Nutrición Hospitalaria
ISSN: 0212-1611
nutricion@grupoaran.com
Sociedad Española de Nutrición Parenteral y Enteral
España

Sousa, Ana S.; Fonseca, Isabel; Pichel, Fernando; Amara, Teresa F.
Triceps skinfold compressibility in hospitalized patients
Nutrición Hospitalaria, vol. 34, núm. 3, 2017, pp. 619-625
Sociedad Española de Nutrición Parenteral y Enteral
Madrid, España

Nutr Hosp. 2017; 34(3):619-625 ISSN 0212-1611 - CODEN NUHOEQ S.V.R. 318

Nutrición Hospitalaria

Trabajo Original

Valoración nutricional

Triceps skinfold compressibility in hospitalized patients

Compresibilidad del pliegue cutáneo del tríceps entre los pacientes hospitalizados

Ana S. Sousa[1], Isabel Fonseca[2], Fernando Pichel[2] and Teresa F. Amaral[1,3]

[1]Faculdade de Ciências da Nutrição e Alimentação. Universidade do Porto. Porto, Portugal. [2]Serviço de Nutrição e Alimentação. Centro Hospitalar do Porto. Porto, Portugal. [3]UISPA-INEGI. Faculdade de Engenharia. Universidade do Porto. Porto, Portugal

Abstract

Objective: To explore triceps skinfold (TSF) compressibility and its associated factors among hospitalized patients.

Methods: A cross-sectional study was conducted among hospitalized adult patients. Evolution of tissue compressibility during two seconds was registered and 120 TSF values were obtained using a digital calliper. Compressibility was determined according to the difference between the initial value and the final value (TSF difference) and according to time (τ). Multivariable linear regression models were performed in order to identify factors associated with TSF compressibility.

Results: One hundred and six patients (30.2% aged ≥ 65 years) composed the study sample. Compressibility based on TSF difference was independently associated with TSF thickness (regression coefficient, 95% confidence interval [CI] = 0.38, 0.01-0.05, p = 0.002) and nutritional risk (regression coefficient, 95% CI = 0.23, 0.12-1.23, p = 0.018), but time of compressibility (τ) was not significantly associated with any of the studied variables.

Conclusions: Among a sample of hospitalized patients, undernutrition risk and higher TSF thickness were factors independently associated with higher compressibility assessed by the difference between the initial and final TSF value. Time of compressibility (τ) was not affected by any of the studied factors.

Key words:

Anthropometry. Body composition. Nutritional assessment. Skinfold thickness.

Resumen

Objetivo: explorar la compresibilidad del pliegue cutáneo del tríceps (PCT) y sus factores asociados entre los pacientes hospitalizados.

Métodos: se realizó un estudio transversal en pacientes adultos hospitalizados. Se registró la evolución de la compresibilidad del tejido durante dos segundos y se obtuvieron 120 valores del PCT utilizando un calibrador digital. La compresibilidad se determinó según la diferencia entre el valor inicial y el valor final (diferencia PCT) y según el tiempo (τ). Se realizaron modelos de regresión lineal múltiple con el fin de identificar los factores asociados con la compresibilidad del PCT.

Resultados: ciento seis pacientes (30,2% ≥ 65 años) compusieron la muestra del estudio. La compresibilidad basada en la diferencia de PCT se asoció independientemente con el espesor del PCT (coeficiente de regresión, intervalo de confianza 95% [IC] = 0,38, 0,01-0,05, p = 0,002) y el riesgo nutricional (coeficiente de regresión, IC del 95% = 0,23, 0,12-1,23, p = 0,018), pero el tiempo de compresibilidad (τ) no se asoció significativamente con ninguna de las variables estudiadas.

Conclusiones: entre una muestra de pacientes hospitalizados, el riesgo de desnutrición y el mayor espesor del PCT fueron factores asociados independientemente con una mayor compresibilidad evaluada por la diferencia entre el valor inicial y final del PCT. El tiempo de compresibilidad (τ) no se vio afectado por ninguno de los factores estudiados.

Palabras clave:

Antropometría. Composición corporal. Evaluación nutricional. Espesor del pliegue cutáneo.

Received: 23/08/2016
Accepted: 14/02/2017

Sousa AS, Fonseca I, Pichel F, Amaral TF. Triceps skinfold compressibility in hospitalized patients. Nutr Hosp 2017;34:619-625

DOI: http://dx.doi.org/10.20960/nh.479

Correspondence:

Ana S. Sousa. Faculdade de Ciências da Nutrição e Alimentação. Universidade do Porto. Rua Dr. Roberto Frias. 4200-465 Porto, Portugal
e-mail: sofia.limas.sousa@gmail.com

INTRODUCTION

Skinfold thickness is often used for body composition assessment and widely used in the clinical practice due to its accessibility, non-invasive features and the ability to measure subcutaneous adiposity (1,2). In skinfold thickness measurement with a skinfold calliper, constant pressure is applied for a defined period of time (3,4). The tissue's dynamic response to this pressure is defined as compressibility (1,5). This characteristic has been studied by comparing skinfold calliper measurements and subcutaneous fat thickness assessed by coarse methods such as imaging methods, cadaver studies and empiric comparisons (1,5).

There are underlying suppositions on the estimation from skinfold measurement: skin thickness is negligible, adipose tissue has constant characteristics, and also that proportion of subcutaneous to visceral fat is equivalent in all subjects (1). Notwithstanding this, it has been previously shown that compressibility varies according to the sites of measurement and between individuals, influencing the relation between the measurement and the actual adipose tissue thickness, introducing error in the estimation of body fatness (1,5).

Gender (5), age (6), hydration status (6), skin thickness (7), subcutaneous tissue pressure (7) and site of measurement (8) have been previously described as factors associated with compressibility. Nevertheless, over the past few years, knowledge in regards to compressibility has not increased significantly.

An integrated system, Lipotool®, was recently developed. This equipment consists of a digital skinfold calliper and a software application. This system registers 60 measurements per second (9). Thus, this novel methodology firstly permits the study of dynamic tissue's response evolution during the measurement (9).

From all skinfold thickness sites, triceps skinfold (TSF) is the most widely used in clinical practice, as, along with mid-arm circumference, it integrates mid-arm muscle circumference formula, a simple method that allows for the estimation of muscle mass (10).

Regarding the wide use of TSF, the minimization of error is of utmost importance in order to provide an adequate use and interpretation for clinical practice. Nonetheless, as far as we are concerned, skinfolds compressibility has not been explored yet in a clinical setting. Therefore, the present study aims to explore, through an innovative technique, TSF compressibility and its associated factors among a sample of hospitalized patients.

MATERIALS AND METHODS

STUDY SAMPLE AND DESIGN

A cross-sectional study was conducted in a general university hospital among a convenience sample of 106 participants, during a six months period. Patients were eligible to participate in the study if they were aged 18 years and over, Caucasian, conscious, cooperative and able to provide written informed consent.

Critically ill patients, i.e., with a life-threatening medical or surgical condition requiring Intensive Care Unit level care, presenting severe organ system dysfunction and requiring active therapeutic support were excluded (11). Pregnancy and patient ward isolation were also defined as exclusion criteria.

ETHICS

This research was carried out according to the recommendations established by the Declaration of Helsinki and approved by institutional ethics and review boards. All study participants provided a written informed consent.

DATA COLLECTION

Demographical data were obtained by a trained registered nutritionist through a structured questionnaire within 72 hours of admission to hospital.

Education was evaluated by the number of completed school years and the following categories were created: 0-4, 5-12 and over 12 years. Marital status was categorized as single, married or in a civil partnership, divorced and widowed. Independence in activities of daily living was assessed with the Katz index (12).

Patients' nutritional status was evaluated with Nutritional Risk Screening (NRS) 2002 (13). Standing height (cm) was measured with a metal tape (Rosscraft, Innovations Incorporated, Surrey, Canada) with a 0.1 cm resolution and with a headboard. Body weight (kg) was assessed with a calibrated portable beam scale with 0.5 kg resolution.

Triceps skinfold thickness (mm) was obtained with the Lipotool® digital calliper after performing the measurement during two seconds, as established by the International Society for the Advancement of Kinanthropometry (ISAK) protocol (3).

All measurements were performed by the same trained registered nutritionist. Intra-observer error ranged from 0.2% to 1.8%. These values are considered as acceptable for a trained anthropometrist (14,15).

Body mass index (BMI) was determined through the standard formula (weight [kg]/height^2 [m]) (16), and BMI categories were created according to the World Health Organization cutoffs (17).

STATISTICS

Results were described as mean and standard deviation (SD) or as median and interquartile range (IQR) according to normality of distribution, assessed with the Kolmogorov-Smirnov test.

Data on TSF measurements were provided by LipoTool® software and the evolution of tissue compressibility during two seconds was registered, as this method registers 60 values per second. Thus, at the end of the measurement, 120 values were obtained.

Compressibility was determined according to a method based on the difference computed between the initial value and the final value, from the 120 TSF measurements acquired by the digital

caliper (18). Thus, high difference between the initial and final TSF value corresponds to high compressibility (18).

Another method was used to define compressibility. This method was based on τ, *tau*, a measurement of time expressed in seconds, that reflects adipose tissue dynamic response to compression, being an individual characteristic (19). Thus, lower τ values mean that the skinfold compresses faster, and, therefore, presents higher compressibility. τ value was obtained after computing the inverse of the exponent of a regression equation displayed for the 120 measurement sets of each patient (19,20).

Data set was divided into tertiles of TSF, tertiles of τ and tertiles of difference between the TSF initial and final values (TSF difference). In order to select variables associated to compressibility, patients' baseline characteristics were compared across τ tertiles and TSF difference tertiles. Patients' baseline characteristics were also compared across TSF tertiles.

All the comparisons were computed by the one-way ANOVA test if distribution was normal, or by the Kruskal-Wallis test in case of non-normal distribution. Categorical variables were reported as frequencies. Differences between proportions were assessed with the Pearson's χ^2 test or Fisher's exact test.

Furthermore, multivariable linear regression models were built in order to identify the independent variables associated with compressibility, assessed by τ or as TSF difference. The following variables were included in the models: TSF value (continuous), age (continuous), nutritional status (categorical; normal nutritional status used as reference) and gender (categorical; women used as reference), as these variables were considered to be potential confounders or covariates.

Table I. Patients' characteristics for the entire sample and according to triceps skinfold tertiles (mm)

Characteristics	Entire sample (n = 106)	1st ≤ 11.5 (n = 35)	2nd 11.8-21.2 (n = 34)	3rd ≥ 21.3 (n = 37)	p
Age (years), mean (SD)	53.1 (15.8)	55.5 (15.7)	53.5 (13.8)	47.0 (16.9)	0.066*
Age categories (years), n (%)					
< 65	74 (69.8)	23 (65.7)	23 (67.6)	28 (75.7)	0.258†
≥ 65	32 (30.2)	12 (34.3)	11 (32.4)	9 (24.3)	
Gender, n (%)					
Women	49 (46.2)	1 (2.9)	19 (55.9)	29 (78.4)	< 0.001†
Men	57 (53.8)	34 (97.1)	15 (44.1)	8 (21.6)	
Education (years), n (%)					
0-4	41 (38.7)	9 (25.7)	17 (50.0)	15 (40.5)	0.188†
5-12	54 (50.9)	20 (57.1)	14 (41.2)	20 (54.1)	
> 12	11 (10.4)	6 (17.1)	3 (8.8)	2 (5.4)	
Marital status, n (%)					
Single	15 (14.2)	6 (17.1)	3 (8.8)	6 (16.2)	0.310†
Married	72 (67.9)	23 (65.7)	25 (73.5)	24 (64.9)	
Widowed	12(11.3)	5 (14.3)	5 (14.7)	2 (5.4)	
Divorced	7 (6.6)	1 (2.9)	1 (2.9)	5 (13.5)	
Katz index, n (%)					
Independent	103 (97.2)	33 (94.3)	34 (100)	36 (97.3)	0.359†
Moderate and severe dependence	3 (2.8)	2 (5.7)	0 (0)	1 (2.7)	
Nutritional status (NRS-2002), n (%)					
Normal	94 (88.7)	28 (80.0)	30 (88.2)	36 (97.3)	0.068†
Risk	12 (11.3)	7 (20.0)	4 (11.8)	1 (2.7)	
BMI (kg/m^2), mean (SD)	26.2 (6.0)	22.6 (5.4)	26.1 (3.5)	29.7 (6.3)	< 0.001*
BMI categories (kg/m^2), n (%)					
Underweight or normal weight	46 (43.4)	25 (71.4)	12 (35.3)	9 (24.3)	< 0.001‡
Overweight or obesity	60 (56.6)	10 (28.6)	22 (64.7)	28 (75.7)	
TSF (mm), mean (SD)	19.1 (12.1)	8.6 (2.0)	16.9 (2.9)	31.7 (11.1)	< 0.001*
τ (s), median (IQR)	0.16 (0.16)	0.15 (0.13)	0.23 (0.14)	0.16 (0.11)	0.015‡
TSF difference (mm)¶, median (IQR)	0.87 (1.02)	0.60 (0.98)	0.72 (0.94)	1.2 (1.3)	0.007‡

*TSF: Triceps skinfold; SD: Standard deviation; IQR: Interquartile range; BMI: Body mass index; NRS-2002: Nutritional Risk Screening-2002. *One-way ANOVA. †Pearson Chi-square test or Fisher's exact test. ‡Kruskal-Wallis test. ¶Triceps skinfold difference: Initial value - Final value, across a set of 120 measurements.*

Statistical significance was set at $p < 0.05$. All analyses were conducted with MATLAB (MathWorks, Inc., Natick, MA) and the Software Package for Social Sciences (SPSS) for Windows (version 20.0; SPSS, Inc., Chicago, IL).

RESULTS

The characteristics of the 106 patients enrolled in the present study are displayed in table I, for the entire sample and stratified by TSF tertiles. Mean age (SD) was 53.1 (15.8), and 30.2% patients were aged ≥ 65 years. There were 56.6% overweight or obese patients and 11.3% patients were at undernutrition risk (Table I). The highest and the lowest time of compressibility (τ) were observed for patients in the 2nd TSF tertile and in the 1st TSF tertile, respectively. The highest TSF difference was observed for patients in the 3rd TSF tertile (Table I).

As shown in table II, BMI, TSF thickness and τ value increased from the 1st to the 3rd TSF difference tertiles. Otherwise, patients' characteristics did not differ across τ tertiles, with the exception of the TSF difference, which was higher in the 2nd and 3rd τ tertiles than in the 1st τ tertile (Table III).

Results from the multivariable linear regression models are presented in table IV. As shown in model 1, compressibility based on the TSF difference was associated with TSF magnitude (regression coefficient = 0.38 [0.01-0.05], p = 0.002) and nutritional status (regression coefficient = 0.23 (0.12-1.23), p = 0.018), after adjusting for age and gender. Thus, presenting a higher TSF

Table II. Patients' characteristics according to triceps skinfold difference *tertiles of sample distribution (mm)

Characteristics	1st ≤ 0.53 (n = 34)	2nd 0.54-1.27 (n = 36)	3rd ≥ 1.28 (n = 36)	p
Age (years), mean (SD)	56.1 (14.3)	52.9 (17.2)	50.4 (15.7)	0.418†
Age categories (years), n (%)				
< 65	23 (67.6)	24 (66.7)	27 (75.0)	0.703‡
≥ 65	11 (32.4)	12 (33.3)	9 (25.0)	
Gender, n (%)				
Women	10 (29.4)	19 (52.8)	20 (55.6)	0.056‡
Men	24 (70.6)	17 (47.2)	16 (44.4)	
Education (years), n (%)				
0-4	10 (29.4)	14 (38.9)	17 (47.2)	0.434‡
5-12	19 (55.9)	20 (55.6)	15 (41.7)	
> 12	5 (14.7)	2 (5.6)	4 (11.1)	
Marital status, n (%)				
Single	1 (2.9)	6 (16.7)	8 (22.2)	0.169‡
Married	24 (70.6)	23 (63.9)	25 (69.4)	
Widowed	6 (17.6)	5 (13.9)	1 (2.8)	
Divorced	3 (8.8)	2 (5.6)	2 (5.6)	
Katz index, n (%)				
Independent	33 (97.1)	35 (97.2)	35 (97.2)	0.999‡
Moderate and severe dependence	1 (2.9)	1 (2.8)	1 (2.8)	
Nutritional status (NRS-2002), n (%)				
Normal	31 (91.2)	33 (91.7)	30 (83.3)	0.459‡
Risk	3 (8.8)	3 (8.3)	6 (16.7)	
BMI (kg/m^2), mean (SD)	24.9 (4.1)	26.6 (7.0)	26.9 (6.3)	< 0.001†
BMI categories (kg/m^2), n (%)				
Underweight or normal weight	19 (55.9)	13 (36.1)	14 (38.9)	0.199‡
Overweight or obesity	15 (44.1)	23 (63.9)	22 (61.1)	
TSF (mm), mean (SD)	14.2 (7.1)	20.6 (12.4)	22.8 (14.0)	< 0.001†
τ (s), median (IQR)	0.13 (0.08)	0.20 (0.24)	0.21 (0.20)	0.002¶
TSF difference (mm), median (IQR)	0.30 (0.18)	0.83 (0.44)	1.92 (1.6)	< 0.001¶

*TSF: Triceps skinfold; SD: Standard deviaton; IQR: Interquartile range; BMI: Body mass index; NRS-2002: Nutritional Risk Screening-2002. *Triceps skinfold difference: Initial value - Final value, across a set of 120 measurements. †One-way ANOVA. ‡Pearson Chi-square test or Fisher's exact test. ¶Kruskall-Walis test.*

Table III. Patients' characteristics according to time of compressibility (τ) tertiles of sample distribution (second)

Characteristics	1st ≤ 0.13 (n = 35)	2nd 0.14-0.23 (n = 35)	3rd ≥ 0.23 (n = 36)	p
Age (years), mean (SD)	54.4 (14.6)	54.0 (15.6)	50.9 (17.4)	0.591*
Age categories (years), n (%)				
< 65	23 (65.7)	24 (68.6)	27 (75.0)	0.682†
≥ 65	12 (34.3)	11 (31.4)	9 (25.0)	
Gender, n (%)				
Women	13 (37.1)	17 (48.6)	19 (52.8)	0.394†
Men	22 (62.9)	18 (51.4)	17 (47.2)	
Education (years), n (%)				
0-4	11 (31.4)	15 (42.9)	15 (41.7)	0.669†
5-12	19 (54.3)	16 (45.7)	19 (52.8)	
> 12	5 (14.3)	4 (11.4)	2 (5.6)	
Marital status, n (%)				
Single	6 (17.1)	4 (11.4)	5 (13.9)	0.472†
Married	23 (65.7)	22 (62.9)	27 (75.0)	
Widowed	5 (14.3)	6 (17.1)	1 (2.8)	
Divorced	1 (2.9)	3 (8.6)	3 (8.3)	
Katz index, n (%)				
Independent	34 (97.1)	34 (97.1)	35 (97.2)	0.984†
Moderate and severe dependence	1 (2.9)	1 (2.9)	1 (2.8)	
Nutritional status (NRS-2002), n (%)				
Normal	28 (80.0)	34 (97.1)	32 (88.9)	0.077†
Risk	7 (20.0)	1 (2.9)	4 (11.1)	
BMI (kg/m^2), mean (SD)	25.9 (6.0)	26.3 (4.0)	26.3 (7.5)	0.952a
BMI categories (kg/m^2), n (%)				
Underweight or normal weight	16 (45.7)	15 (42.9)	15 (41.7)	0.940†
Overweight or obesity	19 (54.3)	20 (57.1)	21 (58.3)	
TSF (mm), mean (SD)	18.9 (13.6)	18.0 (9.2)	21.1 (13.0)	0.542*
τ (s), median (IQR)	0.09 (0.04)	0.16 (0.05)	0.33 (0.14)	<0.001‡
TSF difference (mm)¶, median (IQR)	0.61 (1.0)	0.75 (1.1)	1.19 (1.2)	0.026‡

*TSF: Triceps skinfold; SD: Standard deviation; IQR: Interquartile range; BMI: Body mass index; NRS-2002: Nutritional Risk Screening-2002. *One-way ANOVA. †Pearson Chi-square test or Fisher's exact test. ‡Kruskall-Walis test. ¶Triceps skinfold difference: Initial value - Final value, across a set of 120 measurements.*

Table IV. Multivariable linear regression models for prediction of triceps skinfold (TSF) compressibility

Models	Regression coefficient (95% CI)	p
*Model 1**		
TSF	0.38 (0.01-0.05)	0.002
Nutritional Status (NRS-2002; reference: normal)	0.23 (0.12-1.23)	0.018
Model 2†		
TSF	0.03 (-0.01-0.01)	0.824
Gender (reference: women)	-0.06 (-0.37-0.21)	0.599
Age	-0.04 (-0.01-0.01)	0.695
Nutritional Status (NRS-2002; reference: normal)	-0.16 (-0.71-0.08)	0.112

*CI: Confidence interval; TSF: Triceps skinfold thickness (mm); NRS-2002: Nutrition Risk Screening 2002. Variables included: Age (years; continuous), nutrition status according to NRS-2002 (normal used as reference), gender (women used as reference) and TSF value (mm; continuous). *Dependent variable: TSF compressibility computed as TSF initial value - TSF final value, across a set 120 measurements. †Dependent variable: TSF compressibility defined as time (τ).*

value, i.e., a thicker TSF, and being at risk of undernutrition are factors apparently related to an increase in the difference between TSF initial and final values, meaning that the skinfold was more compressed and, therefore, presents higher compressibility.

In contrast, as displayed in model 2, time of compressibility (τ) was not significantly associated with any of the included variables.

DISCUSSION

The present study results show that quantification of compressibility and its associated factors is dependent on the method used to analyze this adipose tissue feature.

When compressibility was defined as the difference between initial and final TSF values obtained by the digital calliper, only BMI and time of compressibility differed between the tertiles of this variable. Nevertheless, after adjustment for potential confounders, such as gender and age, results from the multivariable linear regression model showed that undernutrition risk and higher TSF thickness were factors associated with higher compressibility.

In contrast, when compressibility was defined as time, i.e., the time taken by the adipose tissue to respond to the pressure exerted by the calliper, differences were observed between TSF thickness tertiles, which could indicate that the skinfold magnitude was associated with compressibility. In addition, it is worth noting that patients in the 2nd TSF tertile presented higher τ than patients in the 3rd TSF tertile. However, after performing a multivariable linear regression model, no independent association was found for any of the included variables, showing that, apparently, time of compressibility was not influenced by any of the studied factors.

Explanations for these associations can be formulated, although only in a theoretical perspective as, with the present data, it is not possible to confirm them. Therefore, a thicker TSF presents a larger area of adipose tissue, and this increases the potential of being compressed. Otherwise, an individual classified as being at risk of undernutrition is potentially likely to present more laxity in skin and adipose tissue, which can influence skinfolds compressibility towards higher values.

Transposing the present results for clinical practice, TSF thickness and undernutrition risk are characteristics susceptible of affecting the association between the actual value and the calliper reading, potentially introducing error by an increase in adipose tissue compressibility. Thus, by causing more compression in the skinfold, this error can lead to an underestimation of TSF thickness, i.e., to a lower value reading and, therefore, to a misinterpretation of the measurement.

Moreover, once τ indicates skinfolds compressibility, as time of response to a constant pressure, a higher time of response is expected to be associated to lower compressibility, as the tissues compress slowly. In contrast, a higher difference between the initial and final TSF values means that the tissue went through more compression, and is, therefore, associated with higher compressibility. Notwithstanding this, our results show that τ and TSF difference vary in the same direction, as τ values are higher in TSF difference 2nd and 3rd tertiles and TSF difference values are higher in the 2nd and 3rd tertiles of τ.

Considering the aforementioned methods for evaluating compressibility and the results actually obtained, there is an apparent counterintuitive observation. Nevertheless, it is worth noting that these two methods are related with two different aspects of compressibility, time of response and the skinfold dimension. Thus, a skinfold that takes more time to be compressed is, therefore, less compressible according to this definition. It may also simultaneously present a higher difference between the value at the beginning of the measurement and the value attained when the process is complete.

Although this novel methodology has been previously used in other settings (21), as far as we are concerned, this is the first report on the exploration of TSF compressibility as a quantifiable variable and its associated factors in a clinical setting. Consequently, there are no previous results to which our findings can be compared. Even though one approach detected consistent associations and the other one did not, they cannot be compared in terms of accuracy as these two methods assess different features.

The absence of association with other factors found for compressibility defined as time is not sufficient to conclude that there are no differences or even that compressibility did not affect measurements performed in the present sample. We can further hypothesize that, in the two seconds the measurement is performed, τ may be related to an earlier moment of the process than the TSF difference. Thus, it is not known if in a larger period of measurement these results could be different.

Present results concern TSF only. As it has been already documented through results from studies (5,8,22) using different methodologies, adipose tissue compressibility varies according to the site of measurement. Thus, it is not known whether these results would be different if other skinfolds were evaluated.

In order to comply with the inclusion criteria, no critically ill or functionally impaired patients were enrolled. Moreover, the majority of the participants were independent in activities of daily living and there was a small proportion of patients at nutritional risk. Thus, the present sample can be considered as homogenous and this feature may have influenced the results obtained. Therefore, it is not known if present results would be different in a wider sample of hospitalized patients or, even, among critically ill or bedridden patients.

In the future, it would be important to further explore compressibility through the present methodologies in other settings, such as in community-dwelling adults and older adults and different ethnic groups. The application of the present methods in different settings could allow for both testing their reproducibility and improving the techniques used.

In conclusion, among a sample of hospitalized patients, undernutrition risk and higher TSF thickness were factors independently associated with higher compressibility assessed by the difference between the initial and final TSF values. Time of compressibility (τ) was not affected by any of the studied factors. Although the present study is merely an exploratory attempt to describe compressibility and its effects, our results emphasize the need for

further research in order to determine the most accurate method to quantify compressibility, to infer on the associated factors and to control its effect.

ACKNOWLEDGEMENTS

The authors thank the Centro Hospitalar do Porto and all ward directors for facilitating the data collection. The authors also thank engineer Tiago Faustino Andrade from UISPA-INEGI, FEUP, for the assistance given in the statistical analysis.

REFERENCES

1. Lohman TG. Skinfolds and body density and their relation to body fatness: A review. Hum Biol May 1981;53(2):181-225.
2. Clarys JP, Provyn S, Marfell-Jones MJ. Cadaver studies and their impact on the understanding of human adiposity. Ergonomics 2005;48(11-14):1445-61.
3. Marfell-Jones M OT, Stewart A, Carter L. International standards for anthropometric assessement. Potchefstroom, South Africa: ISAK; 2006.
4. Lohman TG, Roche AF, Martorell R. Human body composition. 2ª ed. Champaign, IL: Human Kinetics; 2005.
5. Martin AD, Drinkwater DT, Clarys JP, Daniel M, Ross WD. Effects of skin thickness and skinfold compressibility on skinfold thickness measurement. Am J Hum Biol 1992;4(4):453-60.
6. Brozek J, Kinzey W. Age changes in skinfold compressibility. J Gerontol 1960;15:45-51.
7. Hattori K, Okamoto W. Skinfold compressibility in Japanese university students. Okajimas Folia Anat Jpn 1993;70(2-3):69-77.
8. Himes JH, Roche AF, Siervogel RM. Compressibility of skinfolds and the measurement of subcutaneous fatness. Am J Clin Nutr 1979;32(8):1734-40.
9. Amaral TF, Restivo MT, Guerra RS, Marques E, Chousal MF, Mota J. Accuracy of a digital skinfold system for measuring skinfold thickness and estimating body fat. Br J Nutr 2011;105(3):478-84.
10. Jelliffe DB. The assessment of the nutritional status of the community (with special reference to field surveys in developing regions of the world). Monogr Ser World Health Organ 1966;53:3-271.
11. ESPEN. Guidelines for the use of parenteral and enteral nutrition in adult and pediatric patients. J Parenter Enteral Nutr 2002;26(1 Suppl):1SA-138SA.
12. Katz S. Assessing self-maintenance: Activities of daily living, mobility, and instrumental activities of daily living. J Am Geriatr Soc 1983;31(12): 721-7.
13. Kondrup J, Rasmussen HH, Hamberg O, Stanga Z. Nutritional risk screening (NRS 2002): A new method based on an analysis of controlled clinical trials. Clin Nutr 2003;22(3):321-36.
14. Pederson D, Gore C. Anthropometry Measurement Error. Sydney, Australia: University of New South Wales Press; 1996.
15. Zerfas AJ. Checking Continuous Measures: Manual for Anthropometry. Los Angeles, CA: Division of Epidemiology, School of Public Health, University of California; 1985.
16. Quetelet A. Anthropometrie ou measure des différentes facultés de l'homme. Bruxelles, Belgique: C. Muquardt; 1869.
17. WHO. Physical status: The use and interpretation of anthropometry. Report of a WHO Expert Committee. World Health Organ Tech Rep Ser 1995;854:1-452.
18. Bini A, Amaral TF, Oliveira BM, Carvalho P, Teixeira VH. Skinfolds compressibility and calliper's time response in male elite athletes. Eur J Clin Nutr 2015;69:S10-S19. DOI: 10.1038/ejcn.2015.189.
19. Restivo MT, Amaral TF, Chouzal MF, Mota J. A digital calliper for training and study purposes. Asia Pacific J Clin Nutr 2012;21(2):182-90.
20. Katsuhiko O. Modern Control Engineering. 5th ed. Prentice Hall PTR; 2010.
21. Quintas MR, Andrade TF, Restivo MT, Chouzal MF, Amaral TF. LipoWise: A new generation of skinfold calipers. Sensors & Transducers. 2015;185(2): 162-169.
22. Martin AD, Ross WD, Drinkwater DT, Clarys JP. Prediction of body fat by skinfold caliper: Assumptions and cadaver evidence. Int J Obes 1985;9(Suppl 1):31-9.