Skinfold Thickness Pinch Size Can Interfere in the Estimation and Classification of Body Adiposity

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Abstract

The objective was to verify the effect of pinch size on the absolute measure of skinfold thickness and on the consequent interference in the estimation and classification of the components of body adiposity. This was a cross-sectional study conducted with a sample of 29 subjects of both sexes aged 20 to 35 years. The study was conducted in the city of Fortaleza, Ceará, Brazil. Four measurement steps were performed at each site of the eight chosen skinfolds. The first step was performed with a subjective-landmark and the three subsequent steps with fixed-landmarks defined with an expanding secondary line at 2 cm intervals. Body adiposity components were estimated from the skinfold thickness measured at each landmark. Repeated measures ANOVA and Bland-Altman agreement analysis were applied. The subjective-landmark was chosen as the dependent variable. The 6 cm-landmark showed similarity and statistical agreement with the subjective-landmark for all skinfolds except the thigh, and with the sums of five and eight skinfolds. All fixed-landmarks showed agreement below the cut-off point for the percentile classification of subcutaneous adiposity and normative relative body fat. It is concluded that variation in the pinch size of skinfold thickness is a new and important source of technical error in anthropometric measurement.

Introduction

Surface anthropometry is a satisfactorily valid doubly-indirect method to describe and quantify human body composition in different field settings [1]. Skinfold thickness is the main measurable property for estimating the anatomical-tissue or chemical-molecular component of body adiposity [2]. However, some biological limitations are attributed to skinfolds. Skin thickness and static compressibility of adipose tissue differ considerably between sites and subjects [3]. Thus, the reproducibility and reliability of skinfold thickness is dependent on the anthropometrist's accuracy and adherence to the measurement technique [1].

The position of the plicometer's contact jaws and more especially the site location are well-documented sources of measurement error [4, 5]. A leading international organization emphasizes that regardless of the degree of experience and technical skill of the anthropometrist, all skinfold sites should be pre-identified and marked [6]. A site is the anatomical location for skinfold measurement, where a landmark is performed with two intersecting lines. The primary line corresponds to the direction of the vertical, oblique, or horizontal anatomical axis and the secondary line corresponds to the perpendicular position of the index and thumb fingers [7].

The distance between the fingers is equivalent to the skinfold pinch size, however, it is described with divergence in the reference literature. Brozek and Keys [8] and Harrison et al. [9], while recognizing the importance of technical-palpatory subjectivity, suggest about 8 cm as the standard distance for pinching a skinfold. Ross and Marfell-Jones [10] and Esparza-Ros et al. [6] only describe that the distance between the fingers is strictly subjective and that it be sufficient to ensure the formation of a parallel double layer of skin-plus-subcutaneous adipose tissue.

The effect of pinch size on the measurement of skinfold thickness hasn't been keenly investigated. Although there is no experimental evidence, it is hypothesized that the way that skinfold thickness is pinched may increase the degree of variability in the measurement [1, 11]. Thus, the present study aimed to verify the effect of pinch size on the absolute measurement of skinfold thickness and the consequent interference in the estimation and classification of body adiposity components.

Materials And Methods

Study design and sample

Cross-sectional and quantitative study carried out in the last quarter of 2021 in the city of Fortaleza, Ceará, Brazil. The non-probability convenience sample consisted of 29 adults of both sexes recruited at random from a university center. Subjects aged 20 to 35 years and self-reported as healthy were chosen. Subjects who had undergone liposuction surgery and/or abdominoplasty were excluded. In addition, subjects were excluded if during the collection session any skinfold was biologically impossible to measure. The subjects' participation was voluntary and the informed consent form was signed. The study followed the research guidelines of the Brazilian National Health Council on research involving human beings and was approved by the Comitê de Ética em Pesquisa da Universidade de Fortaleza (Research Ethics Committee of the University of Fortaleza) under nº CAAE – 89306918.9.0000.5052.

Measurement of anthropometric variables

An anthropometrist accredited at level 3 by the *International Society for the Advancement of Kinanthropometry (ISAK)* was selected to perform the anthropometric measurements in a private room at a temperature of 24°C, employing the International Standards for Anthropometric Assessment [6]. Biosecurity procedures were applied due to the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) pandemic situation.

Body mass was measured using a digital scale (Toledo®, 2098PP, Brazil) and height using a fixed stadiometer (Sanny®, ES2030, Brazil). The thickness of the triceps, subscapular, biceps, iliac crest, supraspinatus, abdominal, thigh and calf skinfolds were measured using a Harpenden plicometer (Baty International®, England) with a resolution of 0.2 mm and a constant pressure of 10 g/mm². The equipment was previously calibrated with an analog caliper (Mitutoyo®, 530 – 104, Japan). A flexible steel anthropometric tape measure (Cescorf®, Brazil), an anthropometric bench (Anthropos®, Brazil) and a dermographic pen (Viscot Medical®, United States) were used as auxiliary instruments. The equipment is registered with Agência Nacional de Vigilância Sanitária (the National Health Surveillance Agency).

Procedures

The site and landmark of eight skinfolds were identified and marked. For positioning of the plicometer contact jaws, a short guideline [12] was added 1 cm away from the intersection and in the direction of the anatomical axis [6]. Four measurement steps were performed at each site of the eight chosen skinfolds.

The first step was performed with a subjective-landmark and the three subsequent steps with fixed-landmarks defined with a secondary line centered at the intersection of the site and expanding outwards at 2 cm intervals (Fig. 1). The effect of skinfold thickness compressibility [3] was minimized by employing a 10-minute interval between measurement steps.

In the first step, the distance between the fingers was defined subjectively as described in Esparza-Ros et al. [6]. The chosen pinch size was marked with two short vertical lines immediately above the secondary line. In the second step, a fixed distance of 4 cm was marked. In the third step, a fixed distance of 6 cm was marked. In the fourth step a fixed distance of 8 cm was marked.

A duplicate was performed at each landmark of the eight skinfolds. The mean value was used for statistical analyses. In the event of an error > 5%, a triplicate was performed and, consequently, the intermediate value was used. The intra-evaluator relative technical error of measurement was calculated [13] and presented in Table 1.

Table 1
Descriptive characteristics of the sample and comparison between landmarks.

	Mean ± SD (TEM%)				**p-value**					
Variables	**A Subjective landmark**	**B 4 cm landmark**	**C 6 cm landmark**	**D 8 cm landmark**	**A vs B**	**A vs C**	**A vs D**	**B vs C**	**B vs D**	**C vs D**
Triceps skinfold (mm)	13.58 ± 5.02 (1.52%)	13.45 ± 5.08 (1.65%)	13.73 ± 5.19 (1.48%)	14.33 ± 5.43 (1.90%)	1.000	1.000	**0.003**	0.954	**0.025**	**0.002**
Subscapular skinfold (mm)	12.24 ± 3.54 (2.18%)	11.84 ± 3.33 (1.99%)	12.21 ± 3.5 (2.93%)	12.8 ± 3.89 (1.92%)	**0.002**	1.000	**0.009**	**0.001**	0.191	**0.002**
Biceps skinfold (mm)	6.20 ± 5.00 (2.66%)	6.00 ± 4.20 (2.93%)	6.30 ± 4.90 (2.83%)	7.40 ± 4.60 (3.94%)	**0.002**	0.089	**0.002**	**0.001**	**< 0.001**	**0.001**
Iliac crest skinfold (mm)	16.51 ± 6.42 (2.07%)	15.84 ± 5.98 (1.21%)	16.72 ± 6.21 (1.42%)	17.66 ± 6.98 (2.40%)	**0.018**	1.000	**0.034**	**< 0.001**	**0.001**	**0.040**
Supraspinale skinfold (mm)	9.80 ± 6.85 (2.59%)	10.20 ± 6.10 (2.30%)	9.40 ± 18.00 (2.19%)	10.30 ± 6.75 (2.19%)	0.054	0.415	0.092	0.139	**0.012**	**0.002**
Abdominal skinfold (mm)	19.18 ± 6.18 (1.32%)	17.27 ± 5.18 (2.92%)	19.09 ± 6.36 (1.04%)	20.25 ± 7.45 (0.94%)	**0.001**	1.000	1.000	**0.001**	**0.001**	**0.004**
Thigh skinfold (mm)	18.70 ± 9.95 (1.62%)	17.00 ± 8.35 (1.05%)	18.00 ± 9.60 (1.04%)	19.00 ± 9.05 (1.55%)	**0.003**	0.148	**0.021**	0.070	**< 0.001**	**< 0.001**
Calf skinfold (mm)	12.39 ± 4.87 (1.20%)	12.18 ± 4.77 (2.32%)	12.48 ± 4.9 (1.33%)	12.95 ± 5.2 (1.92%)	0.440	1.000	**0.019**	0.051	**0.006**	**0.049**
Sum of 5 skinfolds (mm)	79.79 ± 4.73 *	75.79 ± 4.33 *	79.15 ± 4.51 *	83.80 ± 4.96 *	**< 0.001**	1.000	**0.008**	**0.001**	**< 0.001**	**< 0.001**
Sum of 8 skinfolds (mm)	109.78 ± 34.58 *	104.73 ± 31.46 *	109.28 ± 32.89 *	115.47 ± 36.46 *	**< 0.001**	1.000	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**
Relative body fat (%)	19.51 ± 5.65 *	16.01 ± 5.28 *	17.12 ± 5.75 *	17.11 ± 5.41 *	**< 0.001**	**0.006**	**0.009**	**< 0.001**	**< 0.001**	1.000
SD: Standard deviation; TEM: Technical error of measurement. *TEM not calculated.										

Components of body adiposity were estimated from the skinfold thickness measured at each landmark. Chemical-molecular component: density was estimated from the mathematical models nºM7 and nºF9 of Petroski [14] for males and females, respectively. The value was converted to relative body fat [15] and classified [16] Anatomical-tissue component: subcutaneous adiposity was estimated, in absolute values, from the sum of the thickness of five skinfolds (triceps, subscapular, iliac crest, abdominal and thigh). Percentile curves were applied for classification [17].

Statistical analysis

Descriptive statistics were applied. Normality of the data was analyzed using the Shapiro-Wilk test. Differences between skinfold thicknesses obtained at each landmark were analyzed with analysis of variance (ANOVA) for repeated measures. Skinfold measurements that did not follow the normal distribution were compared using the Friedman test and presented as medians and interquartile range.

The subjective-landmark was defined as a dependent variable and compared with the fixed-landmarks using the Bland-Altman technique. This statistical procedure quantifies measures of agreement by bias and limits of agreement (LOA). The existence of proportional bias was analyzed using the Ordinary Least Square (OLS) regression model, using as independent variable the mean value of the value measured by the compared techniques and as dependent variable the value of the difference between the compared measures. The fixed bias was established with the one-sample t test for the values of differences between measurements [18].

The difference in the number of subjects in each classification of body adiposity components, either by percentile or relative value, was verified using the Chi-Square test. The agreement between the classification parameters was analyzed using the Kappa coefficient. Value $\kappa \geq 0.8$ was considered. The significance level was set at $p < 0.05$. IBM SPSS Statistics, version 26.0 (IBM Corp., Armonk, NY, USA) was used for all analysis.

Results

The sample consisted of 29 subjects (51.7% women) with a mean age of 26.48 ± 3.48 years. Each subject was evaluated on all variables. The mean relative body fat and the sum of the thickness of five skinfolds were 19.51 ± 5.65% and 79.80 ± 25.48 mm, respectively. The results are classified between the 25th and 50th percentiles, characterizing the sample as eutrophic [16, 17].

The comparative analysis between the landmarks is shown in Table 1. The 4 cm-landmark presented similarity with the subjective-landmark for the triceps, supraspinatus and calf skinfolds, as well as with the 6 cm-landmark for the triceps, supraspinatus, thigh, and calf skinfolds, and with the 8 cm-landmark for the subscapular skinfold. The 6 cm-landmark showed similarity with the subjective-landmark for the skinfolds and the sum of the thickness of five and eight skinfolds. The 8 cm-landmark showed similarity with the subjective-landmark for supraspinal and abdominal skinfolds. Furthermore, a significant difference was observed between the landmarks for the relative body fat component, except between the 6 cm-landmark and the 8 cm-landmark (Table 1).

The Bland-Altman agreement analysis between the subjective-landmark and the fixed-landmarks is shown in Table 2. No fixed-landmark presented satisfactory LOA for all skinfold thicknesses. The 4 cm-landmark agreed with the subjective-landmark for triceps and calf skinfolds. The 6 cm-landmark agreed with the subjective-landmark for all skinfolds, except the thigh. It was also the only fixed-landmark that showed agreement with the sums of skinfolds. The 8 cm-landmark agreed with the subjective-landmark for supraspinal, abdominal and thigh skinfolds. All fixed-landmarks showed significant fixed bias for the estimation of relative body fat (Fig. 2).

Table 2
Bland-Altman agreement analysis between the subjective-landmark and the fixed-landmarks.

Variables	Regression				One sample t-test			
	β	LOA	p-value	Bias*	Mean diference (± SEM)	LOA	p-value	Bias**
Triceps skinfold								
4 cm-landmark	-0.055	-0.098; 0.074	0.778	No	0.13 ± 0.2	-0.28; 0.55	0.519	No
6 cm-landmark	-0.255	-0.083; 0.017	0.182	No	-0.15 ± 0.12	-0.4; 0.11	0.245	No
8 cm-landmark	-0.397	-0.149; -0.007	**0.033**	Yes	-0.75 ± 0.19	-1.14; -0.36	**< 0.0001**	Yes
Subscapular skinfold								
4 cm-landmark	0.384	-1.015; 0.388	**0.04**	Yes	0.4 ± 0.1	0.2; 0.6	**< 0.0001**	Yes
6 cm-landmark	0.065	-0.050; 0.070	0.739	No	0.03 ± 0.1	-0.17; 0.23	0.77	No
8 cm-landmark	-0.415	-0.178; -0.013	**0.025**	Yes	-0.56 ± 0.16	-0.88; -0.23	**0.001**	Yes
Biceps skinfold								
4 cm-landmark	0.273	-0.785; 0.628	0.153	No	0.39 ± 0.13	0.12; 0.66	**0.006**	Yes
6 cm-landmark	0.104	-0.089; 0.153	0.592	No	-0.17 ± 0.16	-0.5; 0.15	0.286	No
8 cm-landmark	-0.049	-0.192; 0.150	0.801	No	-0.69 ± 0.23	-1.16; -0.23	**0.005**	Yes
Iliac crest skinfold								
4 cm-landmark	0.393	0.005; 0.137	**0.035**	Yes	0.67 ± 0.21	0.25; 1.1	**0.003**	Yes
6 cm-landmark	0.224	-0.025; 0.094	0.243	No	-0.21 ± 0.18	-0.58; 0.16	0.247	No
8 cm-landmark	-0.273	-0.203; 0.033	0.151	No	-1.14 ± 0.38	-1.93; -0.36	**0.006**	Yes
Supraspinale skinfold								
4 cm-landmark	0.483	0.033; 0.197	**0.008**	Yes	0.45 ± 0.2	0.03; 0.87	**0.035**	Yes
6 cm-landmark	0.309	-0.012; 0.124	0.103	No	0.12 ± 0.16	-0.21; 0.44	0.475	No
8 cm-landmark	-0.045	-0.110; 0.087	0.818	No	-0.44 ± 0.23	-0.9; 0.02	0.061	No
Abdominal skinfold								
4 cm-landmark	0.433	0.033; 0.335	**0.019**	Yes	1.91 ± 0.44	1.01; 2.81	**< 0.0001**	Yes
6 cm-landmark	-0.055	-0.239; 0.181	0.777	No	0.09 ± 0.6	-1.14; 1.32	0.882	No
8 cm-landmark	-0.32	-0.438; 0.034	0.09	No	-1.08 ± 0.77	-2.64; 0.49	0.171	No
Thigh skinfold								
4 cm-landmark	0.472	0.030; 0.198	**0.01**	Yes	0.89 ± 0.37	0.13; 1.65	**0.023**	Yes
6 cm-landmark	0.469	0.039; 0.261	**0.01**	Yes	0.88 ± 0.48	-0.1; 1.86	0.077	No
8 cm-landmark	0.313	-0.012; 0.133	0.098	No	-0.48 ± 0.3	-1.1; 0.15	0.128	No
Calf skinfold								
4 cm-landmark	0.153	-0.030; 0.070	0.428	No	0.21 ± 0.11	-0.02; 0.45	0.073	No
6 cm-landmark	-0.072	-0.045; 0.031	0.71	No	-0.08 ± 0.09	-0.26; 0.09	0.348	No
8 cm-landmark	-0.359	-0.134; 0.002	0.056	No	-0.56 ± 0.17	-0.91; -0.2	**0.003**	Yes
Sum of 5 skinfolds								
4 cm-landmark	0.563	0.037; 0.140	**0.001**	Yes	4.0 ± 0.71	2.54; 5.46	**< 0.0001**	Yes
6 cm-landmark	0.234	-0.030; 0.125	0.223	No	0.64 ± 0.93	− 1.27; 2.55	0.499	No
8 cm-landmark	-0.212	-0.140; 0.041	0.27	No	-4.00 ± 1.12	− 6.30; − 1.69	**0.001**	Yes
Sum of 8 skinfolds								

β: coefficient of the least ordinary squares regression converted to z score; LOA: Bland-Altman limits of agreement; CI: confidence interval;

*Proportional bias if β differs significantly from 0 (p < 0.05); SEM: standard error of the mean; **Fixed bias if p-value from t-test < 0.05 or 95.

Variables	Regression				One sample t-test			
	β	LOA	p-value	Bias*	Mean diference (± SEM)	LOA	p-value	Bias**
4 cm-landmark	0.675	0.054; 0.136	**< 0.0001**	No	5.06 ± 0.86	3.3; 6.81	**< 0.0001**	Yes
6 cm-landmark	0.332	-0.006; 0.107	0.079	No	0.5 ± 0.95	-1.44; 2.44	0.601	No
8 cm-landmark	-0.296	-0.122; 0.015	0.119	No	-5.69 ± 1.19	-8.12; -3.26	**< 0.0001**	Yes
Relative fat (%)								
4 cm-landmark	0.104	-0.218; 0.374	0.592	No	3.49 ± 0.72	2.03; 4.96	**< 0.0001**	Yes
6 cm-landmark	-0.03	-0.272; 0.233	0.877	No	2.39 ± 0.65	1.07; 3.71	**0.001**	Yes
8 cm-landmark	0.071	-0.226; 0.325	0.714	No	2.4 ± 0.68	1.01; 3.79	**0.001**	Yes
β: coefficient of the least ordinary squares regression converted to z score; LOA: Bland-Altman limits of agreement; CI: confidence interval;								
*Proportional bias if β differs significantly from 0 ($p < 0.05$); SEM: standard error of the mean; **Fixed bias if p-value from t-test < 0.05 or 95.								

The absolute and relative frequency of the classification of body adiposity components between the subjective-landmark and the fixed-landmarks is presented in Table 3. There was a significant difference ($p < 0.0001$) for the subcutaneous adiposity classification. All fixed-landmarks showed coefficients of agreement below the cut-off point ($\kappa \geq 0.8$) for the percentile classification of subcutaneous adiposity ($\kappa < 0.759$) and normative relative body fat ($\kappa < 0.075$).

Table 3
Analysis of the classification agreement of body adiposity components.

Classification	A	B	C	D	A vs B			A vs C			A vs D		
	Subjective landmark	4 cm landmark	6 cm landmark	8 cm landmark	χ^2	κ	p-value	χ^2	κ	p-value	χ^2	κ	p-value
Subcutaneous adiposity													
P5	5 (17.2%)	6 (20.7%)	8 (27.6%)	6 (20.7%)	**< 0.0001**	0.489	**< 0.0001**	**< 0.0001**	0.668	**< 0.0001**	**< 0.0001**	0.759	**< 0.0001**
P10	4 (23.8%)	4 (13.8%)	4 (13.8%)	4 (13.8%)									
P25	11 (37.9%)	10 (34.5%)	10 (34.5%)	11 (37.9%)									
P50	9 (31%)	7 (24.1%)	7 (24.1%)	8 (27.6%)									
Relative body fat													
Verylow	0	1 (3.4%)	0	0	0.622	0.075	0.552	0.496	0.016	0.907	0.496	0.016	0.907
Low	16 (55.2%)	22 (75.9%)	21 (72.4%)	21 (72.4%)									
Normal	1 (3.4%)	2 (6.9%)	3 (10.3%)	3 (10.3%)									
High	12 (41.4%)	4 (12.8%)	5 (17.2%)	5 (17.2%)									
χ^2: p-value for the Chi-Square test; κ: interclass coefficient.													

Discussion

The international protocol for anthropometric measurement is from a technical point of view periodically revised [19] in justification for the continuous updating of the literature. Comparative studies have investigated the reading time of skinfold thickness measurement [20], the physical-mechanical characteristics of plicometers [21], interchangeable anthropometric measurement approaches [5, 12; 22] and the location of the skinfold site [5].

A study carried out with a subsample of 62 male subjects observed that variation in the depth position of the plicometer contact jaws produced significant differences in triceps skinfold thickness ($p < 0.05$). The deep position resulted in thicker measurements and the superficial position resulted in less thick measurements, when compared to the middle position [4]. Burkinshaw, Jones and Krupuwicz [23] found that marking the site of the four skinfolds in advance allowed examiners of varying degrees of technical skill to obtain consistent measurements. Subsequently, the importance of accuracy in locating the site of the eight skinfolds in a sample of 10 male subjects was investigated. Variations with significant differences in skinfold measurement values were observed for 70% of the peripheral grid points within a short distance of the defined criterion site [5].

The lack of analysis of the influence of measurement technique in the assessment of body composition or nutritional status is a methodological limitation of some comparative studies (4, 5, 12, 23]. Outcome classification is an important guiding variable for prescriptive interventions. The present study quantified the effect of different pinch sizes on the thickness of eight internationally standardized skinfolds in a sample of 29 subjects, totaling more than 1.800 points of morphological data, and on the consequent interference in the estimation and classification of body adiposity components.

The 6 cm-landmark showed similarity and statistical agreement with the subjective-landmark for all skinfolds, except the thigh, and with the sums of five and eight skinfolds. The 4 cm-landmark showed statistical similarity with subjective-landmark for triceps, supraspinatus and calf skinfolds, however, there was agreement only for appendicular skinfolds. The 8 cm-landmark showed similarity and statistical agreement with subjective-landmark supraspinal and abdominal skinfolds. Thus, it is suggested that skinfold thickness pinching at limb sites needs to be a smaller size (< 6 cm), except the thigh (> 6 cm), and trunk sites needs to be a larger size (> 6 cm).

The suggested opposite size between the lower appendicular sites is trivial. Martin et al. [3], in experiments with cadavers, it was evidenced that, regardless of gender, the thickness of the skin of the thigh is greater than that of the calf. Also, the static compressibility of the thigh is lower. Additionally, the larger musculoskeletal volume characteristic of the segment favors the increase of skin resistance to pinching, principally in subjects undergoing strength training.

The variability of the size of the pinch between the anatomical regions is justified by the intrinsic specificity of the density and compressibility of the skin-plus-subcutaneous adipose tissue of each site and subject, consequently affecting the technical-palpatory sensitivity of the anthropometrist and the degree of reproducibility of repeated measurements. The two aforementioned biological factors are inversely proportional [3, 21]. The negative linear relationship between skinfold density and compressibility partially explains the measurement variation observed between landmarks (Table 1), given that the site with high tissue density is less compressible and the site with low tissue density is more compressible. Therefore, pinching with subjective distance between the fingers is the one that best suits the quanti-qualitative variability of skinfold thickness and, in view of this, standardization of a fixed size of pinching seems to be improbable. And further, add to this the fact that, as described in Esparza-Ros et al. [6], the marking of the iliac crest skinfold site is performed from the technical-palpatory subjectivity with the subcutaneous tissue, making these parameters applicable to all other sites. It is suggested that the fixed-landmarks examined in the present study are not interchangeable for the measurement of skinfold thickness.

Systematic interference of skinfold thickness pinch size was observed in the estimation (Table 1) and classification (Table 3) of body adiposity components. The percentile classification of subcutaneous adiposity differed significantly ($p < 0.0001$) and the normative classification of reactive body fat was the least affected by the size of skinfold thickness pinching. However, independent of the way of classifying body adiposity, there was no agreement between the subjective-landmark and the fixed-landmarks (Table 3). It is noteworthy that when the measurement of skinfold thickness is not performed correctly, potential error is inflated, making the absolute values and estimates of the molecular-chemical and anatomical-tissue component of subcutaneous adiposity questionable and not applicable [24]. Thus, it becomes necessary to standardize the measurement technique and undergo training with experienced tutors.

Access to the principal skinfold thickness measurement protocols is limited, especially in Latin American countries, as such protocols are described in book chapters [7, 9] that have not been reprinted and/or revised in the 21st century, or require participation in commercial refresher courses [6]. The most relevant and instrumental information in the reference literature (6, 7, 9, 25], were compiled to facilitate reproduction by health and/or sport professionals who employ surface anthropometry in intervention scenarios.

These technical procedures have been revised, improved and operationally categorized into two steps: marking and measurement. All of which are sequentially performed on the right side of the body. The left hand should be used to pinch the site and the right hand to handle the plicometer regardless of the anthropometrist's lateral dominance. The use of anthropometric tape and a dermographic pen are essential for the marking stage. We suggest the use of a plicometer with a double spring system developed in accordance with the physical-mechanical characteristics of the prototype proposed by Edwards et al. [26] and described in Tanner and Whitehouse [27].

Marking Step: I) Identify and accurately mark the skin fold site (Fig. 1A-S); II) Mark the line of the vertical, oblique or horizontal anatomical axis of the skinfold (Fig. 1A-L1) and a perpendicular line forming an intersection (Fig. 1A-L2); III) In the direction of the anatomical axis, mark a short guideline for the position of the plicometer's contact jaws at 1 cm from the site (Fig. 1A-L4). [Note: this line ensures that the plicometer jaws are positioned in the same location in repeated measurements.]; IV) Perform pinching on the contact area of the site with the left index finger and thumb tips flexed, perpendicular to the anatomical axis, in order to become familiar with the skin-plus-subcutaneous adipose tissue. [Note: increasing pinching size is suggested (< to >) until two parallel layers of tissue are properly joined without excessive stretching of the skin in the outer region of the pinch]; V) Subjectively define the size of the skinfold thickness at the site, keeping it held, then undo it keeping the fingers in contact with the site, and finish by marking the chosen pinching size with two short vertical lines (Fig. 1A-L4). A demo with images is provided in the Supplementary Material.

Measuring Step: I) Position the fingertips on the guidelines (Fig. 1A-L4), then pinch and firmly detach the skinfold, with the back of the hand facing the anthropometrist, just above the intersection and perpendicular to the anatomical axis; II) Apply the plicometer contact jaws on the short guideline (Fig. 1A-L3) and at median depth proportionally to the middle of the fingernail. [Note: this depth is also understood as the alignment between the distal interphalangeal curve of the thumb and the curve of the fixed rod of the plicometer.]; III) Carefully observe the measurement resolution scale and then gradually release the plicometer trigger, keeping the skinfold firmly held; IV) Take the measurement reading 2 seconds after complete pressure is exerted by the plicometer spring system; V) Carefully remove the contact jaws, activating the plicometer trigger and then releasing the skinfold.

A minimum of two sequential measurements should be taken at each skinfold site. The mean value is used. In the event of a technical measurement error of > 5%, a triplicate is performed and the intermediate value used for the site that presents this variation. After finishing the measurement step, the landmarks should be cleaned with a moistened tissue.

Limitations

This study involved intentional sampling and not representative of the morphological heterogeneity inherent in the population investigated. Therefore, the results are limited, in their ability to generalize, to groups with characteristics at the extremes of skinfold thicknesses composition and compressibility. Additionally, the lack of statistical analysis stratified by gender has been highlighted, which consequently limits the understanding of the results regarding sexual dimorphism.

Practical implications

The experimental evidence from this study is important in updating the internationally standardized skinfold thickness measurement technique. It is suggested that the anthropometrist identify and mark in advance, not only the site, but also the size of the pinch with subjective distance between the fingers.

Conclusion

Variation in skinfold thickness pinch size is a new and important source of technical error for anthropometric measurement which can affect the reproducibility of the absolute measurement and systematically interfere with the reliability of the estimation and classification of body adiposity components in adults.

Declarations

Ethical approval

The study followed the research guidelines of the Brazilian National Health Council on research involving human beings and was approved by the Research Ethics Committee of the University of Fortaleza under nº CAAE - 89306918.9.0000.5052.

Conflict of interest statement

The authors have no conflict of interests to declare.

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Author Contributions

Conceived and designed experiments: JHCA; FOB. Performed experiments: JHCA. Analyzed data: FOB. Contributed with reagents/materials/analysis tools: JHCA; FBO; MIFC; RFC; WLR. Wrote the paper: RFC; WLR. All authors read and approved the final version of the manuscript.

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Figures

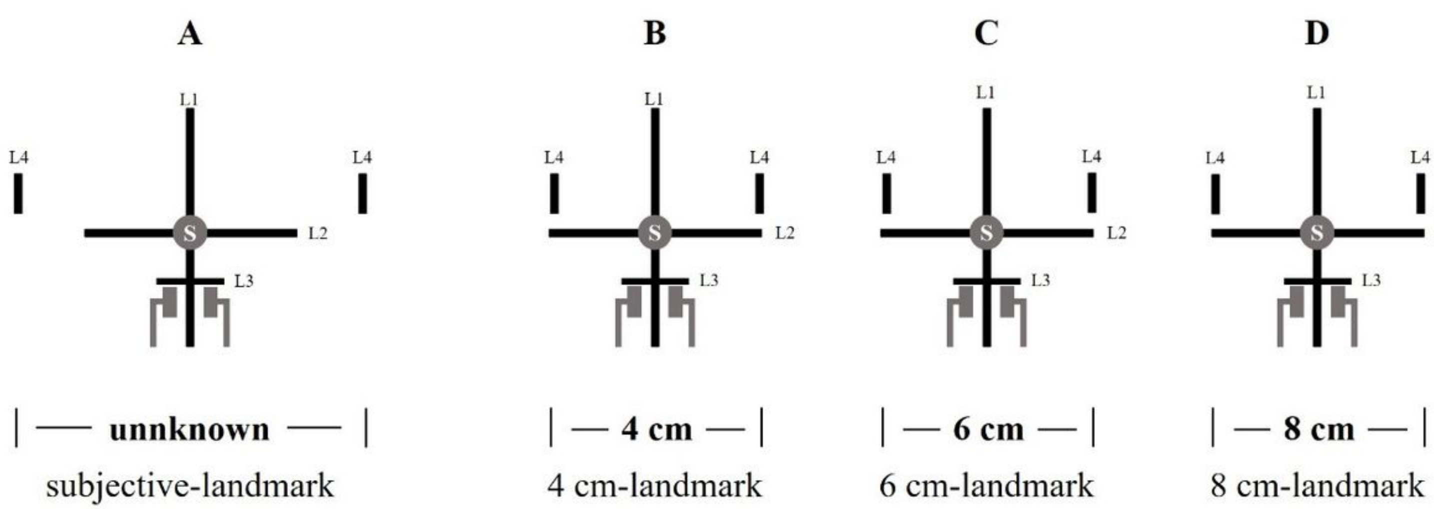

Figure 1

Description of landmarks. Site (S); Primary line of the anatomical skinfold axis* (L1); Secondary and perpendicular line (L2); Short line of position of the plicometer contact jaws (L3); Short line of position for the tips of the index finger and thumb. *Only the vertical anatomical axis was illustrated.

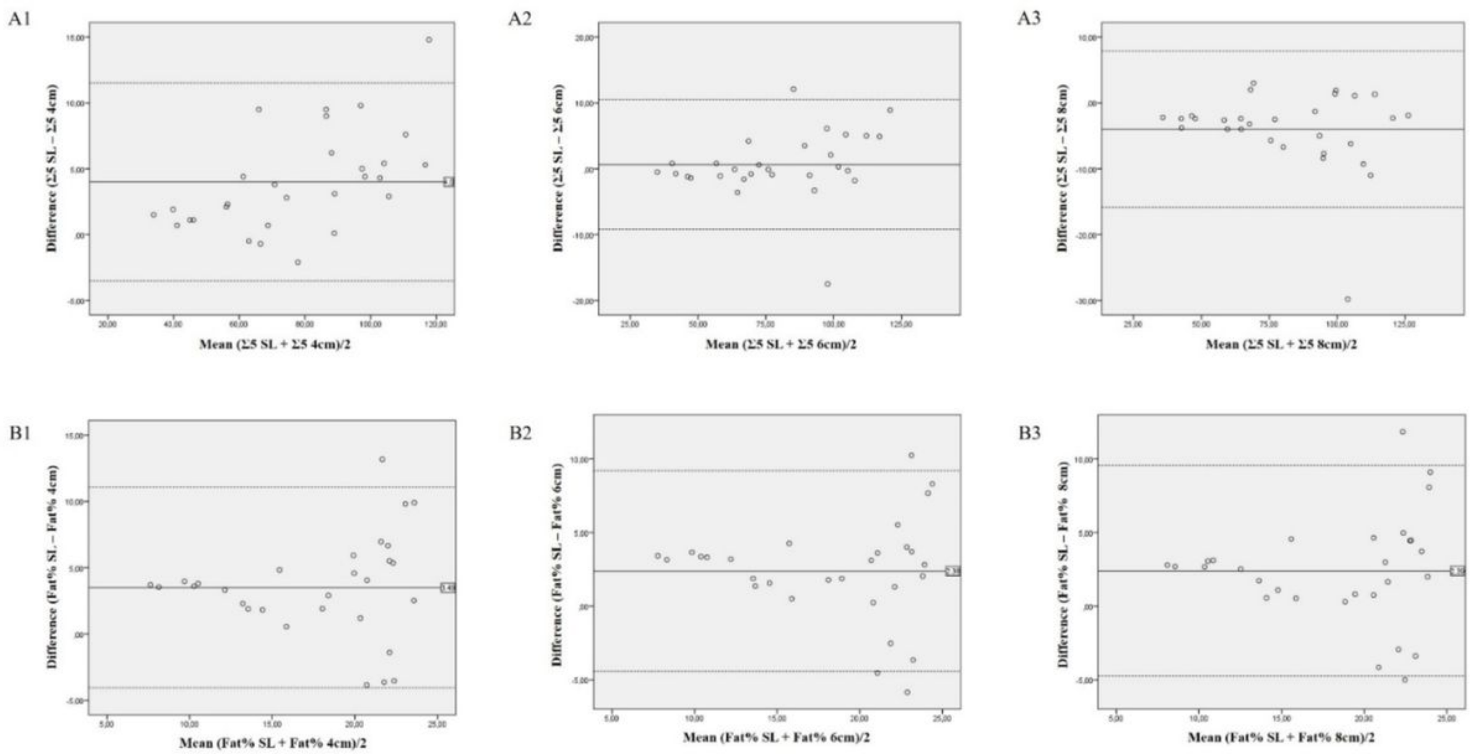

Figure 2

Bland-Altman plots between subjective-landmark and fixed-landmarks for subcutaneous adiposity (A) and relative body fat (B).