.81	7.07	9.64	13.30	17.97	23.19	26.84	29.44
17.0	0.2289	13.4230	0.4578	5.14	5.87	7.15	9.74	13.42	18.09	23.28	26.89	29.46
17.5	0.2416	13.5506	0.4550	5.19	5.93	7.23	9.85	13.55	18.22	23.38	26.96	29.50
18.0	0.2542	13.7037	0.4523	5.25	6.01	7.32	9.97	13.70	18.38	23.53	27.09	29.60

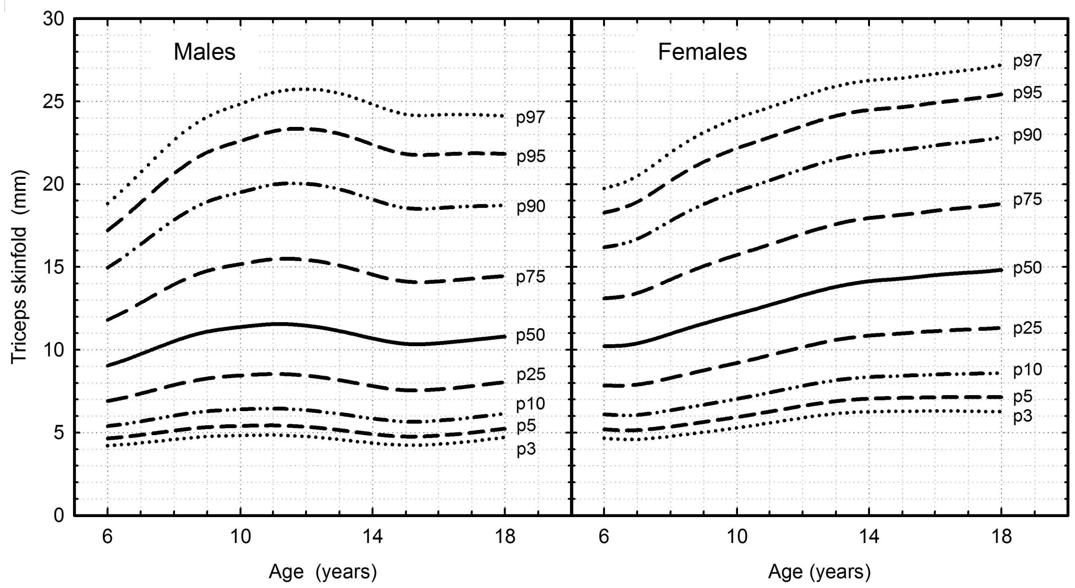


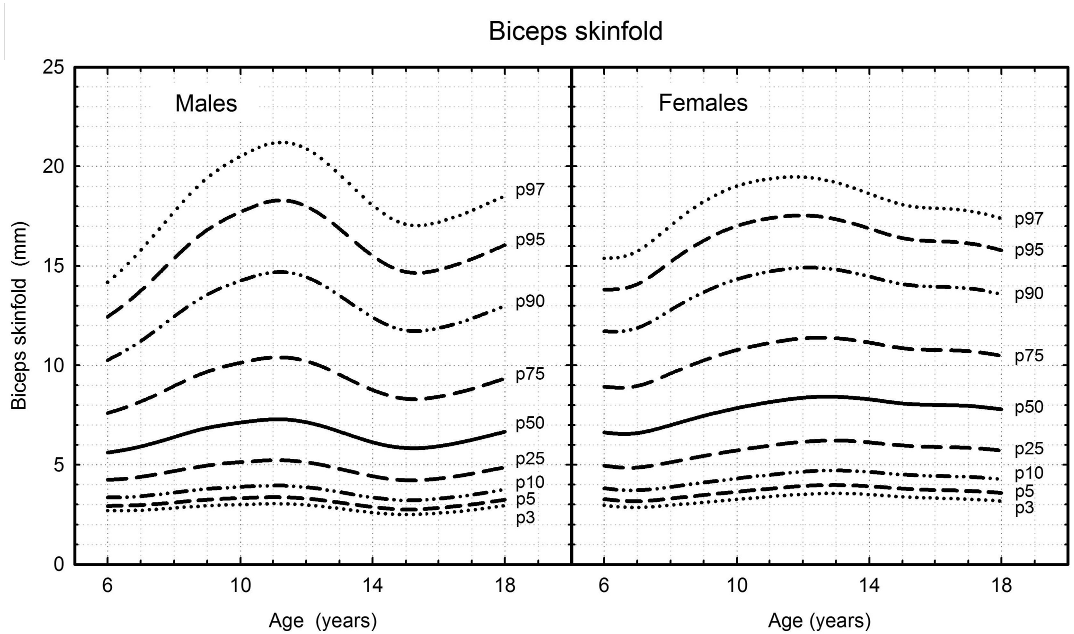
p95
p90
p75
p50

Subscapular skinfold



Triceps skinfold




Biceps skinfold
Males
Females
Biceps skinfold (mm)
0
5
10
15
20
25
6
10
14
18
Age (years)
p97
p95
p90
p75
p50
p25
p10
p5
p3