Reliability of portable electrical impedance myograph SKULPT® for morphological measures of *vastus lateralis*

Confiabilidade da impedância elétrica do miógrafo portátil SKULPT® a partir de medidas morfológicas do *vastus lateralis*

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ABSTRACT

New devices with clinical applicability are needed to provide fast and precise diagnostics. In this way, the aim of this study was to verify the reliability of the portable electrical impedance myograph (PEIM) Skulpt® for morphological measures of the *vastus lateralis* (VL). MATERIALS AND METHODS: A cross-sectional evaluation was designed on an independent limb to verify reliability between the PEIM Skulpt® and ultrasound (US) for VL muscle morphological measures. Twelve health men (age=32.17±8.90 years) participated in the study, being evaluated muscle quality (MQ) and fat mass (%FAT) with the PEIM on the frontal thigh position, and echo intensity (EI) and muscle and fat thickness (MT and FT) with the US. RESULTS: Equipment reliability (US vs. PEIM) indicated a moderate correlation [r=-0.53; p=0.770] between MQ and EI. Conversely, intra-rater reliability indicated moderate consistency for EI (p=0.021) and excellent for MT (p=0.008) and FT (p<0.001). In addition, excellent consistency was indicated for MQ (p<0.001) and %FAT (p<0.001). Proposed equations were applied in the contralateral lower limb (n=12). Subsequently, a Bland-Altman plot presented lower bias and higher agreement limits for both adjustment equations for PEIM between the MT and FT with MQ and %FAT, respectively. CONCLUSION: In summary, our results indicate moderate intra-rater reliability consistency for EI, excellent for MT and FT, and excellent for MQ, and %FAT. In addition, our proposed adjustment equation presents clinical application to control %FAT and MQ with different possibilities of application in adults, as it can be applied in aesthetics, health control, and even physiotherapeutic treatments.

Keywords: Muscle quality, portable electrical impedance, vastus lateralis.

RESUMO

Novos dispositivos com aplicabilidade clínica são necessários para fornecer diagnósticos rápidos e precisos. Dessa forma, o objetivo deste estudo foi verificar a confiabilidade do miógrafo portátil de impedância elétrica (PEIM) Skulpt® para medidas morfológicas do músculo vasto lateral (VL). MATERIAIS E MÉTODOS: Foi elaborada uma avaliação transversal em membros inferiores independentes para verificar a confiabilidade entre o PEIM Skulpt® e o ultrassom (US) para medidas morfológicas do músculo VL. Doze homens saudáveis (idade=32,17±8,90 anos) participaram do estudo, sendo avaliados a qualidade muscular (QM) e a massa gorda (%GORDURA) com o PEIM na posição frontal da coxa, e eco intensidade (EI) e espessura muscular e do tecido adiposo subcutaneo (EM e ETAS) com o US. RESULTADOS: A confiabilidade do equipamento (US vs. PEIM) indicou correlação moderada [r=-0,53; p=0,770] entre QM e EI. Por outro lado, a confiabilidade intra-examinador indicou consistência moderada para EI (p=0,021) e excelente para EM (p=0,008) e ETAS (p<0,001). Além disso, excelente consistência foi indicada para QQ (p <0,001) e %GORDURA (p <0,001). As equações propostas foram aplicadas no membro inferior contralateral (n=12). Posteriormente, um gráfico de Bland-

Altman apresentou menor viés e maiores limites de concordância para ambas as equações de ajuste para PEIM entre EM e ETAS com QM e %GORDURA, respectivamente. CONCLUSÃO: Em resumo, nossos resultados indicam consistência moderada de confiabilidade intra-examinador para EI, excelente para EM e ETAS, bem como para QM e %GORDURA. Além disso, nossa proposta de equação de ajuste apresenta aplicação clínica para controle do %GORDURA e QM com diferentes possibilidades de aplicação em adultos, pois pode ser aplicada em estética, controle de saúde e até mesmo em tratamentos fisioterapêuticos.

Palavras-chave: Qualidade muscular, impedância elétrica portátil, vasto lateral.

1 INTRODUCTION

Skulpt® is a portable electrical impedance myograph (PEIM) device with twelve electrodes, which measures electrical current flow in different directions and to different depths. Impedance-based devices assess two components (i.e.; fat mass and fat free mass), however, the bioelectric impedance technique reports a constant measurement error and greater variability (BOSY-WESTPHAL et al. 2017; DUREN et al. 2008). An example, is that the fat mass percentage ranged from 0.6% to 78.5% when using bioelectrical impedance (VANSANT et al. 1994). Proper interpretation of bioelectric impedance results requires acknowledgement that the tool actually only measures the response to the passage of an electric current through the body (GONZALES et al. 2019); and the results of bioelectric impedance are dependent on the chosen device.

According to the manufacturer, this specific PEIM can separate out the muscle from fat in just a matter of seconds, and is also capable of measuring body fat percentage (%FAT) and muscle quality (MQ). Despite information that the device has a measurement accuracy of 1-2% for fat percentage compared to the gold standard (Dual Energy X-ray Absorptiometry - DEXA), further studies are needed to verify the reliability and validity for both fat percentage and muscle quality measures. A useful, non-invasive, and easy to handle technique that allows real-time visualization of the muscle and fat content for comparison with results of the PEIM, is muscle ultrasound - US (PILLEN; VAN ALFEN, 2011).

US is commonly used for muscle thickness (MT) measurement (BJORNSEN et al. 2016; DE BOER et al. 2008; LI et al. 2013; REEVES et al. 2009). However, the US has also been used to quantify echo intensity (EI), which reflects muscle quality (LANFERDINI et al. 2019; PALMER et al. 2015; RUAS et al. 2017; SANTOS; ARMADA-DA-SILVA, 2017). The infiltration of fat and fibrous tissues increases the number of echoes or reflections from the ultrasound within the muscle, which is directly correlated with increases in EI and, consequently, worsening muscle quality (WATANABE et al. 2018). Another possibility for US is the measure of fat thickness (FT), which presents high reliability (ISHIDA et al. 1992; WAGNER et al. 2020).

Based on the high quality of muscle measures provided by US, we used the measures of FT and EI to qualify the results of %FAT and MQ of the PEIM Skulpt®. The aim of this study was to verify the reliability of the PEIM Skulpt® for morphological measures of the vastus lateralis (%FAT and MQ).

2 MATERIALS AND METHODS

2.1 STUDY DESIGN

A cross-sectional study in an independent limb was designed to verify reliability between the PEIM Skulpt® and US for lower limb skeletal muscle morphological measures (muscle quality and fat mass). Participants came to the laboratory once and after a brief explanation about the experimental procedure, they signed a consent form. Anthropometric measures were taken, and each lower limb was measured with manual portable bioimpedance on the frontal thigh position (recommended in the PEIM manual), followed by the US measure. All measures were taken in a lying position.

2.2 PARTICIPANTS

Twelve men volunteered for this study, (age=32.17±8.90 years; height= 1.78±0.04 m; weight=75.82±12.61 kg). The volunteers had not experienced muscle damage in the previous 3 months, and were instructed not to perform physical activity in the 48 hours prior to data collection, and to maintain their usual diet. This study was conducted according to the declaration of Helsinki, and all procedures were approved by the local Institutional Research Ethics Committee (nº 32063720.9.0000.0121). All participants were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study.

2.3 ELECTRICAL IMPEDANCE MYOGRAPH PROCEDURE

The PEIM (Skulpt Scanner™, San Francisco, USA) device is registered in the United States under a published patent application (US 2016/0157749 A1). This document contains all information necessary to calculate the muscle quality and fat mass percentage (https://patents.google.com/patent/US20160157749A1/en). According to the manufacturer, the device emits an electrical current with different frequencies, directions, and depths. Thereafter, an application on a smartphone, connected to the device, provides information regarding the body fat percentage.

A smartphone interface is able to access a full body (12 muscle groups), a quick (3 muscle groups), or a single (individual muscle of the 12 available) analysis (Figure 1). To address reproducibility, three measurements were conducted on the anterior thigh measure with a 3 min interval between them. The mean value between the 3 measurements was adopted for the reliability statistics. Muscle quality score represents: 0-20: needs work; 20-40: fair; 40-60: good; 60-80: fit; 80-100: athletic. In addition, the fat mass percentage score represents: 26-100: needs work; 22-25: fair; 19-21: good; 13-18: fit; 4-12: athletic.

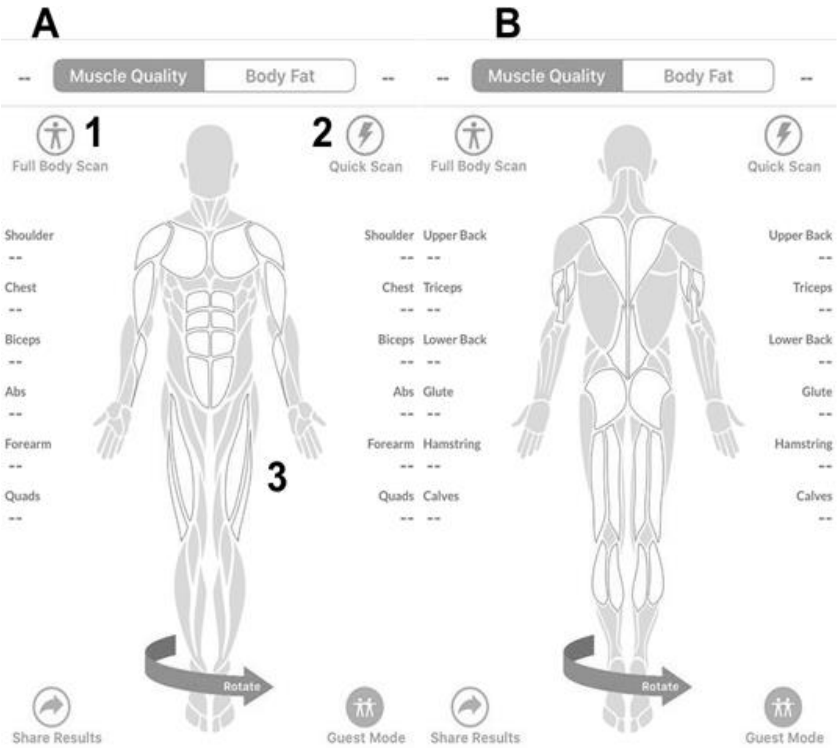

Figure 1. Smartphone interface available during PEIM analysis: A. anterior view and B. posterior view. Numbers indicate three options for muscle quality or body fat analysis: 1. Full body [white contrast area, 12 muscle groups on each side of body (left/right)], 2. Quick scan [arm posterior, abdominal, and thigh muscle], and 3. Specific site [thigh muscle].

2.4 MUSCLE MORPHOLOGIC BY ULTRASOUND

Data collection of US variable images was conducted using the ultrasound system in B-mode (LOGIQ S7 Expert, General Electric, Milwaukee, USA). A 50 mm wide linear probe (6 -15 MHz linear array) was used to extract the image of the vastus lateralis (VL) muscle with the probe placed longitudinal to the thigh, without pressure distortion. The measurements were recorded from the central point of a straight line, connecting the greater trochanter and the lateral epicondyle of the femur with the ventral iliotibial band. The equipment was configured as: image depth of 60 mm, 90 dB of general gain, and time gain control at the neutral position of hip and knee joints (SANTOS; ARMADA-DA-SILVA, 2017).

US analysis was conducted using ImageJ 1.42q software (National Institute of Health, Bethesda, USA) and included measurements of the FT, MT, and EI. FT was determined by the perpendicular distance between skin and superficial aponeurosis (Figure 2A). MT was defined as the perpendicular distance between the superficial and deep aponeurosis of the VL (Figure 2A). EI was determined in the regions of interest using the mean value of a standard gray-scale histogram function, with values ranging between 0 (black) and 255 (white). The regions of interest consisted of the largest rectangle positioned between the aponeurosis of the VL (Figure 2B) as proposed by Santos e Armada-da-Silva (2017).

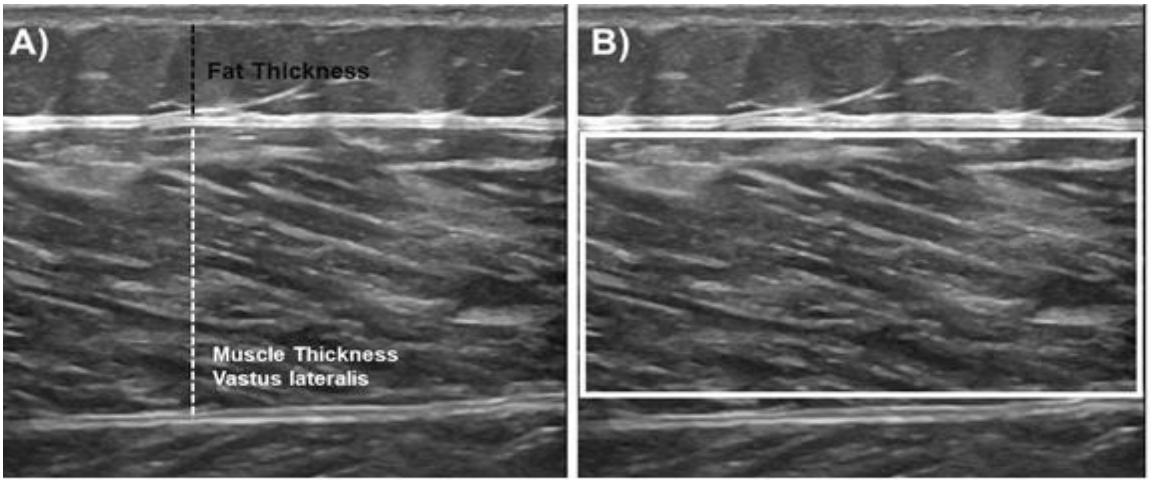

Figure 2. Ultrasonography of vastus lateralis muscle. Illustration measurement of ultrasound of the fat and muscle thickness (A) and region of interest of echo intensity analysis (B).

2.5 STATISTICAL ANALYSIS

Data normality and homogeneity were verified by the Shapiro-Wilk and Levene's tests, respectively. All skeletal muscle morphological and under skin fat measures were analyzed from the mean, standard deviation (SD), coefficient of variation (CV), standard error of the measurement (SEM), minimum detectable change (MDC), and intraclass correlation coefficient (ICC). The ICC was used to correlate the skeletal muscle morphological measures between the two devices (PEIM *vs.* US) and intra-rater reliability, analyzing the variation in data measured by 1 rater across 2 or more trials for MQ and %FAT, and EI, MT, and FT. The ICC was classified as excellent ($r > 0.90$); good (r = 0.75 - 0.90); moderate (r = 0.50 - 0.75); or poor (r < 0.50) described in Koo e Li (2016).

The paired-sample t-test was used to compare the between-instruments difference. Significance level was set at $p < 0.05$ for all analyses, with SPSS software (IBM SPSS, Armonk, New York, USA). The SEM was calculated for both devices according to the method described in Weir (2005) and the MDC was estimated based on a 95% confidence interval (95% CI), where MDC = 1.96 * SEM (SCHWENK et al. 2012). The Bland-Altman graph was used to illustrate the correlation between the measurements obtained by the two instruments, and aimed at identifying the bias [mean difference between US (validated standard) and PEIM Skulpt® (predictor)] and the limits of agreement (±1.96 standard deviations or the 95% limits of agreement). All Bland-Altman analysis was performed using the MedCalc statistical software package (MedCalc Software Ltd, Ostend Belgium).

3 RESULTS

3.1 INTRACLASS CORRELATION COEFFICIENT (ICC)

Equipment reliability (US *vs.* PEIM) indicated a moderate correlation [r=-0.53, p=0.770, 95% confidence interval (IC)=-3.81 − 0.54] for the muscle quality measure between the PEIM and US. Conversely, intra-rater reliability indicated moderate consistency for EI (p=0.021), excellent for MT (p=0.008), and excellent for FT (p<0.001) for the US device, as well as, excellent for muscle quality (p<0.001), and FAT% (p<0.001) for the PEIM device, as shown in Table 1.

Table 1. Intra-rater reliability (intraclass correlation coefficient - ICC), 95% confidence interval (95%IC), coefficient of variation (CV), standard error of the measurement (SEM), and minimum detectable change (MDC), for morphologic muscle and under skin fat measures in ultrasound (US) and portable electrical impedance myograph (PEIM) devices.

Morphologic Measures	**Device**	**M1**	**M2**	**r**	**Lower 95% IC**	**ICC** **Upper 95% IC**	**CV (%)**	**SEM**	**MDC**
EI (A. U.)	US	75.1±11.9	75.4±12.7	0.75	0.53	0.92	14.5	3.15	6.17
MT (cm)		2.2±0.4	2.2±0.4	0.99	0.98	0.99	18.3	0.11	0.21
FT (cm)		0.30±0.12	0.30±0.12	0.99	098	0.99	43.3	0.38	0.75
MQ (%)	PEIM	66.3±22.7	63.7±21.8	0.98	0.93	0.99	33.8	6.35	12.4
FAT (%)		16.7±6.2	17.6±7.5	0.97	0.92	0.99	39.9	1.97	3.86

Note: M1: first measure; M2: second measure; EI - echo intensity; MT - muscle thickness; FT - fat thickness; MQ - muscle quality (percentage); FAT - fat mass.

3.2 LINEAR REGRESSION EQUATION

The paired t-test did not show a difference between EI and MQ (75.28 ± 10.91 and 65.0 ± 22.01, respectively, p=0.210). Despite this, Pearson´s analysis presented a poor correlation between EI and MQ (r=-0.31, p=0.310). Conversely, a significant correlation was observed between MQ and MT (r=0.60, moderate, p=0.042). In addition, FT also presented a significant correlation with %FAT (r=0.62, moderate, p=0.030). The linear regression analysis is presented in table 2 for MT and FT measures (dependent variables) and MQ and %FAT (independent variables).

Table 2. Parameters of the simple linear regression for portable electrical impedance myograph measures (randomized lower limb, n=12).

	Coefficient	**Std. error**	**95%CI**	**p**	**R^2**
Constant	1.5236	0.0040	0.00051 – 0.022	0.041	0.35
MQ-PEIM	0.0113				
Constant	0.116	0.0043	0.00110 – 0.020	0.032	0.39
%FAT-PEIM	0.0109				

Note: MQ-PEIM - Muscle quality (BIA-MQ); %FAT-PEIM - fat mass percentage.

Thus, the following equation was built to adjust the agreement with the US measure for MT and FT based on MQ and %FAT:

$$\text{Eq1: Muscle thickness (cm)} = 1.5236 + 0.01128 * (\text{MQ})$$

$$\text{Eq2: Fat thickness (cm)} = 0.116 + 0.0109 * (\text{\%FAT})$$

3.3 AGREEMENT

The equations expressed above were applied to the contralateral lower limb (n=12). Bland-Altman plots showing bias and limits of agreement between the MT and FT with MQ and %FAT is shown in Figure 3, respectively.

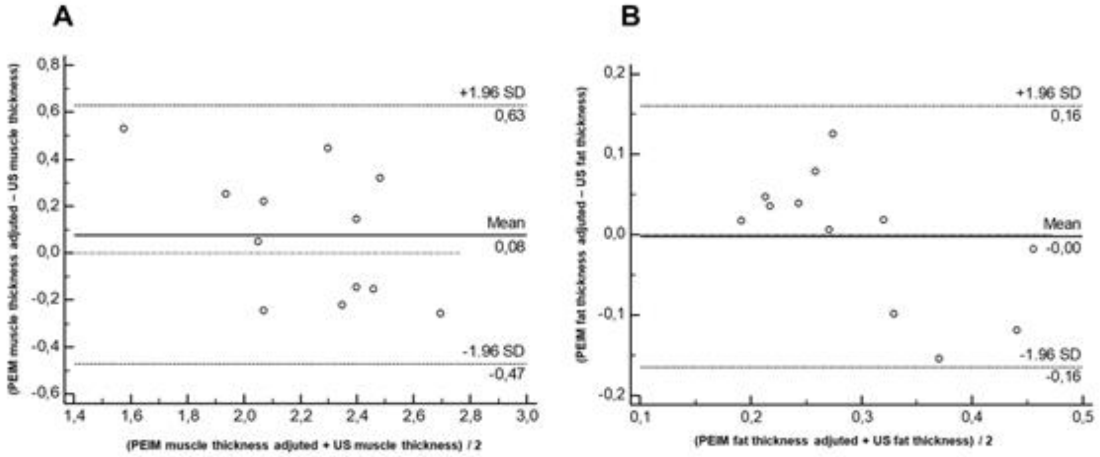

Figure 3. Bland-Altman plot between ultrasound (US) and portable electrical impedance myograph (PEIM) measures: **A)** PEIM muscle thickness adjusted and US muscle thickness; **B)** PEIM fat thickness adjusted and US fat thickness. Dashed lines represent 95% upper and lower limits of agreement (± 1.96 SD) and mean difference. Continuous line represents a reference for zero mean difference.

4 DISCUSSION

The purpose of this study was to analyze reliability and validity between the PEIM Skulpt® and US for lower limb skeletal muscle morphological measures in recreationally active men. A significant finding of the current study was that US versus PEIM reliability indicated a moderate correlation for the muscle quality measure (EI vs. MQ). Furthermore, intra-rater reliability indicated moderate consistency for EI, and excellent for MT and FT in the US device, as well as, excellent for MQ, and %FAT in the bioimpedance device. Conversely, EI and MQ presented a poor correlation, and moderate correlations were observed between MQ and %FAT with MT and FT, respectively. For these reasons, we proposed an adjustment equation that presented lower bias and higher agreement limits for both adjustment equations to BIA in the Bland-Altman plot.

Results of reliability of EI (r=0.75) and MT (r=0.99) demonstrated good-excellent values, which agrees with previous studies that evaluated the reliability of the measurements obtained by the US (LANFERDINI et al. 2019; LIN et al. 2015; PALMER et al. 2015; RUAS et al. 2017; SANTOS; ARMADA-DA-SILVA, 2017). However, a moderate correlation was found between MT and MQ (r=0.60), and EI presented a poor negative correlation with MQ (r=-0.31). These results demonstrate that MQ is more associated with muscle size (MT) than with possible internal changes in muscle tissue (EI). Therefore, MQ can be used, for example, to assess muscle hypertrophy in a strength training program. However, EI and MT data showed lower SEM and MDC values when compared to MQ data (Table 1). Therefore, we propose that the MQ data could be corrected using Equation 1 proposed by the present study, although the Bland-Altman test does not show any differences between EI and MQ measurements.

Moreover, FT (r=0.99) and anterior thigh %FAT results (r=0.97) showed excellent reliability of measurements. However, FT data showed lower SEM and MDC values when compared to %FAT data (Table 1). Therefore, we propose a second equation to correct the MQ data, although the Bland-Altman test does not show any differences between FT and %FAT measurements. The estimate of the percentage of fat through bioimpedance assessment may have measurement errors of approximately <4% for male bodybuilders (GRAYBEAL et al. 2020). While the direct measurement of subcutaneous fat performed using the US technique is highly reliable, it does not consider the internal fat of the muscle tissue (WAGNER, 2013). Therefore, these differences in data collection and analysis by different devices could partially explain the differences found between the FT and %FAT.

Another possible explanation for the non-linearity of the results (US *vs.* PEIM) is related to the specific characteristics of each device. The US system acquires data using linear probes (e.g., 50mm) that propagate waves using piezoelectric crystals (ZHOU et al. 2014). The PEIM system is 72.4 cm^2 and emits an electrical current with different frequencies, directions, and depths. These different characteristics between the two devices could explain the poor correlation between EI and MQ.

Our study has several limitations and delimitations that must be considered when attempting any extrapolation. First, the results are specific to the quadriceps and cannot necessarily be generalized to other muscle groups. Second, the results are specific to recreationally active men, and cannot necessarily be generalized to women, or other age ranges. Third, we found a moderate association between MT and MQ; however, cross-sectional area and muscle volume measurements are more reliable for assessing muscle size, which is directly related to the ability of skeletal muscle to produce strength (AKAGI et al. 2018; JONES et al. 2008). Therefore, it would be interesting in future studies to assess the reliability of MQ measurements by cross-sectional area. Despite this, MT demonstrated a good correlation (0.82) with cross-sectional area measurements by magnetic resonance imaging on VL muscle (FRANCHI et al. 2018). FT represents a reliable measure of the subcutaneous adipose tissue, although %FAT is an indirect measure, our results showed that it is possible to estimate the adipose tissue site (e.g., anterior thigh) almost as for MT by ultrasound, by applying an adjustment equation.

Based on our results, intra-rater reliability indicated consistency for US measures (EI, MT, and FT) and PEIM measures (MQ and %FAT). In addition, the proposed adjustment equation could be applied to correct the measure of MQ and %FAT for the quadriceps muscle provided by PEIM, decreasing any potential error of measurement. Future research using the total muscle analysis could help to provide clarity on the association of the US measure and PEIM responses. Furthermore, other populations could benefit from the clinical measure of PEIM, such as women and older adults.

Therefore, the results of the present study have the following clinical relevance: [1] PEIM is able to assess fat and muscle quality of the anterior thigh with moderate reliability; [2] A simple equation raises the accuracy of PEIM, giving results close to the ultrasound measure.

5 CONCLUSION

In summary, our results indicate moderate intra-rater reliability consistency for EI, excellent for MT and FT, and excellent for MQ and %FAT. In addition, our proposed adjustment equation presents clinical applicability to control FAT and MQ with different application possibilities in adults, and it can be applied in aesthetic, health control, and even physiotherapeutic treatments.

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