Triceps and Subscapular Skinfold Thicknesses Percentiles and Cut-offs for Overweight and Obesity in a Population-Based Sample of Schoolchildren in Bogota, Colombia

By

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ABSTRACT

OBJECTIVES: The aims of this study were to establish a Colombian smoothed centile charts and LMS tables for tríceps, subscapular and sum tríceps+subscapular skinfolds; appropriate cut-offs were selected using receiver operating characteristic analysis based in a population-based sample of schoolchildren in Bogota, Colombia and to compare them with international studies.

METHODS: A total of 9 618 children and adolescents attending public schools in Bogota, Colombia (55.7% girls; age range of 9–17.9 years). Height, weight, body mass index (BMI), waist circumference, triceps and subscapular skinfold measurements were obtained using standardized methods. We have calculated tríceps+subscapular skinfold (T+SS) sum. Smoothed percentile curves for triceps and subscapular skinfold thickness were derived by the LMS method. Receiver operating characteristics curve (ROC) analyses were used to evaluate the optimal cut-off point of tríceps, subscapular and sum tríceps+subscapular skinfolds for overweight and obesity based on the International Obesity Task Force (IOTF) definitions. Data were compared with international studies.

RESULTS: Subscapular, triceps skinfolds and T+SS were significantly higher in girls than in boys (P <0.001). The median values for triceps, subscapular as well as T+SS skinfold thickness increased in a sex-specific pattern with age. The ROC analysis showed that subscapular, triceps skinfolds and T+SS have a high discrimination power in the identification of overweight and obesity in the sample population in this study. Based on the raw non-adjusted data, we found that Colombian boys and girls had high triceps and subscapular skinfolds values than their counterparts from Spain, UK, German and US.

CONCLUSIONS: Our results provide sex- and age-specific normative reference standards for the triceps and subscapular skinfold thickness values in a large, population-based sample of schoolchildren and adolescents from an Latin-American population. By providing LMS tables for Latin-American people based on Colombian reference data, we hope to provide quantitative tools for the study of obesity and its complications.

Keywords: skinfold thickness; percentile curves; children and adolescents; obesity

INTRODUCTION

The prevalence of overweight and obesity has become a public health problem worldwide[1]. International organisations[2,3] and previous epidemiological cross-sectional studies[4,5] have suggested that individuals with a large accumulation of body fat in the abdominal region are at greater risk of development of adverse health consequences including hypertension, cardiovascular disease, metabolic disorders, osteoarthritis, gallbladder stone disease, asthma, as well as multiple malignancies[2-7]. To estimate the magnitude of this problem, direct indicators were used to assess various anthropometric indicators, such as body mass index (BMI)[6], waist circumference (WC)[7] and double thicknesses of skin and subcutaneous fat measured as skinfold thicknesses[8]. Skinfold thickness measurements are widely used to assess body fat because the measurements are non-invasive, simple and less expensive than laboratory-based techniques,[9] because of its simplicity; however, standardization and experience are required to achieve precise measurement[10].

There are a number of cross-sectional studies showing that high subcutaneous fat in youth is independently associated with a higher cardio-metabolic risk[11,12,13]. In addition, longitudinal studies have shown that a healthy body composition in childhood and adolescence is associated with a healthier cardio-metabolic profile later in life[14,15]. These findings have been replicated in clinical adult populations with diabetes mellitus, hypertension, metabolic syndrome, and several types of cancer[16,17]. The two most frequently taken skinfold measurements are the triceps and subscapular sites[18]. Expert panels from the United States of America suggest measurement of these two skinfolds as part of in-depth medical assessments for adolescents with increased BMI[19]. However, Kromeyer-Hauschild et al.[18] found that the additional information provided by skinfolds varies substantially according to the BMI level.

Sex- and age-specific normative values for two skinfolds in youth have been published[18,20,21,22]. However, the majority of the published aerobic fitness reference values are for schoolchildren from high income countries in North America[20], and Europe[18,21,22]. There is a scarcity of reference values for children using harmonized measures of body composition in Latin America[23,24] and other low-middle income countries (LMICs) undergoing rapid epidemiologic and nutrition transitions[25], making it impossible to evaluate secular trends within these regions and identify high risk groups for which risk reduction interventions should be prioritized. In particular, no population-based studies have been conducted to assess skinfold thicknesses for youth living at high altitude (over 2,000 meter over sea level).

The aims of this study were to establish a Colombian smoothed centile charts and LMS tables for tríceps, subscapular and sum tríceps + subscapular skinfolds; appropriate cut-offs were selected using receiver operating characteristic analysis based in a population-based sample of 9 to 17 year old schoolchildren in Bogota, Colombia and to compare them with international studies.

SUBJECTS AND METHODS

Study population

In Colombia, measures of weight and physical activity have been added to youth health monitoring systems by the government[26] and research institutions. Recently (2015), physical fitness assessment was added to the FUPRECOL study (*in Spanish* ASOCIACIÓN DE LA **FU**ERZA **PRE**NSIL CON MANIFESTACIONES DE RIESGO CARDIOVASCULAR TEMPRANAS EN NIÑOS Y ADOLESCENTES **COL**OMBIANOS). The FUPRECOL study seeks to establish the general prevalence of cardiovascular risk factors (anthropometric, metabolic and genetic markers) in the study population (children and adolescents aged 9 to 17.9 years living in Bogota, Colombia)[27,28] and examine the relationships between physical fitness levels, body composition and cardio-metabolic risk factors.

The FUPRECOL study assessments were conducted during the 2014–2015 school year. The sample consisted of children and adolescents (boys n = 4 253 and girls n = 5 365) ages 9–17.9 years. All schoolchildren were of low-middle socioeconomic status (SES, 1–3 in a scale 1-6 defined by the Colombian government) and enrolled in public elementary and high schools (grades 5 through 11) in the capital district of Bogota, Cundinamarca Department in the Andean region. This region is located at approximately 4°35′56″N 74°04′51″W and at an elevation of approximately 2 625 meters (min: 2 500; max: 3 250) above sea level. Bogota is considered an urban area, with approximately 7,862,277 inhabitants[29]. A convenience sample of volunteers was included and grouped by sex and age with 1-year increments (a total of 9 groups). Power calculations were based on the mean of overweight and obesity from the first 200-400 participants in the ongoing data collection (range, 26-32 kg/m^2), with a group SD of approximately 5.2 kg/m^2. The significance level was set to 0.05, and the required power was set to at least 0.80. The sample size was estimated to be approximately 250 to 500 participants per group. Exclusion factors included a clinical diagnosis of cardiovascular disease, diabetes mellitus 1 and 2, pregnancy, the use of alcohol or drugs, and, in general, the presence of any disease not directly associated with nutrition. Exclusion from the study was made effective *a posteriori*, without the students being aware of their exclusion to avoid any undesired situations.

Data collection

Anthropometric variables were measured by a Level 2 anthropometrist certified by the International Society for the Advancement of Kinanthropometry (ISAK) in accordance with the ISAK guidelines[30]. Variables were collected at the same time in the morning, between 7:00-10:00 a.m., following an overnight fast. Body weight of the subjects was measured when the subjects were in underwear and did not have shoes on, using electronic scales (Tanita® BC544, Tokyo, Japan) with a low technical error of measurement (TEM = 0.510%). Height was measured using a mechanical stadiometer platform (Seca® 274, Hamburg, Germany; TEM = 0.019%). BMI was calculated as the body weight in kilograms divided by the square of the height in meters. Waist circumference was measured at the midpoint between the last rib and the iliac crest using a tape measure (Ohaus® 8004-MA, New Jersey, USA; TEM = 0.086%). Triceps and subscapular skinfold thicknesses were measured by highly trained and standardized technicians following recommended protocols[20]. Skinfold thicknesses were measured at the left side of the body to the nearest 0.1 mm using a Holtain skinfold caliper (Holtain Ltd, Crymych, United Kingdom) at the following sites: (1) triceps, halfway between the acromion process and the olecranon process, and (2) subscapular, approximately 20 mm below the tip of the scapula, at an angle of 45° to the lateral side of the body. The TEM was 3.248% for the triceps skinfold and 3.839% for the subscapular skinfold. The corresponding intra-observer technical error (Reliability) of measurement was 0.976% for the triceps skinfold and 0.979% for the subscapular skinfold[20]. Mean values were obtained from the three measurements and we have calculated tríceps+subscapular skinfold (T+SS) index[31]. The data were recorded on paper by the FUPRECOL evaluators.

Ethics Statement

The Review Committee for Research on Human Subjects at the University of Rosario [Code Nº CEI-ABN026-000262] approved all of the study procedures. A comprehensive verbal description of the nature and purpose of the study and its experimental risks was given to the participants and their parents/guardians. This information was also sent to parents/guardians by mail. Written informed consent was obtained from parents and subjects before participation in the study. The protocol was in accordance with the latest revision of the Declaration of Helsinki and current Colombian laws governing clinical research on human subjects (Resolution 008430/1993 Ministry of health).

Statistical analysis

Anthropometric and skinfold thicknesses characteristics of the study sample are presented as means and standard deviations (SD). Normality of selected variables was verified using histograms and Q-Q plots. Differences were analyzed by two-way analysis of variance (ANOVA) or Chi-square test (χ^2) to explore sex and age differences. Smoothed and specific curves for each age were obtained via a penalized maximum likelihood with the following abbreviations: (1) L (Box-Cox transformation), (2) M (median), and (3) S (coefficient of variation)[32]. The LMS method assumes that the outcome variable has a normal distribution after a Box-Cox power transformation is applied using the LMS method implemented in the LMSChartMaker Pro Version 2.54, (Medical Research Council, London, UK, http://www.healthforallchildren.com/shop-base/software/lmschartmaker-light/). The appropriate number of degrees of freedom was selected on the basis of deviance, Q-tests and worm plots, following the suggestions of Royston & Wright[33]. The 3rd, 10th, 25th, 50th, 75th, 90th and 97th smoothing percentiles were chosen as age- and gender-specific reference values. The associations between WC, WHtR and BMI were tested by means of *Pearson* correlation coefficients. The relation between skinfold thicknesses (tríceps, subscapular and sum T+SS) and overweight/obesity as defined by IOTF[34] was investigated with Receiver operating characteristic curves (ROC). Cut-off values were derived mathematically from the ROC curves, using the point on the ROC curve with the lowest value for the formula: $(1\text{-sensitivity})^2 + (1\text{-specificity})^2$. The positive likelihood ratio LR (+) and the negative likelihood ratio LR (-) were also determined. We used SPSS V. 21.0 software for Windows (SPSS, Chicago, Illinois, USA) for all but the LMS method calculations. Statistical significance was set at $P < 0.05$

RESULTS

Descriptive characteristics

Descriptive statistics by sex are shown in Table 1. All anthropometric variables, except BMI (normal weight status) body weight and height were higher in boys than in girls (*P* <0.001). The prevalence of overweight and obesity differed by sex (*P* <0.001). One-way ANOVA tests showed that subscapular, triceps skinfolds and T+SS were significantly higher in girls than in boys (*P* < 0.001).

**** Table 1 here ****

Normative skinfold thickness values

Smoothed LMS curves (3rd, 10th, 25th, 50th, 75th, 90th and 97th percentile) for boys' and girls' skinfolds (subscapular, triceps and T+SS) are shown in 2, 3 and 4. The equivalent numerical values are available in Figures (**Supplementary Figure 1, Supplementary Figure 2, Supplementary Figure 3**). Together, these data show that girls were significantly higher subscapular, triceps skinfolds and T+SS at all ages compared with boys. In boys, the 50th percentile of subscapular, triceps and T+SS ranged from 10.0 to 14.0 mm, 10.0 to 15.0 mm, and 23.0 to 28.0 mm respectively. In girls, the 50th percentile ranged from 17.0 to 22.0 mm, 12.0 to 21.0 mm, and 28.0 to 42.0 mm respectively. The median values for triceps, subscapular as well as T+SS skinfold thickness increased in a sex-specific pattern with age. In all age classes, girls had higher median values than boys. In boys, the triceps skinfold peaked at 10 to 13.9 years and subsequently decreased, whereas in girls the triceps skinfold steadily increased. The subscapular skinfold rose steadily in both sexes between 9 and 14 years of age. The percentile distribution was more disperse towards higher values mainly for T+SS skinfold.

**** Table 2, Table 3 and Table 4 here ****

Receiver operating characteristic analysis showed that triceps, subscapular and sum T+Sb skinfolds had a high discriminating power to detect IOTF overweight and obesity (Table 5, **Supplementary Figure 4, Supplementary Figure 5**). For example, to overweight category in boy's children 9-11 years old, the cut-off point value of 18.1 mm for the triceps skinfolds provided a sensitivity of 82.3%, a LR (+) value of 4.06, specificity of 71.9% and LR (-) value of 0.34. In girl's children 9-11 years old, the cut-off point value of 20.1 mm for the triceps skinfolds provided a sensitivity of 67.0%, a LR (+) value of 3.72, specificity of 82.0% and LR (-) value of 0.40. For obesity category in boys 15-17 years old, the cut-off point value of 21.8 mm for the subscapular skinfolds provided a sensitivity of 70.6%, a LR (+) value of 4.94, specificity of 85.7% and LR (-) value of 0.34. In girls 15-17 years old, the cut-off point value of 28.7 mm for the subscapular skinfolds provided a sensitivity of 63.2%, a LR (+) value of 5.06, specificity of 87.5% and LR (-) value of 0.42. (Table 5)

ROC curve for sum T+Sb skinfolds was also obtained (**Supplementary Figure 6**). In overweight category in boy's children 9-11 years old, the cut-off point value of 34.6 mm for the sum T+Sb skinfolds provided a sensitivity of 70.5%, a LR (+) value of 7.42, specificity of 90.5% and LR (-) value of 0.33. In girls 12-14 years old the cut-off point value was 43.1 mm, sensitivity 61.7%, LR (+) value of 3.98, specificity 84.5% and LR (-) 0.45. To obesity in boys 15-17 years old the cut-off point value of 48.6 was used. The sensitivity was 58.0%, LR (+) value of 3.43, specificity 83.1% and LR (-) 0.51. In women 15-17 years old, the cut-off point value was 39.9 mm with sensitivity 76.5%, LR (+) value of 4.11, specificity 81.4% and LR (-) 0.29. Another value are shown in Table 5.

**** Table 5 here ****

International Comparison

Finally, comparisons of the percentile 50^{th} for the triceps and subscapular skinfolds (mm) from this study are presented in Table 6. Based on the raw non-adjusted data, we found that Bogota boys and girls had high triceps and subscapular skinfolds values than their counterparts from Spain, UK, German and US.

**** Table 6 here ****

DISCUSSION

The results obtained in this study presented for the first time smoothed reference values for the triceps and subscapular skinfold thicknesses of a large, population-based sample of schoolchildren from Bogota, Colombia. Although the boys had higher weight and height values, the girls had a higher BMI (ratio of weight to height). As a result, there was a greater prevalence of normal weight among the boys, followed by a higher rate of overweight and obesity in the girls. These results coincide with those obtained by Freedman et al.[35], who performed a prospective study of 6 866 boys and girls, 5-17 years of age, in Louisiana (USA). In this research, the BMI values of the girls were considerably higher than those of the boys.

In contrast, our results differed somewhat from Aristizabal et al.[36] According to their study of 232 schoolchildren in Medellín (Colombia), there was a higher prevalence of normal weight and overweight among girls whereas higher values of obesity were detected among the boys. A possible explanation for this partial divergence in results could be the age difference between our sample population and theirs. More specifically, the schoolchildren in Medellin were younger than the children in our sample.

In regards to the subcutaneous fat distribution, striking differences were observed in the triceps and subscapular skinfold thicknesses as well as the sum of both values (T+SS). In fact, these values were significantly higher for the girls in the study than for the boys. This coincided with the findings of Aristizabal et al.[36] in a population of schoolchildren in Medellín (Colombia). Our results also agreed with those reported by Nagy et al.[37] for a sample of 16 228 boys and girls from different European countries (Sweden, Germany, Hungary, Italy, Cyprus, Spain, Belgium, and Estonia), where the girls also had higher scores for triceps and subscapular skinfold thicknesses as well as the sum of both (T+SS).

In the case of waist circumference, there were significant differences between both sexes with higher values for the boys. These results agree with those of Hirschler's study of a population of Argentinian children, in which the boys were found to have a larger waist circumference than the girls[38]. Since our data are longitudinal, it is impossible to affirm that the waist conference progressively increases with age. Nevertheless, the modification of the subcutaneous fat distribution over time is widely documented in the literature. More specifically, with age, subcutaneous fat tends to move from the periphery to the trunk. This increases the risk of cardiovascular disorders at an earlier age[39,40].

As can be observed, the smoothed LMS curves show higher values for triceps, subscapular skinfold thicknesses, and (T+SS) for the girls, whatever their age, in comparison to the boys. These results are similar to those reported by Kromeyer-Hauschild et al.[18] for a population of 2 132 boys and girls in the city of Jena (Germany). In this study, the girls in all age groups had the highest mean values for these skinfolds. In regards to the boys, the 50th percentile of the triceps and subscapular skinfold thicknesses and (T+SS) varied from 10.0 to 14.0 mm, from 10.0 to 15.0 mm, and from 23.0 a 28.0 mm, respectively. Among the girls, the 50th percentile for these same skinfold thicknesses ranged from 17.0 to 22.0 mm, from 12.0 to 21.0 mm, and from 28.0 to 42.0 mm, respectively.

As also reported by Aristizabal et al.[36] and Addo & Himes[20], the girls in all age groups had higher mean values for these skinfolds than the boys. Among the boys, the triceps skinfold reached a maximum value of 10 mm at the age of 13.9 years, after which it decreased. In contrast, for the girls, the values of this skinfold progressively increased.

As for the subscapular skinfold thickness, it steadily increased in both sexes from 9 to 14 years of age. Similar findings were reported in previous studies of schoolchildren though in other geographic areas, namely, Warsaw[41], Krakow[42] and Turkey[43].

In the case of the (T+SS), the percentage distribution of the values was more disperse with higher values for the girls. These results differed somewhat from those of Moreno et al.[21], who obtained higher (T+SS) values for the boys in their study of 2 160 Spanish adolescents, 13-18 years of age.

Receiver operating characteristic analysis showed that triceps, subscapular and sum T+Sb skinfolds had a high discriminating power to detect overweight and obesity. This coincided with Cickek et al.[44] in their study of a population of Turkish children and adolescents. In the overweight category of boys, 9-11 years of age, the cut-off value for the triceps skinfold was 18.1 mm, whereas for girls in the same age group, the cut-off value was 20.1 mm. These results agreed with those of Brannsether et al.[45] in their study of 4 606 Norwegian children in which higher cut-off values were reported for the girls in all age groups. Similar results were obtained by Khadilkar et al.[46], who studied a population of 13 375 schoolchildren in India.

In the obesity category for boys 15-17 years old, the cut-off point value for the subscapular skinfold was 21.8 mm. In contrast, for girls of the same age, the cut-off point value was considerably higher (28.7 mm). These results were similar to those of Kromeyer-Hauschild et al.[18] for a sample population of 213 school children in Jena (Germany). In this study, the cut-off point values of the subscapular skinfold were much higher for the girls, which reflected that they had a higher level of subcutaneous adiposity than the boys.

Furthermore, the cut-off point for the sum T+Sb skinfolds in both the overweight as well as the obesity categories (especially in 15-17 year age group) was higher for the girls. This could be explained by the marked sexual dimorphism in regard to the development and accumulation of subcutaneous fat, which increased as the subjects become older[47].

This comparative study based on non-fitted raw data showed that both boys and girls in Bogotá had higher values for tricipital and subscapular skinfolds in all of the age groups than children of similar ages in Spain, the United Kingdom, Germany, and the United States. This signifies that this sample population of school children in Bogotá generally had higher levels of adiposity than similar samples in other studies in other countries. This situation poses important health risks for this population, such as the development of type 2 diabetes mellitus, insulin resistance, and cardiovascular illnesses at a very early age[48,49].

Evidently, this is an important public health problem in Colombia. For this reason, it is necessary to carry out new studies that will help to identify and control the factors leading to this higher level of adiposity among schoolchildren in Bogotá. Moreover, these results should be a wake-up call for the Columbian government, who needs to implement policies that will encourage healthier life styles among young people. This includes regular physical exercise and a balanced diet from early childhood.

This study had some limitations. First, this study includes participants from only a single region in Colombia; therefore, inferences to all Colombian children and adolescents should be made cautiously. Second, we have not considered the potential impact of recognized determinants such as socio-economic, dietary and physical activity patterns, and ethnic factors that modulate growth and levels of adiposity. It is important to emphasise that these charts were derived using the skinfold thicknesses using a Holtain skinfold caliper (Holtain Ltd, Crymych, United Kingdom). The charts should not be used in conjunction with other makes and models of skinfold caliper until cross-calibration studies have been performed in children. Finally, these curves should only be used for Colombian children. This is an area for future research. However, such limitations do not compromise the results obtained when validating our results.

This study also has various strong points that should be highlighted. The results presented for the first time smoothed reference values for the triceps and subscapular skinfold thicknesses among a large, population-based sample of schoolchildren from Bogota, Colombia. Also worth mentioning is the use of the LMS method to smooth the percentile values. This allowed the accurate description of the body composition and the pattern of fat distribution in the sample population as well as its variation, depending on sex and age. Still another positive aspect is the fact that the sample of children recruited for the study came from both public and private schools that were located in many different districts in the city of Bogotá.

In conclusion, this is the first paper to provide sex- and age -specific reference values of triceps and subscapular skinfolds in Colombian children and adolescents aged 9–17.9 years, based on a large and apparently healthy cross-sectional study. The percentile values of the skinfolds as well as their cut-off points permitted the comparison of a population of Bogotá schoolchildren with other reference samples in order to estimate the proportion of adolescents with higher or lower levels of general adiposity. These results can be used as a baseline for long-term health surveillance in the city, the country and the Latin American region.

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Figure S1: Smoothed percentile curves for triceps skinfolds (in mm) for boys and girls across age from Bogota, Colombia

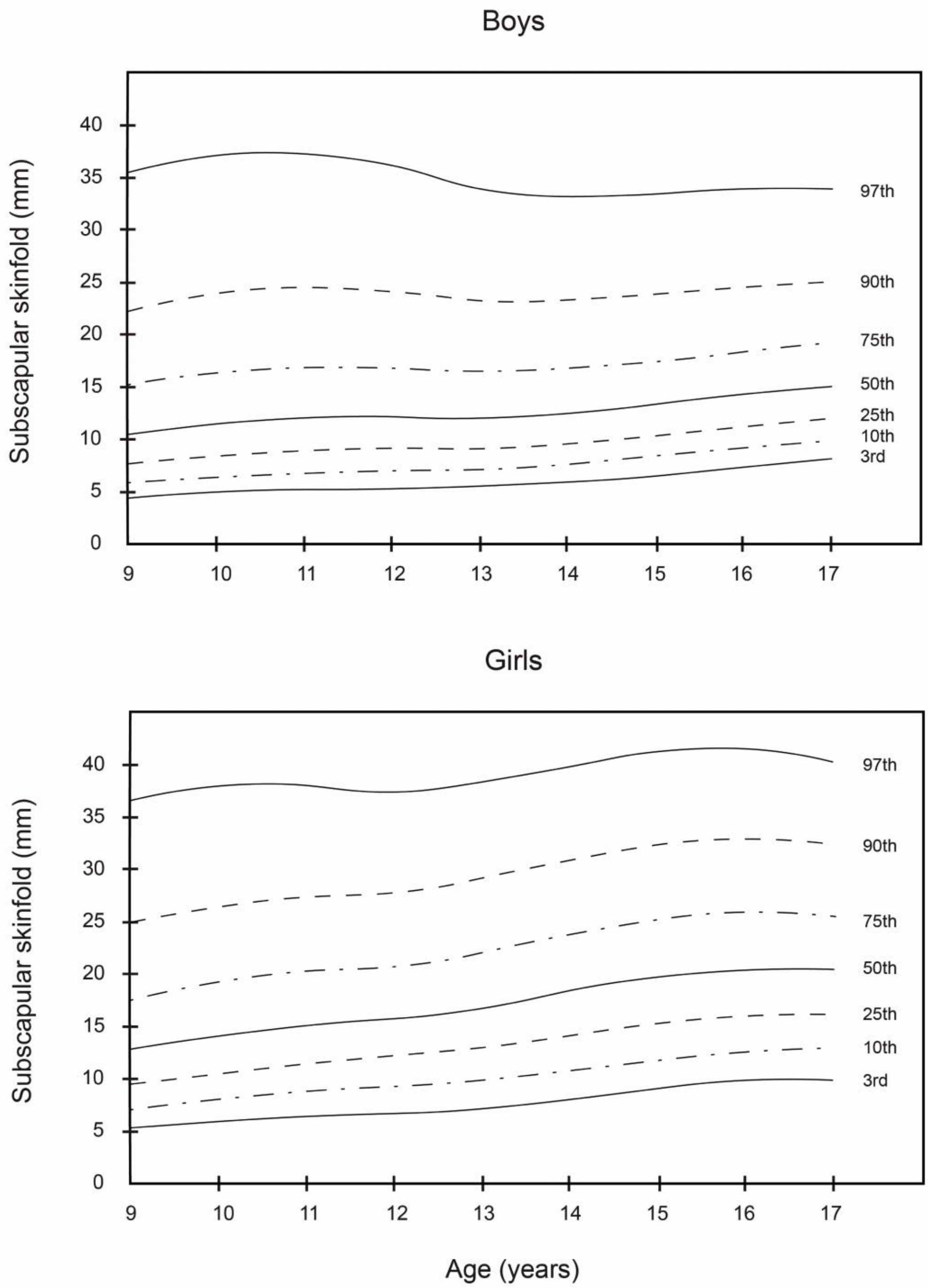

Figure S2: Smoothed percentile curves for subscapular skinfolds (in mm) for boys and girls across age from Bogota, Colombia

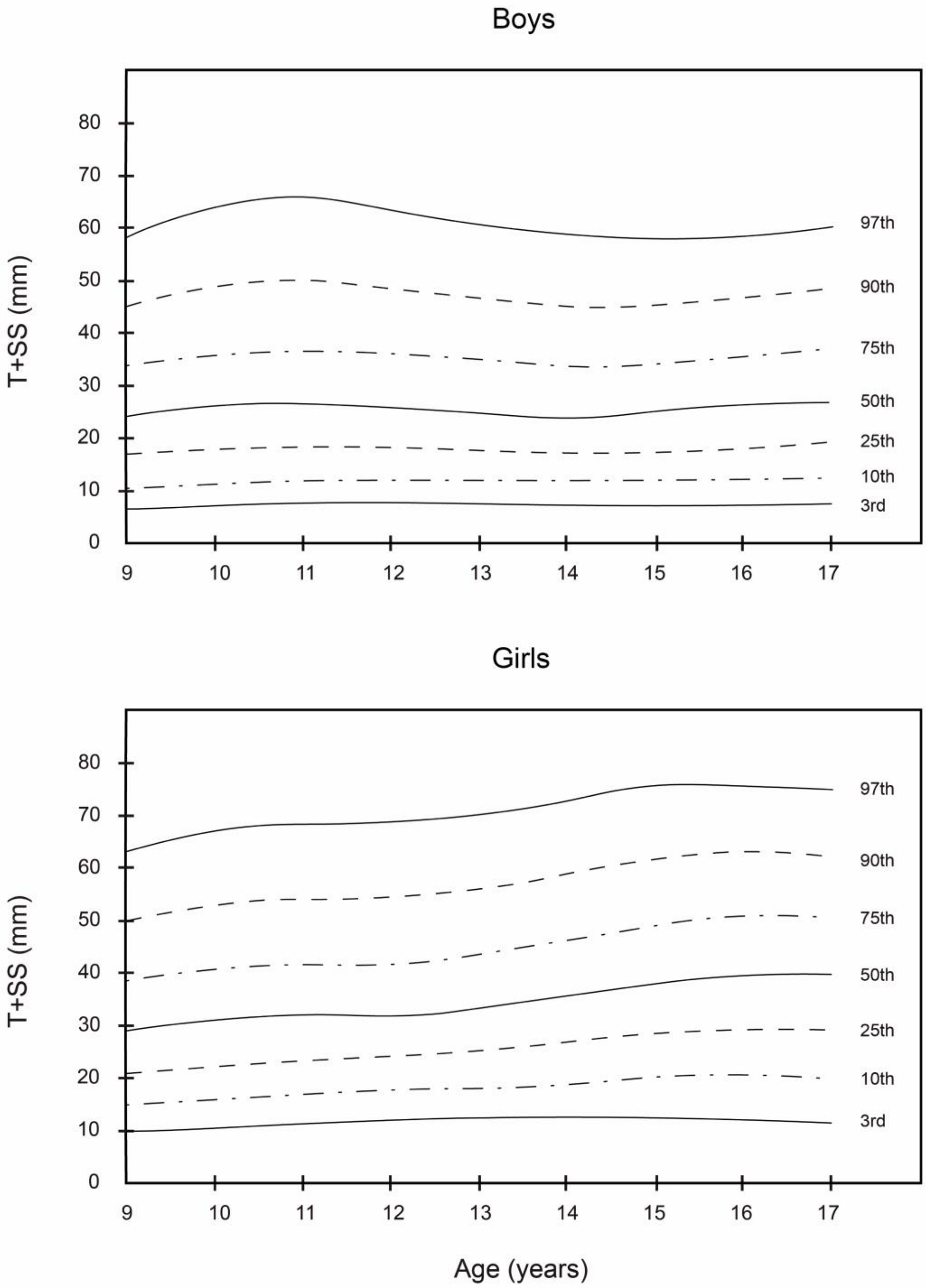

Figure S3: Smoothed percentile curves for triceps subscapular skinfolds sum (in mm) for boys and girls across age from Bogota, Colombia

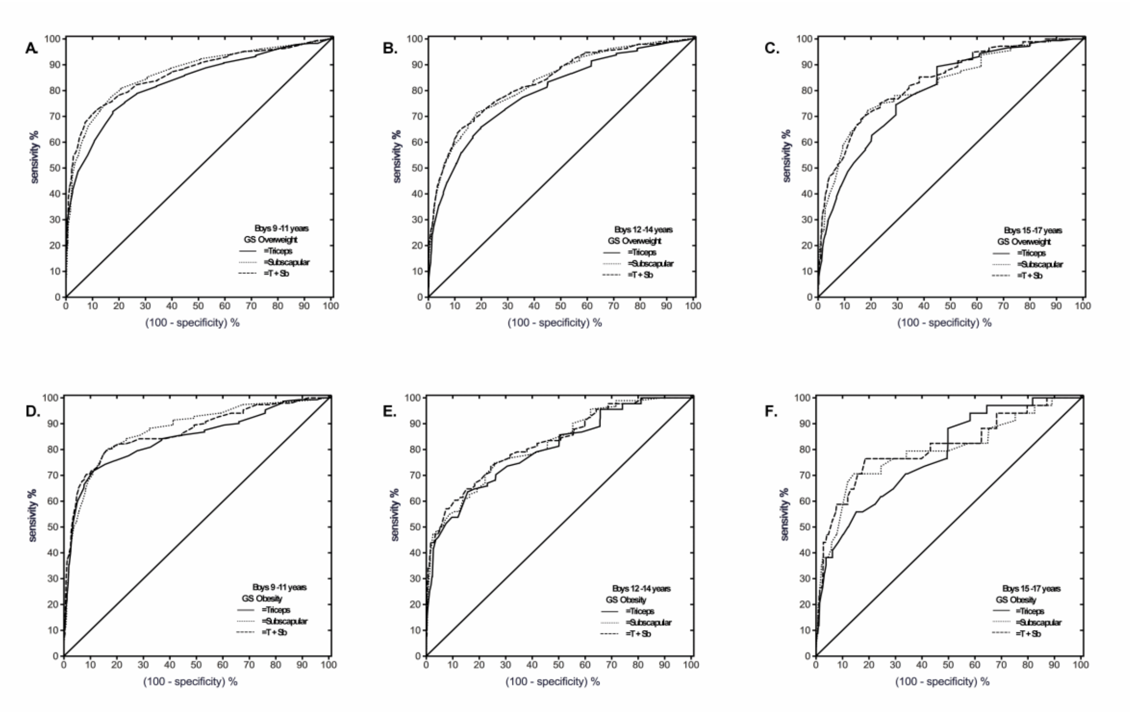

Figure S4: Receiver operating characteristic (ROC) curve of the for tríceps, subscapular subscapular and sum (T+S) skinfolds to detect overweight (up) or obesity (down) according to the IOTF definitions in boys for the different age groups. GS: gold standard.

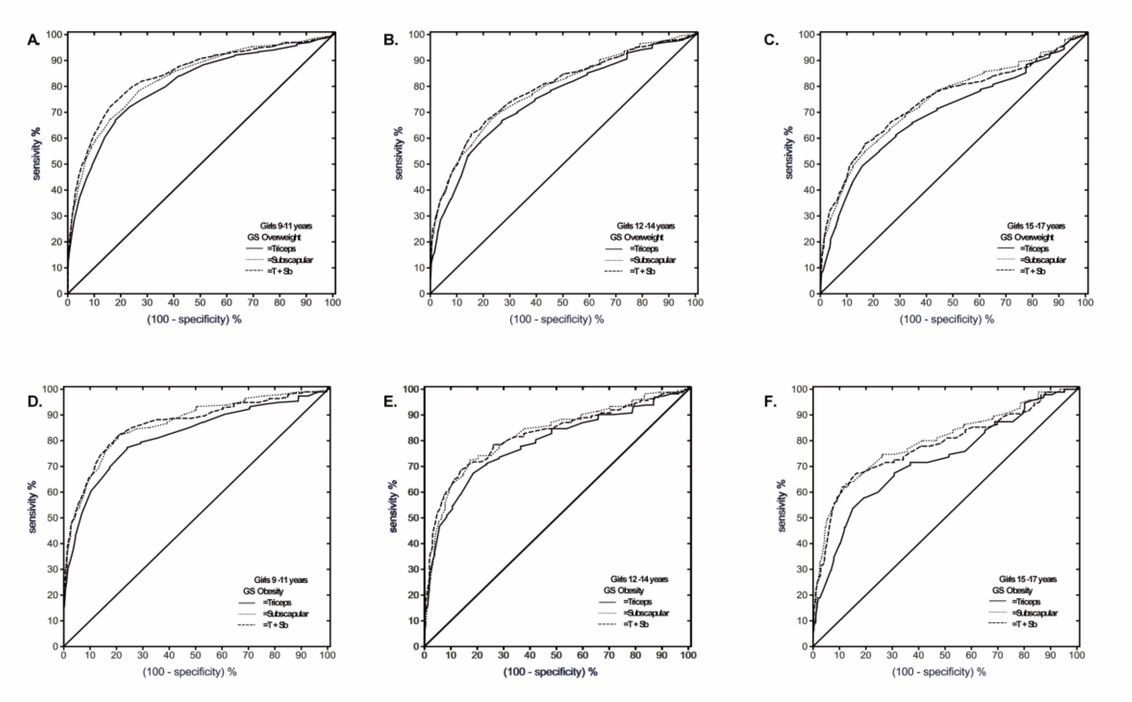

Figure S5: Receiver operating characteristic (ROC) curve of the for tríceps, subscapular subscapular and sum (T+S) skinfolds to detect overweight (up) or obesity (down) according to the IOTF definitions in girls for the different age groups. GS: gold standard.

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Table 1. Characteristics of among a population-based sample of schoolchildren and adolescents in Bogota, Colombia [mean (SD) or frequencies]

Characteristics	Boys (*n* = 4243)	Girls (*n* = 5365)	Total (*n* = 9618)
Age (years)	12.9 (2.3)	12.8 (2.4)	12.8 (2.3)
Body weight (kg)	45.0 (13.0)	44.8 (11.4)**	44.6 (12.3)
Height (m)	1.50 (0.13)	1.47 (0.10)*	1.49 (0.12)
BMI (kg/m^2)	19.3 (3.3)	20.3 (3.5)*	19.7 (3.4)
Weight status (%)			
Underweight	29 %	31 %*	29 %
Normal weight	53 %	45 %*	49 %
Overweight	13 %	16 %*	15 %
Obese	6 %	8 %*	7 %
Waist circumference (cm)	65.0 (8.1)	66.3 (8.2)*	65.6 (8.1)
Triceps skinfold thickness (mm)	15.7 (6.2)	20.3 (6.2)*	18.2 (6.6)
Subscapular skinfold thickness (mm)	14.2 (7.5)	18.3 (8.0)*	16.4 (8.0)
Triceps + subscapular skinfolds (mm)	27.5 (13.8)	35.5 (15.0)*	31.8 (15.1)

Data are shown as mean (SD) *or* frequencies
Significant between-sex differences (ANOVA one way test or Chi-square; *P <0.001; **P <0.01)

Table 2. Smoothed age- and sex-specific percentile values of triceps skinfold thickness (mm) among a population-based sample of Schoolchildren and adolescents in Bogota, Colombia

	n	M	SD	P_3	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	P_{97}
Boys										
9 to 9.9	319	12.0	6.8	5.0	6.0	7.0	10.0	15.0	21.0	32.0
10 to 10.9	538	16.8	6.5	7.0	9.0	12.0	15.0	21.0	25.0	32.0
11 to 11.9	524	17.0	6.5	8.0	10.0	12.0	16.0	22.0	26.0	31.0
12 to 12.9	497	16.4	6.3	7.9	9.5	12.0	15.0	20.0	25.0	31.1
13 to 13.9	500	15.7	6.2	7.0	9.0	11.0	15.0	19.0	24.0	31.0
14 to 14.9	557	15.0	6.1	7.0	8.0	11.0	14.0	18.0	23.2	29.9
15 to 15.9	528	15.0	6.0	7.0	8.0	11.0	14.0	18.0	23.0	30.0
16 to 16.9	463	15.0	5.8	7.0	9.0	11.0	14.0	17.0	22.7	29.0
17 to 17.9	327	15.1	5.9	7.0	8.0	11.0	14.0	18.2	24.0	29.1
Total	*4253*	15.7	6.2	7.0	9.0	11.0	14.8	19.0	24.0	30.0
Girls										
9 to 9.9	367	17.8	5.7	7.0	11.0	14.0	17.0	21.0	25.0	29.0
10 to 10.9	761	19.1	6.0	10.0	12.0	15.0	18.0	22.0	26.0	32.0
11 to 11.9	742	19.1	5.8	10.0	12.0	15.0	18.0	23.0	26.0	31.0
12 to 12.9	647	19.1	5.8	10.0	12.0	15.0	18.0	22.0	27.0	33.0
13 to 13.9	583	20.1	6.1	10.0	12.0	15.0	20.0	23.5	28.0	33.0
14 to 14.9	746	21.7	6.4	11.4	14.0	17.0	22.0	25.0	30.0	34.0
15 to 15.9	621	22.0	6.4	10.0	14.0	17.0	22.0	26.1	30.2	34.0
16 to 16.9	529	22.3	5.8	12.0	15.0	18.0	22.0	26.0	30.0	34.0
17 to 17.9	369	21.5	6.3	12.0	14.0	17.0	21.4	25.0	29.0	34.0
Total	*5365*	20.3	6.2	10.0	12.9	16.0	20.0	24.0	28.0	33.0

M, mean; SD, standard deviation; P, percentile

Table 3. Smoothed age- and sex-specific percentile values of subscapular skinfold thickness (mm) among a population-based sample of Schoolchildren and adolescents in Bogota, Colombia

	n	M	SD	P_3	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	P_{97}
Boys										
9 to 9.9	319	12.0	6.8	5.0	6.0	7.0	10.0	15.0	21.0	32.0
10 to 10.9	538	13.3	7.4	5.0	6.0	8.0	11.0	16.0	24.0	32.0
11 to 11.9	524	14.5	8.3	5.0	7.0	9.0	12.0	18.0	27.0	35.0
12 to 12.9	497	14.2	8.1	6.0	7.0	8.0	12.0	17.0	25.0	35.0
13 to 13.9	500	13.6	7.4	5.0	7.0	9.0	12.0	16.0	22.0	33.0
14 to 14.9	557	13.8	6.9	6.0	7.0	9.0	12.0	16.0	23.0	30.0
15 to 15.9	528	14.8	6.6	7.0	8.0	10.0	13.0	17.0	24.0	31.1
16 to 16.9	463	15.6	6.4	8.0	9.0	12.0	14.0	18.0	23.0	32.1
17 to 17.9	327	16.4	8.8	8.0	9.0	12.0	15.0	20.0	24.1	31.3
Total	*4253*	*14.2*	*7.5*	*6.0*	*7.0*	*9.0*	*12.0*	*17.0*	*24.0*	*33.0*
Girls										
9 to 9.9	367	14.2	7.0	6.0	7.0	9.0	12.0	17.0	23.0	31.1
10 to 10.9	761	16.0	7.9	7.0	8.0	10.0	14.0	20.0	26.0	35.0
11 to 11.9	742	16.7	8.1	7.0	9.0	11.0	15.0	20.0	27.0	35.0
12 to 12.9	647	17.0	7.8	7.0	9.0	12.0	15.0	21.0	27.5	36.0
13 to 13.9	583	17.8	7.5	7.0	10.0	12.0	16.3	22.0	27.0	35.0
14 to 14.9	746	19.7	7.7	9.0	11.0	14.0	18.0	24.0	30.0	36.0
15 to 15.9	621	21.0	7.6	10.0	12.0	16.0	20.0	25.0	31.0	38.5
16 to 16.9	529	21.6	7.7	10.0	12.0	16.0	21.0	26.0	32.0	38.0
17 to 17.9	369	21.1	7.7	10.0	12.0	16.0	20.0	25.0	32.0	40.0
Total	*5365*	*18.3*	*8.0*	*7.0*	*10.0*	*12.0*	*17.0*	*23.0*	*29.0*	*36.0*

M, mean; SD, standard deviation; P, percentile

Table 4. Smoothed age- and sex-specific percentile values of triceps + subscapular skinfolds (mm) among a population-based sample of Schoolchildren and adolescents in Bogota, Colombia

	n	M	SD	P_3	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	P_{97}
Boys										
9 to 9.9	319	25.7	13.2	6.5	9.0	17.0	23.0	33.0	43.0	54.5
10 to 10.9	538	28.6	14.0	7.0	13.9	19.0	26.0	35.0	49.2	60.0
11 to 11.9	524	29.7	14.9	7.5	13.3	20.0	26.0	37.0	52.0	62.5
12 to 12.9	497	28.4	14.9	7.0	10.5	18.0	26.0	35.0	49.0	64.2
13 to 13.9	500	26.9	13.7	7.5	10.5	18.0	25.5	33.0	43.0	60.0
14 to 14.9	557	26.2	13.2	7.5	10.5	18.0	25.0	31.0	44.1	56.0
15 to 15.9	528	27.3	12.8	8.0	10.5	19.0	26.0	33.5	45.0	56.0
16 to 16.9	463	27.9	13.1	8.0	10.2	21.0	27.0	34.0	45.0	55.1
17 to 17.9	327	28.7	13.6	8.0	10.0	20.0	28.0	37.0	47.0	56.2
Total	*4253*	*27.5*	*13.8*	*7.5*	*10.5*	*18.0*	*26.0*	*34.0*	*46.0*	*59.0*
Girls										
9 to 9.9	367	30.0	13.2	9.0	14.0	21.0	28.0	37.0	49.0	60.0
10 to 10.9	761	33.3	14.3	12.0	16.9	23.4	30.0	41.0	51.2	66.0
11 to 11.9	742	33.7	14.1	12.1	17.5	24.0	32.0	41.0	52.0	66.0
12 to 12.9	647	33.5	14.2	11.5	15.7	24.0	32.0	41.0	52.0	68.0
13 to 13.9	583	34.3	14.3	12.5	17.0	22.8	33.0	43.0	52.0	66.1
14 to 14.9	746	37.7	14.8	15.0	20.0	27.0	36.0	46.0	57.0	71.6
15 to 15.9	621	39.4	15.3	13.3	18.9	27.8	40.0	50.0	59.0	70.0
16 to 16.9	529	41.1	15.2	12.4	18.5	32.0	42.0	50.0	61.0	70.0
17 to 17.9	369	39.0	15.9	12.0	16.0	28.0	40.0	48.0	60.0	72.8
Total	*5365*	*35.5*	*15.0*	*12.0*	*17.0*	*24.0*	*34.0*	*45.0*	*55.0*	*68.0*

M, mean; SD, standard deviation; P, percentile

Table 5. Area under the receiver-operating characteristic curves (AUC) for triceps, subscapular and Sum T+Sb skinfolds among Colombian children and adolescents aged 9–17.9 years

	9-11 years				**12-14 years**				**15-17 years**			
	Overweight		Obesity		Overweight		Obesity		Overweight		Obesity	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Triceps skinfold												
AUC	0.87 (0.84-0.89)	0.83 (0.81-0.85)	0.88 (0.84-0.91)	0.87 (0.84-0.90)	0.83 (0.81-0.86)	0.78 (0.76-0.81)	0.82 (0.77-0.87)	0.82 (0.79-0.86)	0.82 (0.79-0.86)	0.74 (0.71-0.77)	0.79 (0.70-0.89)	0.80 (0.74-0.85)
Cut-off	18.1	20.1	22.1	21.1	18.3	21.2	21.6	24.6	16.2	25.5	21.5	27.5
J-Youden	0.54	0.49	0.61	0.53	0.46	0.40	0.48	0.49	0.45	0.34	0.41	0.39
Sensitivity (%)	71.9	67.0	71.7	77.4	65.9	66.9	63.7	67.5	74.6	49.4	55.9	53.7
Specificity (%)	82.3	82.0	88.9	75.9	80.1	72.9	84.3	81.5	70.6	84.1	84.8	84.9
LR (+)	4.06	3.72	6.46	3.21	3.31	2.47	4.06	3.65	2.54	3.11	3.68	3.56
LR (-)	0.34	0.40	0.32	0.30	0.43	0.45	0.43	0.40	0.36	0.60	0.52	0.55
Subscapular skinfold												
AUC	0.83 (0.81-0.86)	0.80 (0.78-0.83)	0.84 (0.80-0.88)	0.82 (0.78-0.85)	0.79 (0.76-0.82)	0.75 (0.73-0.77)	0.80 (0.75-0.85)	0.79 (0.75-0.83)	0.80 (0.76-0.83)	0.69 (0.67-0.72)	0.78 (0.70-0.86)	0.72 (0.66-0.78)
Cut-off	13.5	14.4	16.9	18.3	15.1	19.8	15.9	23.2	18.6	24.4	21.8	28.7
J-Youden	0.61	0.52	0.64	0.61	0.53	0.44	0.49	0.55	0.54	0.38	0.56	0.51
Sensitivity (%)	77.5	78.3	79.6	82.1	71.5	67.7	74.7	72.4	72.3	55.0	70.6	63.2
Specificity (%)	83.0	73.3	83.9	79.3	81.7	76.7	74.3	82.9	81.4	83.2	85.7	87.5
LR (+)	4.56	2.93	4.94	3.97	3.91	2.91	2.91	4.23	3.89	3.27	4.94	5.06
LR (-)	0.27	0.30	0.24	0.23	0.35	0.42	0.34	0.33	0.34	0.54	0.34	0.42
Sum T + Sb skinfold												
AUC	0.86 (0.84-0.89)	0.84 (0.82-0.86)	0.87 (0.83-0.90)	0.86 (0.83-0.90)	0.83 (0.81-0.86)	0.79 (0.77-0.81)	0.83 (0.78-0.87)	0.82 (0.78-0.86)	0.84 (0.80-0.87)	0.74 (0.71-0.77)	0.81 (0.72-0.90)	0.78 (0.72-0.84)
Cut-off	34.6	36.5	37.0	40.0	36.8	43.1	43.5	48.7	37.1	48.6	39.9	53.7
J-Youden	0.61	0.56	0.64	0.61	0.53	0.46	0.50	0.55	0.53	0.41	0.58	0.51
Sensitivity (%)	70.5	72.2	80.3	82.6	65.6	61.7	60.4	68.7	68.9	58.0	76.5	67.4
Specificity (%)	90.5	84.0	83.4	78.7	87.1	84.5	89.2	86.0	83.8	83.1	81.4	83.5
LR (+)	7.42	4.51	4.84	3.88	5.09	3.98	5.59	4.91	4.25	3.43	4.11	4.08
LR (-)	0.33	0.33	0.24	0.22	0.39	0.45	0.44	0.36	0.37	0.51	0.29	0.39

AUC: area under curve; LR (+): positive likelihood ratio; LR (-): negative likelihood ratio

Table 6. Comparison of empirical triceps and subscapular skinfold thickness (mm) percentile 50th from international studies

Study	FUPRECOL Study (2015) *n* = 9 618	Spain[21] (2007) *n* = 2 160	Germain[18] (2012) *n* = 2 132	UK[22] (1974) *n* = 19 700	EE.UU[20] (2007) *n* = 32 783	FUPRECOL Study (2015) *n* = 9 618	Spain[21] (2007) *n* = 2 160	Germain[18] (2012) *n* = 2 132	UK[22] (1974) *n* = 19 700	EE.UU[20] (2007) *n* = 32 783
Boys	**Triceps skinfold** (mm)					**Subscapular skinfold** (mm)				
9 to 9.9	10.0	-	11.0	8.1	9.1	10.0	-	6.0	5.2	5.2
10 to 10.9	15.0	-	11.4	8.5	9.5	11.0	-	6.5	5.6	5.5
11 to 11.9	16.0	-	14.0	8.9	9.7	12.0	-	7.3	6.0	5.8
12 to 12.9	15.0	-	14.0	9.0	9.5	12.0	-	8.0	6.4	6.1
13 to 13.9	15.0	11.4	13.0	8.8	9.1	12.0	8.9	8.0	6.6	6.4
14 to 14.9	14.0	11.0	13.3	8.2	8.6	12.0	9.5	10.0	6.8	6.8
15 to 15.9	14.0	10.3	-	7.8	8.3	13.0	9.4	-	7.4	7.3
16 to 16.9	14.0	9.9	-	8.0	8.1	14.0	9.6	-	8.0	7.9
17 to 17.9	14.0	10.9	-	9.0	8.1	15.0	10.6	-	9.0	8.6
Girls	**Triceps skinfold** (mm)					**Subscapular skinfold** (mm)				
9 to 9.9	17.0	-	12.5	10.8	11.6	12.0	-	7.0	6.6	6.5
10 to 10.9	18.0	-	12.0	11.1	12.2	14.0	-	7.0	7.0	7.1
11 to 11.9	18.0	-	15.0	11.5	12.8	15.0	-	9.0	7.8	7.8
12 to 12.9	18.0	-	15.5	11.8	13.4	15.0	-	11.0	8.8	8.5
13 to 13.9	20.0	15.9	15.1	12.0	14.1	16.3	12.3	10.0	9.4	9.2
14 to 14.9	22.0	15.3	16.0	13.0	14.9	18.0	11.5	11.0	10.2	10.0
15 to 15.9	22.0	15.6	-	14.2	15.7	20.0	11.7	-	11.4	10.7
16 to 16.9	22.0	16.6	-	15.5	16.5	21.0	12.2	-	12.0	11.4
17 to 17.9	21.4	16.8	-	16.0	17.2	20.0	12.2	-	12.4	12.0