Progress in Nutrition 2018; Vol. 20, N. 2: 273-278 DOI: 10.23751/pn.v20i2.5729

Original article

Skinfolds compressibility and calliper's time response in male athletes

Alessandro Bini[1], *Teresa F. Amaral*[1,2], *Bruno MPM Oliveira*[1,3], *Pedro Carvalho*[1], *Vitor Hugo Teixeira*[1,4]

[1]Faculdade de Ciências da Nutrição e Alimentação, Universidade do Porto, Porto, Portugal; [2]UISPA-IDMEC, Faculdade de Engenharia, Universidade do Porto, Porto, Portugal - E-mail: amaral.tf@gmail.com; [2]LIAAD, INESC TEC Porto, Portugal; [4]CIAFEL, Faculdade de Desporto, Universidade do Porto, Porto, Portugal.

Summary. *Introduction*: The body skinfolds compressibility is an individual characteristic determined by tissues properties. Compressibility could affect the skinfold thicknesses inducing error in the assessment of subcutaneous adipose tissue and in the estimation of body composition. *Objectives*: This study aims to firstly describe the time behaviour of eight body skinfolds' physical response to the skinfold calliper pressure during measurement. *Methods:* Using a digital skinfold calliper that gathers 60 measurements per second, the dynamic response of height skinfolds to pressure was characterized in 36 adult male athletes. To assess the skinfolds compressibility, two points were defined L and H: the S_L corresponds to the lowest value within the 120 measurement the time when it was obtained was defined as T_L. The T_H corresponds to the first moment where the 110% of of the value S_L was measured. The equations of the average of each skinfold as a function of time were obtained from a non-linear fitting. *Results:* Skinfold compressibility varied according subjects ($p<0.05$). Significant differences were found among skinfold sites within S_H, S_L, T_H and T_L, confirming that each skinfold compressibility is different from the other, even within a homogeneous study group. Biceps was the first skinfold to reach the minimum thickness value (T_L=1.08 ± 0.38s), while iliac crest was the last one (T_L=1.63±0.27s). Given the very good fits that were obtained for all skinfolds ($R^2 \geq 0.997$), it was postulated that the skinfold thickness *y* changes with time *t* according to the equation: $y = y0 + a/(b + t^n)$. *Conclusions:* Inter and intraindividual skinfolds' variation in compressibility was documented, supporting a reduction in protocolled time during evaluations.

Key words: Skinfold thickness, anthropometry, body composition; response time, calliper.

Abbreviations

S_L = Lowest of the 120 measurements.
S_H = 110% of of the value S_L.
S_S = Skinfold thickness measured at the maximum value of T_H+2SD.
T_L = First moment where the lowest of the 120 measurements was measured.
T_H = First moment where the 110% of pof the value S_L was measured.
T_S = The maximum T_H among skinfolds plus 2 standard deviations.

Introduction

The skinfold thickness measurement is a widely used technique for estimating subcutaneous adiposity, given the easy accessibility to different subcutaneous layers in a non-invasive nature (1-4). The thickness of a compressed double layer of subcutaneous adipose tissue obtained using a skinfold calliper is also used to predict overall adiposity in a wide range of nutritional, health, occupational and sport science disciplines (1).

Callipers readings decline after the initial application of the calliper to the skinfold and this inherent quality of compressibility of the subcutaneous tissue justified the initial establishment of a standard pressure of 10 gf/mm^2 exerted by skinfold calliper jaws (5). This method assumes that skinfolds' compressibility is constant, however early reports based on radiographs (2) and cadaver studies (6) have shown that compressibility of the skinfold varies according body sites and individuals, reflecting differences in skin thickness and in tissue pattern (6). This compressibility variation affects the skinfold calliper reading at the particular site on the body and the real adipose thickness at that site, thus inducing error in the assessment of subcutaneous adipose tissue and in body composition estimates (7).

In order to overcome these factors and to avoid bias, different protocols have been issued to guarantee a correct skinfold measurement. For instance, Lohman (1981) (4) and Kramer HJ & Ulmer HV (1981) (8) protocols require, respectively, three and two seconds to obtain the skinfolds values. But these standardizations could be insufficient to overcome the error consequences related to variability of the skinfolds compressibility in the body adiposity and composition assessments.

An early exploratory analysis from 29 adults´ tricipital skinfold measurements lasting three seconds has revealed that the dynamic evolution of tissue compressibility shows very different characteristics among free-living adults (9). This analysis on the tissue compression pattern, suggests that the skinfold behaviour under compression is like a first order system response to the constant force applied by the calliper end tips (9). Aside from this, only the association between skin thickness, skinfold sites and outcomes has been assessed, keeping this topic unexplored.

It will be of major relevance to explore the type of function that describes the behaviour of the different skinfold thicknesses. The advancement of knowledge in this area could contribute to the optimization of the measuring process of subcutaneous fat, being a first step in minimizing the skinfold measurement error and on the estimation of body composition.

Therefore, the aim of this study was to firstly describe the physical behaviour of skinfold tissues time response to skinfold calliper pressure and to explore differences between sites and subjects' skinfolds compressibility.

Methods

Participants/Design

A convenience selected sample of 36 adult male professional players was recruited for a cross-sectional study. The participants belonged to three different sports teams, 14 players from handball, 10 from roller hockey, and 12 from basketball. The ethnicity was represented by 30 white and 6 black athletes.

Data were collected circa three weeks after the season ended except for the roller hockey team which still had to compete. All the evaluations were carried out at the training centre in the morning.

The study was designed and conducted in accordance to the Helsinki Declaration (10). This research protocol was approved by the Ethics Committee of the Faculty of Sport from the University of Porto (reference CEFADE 30.2014).

Skinfolds measurement

Eight skinfolds - triceps, biceps, subscapular, iliac crest, abdominal, supraspinale, front-thigh, and medial-calf - were measured following the ISAK protocol (11) using the Lipotool (12-14). This automatized system acquires 60 measurements per second with a resolution of 0.1mm. It is simple to use and provides highly accurate skinfold measurement (12). To document skinfolds compressibility, 120 skinfold thickness were obtained during the protocolled two seconds time period for each of the height skinfolds.

In order to analyse the compressibility, points L and H were identified from the 120 measurements of each skinfold. The point L corresponds to the lowest skinfold thickness value within the 120 measurements (S_L, in mm) and the time when it is obtained for the first time was defined as T_L, in seconds (s). The point H corresponds to 110% of the skinfold thickness of point L ($S_H = 110\% \times S_L$) and time where it is obtained for the first time was defined as T_H. In addition, it has been set a specific point (S) which represents the skinfold thickness (S_S, in mm) measured at a specific time (T_S), correspondent to the maximum T_H among skinfolds plus a margin of error of two standard deviations.

Anthropometrical evaluations were conducted by a ISAK (International Society for the Advancement of Kinanthropometry) level two anthropometrist (11).

Body weight was measured using a Tanita scale, model MC-180MA® (Tanita Corporation, Tokyo, Japan) to the nearest 0.01 kg and height was measured with a stadiometer (Seca 708; Seca limited, Birmingham, UK), with a resolution of 0.001 m.

Statistical analysis

The values are expressed as mean ± standard deviation. Normality of parameters´ distributions was assessed with Kolmogorov-Smirnov test. All the continuous variables had a distribution close to the Normal distribution. Differences in skinfolds between teams were assessed using one-way ANOVA. Bonferroni correction was utilized to adjust for multiple comparisons. Friedman test was applied to assess differences among skinfold sites and the calliper time response. Non-linear regression models were performed to predict how the average (*y*) of the measurements of all athletes for each skinfold change in time (*t*). We hypothesized the relation to be of the form $y = y0 + a/(b + t^n)$, with the parameters *y0*, a, b, and n, being obtained from a non-linear fitting of the curve. Statistical analyses were carried out using the Software Package for Social Science, SPSS, version 21.0 for Macintosh (SPSS, IBM corporation, Armonk, NY, USA). Statistical significance was set at 0.05.

Results

Since the skinfold thickness did not differ significantly between team sports all athletes were merged into one group. Descriptions of the physical characteristics of the participants are shown in Table 1.

Table 2 presents the average values among all athletes of the lowest skinfold thickness (S_L), the first moment (T_L) where the lowest is reached, the 110% of the skinfold thickness of point L (S_H) and the time (T_H) corresponding to the first moment where that measurement is obtained and the skinfold thickness (S_S) measured at the maximum T_H + 2 standard deviations (T_S = 0.11 + 2 SD) = 0.33 s.

Abdominal skinfold was the thickest (S_H = 13.42 mm; S_L = 12.20 mm) while biceps skinfold was the thinnest (S_H = 4.83 mm; S_L = 4.39 mm). Biceps was the first skinfold site to reach the minimum values measured (T_L= 1.08 ± 0.38 s), while iliac crest was the last one to reach the minimum value (T_L= 1.63 ± 0.27 s). Therefore, at the Kramer HJ & Ulmer HV (8) protocolled time (2 s) all the skinfolds thicknesses have already reached their lowest point (Table 2).

Both comparisons between skinfold sites and skinfold thicknesses, and between skinfold sites and time responses, resulted in statistically significant differences ($p<0.005$). The highest mean time needed to reach the minimum values of S_H was for the medial-calf skinfold ($T_{H\ medial\text{-}calf}$ = 0.11 ± 0.11 s) and the lowest was for the subscapular skinfold ($T_{H\ subscapular}$ = 0.03 ± 0.06 s). Accordingly, the T_S time point was set at 0.33 s, corresponding to the medial-calf T_H plus 2 SD. The average skinfold thickness (S_S) at this time was 9.16 ± 1.51 mm, very close to the 8.91 ± 3.32 mm at T_L.

Figure 1 displays the average (y), among all athletes, of each skinfold thickness in time (t) and the respective non-linear fits of the parameters y_0, *a*, *b,* and *n* of the equation: $y = y0 + a/(b + t^n)$. We obtained very good fits for all skinfolds, with $R^2 \geq 0.997$.

Table 1. Characteristics of the players*

	Age (years)	Height (cm)	Weight (kg)
All Players (n=36)	24.4 ± 5.2	187.1 ± 7.4	84.36 ± 9.54
Handball (n=14)	25.3$^{¥†}$ ± 3.0	191.4† ± 6.5	92.10$^{¥†}$ ± 8.03
Roller hockey (n=10)	29.5§† ± 4.8	181.4† ± 4.5	83.05† ± 6.20
Basketball (n=12)	19.2$^{¥§}$ ± 1.7	186.8 ± 7.5	76.43$^{¥}$ ± 5.94

**Values are expressed as mean ± standard deviation.*

Significance difference (p<0.05) between: † Handball vs Roller Hockey; ¥ Handball vs Basketball; § Roller Hockey vs Basketball.

Table 2. Skinfold sites, skinfold thicknesses and time responses

Skinfolds*	S_H (mm)	S_L (mm)	S_S (mm)	T_H (s)	T_L (s)
Triceps	9.25 ± 3.04	8.41 ± 2.76	8.63 ± 2.81	0.08 ± 0.08	1.40 ± 0.32
Biceps	4.83 ± 1.17	4.39 ± 1.06	4.50 ± 1.10	0.09 ± 0.07	1.08 ± 0.38
Subscapular	11.57 ± 3.08	10.52 ± 2.80	10.74 ± 2.87	0.03 ± 0.06	1.46 ± 0.35
Iliac crest	11.04 ± 4.91	10.04 ± 4.47	10.33 ± 4.67	0.08 ± 0.05	1.63 ± 0.27
Abdominal	13.42 ± 6.34	12.20 ± 5.76	12.52 ± 5.93	0.05 ± 0.06	1.51 ± 0.35
Supraspinale	10.18 ± 3.95	9.26 ± 3.59	9.51 ± 3.71	0.05 ± 0.05	1.51 ± 0.42
Front-thigh	11.35 ± 4.39	10.32 ± 3.99	10.59 ± 4.08	0.08 ± 0.07	1.57 ± 0.25
Medial-calf	6.83 ± 2.34	6.21 ± 2.12	6.44 ± 2.21	0.11 ± 0.11	1.53 ± 0.40
p value*	*<0.001*	*<0.001*	*<0.001*	*0.001*	*<0.001*
Mean	9.80 ± 3.66	8.91 ± 3.32	9.16 ± 1.51	0.07 ± 0.07	1.46 ± 0.34
Sum 8 Skinfolds	78.48 ± 24.47	71.34 ± 22.25	73.26 ± 27.37	0.57 ± 0.30	11.70 ± 1.41

**Values are expressed as mean ± standard deviation; **Friedman test.*
S_L = Lowest of the 120 measurements; S_H = 110% of point L; S_S = Skinfold thickness measured at the maximum value of T_H+2SD; T_L = First moment where the minimum skinfold thickness was measured, T_H = First moment where the 110% of point L was measured.

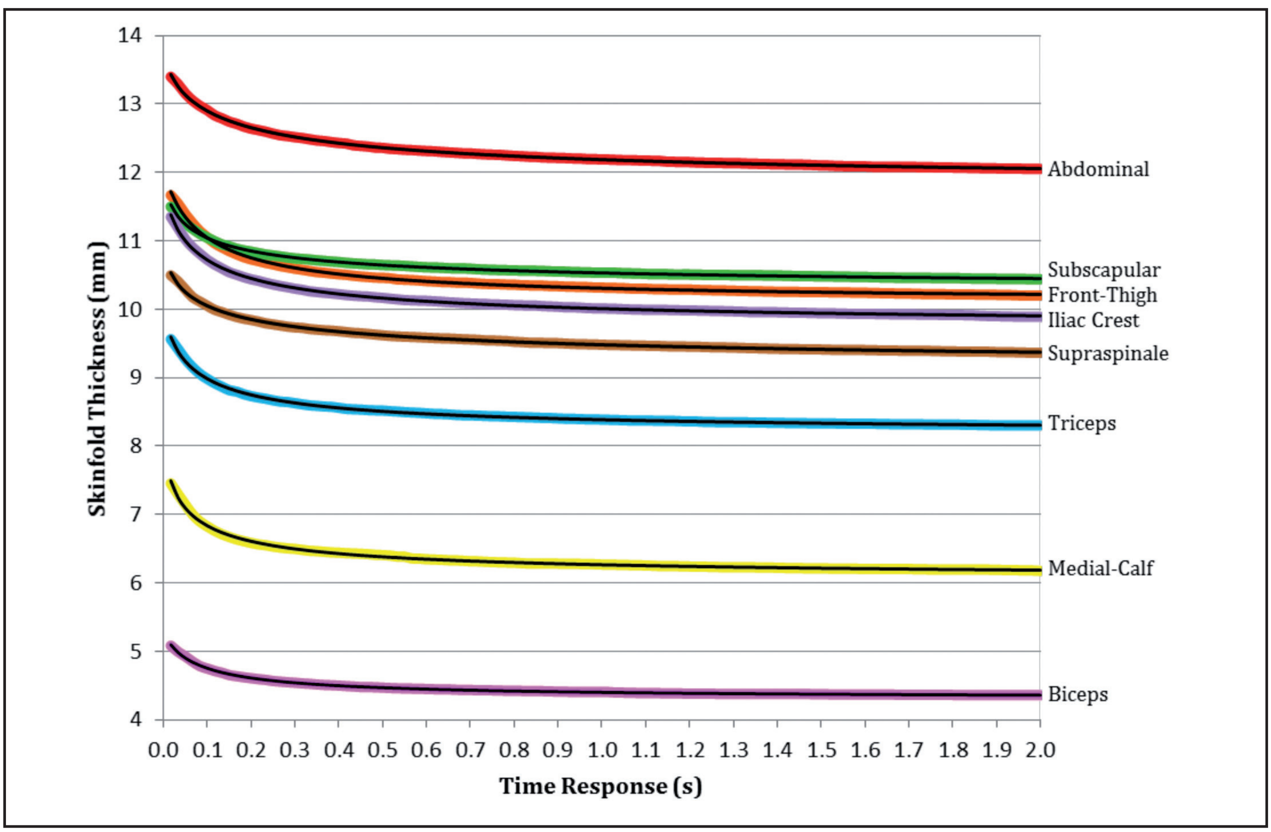

Figure 1. Skinfold measurement (in colour) and time response curve of tendency (in black).
The equations of the average (y) of each skinfold as a function of time (t) obtained from a non-linear fitting were:
Abdominal: $y=11.793+0.488/0.240+t^{0.695}$, $R^2=0.999$; Front Thigh: $y=10.102+0.229/0.116+t^{0.898}$, $R^2=0.998$;
Subscapular: $y=10.288+0.283/0.166+t^{0.678}$, $R^2=0.999$; Iliac Crest: $y=9.730+0.321/0.149+t^{0.757}$, $R^2=0.999$;
Supraspinale: $y=9.110+0.457/0.235+t^{0.598}$, $R^2=0.998$; Triceps: $y=8.180+0.230/0.122+t^{0.784}$, $R^2=0.999$;
Medial Calf: $y=6.051+ 0.238/0.112+t^{0.719}$, $R^2=0.997$; Biceps: $y=4.303+0.107/0.109+t^{0.884}$, $R^2=0.999$.

Discussion

According to our knowledge, the physical behaviour of eight skinfolds time response to the skinfold calliper pressure was firstly described and analysed in the present study. As expected, significant differences were found among skinfold sites within S_H, S_L. T_H and T_L, confirming that each skinfold compressibility is different from the other, even within a homogeneous study group.

Comparison between skinfold sites and skin thickness demonstrated that abdominal represent the thickest and the biceps the thinnest skinfold, in agreement with previous results (1, 15). All the players belong to elite teams and they were continuously under exercise and medical control, leading to an ideal fitness. Therefore even among these different sports (handball, roller hockey, and basketball), no significant differences were observed when comparisons between skinfold thicknesses and teams were assessed.

Figure 1 displays how every skinfold is related to time response. At the beginning it is noticeable that all the lines drop in a short interval of time, after which they decrease slowly until the end of the two seconds´ evaluation. Hence, after the initial decrease, all the measurements of each skinfold are similar to each other. Moreover, our data shows that the mean value for T_L was 1.46 ± 0.34 s, with the highest value at 1.63 ± 0.27 s for the iliac crest and the lower at 1.08 ± 0.38 s for the biceps skinfold. These results allow us to confirm that the Lohman TG (1981) (4) and Kramer HJ & Ulmer HV (1981) (8) protocoled times were sufficient to complete this sample assessment.

We also found out that the estimation of the skinfold thickness S_S, could be used as a fair value instead of the minimum value S_L, leading to a saving of time during evaluations. Even if we cannot assume that these results are applicable to other samples, we can presume that in our pool of subjects 0.33 s are sufficient for every skinfold measurement. Nevertheless, it would be relevant in a future study, to use the value S_S in a different sample, to verify if this value could effectively confirm the present findings.

With the Lipotool calliper it has been possible for the first time to collect 120 measurements of the skinfold thickness during the whole length of the evaluation (2 s) and to document the time response to the skinfold pressure of this physical system. In particular, given the very good fits that we obtained, it allows us to postulate that the skinfold thickness *y* changes with time *t* according to the equation: $y = y0 + a/(b + t^n)$.

In conclusion, this study explored the novel possibility of evaluating the skinfold time response. Although skinfolds showed a different compressibility they followed a similar compressibility path. After applying a skinfold calliper, skinfold thickness first decreases quickly and then it decreases slightly until the end of the evaluation. Present data shows that 0.33 seconds was sufficient for every skinfold, supporting a reduction in the two seconds protocolled time and consequently saving time during evaluations.

Funding

The authors declare that they did not receive any funding for this study.

Authorship

Alessandro Bini, Teresa F. Amaral, and Vitor Hugo Teixeira designed the study; Pedro Carvalho, Alessandro Bini, and Vitor Hugo Teixeira collected data; Alessandro Bini, Teresa F. Amaral, Bruno MPM Oliveira and Vitor Hugo Teixeira conducted data analysis; Alessandro Bini, Pedro Carvalho, Teresa F. Amaral, Bruno MPM Oliveira and Vitor Hugo Teixeira drafted the manuscript and all the authors contributed for the final version.

Partial study data was presented in the 10th International Symposium on Body Composition, held in Cascais, Portugal 2014 and its abstract was published at European Journal of Clinical Nutrition 2015; 69: 1; S19.

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Correspondence:
Teresa F. Amaral
Faculdade de Ciências da Nutrição e Alimentação,
Universidade do Porto, Porto, Portugal.
Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
Tel. +351 225 074 320
E-mail: amaral.tf@gmail.com